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Nur Nihal Türkel, Ceyhun Hacıyev, Elvan İşeri & Behçet Coşar

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Network analysis of depressive and anxiety symptoms in adolescents during the COVID-19 pandemic

Nur Nihal Türkel[1], Ceyhun Hacıyev[2], Elvan İşeri[3], Behçet Coşar[4]

1. Department of Psychiatry, Ministry of Health Eskişehir City Hospital, Eskişehir, Turkey.
2. Department of Psychiatry, NP İstanbul Hospital, İstanbul, Turkey.
3. Department of Child and Adolescent Psychiatry, Gazi University Faculty of Medicine, Ankara, Turkey.
4. Department of Psychiatry, Gazi University Faculty of Medicine, Ankara, Turkey.

***Correspondence:** Nur Nihal Türkel

E-mail: n.nihalqw@gmail.com

Adress: Avenue of Mevlana No:29, Yenimahalle/Ankara/Turkey **Post code**: 06590
Tel: 0 312 202 44 43

Mobile phone: +905066584955

Nur Nihal Türkel: 0000-0002-8352-8382

Ceyhun Hacıyev: 0000-0002-2304-0385

Elvan İşeri: 0000-0001-6833-6262

Behçet Coşar: 0000-0002-6422-499X

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Abstract:

Adolescence represents a critical period of vulnerability for the development of mental health disorders. The COVID-19 pandemic has exerted psychological impacts not only on adults but also on adolescents, largely due to various containment and transmission control measures. Identifying these psychological effects and exploring their interrelationships is essential for informing mental health services. The present study aimed to use network analysis to cross-sectionally identify the most central symptoms within the depressive-anxiety symptom network in a sample of adolescents during the pandemic. Depressive symptoms were assessed using The Patient Health Questionnaire-9 (PHQ-9), while anxiety symptoms were measured with The Generalized Anxiety Disorder-7 (GAD-7) scale. The network analysis revealed that PHQ-2 (sad mood), GAD-1 (nervousness), PHQ-4 (fatigue), and GAD-2 (uncontrollable worry) emerged as the most central symptoms in the network model. Additionally, the key bridge symptoms linking depressive and anxiety symptom clusters were PHQ-6 (feelings of guilt), PHQ-2 (depressed mood), and GAD-5 (restlessness). Identifying these central and bridge symptoms through network analysis may offer valuable insights for designing targeted interventions for adolescents. Furthermore, this study provides an important foundation for future research, representing the first investigation conducted within a Turkish adolescent sample.

Keywords: Adolescents, anxiety, covid-19, depression, network

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1. Introduction

During the COVID-19 pandemic, which affected populations worldwide, a series of control measures—including mass quarantines, home confinement, and school closures—were implemented to curb the rapid transmission of the virus. These interventions significantly disrupted the normal flow of daily life. Numerous studies have indicated that such disruptions had adverse effects on the mental health of adolescents [1]. Research conducted during the pandemic has consistently found elevated levels of depressive and anxiety symptoms among adolescents [2].

Adolescence is a pivotal developmental phase characterized by distinct biological, psychological, and social alterations. Given that the onset of most mental disorders typically occurs during adolescence, mental health professionals need to examine the challenges faced by individuals in this age group [3]. Although depression and anxiety are classified as distinct diagnostic categories, they frequently co-occur. Traditional psychopathological approaches, which rely on total scale scores, may overlook important associations between specific symptoms contributing to comorbidity [4].

Network analysis has arisen as a viable methodological strategy to overcome this limitation. Unlike traditional models, network analysis focuses on the structure and interplay of individual symptoms, identifying how they cluster and influence one another. In this framework, each node represents a psychiatric symptom, and some

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nodes may act as bridge symptoms—linking distinct disorders and contributing to comorbidity [5,6]. Network analysis thus provides valuable insights into both the underlying mechanisms of comorbid conditions and the mapping of symptom-specific interactions.

Numerous network analysis investigations have been performed across various communities during the COVID-19 pandemic [3,7]. For example, a study among Chinese adolescents identified sad mood, irritability, and guilt as central symptoms, while sad mood, suicidal ideation, and guilt were identified as bridge symptoms [3]. In Turkey, recent epidemiological reports have documented elevated rates of depressive and anxiety symptoms among adolescents during the pandemic, likely driven by prolonged school closures, social isolation, academic uncertainty, and disruption of daily routines [2,8]. However, to date, no study has applied network analysis to examine anxiety and depressive symptoms among adolescents in Turkey during the pandemic. Therefore, the present study aims to fill this gap by conducting a network analysis of anxiety and depressive symptoms in a Turkish adolescent sample during the COVID-19 pandemic. Guided by prior international findings, the study explores the following question: Which depressive and anxiety symptoms emerge as the most central and interconnected within this population? This research seeks to inform future symptom-targeted interventions for adolescents in the context of large-scale public health crises.

2. Methods

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2.1. Participants and Procedure

This research utilized a cross-sectional design with an online questionnaire disseminated via Google Forms. The survey link was disseminated throughout multiple social media sites, including Facebook, Instagram, and Twitter, and was available from June 22 until July 5, 2020. A snowball sampling technique was adopted to recruit participants through these platforms. Participation criteria included (1) secondary school students residing in Turkey during the COVID-19 pandemic who were (2) capable of comprehending the goal and content of the study.

Only adolescents were included in the study, consistent with the World Health Organization definition of adolescence. A total of 655 individuals completed the survey. However, data from 10 respondents were excluded due to invalid or inappropriate responses. As a result, the final sample comprised 645 participants.

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2.2. Measures

The sociodemographic data form was developed by the study's authors and included items assessing participants' sex, age, living environment, perceived financial status, history of psychiatric or physical illnesses, and the amount of time spent online.

Generalized Anxiety Disorder Scale -7 (GAD-7): The GAD-7 is a self-report scale used to assess symptoms of generalized anxiety experienced over the past two weeks. Each of the seven items is evaluated on a scale from 0 (not at all) to 3 (almost every day), yielding a cumulative score that indicates the severity of anxiety symptoms [9]. The Turkish validity and

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reliability results show that the scale has good psychometric properties for Turkish society [10]. Cronbach's Alpha GAD-7 is 0.905 in the current study.

Patient Health Questionnaries-9 (PHQ-9): The severity of depression was assessed using the Turkish version of PHQ-9. PHQ-9 is a scale that scores nine depression symptoms according to DSM-4 criteria in the range of 0-3 and was developed by Kroenke et al.[11] The Turkish validity and reliability results show that the scale has good psychometric properties for the Turkish society [12]. Cronbach's Alpha PHQ-9 is 0.882 in the current study.

2.3. Ethics Approval

No financial compensation was offered for participation. Data collection ensured anonymity to maintain confidentiality and enhance the reliability of responses. Ethical approval for the study was granted by the Ethics Committee of Gazi University Faculty of Medicine (Approval No: 704/2020, date: 07.08.2020) in accordance with the Declaration of Helsinki.

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2.4. Statistical Analysis

Descriptive statistics were performed using SPSS version 22.0, including sociodemographic distribution and mean scores (IBM Corp., Armonk, NY, USA).

Network estimation: The R package "qgraph" was utilized to estimate and visualize the network [13]. The network structure was assessed utilizing the Enhanced Least Absolute Shrinkage and Selection Operator

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(eLASSO) approach, which integrates logistic regression analysis with an optimization process to identify the optimal connection strategy for each symptom. All PHQ-9 and GAD-7 items were retained in their original 0–3 ordinal format, and no dichotomization was applied. To appropriately account for the ordinal nature of the data, a polychoric correlation matrix was computed using the “cor_auto” function in “qgraph”, after which the network was estimated with the EBICglasso algorithm. The tuning parameter was established at 0.25 to equilibrate the sensitivity and specificity of the actual network edges [14].

The symptom network was analyzed utilizing Expected Influence (EI), bridging Expected Influence (bEI), and node predictability with the R packages qgraph, networktools, and mgm, respectively [5,15]. Expected Influence (EI) was selected as the primary centrality index because it incorporates both the magnitude and sign of edges, offering a more informative estimate of a symptom’s influence within psychopathology networks compared to Strength or Betweenness, which may overlook negative associations or show instability. A higher EI value signifies a heightened significance of the node within the network. A higher bEI value indicates a heightened probability of contagion to other communities, with one-step and two-step bEI denoting direct and indirect bridge effects between a node and other nodes, respectively. In line with the aims of the study, interpretation focused on Expected Influence (EI) and Bridge Expected Influence (bEI), while other centrality indices were not interpreted. The threshold for diagnosing bridging symptoms was established at the 80th percentile [5]. Predictability was quantified by the

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ratio of explained variance, spanning from 0 to 1, where 0 signifies a complete lack of predictive capability of one node by others in the network, and 1 denotes precise predictive efficiency.

The network's accuracy and stability were assessed using the R program bootnet [16]. A non-parametric bootstrapping technique was employed to calculate the 95% confidence interval (CI) for each edge weight. Subsequently, the stabilities of EI and bEI were assessed using the correlation stability coefficient (CS) by the case-dropping subset bootstrap method, with the stipulation that the CS value should not be less than 0.25 and ideally exceed 0.50.

3. Results

3.1. Descriptive Statistics

Six hundred fifty-five adolescents were invited to participate in the study, with 645 individuals completing the survey and being included in the final analysis. The mean age of participants was 17.46 years (SD = 2.10), with an age range of 13 to 19 years, and 61.6% were female. Most participants resided in highly urbanized metropolitan areas, with 64.3% living in cities with populations exceeding five million. In terms of educational background, 60.2% were enrolled in public schools. Perceived family socioeconomic status was generally favorable: 76.1% reported that their household could meet essential needs and some discretionary wants, 13.3% stated that they could purchase anything they desired, 9.3% indicated having just enough income to cover basic necessities, and only 1.2% reported difficulty meeting essential expenses. Together, these

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characteristics suggest that the sample largely reflects adolescents from middle socioeconomic backgrounds living in metropolitan settings.

The mean scores on the PHQ-9 and GAD-7 were 12.36 (SD = 7.03) and 10.73 (SD = 5.95), respectively. Detailed participant characteristics are shown in Table 1.

Table 1. Demographic characteristics of the participants (n = 645)

Variables	Sample	Percentage	Variables	Sample	Percentage
Gender			**Living area**		
Male	248	38.4%	Metropolitan	415	64.3%
Female	397	61.6%	Medium City	114	17.6%
			Small City	116	18.0%
Educational level			**Previous psychiatric admission**		
Secondary school	56	8.7%	Yes	167	25.8%
High School	589	91.3%	No	478	74.2%
School Type					
Public school	388	60.2 %			
Private school	257	38.8 %			

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Table 2 presents the mean scores, standard deviations, normality, item abbreviations, and predictability for each symptom detailed in the GAD-7 and PHQ-9. Predictability values for individual nodes ranged from 0.07 to 0.19, indicating that a relatively small proportion of each symptom's variance was explained by its direct connections within the network. While low predictability may limit the explanatory power of the network for some nodes, it does not undermine the utility of centrality and bridge analyses,

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which remain informative for identifying key symptom targets in intervention planning.

Table 2. Item abbreviation, Mean scores, predictability normality, and Expected Influence of each symptom noted in the GAD-7 and PHQ-9

	Item abbreviation	***M*± *SD***	***Predictability***	***S-W***	**Expected Influence**	
Anxiety (GAD-7)					Mean	CL lower/ CL Upper
GAD 1	Nervousness	1.87±0.991	0.172	0.851***	1.148	1.056/1.256
GAD 2	Uncontrollable worry	1.31±1.051	0.159	0.864***	1.133	1.030/1.237
GAD 3	Excessive worry	1.71±1.078	0.155	0.855***	0.989	0.895/1.090
GAD 4	Trouble relaxing	1.40±1.065	0.109	0.864***	0.899	0.788/1.011
GAD 5	Restless	1.09±1.064	0.098	0.826***	0.879	0.783/0.993
GAD 6	Irritability	1.80±1.063	0.115	0.848***	0.787	0.701/0.881
GAD 7	Feeling Afraid	1.56±1.141	0.087	0.847***	0.835	0.746/0.927
Depression (PHQ9)						
PHQ1	Anhedonia	1.65±1.053	0.148	0.863***	0.780	0.686/0.871
PHQ2	Sad Mood	1.59±1.074	0.181	0.864***	1.219	1.122/1.322
PHQ3	Sleep	1.63±1.160	0.123	0.839***	0.718	0.630/0.808
PHQ4	Fatigue	1.73±1.080	0.190	0.854***	1.144	1.042/1.243

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PHQ5	Appetite	1.60±1.128	0.104	0.851***	0.834	0.746/0.927
PHQ6	Feelings of Guilt	1.67±1.165	0.082	0.833***	0.821	0.732/0.912
PHQ7	Concentration	0.98±1.107	0.074	0.781***	0.759	0.665/0.860
PHQ8	Motor Disturbance	0.79±1.016	0.078	0.748***	0.769	0.675/0.873
PHQ9	Suicidal Ideation	0.73±1.080	0.070	0.679***	0.751	0.655/0.860

Notes: SD = standard deviation, S-W = Shapiro-Wilk test, GAD-7 = Seven-Item Generalized Anxiety Disorder scale, PHQ-9 = Nine-Item Patient Health Questionnaire, ***$p < 0.001$

The network structure of anxiety-depression symptoms

Figure 1 illustrates the network structure of anxiety and depressive symptoms. The average edge weight in the constructed network model was 0.084, with 35.8% of the edges displaying values near zero. The network density was calculated at 0.725. These metrics suggest the model demonstrates high specificity, retaining primarily meaningful associations. Overall, the relationships among symptoms appear moderate, with certain symptom clusters emerging as more prominent within the network. The strongest edge within the anxiety symptoms was the edge GAD1 (Nervousness) - GAD6 (Irritability) (edge weight = 0.366), followed by GAD2 (Uncontrollable worry) - GAD3 (Excessive worry) (edge weight =0.306). The strongest edge within the depressive symptoms was the edge PHQ1 (Anhedonia) - PHQ2 (Sad mood) (edge weight = 0.398), and all the aforementioned strongest edges were much larger than any other edges,

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according to the edges difference test. (see Supplementary Figure 1). The correlation stability (CS) coefficients for both strength and expected influence were 0.75, indicating a high level of reliability in node centrality estimates across resampled data.

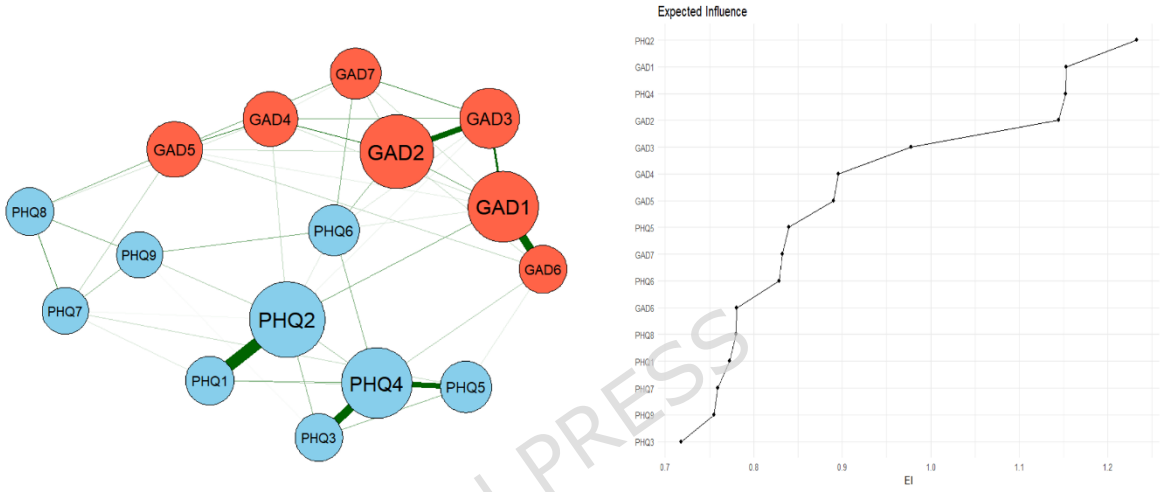


Figure 1. Network structure of anxiety and depressive symptoms in adolescents.

NOTES**:** In the left panel, blue nodes denoted depressive symptoms, whilst red nodes indicated anxiety symptoms. The edge thickness indicated the intensity of the association between two nodes, with greater thickness signifying stronger relationships. The EI (expected influence) values of the nodes are graphically displayed in the right panel.

Central symptoms and bridge symptoms

Examination of the centrality plot (Figure 1) revealed that PHQ-2 (sad mood), GAD-1 (nervousness), PHQ-4 (fatigue), and GAD-2 (uncontrollable worry) demonstrated the highest Expected Influence (EI)

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values, indicating their roles as the most central symptoms within the network. In contrast, PHQ-3 (sleep) and PHQ-9 (suicidal ideation), both associated with depressive symptomatology, exhibited the lowest EI values, indicating that these symptoms had the lowest degree of interconnection within the network structure. Bootstrap difference tests of EI values confirmed that the centrality of these key symptoms was significantly higher than that of the others (see Supplementary Figure 2)

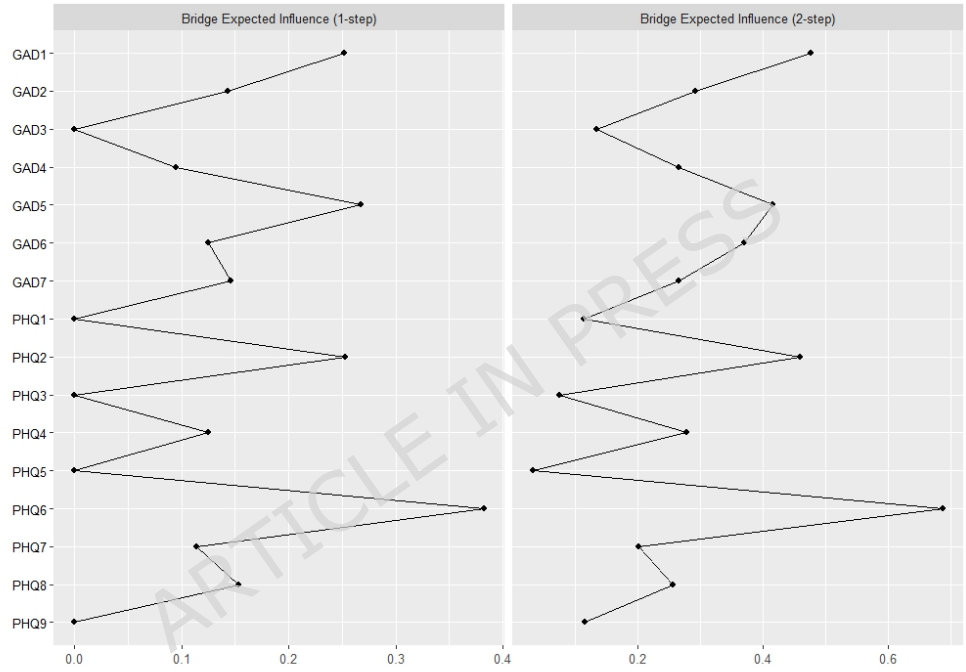


Figure 2. **Bridge symptom analysis in the depression-anxiety network among adolescents**

Bridge expected influence (1-step and 2-step) were computed to identify the key symptoms linking depressive and anxiety clusters. (Figure 2). Across indices, PHQ-2 (sad mood) and PHQ-6 (feelings of guilt) consistently emerged as the most influential bridge symptoms. These nodes demonstrated the highest bridge expected influence values in both

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1-step and 2-step calculations, underscoring their prominent role in connecting the two symptom communities.

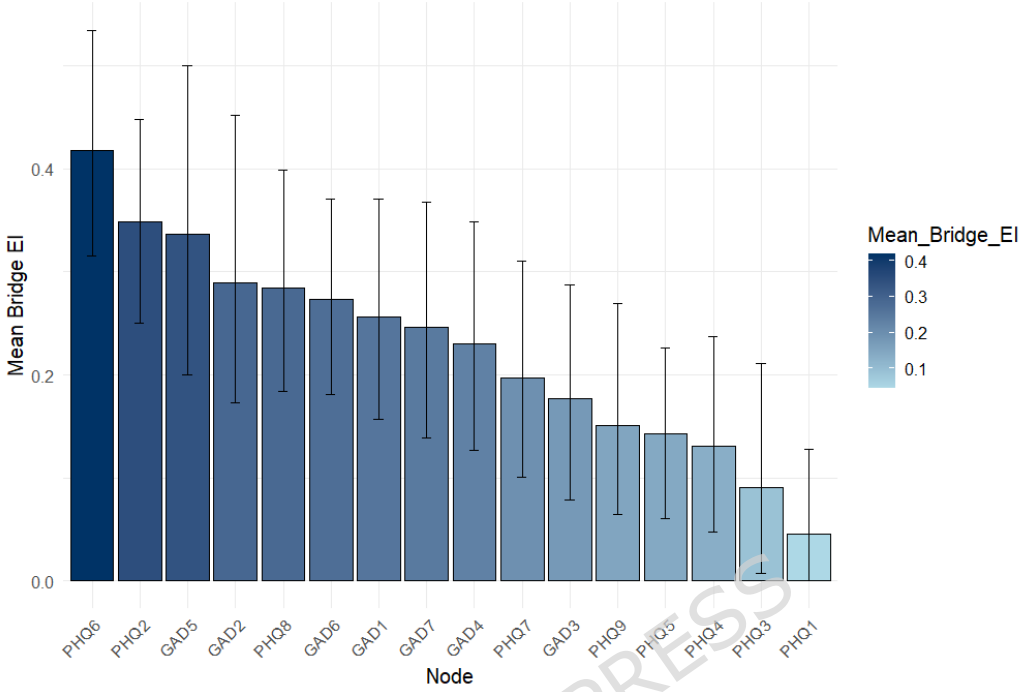


Figure 3. Mean bridge expected influence (bEI) and 95%CL

To evaluate the robustness of the findings, a non-parametric bootstrap procedure with 500 iterations was applied to the manually estimated bridge expected influence values. This analysis produced narrow 95% confidence intervals for nodes with high bridge centrality, indicating the stability and reliability of these estimates. A visual representation of the bridge expected influence values and their corresponding confidence intervals is provided in Figure 3.

Furthermore, pairwise bootstrap difference testing revealed several statistically significant contrasts. Specifically, the bootstrapped difference test indicated that these key bridge symptoms significantly differed from 47% to 80% of the other symptoms (see Supplementary Figure 3). Notably,

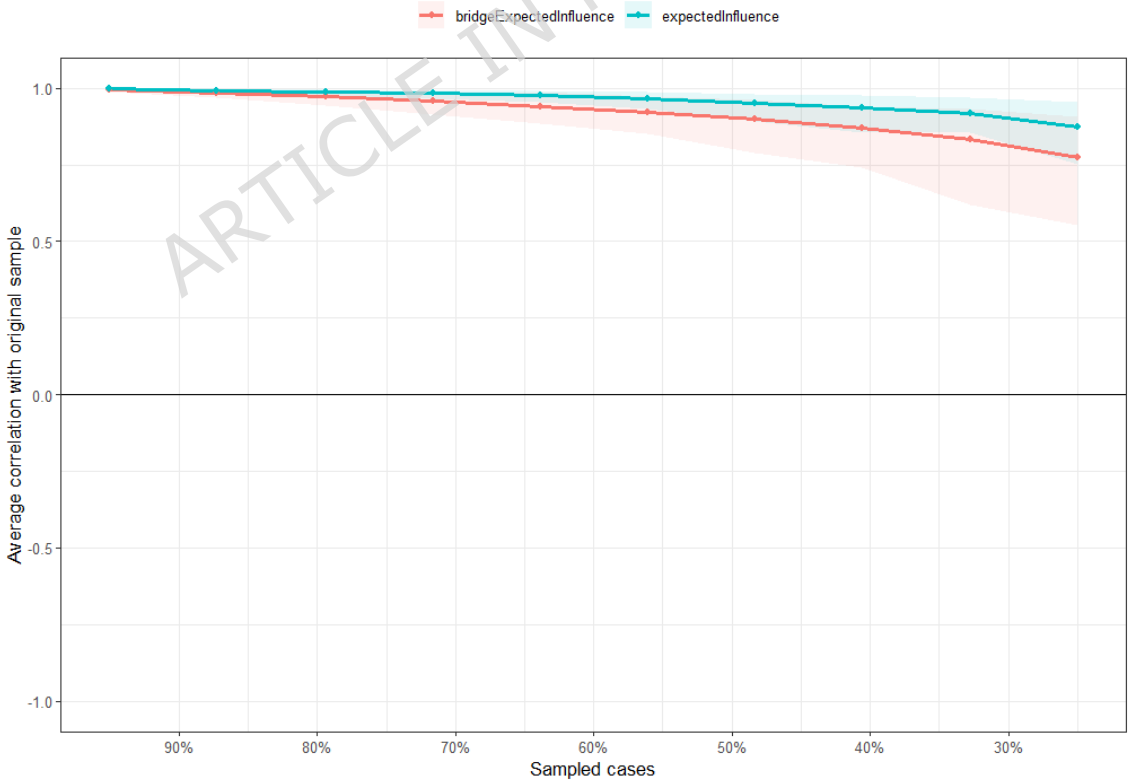
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PHQ-2 (sad mood) and PHQ-6 (feelings of guilt) exhibited significantly higher bridge centrality than nearly all other nodes, underscoring their critical role in linking depressive and anxiety symptom clusters.

Network Stability

The anxiety-depression network demonstrated remarkable stability. The CS-C of node EI was 0.75, indicating that EI remained associated with the original data (r = 0.75) after excluding 75% of the data. The CS-C of bEI was 0.594, indicating a commendable performance (Figure 4). Figure 5 illustrates the outcome of the non-parametric bootstrap procedure. The bootstrapped 95% confidence intervals were narrow, signifying high accuracy.

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Figure 4. The stability of network structure by case dropping subset bootstrap. Correlation stability coefficients (CS) for the nodes' centrality and edge weights

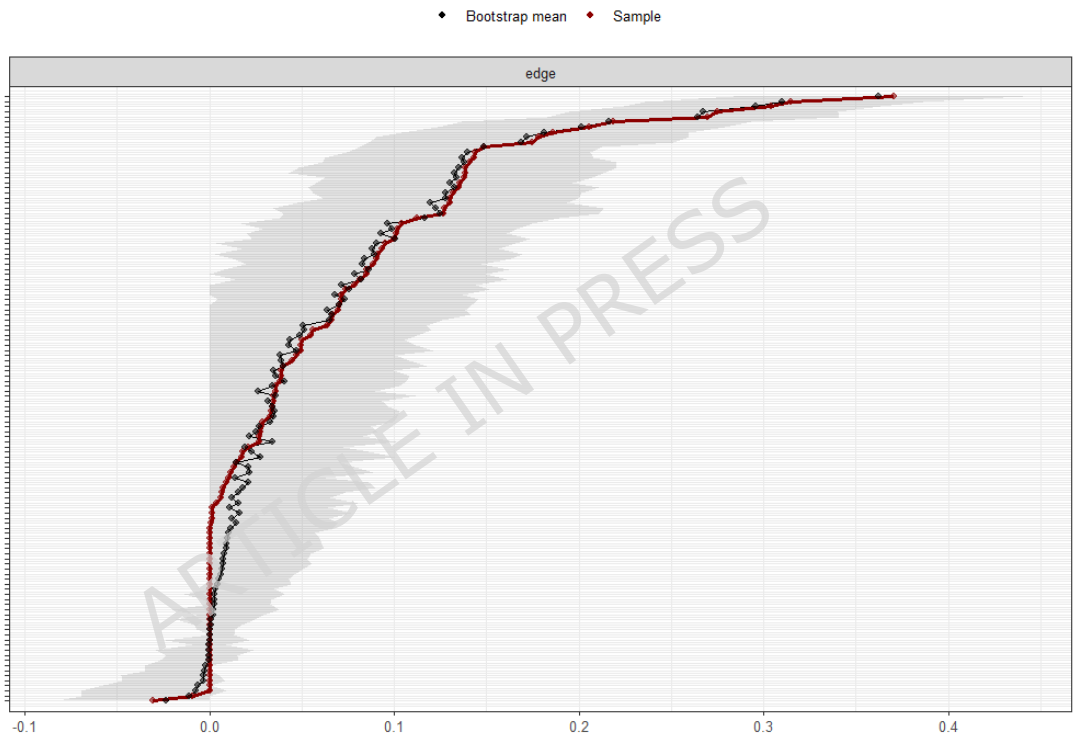


Figure 5. Non-parametric bootstrapped confidence intervals for calculated edge weights.

NOTES: The red line denotes the boundary approximated in the sample. The gray area represents the 95% bootstrapped confidence interval. The x-axis denotes the edges, whereas each line on the y-axis signifies a particular edge.

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4. Discussion

This is the initial network analysis study examining depressive and anxiety symptoms in a general adolescent sample in Turkey during the COVID-19 pandemic. Analysis indicated that PHQ-2 (sad mood), GAD-1 (nervousness), PHQ-4 (fatigue), and GAD-2 (uncontrollable worry) were central symptoms in the network model. Also, bridge symptoms linking anxiety and depressive symptoms in this sample were nodes PHQ-6 (feelings of guilt), PHQ-2 (sad mood), and GAD-5 (restlessness). A review of 33 studies employing network analyses on anxiety and depression identified PHQ-2 (Sad mood), GAD-2 (Uncontrollable worry), and GAD-3 (Excessive worry) as the most central symptoms across networks. Additionally, PHQ-2 (Sad mood), GAD-5 (Restlessness), and PHQ-8 (Motor disturbance) emerged most frequently as symptoms with high bridge centrality [17].

Network theory proposes that symptoms occupying central positions—reflected by high Expected Influence (EI)—may play a disproportionate role in maintaining the broader symptom structure by being more strongly connected to other nodes within the network. [18,19] Within this framework, highly central symptoms are often considered promising points of focus for clinical attention, as changes in such nodes may have downstream effects on the wider network. PHQ-2 (sad mood) was one of the most central symptoms to emerge within the depression-anxiety

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network of Turkish Adolescents. Comparable findings have been reported in prior network analysis studies examining depressive and anxiety symptoms among U.S. children and adolescents, as well as adults with psychiatric disorders [6,20].

Furthermore, studies conducted during the COVID-19 pandemic consistently identified sad mood as a central symptom in adults, nursing students, and general adolescent populations[3,7,21-23]. Georgiades et al. also identified sad mood as a highly salient symptom within depressive presentations, which is consistent with the central role of PHQ-2 observed in our network [24]. Adolescence is a developmental stage during which peer relationships play a crucial role in emotional growth. Peer interactions have been recognized as significant social predictors of adolescents' psychological well-being, while a lack of social support has been linked to an increased risk for depression [25]. The social isolation measures implemented to mitigate the spread of COVID-19 disrupted the typical face-to-face nature of peer interactions. Additionally, global uncertainty and deviation from daily routines during this study may have contributed to heightened feelings of hopelessness among adolescents. Together, these factors—social isolation and the interruption of routine life—may have elevated the risk of depressive symptoms in this population [26,27].

GAD-1(Nervousness) and GAD-2 (Uncontrollable worry) also emerged as prominent nodes within the anxiety–depression symptom network. Nervousness reflects anticipatory anxiety regarding potential threats or disasters, whereas uncontrollable worry represents a cognitive

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process marked by recurrent and intrusive thoughts about possible negative events, dangers, or risks [28]. At the time the study was conducted, lockdown measures were widely implemented in Turkey, as in many other countries, and education had transitioned to online platforms. Moreover, a COVID-19 vaccine was not yet available in Turkey, and daily death tolls were regularly broadcast on media outlets. The disruption of typical means of social interaction, coupled with misinformation about the pandemic circulating through various media channels, may have contributed to heightened feelings of helplessness, fear, and anxiety among adolescents [2]. Additionally, difficulties adapting to online learning environments may have exacerbated concerns related to academic demands and performance [29].

PHQ-4 (Fatigue) emerged as a key node within the anxiety–depression network, a finding that aligns with previous research [19,22,30]. In the context of Turkey, Morgul et al. reported that 64.1% of participants experienced fatigue during the COVID-19 pandemic [31]. Fatigue in this period has been attributed to several factors, including increased academic demands, reduced physical activity, and poor sleep quality [19,22]. Beyond behavioral and environmental explanations, psychobiological processes may also account for the centrality of fatigue in the network. Prolonged stress and uncertainty associated with the pandemic may dysregulate the hypothalamic–pituitary–adrenal (HPA) axis and autonomic nervous system functioning, contributing to diminished energy and physiological exhaustion [32,33]. These interacting biological and contextual factors may

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help explain why fatigue emerged as a central symptom within the adolescent anxiety–depression network.

PHQ-9 (suicidal ideation) and PHQ-3 (sleep disturbance) emerged as the two most isolated symptoms in the network, showing the lowest Expected Influence values. This pattern suggests that both symptoms may function less as drivers of other internalizing symptoms and more as downstream outcomes of broader emotional distress. Supporting this interpretation, Wang et al. used a directed acyclic graph (DAG) approach and identified PHQ-9 as a receiver node—one that was influenced by other symptoms but did not exert effects on them[34]. In the case of suicidal ideation, prior research indicates that such thoughts in adolescents are frequently shaped by higher-order constructs such as hopelessness, perceived burdensomeness— domains not fully represented within the PHQ-9 or GAD-7 [35,36]. Its low connectivity may therefore reflect influences external to the depressive–anxiety symptom constellation assessed here. Similarly, sleep disturbance may arise from lifestyle, behavioral, environmental, or physiological factors (e.g., circadian rhythm disruption, screen exposure, irregular routines) that operate partly independently of core internalizing processes [37,38]. While these interpretations should be approached cautiously given the cross-sectional design, the relative isolation of PHQ-9 and PHQ-3 suggests that they may represent outcome-oriented or context-sensitive nodes rather than central drivers within this adolescent internalizing network.

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Bridge Expected Influence (bEI) values provide valuable insights into identifying bridge symptoms contributing to mental disorders' comorbidity [39]. Comorbid symptoms of anxiety and depression have been associated with poorer treatment outcomes and increased rates of hospitalization [40]. In the present study examining the anxiety–depression network, PHQ-6 (feelings of guilt), PHQ-2 (sad mood), and GAD-5 (restlessness) emerged as key bridge symptoms. This finding is consistent with previous network analyses conducted in adolescent populations, which identified 'guilt' and 'sad mood' as prominent bridge symptoms linking anxiety and depression [3,41]. Similarly, a network study conducted among children aged 5 to 14 reported comparable results, with both 'guilt' and 'sad mood' demonstrating central bridging roles [20]. With specific reference to PHQ-6 (feelings of guilt), it is noteworthy that data collection coincided with a period in which national high school and university entrance examinations were administered and report cards were distributed. This timeframe typically involves heightened academic expectations from adults, which may evoke feelings of guilt among adolescents. In response to such external pressures, adolescents may experience increased anxiety and self-criticism, potentially contributing to the development of depressive symptoms [42]. Additionally, PHQ-2 (sad mood) has consistently been identified as a bridge symptom in previous research, highlighting its central role in the comorbidity between anxiety and depression. [43].

GAD-5 (restlessness) also emerged as a prominent bridge symptom in the anxiety–depression network. The transdiagnostic nature of "restlessness" has been supported by previous network studies [22,39,44].

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While restlessness is a fundamental characteristic of anxiety, findings from at least one study indicate that early alleviation of restlessness symptoms correlates positively with remission from major depressive disorder, underscoring the potential benefit of addressing restlessness in the treatment of major depressive disorder [45]. A study indicated that psychomotor symptoms, including restlessness, were more prominent during the COVID-19 pandemic than in the pre-pandemic period [21].

Interestingly, PHQ-8 (psychomotor disturbance) did not emerge as a central or bridging symptom in our network. Although this result aligns with Tao et al.'s findings in a large adolescent sample from China, it contrasts with the broader literature, in which PHQ-8 has frequently served as a connector between depressive and anxiety clusters [46]. One possible explanation is its conceptual overlap with GAD-5 (restlessness), which demonstrated stronger associations with both symptom domains in our sample. Restlessness may be particularly salient in this population, as the sample predominantly consisted of female adolescents, and previous studies have reported a stronger bridging effect of restlessness among females [39,44]. Several studies suggest that restlessness may represent a prodromal or early emerging feature of depression[47,48]. Together, these developmental, demographic, and physiological factors may help explain why GAD-5 captured motor-related variability more strongly than PHQ-8 in our dataset, resulting in the relatively peripheral role of PHQ-8 within the network.

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To our knowledge, this is the first network analysis study investigating anxiety and depressive symptoms among adolescents in Turkey. Nonetheless, the study possesses specific limitations. A major limitation of the present study is its cross-sectional design, which restricts the interpretation of the network structure. Mathematically, the partial correlations estimated by EBICglasso reflect only contemporaneous conditional associations rather than temporal dependencies. As highlighted in recent methodological critiques, cross-sectional psychological networks risk producing spurious or misleading edges because they cannot separate true symptom–symptom influence from shared variance[49]. Consequently, the present network should be interpreted as exploratory and hypothesis-generating rather than evidence of dynamic symptom interactions. Future longitudinal network studies are needed to determine whether central symptoms identified here prospectively predict the emergence or persistence of internalizing difficulties in adolescence. Such work would advance causal inference and strengthen the translational relevance of symptom network models. Second, although snowball sampling increased the feasibility of data collection during pandemic restrictions, this method may have limited sample representativeness. Snowball recruitment typically spreads through existing social or digital networks, which increases the likelihood that adolescents already engaged with mental-health content, exposed to similar stressors, or connected through the same online communities and peer groups are overrepresented. This may have contributed to higher symptom reports in our sample and reduced the generalizability of the

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findings to the broader adolescent population. Third, many participants were female and residing in metropolitan areas. Female adolescents are more likely to report higher levels of internalizing symptoms, and the metropolitan composition of the sample may not accurately reflect the demographic distribution of the national adolescent population. Fourthly, anxiety and depressive symptoms were assessed using self-report measures, which may introduce recall bias.

5. Conclusion

Despite these limitations, identifying central and bridge symptoms within the anxiety–depression network has important implications for intervention strategies. The current findings demonstrate that 'sad mood' (PHQ-2) functions as both a central and bridge symptom in the adolescent network, while 'feelings of guilt' (PHQ-6) and 'restlessness' (GAD-5) also serve as bridge symptoms. Given that adolescence is a critical period for the onset of mental disorders, early identification of symptoms contributing to comorbidity is essential.

In school-based counseling services—whether delivered face-to-face or through telehealth platforms—screening initiatives aimed at identifying persistent sad mood may help facilitate early referral and preventive support. For example, during pandemic-related academic disruptions, an adolescent experiencing guilt (PHQ-6) about perceived academic failure, restlessness (GAD-5) and sadness (PHQ-2). In such cases, targeted interventions such as cognitive restructuring and other cognitive-behavioral strategies could strategically address central and bridging

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symptoms like sadness and guilt, thereby reducing broader internalizing distress [50]. For restlessness, a documented bridge symptom in the anxiety–depression network, mindfulness-based and behavioral regulation approaches have shown effectiveness and may help interrupt cross-diagnostic symptom spread [51].

Collectively, interventions focused on these bridge symptoms may support more efficient prevention and treatment efforts by reducing the likelihood of co-occurring anxiety and depression in adolescents.

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Author Contributions

NNT designed the study; CH processed the data; NNT and BC drafted the manuscript; NNT and EI conducted the analysis and interpreted the results; all authors reviewed the paper for intellectual content; all authors reviewed the final manuscript and consented.

Competing Interests Statement

The author(s) declare no competing interests.

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Data availability statement

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

Informed Consent

Informed consent was obtained from all the parents/legal guardians of the participants under 18. Before beginning the questionnaire, participants were presented with information about the study's purpose and procedures. Consent to participate was obtained by checking a box, which also acknowledged their right to withdraw at any time without providing a reason.

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References

1. Golberstein, E., Wen, H. & Miller, B.F. Coronavirus disease 2019 (COVID-19) and mental health for children and adolescents. *JAMA pediatrics* **174**, 819-820 (2020).
2. Kılınçel, Ş., Kılınçel, O., Muratdağı, G., Aydın, A. & Usta, M.B. Factors affecting the anxiety levels of adolescents in home-quarantine during COVID-19 pandemic in Turkey. *Asia-Pacific Psychiatry* **13**, e12406 (2021).
3. Cai, H.*, et al.* Network analysis of depressive and anxiety symptoms in adolescents during the later stage of the COVID-19 pandemic. *Translational Psychiatry* **12**, 98 (2022).
4. Fried, E.I. & Nesse, R.M. The impact of individual depressive symptoms on impairment of psychosocial functioning. *PLoS One* **9**, e90311 (2014).
5. Jones, P.J., Ma, R. & McNally, R.J. Bridge centrality: a network approach to understanding comorbidity. *Multivariate behavioral research* **56**, 353-367 (2021).
6. Beard, C.*, et al.* Network analysis of depression and anxiety symptom relationships in a psychiatric sample. *Psychol. Med.* **46**, 3359-3369 (2016).
7. Liu, R.*, et al.* Network analysis of depressive and anxiety symptoms in adolescents during and after the COVID-19 outbreak peak. *J. Affect. Disord.* **301**, 463-471 (2022).
8. Selçuk, E.B.*, et al.* Anxiety, depression and post-traumatic stress disorder symptoms in adolescents during the COVID-19 outbreak and associated factors. *Int. J. Clin. Pract.* **75**, e14880 (2021).

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9. Spitzer, R.L., Kroenke, K., Williams, J.B. & Löwe, B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch. Intern. Med.* **166**, 1092-1097 (2006).
10. Konkan, R., Şenormanci, Ö., Güçlü, O., Aydin, E. & Sungur, M.Z. Yaygın Anksiyete Bozukluğu-7 (YAB-7) Testi Türkçe Uyarlaması, Geçerlik ve Güvenirliği. *Archives of Neuropsychiatry/Noropsikiatri Arsivi* **50**(2013).
11. Kroenke, K., Spitzer, R.L. & Williams, J.B. The PHQ-9: validity of a brief depression severity measure. *J. Gen. Intern. Med.* **16**, 606-613 (2001).
12. Güleç, M.Y., Güleç, H., Şimşek, G., Turhan, M. & Sünbül, E.A. Psychometric properties of the Turkish version of the patient health questionnaire–somatic, anxiety, and depressive symptoms. *Compr. Psychiatry* **53**, 623-629 (2012).
13. Epskamp, S., Cramer, A.O.J., Waldorp, L.J., Schmittmann, V.D. & Borsboom, D. qgraph: Network Visualizations of Relationships in Psychometric Data. *Journal of Statistical Software* **48**, 1 - 18 (2012).
14. Epskamp, S. & Fried, E.I. A tutorial on regularized partial correlation networks. *Psychol. Methods* **23**, 617 (2018).
15. Haslbeck, J.M. & Waldorp, L.J. How well do network models predict observations? On the importance of predictability in network models. *Behav. Res. Methods* **50**, 853-861 (2018).
16. Epskamp, S., Borsboom, D. & Fried, E.I. Estimating psychological networks and their accuracy: A tutorial paper. *Behav. Res. Methods* **50**, 195-212 (2018).
17. Cai, H.*, et al.* A network model of depressive and anxiety symptoms: a statistical evaluation. *Mol. Psychiatry* **29**, 767-781 (2024).
18. Borsboom, D. A network theory of mental disorders. *World psychiatry* **16**, 5-13 (2017).
19. Ren, L.*, et al.* Network structure of depression and anxiety symptoms in Chinese female nursing students. *BMC Psychiatry* **21**, 1-12 (2021).
20. McElroy, E., Fearon, P., Belsky, J., Fonagy, P. & Patalay, P. Networks of depression and anxiety symptoms across development. *J. Am. Acad. Child Adolesc. Psychiatry* **57**, 964-973 (2018).
21. Hoffart, A., Johnson, S.U. & Ebrahimi, O.V. The network of stress-related states and depression and anxiety symptoms during the COVID-19 lockdown. *J. Affect. Disord.* **294**, 671-678 (2021).
22. Bai, W.*, et al.* Network analysis of anxiety and depressive symptoms among nursing students during the COVID-19 pandemic. *J. Affect. Disord.* **294**, 753-760 (2021).
23. Ochnik, D.*, et al.* Network analysis of depressive and anxiety symptoms with well-being in students during the COVID-19 pandemic: a repeated cross-sectional study. *Sci. Rep.* **14**, 28789 (2024).
24. Georgiades, K., Lewinsohn, P.M., Monroe, S.M. & Seeley, J.R. Major depressive disorder in adolescence: The role of subthreshold symptoms. *J. Am. Acad. Child Adolesc. Psychiatry* **45**, 936-944 (2006).
25. Adedeji, A.*, et al.* Peer relationships and depressive symptoms among adolescents: Results from the German BELLA study. *Front. Psychol.* **12**, 767922 (2022).
26. Courtney, D., Watson, P., Battaglia, M., Mulsant, B.H. & Szatmari, P. COVID-19 impacts on child and youth anxiety and depression: challenges and opportunities. *The Canadian Journal of Psychiatry* **65**, 688-691 (2020).
27. Liu, J.J., Bao, Y., Huang, X., Shi, J. & Lu, L. Mental health considerations for children quarantined because of COVID-19. *The Lancet Child & Adolescent Health* **4**, 347-349 (2020).

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28. Zhang, L.*, et al.* Seeking bridge symptoms of anxiety, depression, and sleep disturbance among the elderly during the lockdown of the COVID-19 pandemic—A network approach. *Frontiers in Psychiatry* **13**, 919251 (2022).
29. Barbosa-Camacho, F.J.*, et al.* Depression, anxiety, and academic performance in COVID-19: a cross-sectional study. *BMC Psychiatry* **22**, 443 (2022).
30. Garabiles, M.R., Lao, C.K., Xiong, Y. & Hall, B.J. Exploring comorbidity between anxiety and depression among migrant Filipino domestic workers: a network approach. *J. Affect. Disord.* **250**, 85-93 (2019).
31. Morgul, E.*, et al.* COVID-19 pandemic and psychological fatigue in Turkey. *Int. J. Soc. Psychiatry* **67**, 128-135 (2021).
32. Doerr, J.M., Nater, U.M., Feneberg, A.C. & Mewes, R. Differential associations between fatigue and psychobiological stress measures in women with depression and women with somatic symptom disorder. *Psychoneuroendocrinology* **132**, 105343 (2021).
33. Wu, Q., Zhang, T.-M., Wang, X. & Zhang, Y. Pandemic fatigue and depressive symptoms among college students in the COVID-19 context: indirect effects through sense of control and intolerance of uncertainty. *BMC psychology* **12**, 21 (2024).
34. Wang, Y., Li, Z. & Cao, X. Investigating the network structure and causal relationships among bridge symptoms of comorbid depression and anxiety: A Bayesian network analysis. *J. Clin. Psychol.* **80**, 1271-1285 (2024).
35. Buitron, V.*, et al.* Interpersonal stress and suicidal ideation in adolescence: An indirect association through perceived burdensomeness toward others. *J. Affect. Disord.* **190**, 143-149 (2016).
36. Wolfe, K.L.*, et al.* Hopelessness as a predictor of suicide ideation in depressed male and female adolescent youth. *Suicide and Life-Threatening Behavior* **49**, 253-263 (2019).
37. Crowley, S.J., Acebo, C. & Carskadon, M.A. Sleep, circadian rhythms, and delayed phase in adolescence. *Sleep Med.* **8**, 602-612 (2007).
38. Pirdehghan, A., Khezmeh, E. & Panahi, S. Social media use and sleep disturbance among adolescents: A cross-sectional study. *Iranian journal of psychiatry* **16**, 137 (2021).
39. Kaiser, T., Herzog, P., Voderholzer, U. & Brakemeier, E.L. Unraveling the comorbidity of depression and anxiety in a large inpatient sample: Network analysis to examine bridge symptoms. *Depress. Anxiety* **38**, 307-317 (2021).
40. Lamers, F.*, et al.* Comorbidity patterns of anxiety and depressive disorders in a large cohort study: the Netherlands Study of Depression and Anxiety (NESDA). *J. Clin. Psychiatry* **72**, 341 (2011).
41. Lu, G., Zhu, L., Huang, R., Lai, P. & Wang, C. The association between adaptability and the symptoms of depression and anxiety in early adolescents: a network analysis in a longitudinal design. *BMC Psychiatry* **25**, 1-11 (2025).
42. Ma, Y., Siu, A. & Tse, W.S. The role of high parental expectations in adolescents' academic performance and depression in Hong Kong. *Journal of family issues* **39**, 2505-2522 (2018).
43. Marian, S., Costantini, G., Macsinga, I. & Sava, F.A. The dynamic interplay of anxious and depressive symptoms in a sample of undergraduate students. *Journal of Psychopathology and Behavioral Assessment* **45**, 150-159 (2023).
44. Peng, P.*, et al.* A network analysis of anxiety and depression symptoms among Chinese nurses in the late stage of the COVID-19 pandemic. *Frontiers in Public Health* **10**, 996386 (2022).

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45. Sakurai, H.*, et al.* Trajectories of individual symptoms in remitters versus non-remitters with depression. *J. Affect. Disord.* **151**, 506-513 (2013).
46. Tao, Y.*, et al.* Mapping network connection and direction between anxiety and depression symptoms across the early, middle, and late adolescents: insights from a large Chinese sample. *J. Psychiatr. Res.* **169**, 174-183 (2024).
47. Smit, A.C. & Snippe, E. Real-time monitoring of increases in restlessness to assess idiographic risk of recurrence of depressive symptoms. *Psychol. Med.* **53**, 5060-5069 (2023).
48. Benasi, G., Fava, G.A. & Guidi, J. Prodromal symptoms in depression: a systematic review. *Psychother. Psychosom.* **90**, 365-372 (2021).
49. Epskamp, S., Borsboom, D. & Fried, E.I. Estimating psychological networks and their accuracy: A tutorial paper. *Behav. Res. Methods* **50**, 195-212 (2018).
50. Rasing, S.P., Creemers, D.H., Janssens, J.M. & Scholte, R.H. Depression and anxiety prevention based on cognitive behavioral therapy for at-risk adolescents: a meta-analytic review. *Front. Psychol.* **8**, 1066 (2017).
51. Azhdari, A., Mardani, N., Javanbakht, M., Mombeni, T. & Ahmadi, M. Investigating the Comparative Effectiveness of Yoga and Relaxation Therapy on Restlessness, Fatigue and Difficulty Concentrating in Multiple Sclerosis Patients. *Health Technology Assessment in Action* (2024).

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