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A Network Structure of Mental Health and Problematic Mobile Phone Use Among Middle School Students

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Objective: Numerous studies have shown that the mental health of middle school students is closely related to problematic mobile phone use. The purpose of this study is to investigate the network structure between the dimensions of the Middle School Students Mental Health Scale and the items of the Self-Rating Questionnaire for Adolescent Problematic Mobile Phone Use by using the network analysis, to clarify the core symptoms and bridge symptoms of the network structure, and to provide ideas and methods for intervening in the mental health and problematic mobile phone use of middle school students.

Methods: A stratified cluster sampling method was used to select 1637 students from four general middle schools in Xiamen in June 2020 for the survey, and the Middle School Students Mental Health Scale (MSSMHS-60) and the Self-Rating Questionnaire for Adolescent Problematic Mobile Phone Use (SQAPMPU) were used. SPSS28.0 was used for descriptive statistical analysis and R (version 4.2.1) for network analysis.

Results: 1. The core symptoms of the network of middle school students' mental health and problematic mobile phone use were "spending more time playing with the phone in order to be satisfied", anxiety, and depression; 2. The bridge symptoms of the network of middle school students' mental health and problematic mobile phone use were academic stress, psychological disequilibrium, and "depression without phone".

Conclusion: Reducing the time of smartphone use and relieving anxiety and depression can improve the mental health of middle school students and reduce the incidence of problematic mobile phone use; helping middle school students adjust their study pressure and improving their social support level can reduce the severity of problematic mobile phone use.

Keywords: problematic mobile phone use, network analysis, middle school students, mental health

The 51st China Internet Network Information Center (CNNIC) report shows that as of June 2023, the size of China's phone netizens reached 1.076 billion, of which nearly 200 million are teenagers, accounting for 13.9%.[1] Smartphones bring convenience to middle school students' learning and daily life entertainment, but they may also lead to the situation of problematic mobile phone use among middle school students. Problematic mobile phone use refers to significant impairment of an individual's physiological, psychological, and social functioning due to overuse of a smartphone in the absence of addictive substances.[2] The mental health of middle school students is closely related to problematic mobile phone use, and studies have shown that excessive use of mobile phones can lead to depression and anxiety, low self-regulation, poor sleep quality, low academic self-efficacy, and poor life satisfaction,[3–7] jeopardizing middle school students' academic performance and quality of life.[8] Problematic mobile phone use is even strongly associated with

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suicide. A study of 18,723 college students showed that problematic mobile phone use was significantly associated with increased odds of suicide attempts and suicidal ideation.[9] For middle school students with psychological distress, excessive use of mobile phones is a coping mechanism to escape from real life.[10,11] Previous studies have focused on exploring the detection rates and influencing factors of problematic mobile phone use, proposing risk factors and protective factors that predict problematic mobile phone use, and discussing influencing factors and problematic mobile phone use as separate entities without fully analyzing the inter-mechanisms and relationships between them. The network theory of psychopathology describes mental disorders as causal systems of interacting symptoms,[12] with symptoms as dynamic components of the system.[13] Therefore, this study aims to investigate the network structure (the relationship between symptoms) and its influence on the network status (symptom activation) of middle school students' mental health and problematic mobile phone use, analyze the relationship between the dimensions of middle school students' mental health and the items of problematic mobile phone use, and find out the core symptoms and bridge symptoms that influence the network structure of middle school students' mental health and problematic mobile phone use, with a view to providing ideas and methods of intervening in middle school students' problematic mobile phone use and improving their mental health.

Objects and Methods

Participants

In June 2020, the stratified cluster sampling method was adopted to randomly select three classes in each year section of four general middle schools (two junior high schools and two senior high schools) in Xiamen, and the total number of classes participating in the survey was 36. A total of 1692 questionnaires were distributed in this study, and after screening out invalid questionnaires such as incomplete answers and nonsense, 1637 valid questionnaires were obtained, and the validity rate of questionnaire recovery was 96.75%. The middle school students and their guardians (parents) signed an informed consent form, and the study complied with the Declaration of Helsinki and was approved by the Ethics Review Committee of Xiamen Xianyue Hospital (Ethics No. 2019-K-Y-016).

Methods

Middle School Students Mental Health Scale (MSSMHS-60).[14]

It was compiled by Wang Jisheng to assess the mental health status of middle school students. The scale consists of 60 entries and 10 subscales, namely obsessive-compulsive symptoms, paranoia, hostility, interpersonal tensions and sensitivities, depression, anxiety, academic stress, maladaptation, emotional instability, and psychological disequilibrium, and is rated on a 5-point scale. The re-test reliability of the subscales ranged from 0.716 to 0.905, and the correlation coefficients between the subscales and the total scale ranged from 0.765 to 0.87.

Self-Rating Questionnaire for Adolescent Problematic Mobile Phone Use (SQAPMPU)[15]

The scale was developed by Tao Fangbiao et al of Anhui Medical University School of Public Health in 2012, with a total of 13 items divided into three dimensions: withdrawal symptoms, craving, and physical and psychological effects. The Cronbach's alpha coefficient for the total questionnaire was 0.87, with higher total scores indicating higher levels of problematic mobile phone use.

Data Analysis

Descriptive Statistical Analysis and Network Analysis

Descriptive statistical analyses were performed in this study using SPSS28.0 software, and all network analyses were performed using the R (version 4.2.1). The networks were estimated and constructed using "qgraph" in the R package, which uses the Extended Bayesian Information Criterion (EBIC), the Least Absolute Shrinkage and Selection Operator (LASSO), the Graphical Gaussian Model (GGM), and the polynomial coefficients to construct the network structure for the middle school students' mental health and problematic mobile phone use.[16,17] Among them, EBIC is used to select the best network model, LASSO is used to control the sparsity of the network to prevent redundancy in the network structure, and GGM is used to present the network structure graph. In the network model, each dimension of the Middle

school students mental health scale and each item of the Self-Rating Scale for Adolescent Problematic mobile phone use are regarded as "nodes", and the connecting lines between the nodes are regarded as "edges", and the thickness of the edges represents the correlation between the nodes, with the blue edges denoting positive correlation, and the red edges denoting positive correlation, and the red edges denoting positive correlation. The thickness of the edges represents the strength of the correlation between the nodes, with blue edges indicating positive correlation and red edges indicating negative correlation.

Centrality and Stability

The centrality index was measured using the "bootnet" in the R package, and the centrality index was measured using the Expected influence (EI), which was used to estimate the central symptom affecting the network structure,[18] and to explore the core symptom affecting the network structure of the mental health and problematic mobile phone use of middle school students; Bridge expected influence (bEI) was used to assess bridge symptoms[19] to explore the connectivity between middle school students' mental health and problematic mobile phone use. Predictable values were represented as a pie chart with a ring around each node in the network, with a fuller ring indicating a higher predictability value. The predictive value was calculated using the "mgm" in the R package,[20] which indicates the extent to which a node can be explained by other nodes in the network structure.[20]

In order to verify the stability and accuracy of the whole network structure, the stability of centrality as well as the accuracy of edges were calculated in this study.[21] The stability of the nodes in the network structure of this study was performed using the case-dropping bootstrap test for 1000 bootstraps. And the stability of EI and bEI was quantified by calculating the correlation stability coefficient, with CS coefficients greater than 0.50 or more being optimal, and a minimum CS of not less than 0.25.[16] The accuracy of the edges was determined using a Non-parametric bootstrapping test for 1000 bootstraps to estimate the 95% confidence intervals of the edges, with less overlap of these confidence intervals indicating higher accuracy. The variability of nodes as well as the variability of edges was likewise subjected to 1000 bootstraps using the Non-parametric bootstrapping test.[21]

Results

Descriptive Statistics

A total of 1637 middle school students were included in this study, including 832 junior school students and 805 high school students; 842 boys and 795 girls; the average age was (16.04±1.29). Descriptive statistics were analyzed for each dimension of middle school students' mental health and each item of the Self-rating questionnaire for adolescent problematic mobile phone use (Table 1), and for the convenience of labeling, each dimension of middle school students' mental health was named with MH1–MH10 (MH1 = Obsessive-compulsive symptoms, MH2 = Paranoid, MH3 = Hostile, MH4 = Interpersonal tensions and sensitivities, MH5 = Depression, MH6 = Anxiety, MH7 = Academic stress, MH8 = Maladaptation, MH9 = Emotional instability, MH10 = Psychological disequilibrium), the items of the Self-rating questionnaire for adolescent problematic mobile phone use were named with PMPU1–PMPU13, and the items of the adolescent phone dependence self-assessment scale were summarized and abbreviated after the literature readings and the discussion among the members of the study (Table 2). The total mean score of middle school students' mental health was 11.84 ± 4.093, and the mean score of self-rating questionnaire for adolescent problematic mobile phone use was 23.20 ± 8.938.

Network Structure of Middle School Students' Mental Health and Problematic Mobile Phone Use

R was used to conduct a network analysis of the dimensions of middle school students' mental health and the items of the self-rating questionnaire for adolescent problematic mobile phone use to explore the relationship between middle school students' mental health and problematic mobile phone use. Figure 1 presents the network structure of middle school students' mental health and problematic mobile phone use. Among the mental health dimensions of middle school students, MH5 and MH6 were most strongly connected (strength = 0.52), followed by MH2 and MH4 (strength = 0.29). Among the items of self-rating questionnaire for adolescent problematic mobile phone use, PMPU1 and PMPU2 were

Table 1 Descriptive Statistics of Mental Health and Problematic Mobile Phone Use Among Middle School Students

Item	M±SD	EI	bEI	Predictability
MH1	2.12±0.703	−1.593	−0.055	0.602
MH2	1.88±0.790	1.201	0.022	0.764
MH3	1.78±0.811	−0.161	0.122	0.685
MH4	2.01±0.799	1.130	0.069	0.786
MH5	2.01±0.893	1.134	0.019	0.833
MH6	2.11±0.966	1.385	−0.013	0.835
MH7	2.15±0.888	0.135	0.312	0.629
MH8	1.87±0.705	−0.056	0.090	0.640
MH9	2.16±0.789	0.629	0.092	0.716
MH10	1.66±0.636	−0.443	0.128	0.600
PMPU1	2.19±1.145	−2.086	0.084	0.317
PMPU2	1.97±1.097	0.573	0.122	0.495
PMPU3	1.98±1.101	−0.058	0.059	0.458
PMPU4	1.37±0.794	0.123	0.034	0.457
PMPU5	1.74±1.051	−0.114	0.092	0.480
PMPU6	1.47±0.946	−0.656	0.026	0.413
PMPU7	1.64±0.969	1.732	0.054	0.574
PMPU8	2.04±1.250	−0.704	0.063	0.402
PMPU9	1.92±1.098	−0.042	0.044	0.451
PMPU10	1.19±0.594	−1.659	0.041	0.303
PMPU11	1.58±0.992	0.170	0.012	0.456
PMPU12	2.25±1.202	−1.119	0.059	0.396
PMPU13	1.87±1.150	0.478	0.095	0.491

Note: EI indicates the expected influence, bEI indicates the expected bridge influence.

Table 2 Abbreviations for Each Item in the Self-Rating Questionnaire for Adolescent Problematic Mobile Phone Use

Item		Abbreviations
PMPU1	I always feel like I do not spend enough time on my cell phone;	loss of control
PMPU2	When I attempt to reduce or stop using my phone, I feel frustrated, depressed or short-tempered;	depressed without mobile phone
PMPU3	I do not get enough sleep from playing with my phone too much;	sleep deprivation
PMPU4	Getting annoyed when the phone has to be turned off for classes, get-togethers, etc;	anxious without mobile phone
PMPU5	I would sometimes rather play with my phone than deal with some other more pressing matter;	neglecting urgent matters
PMPU6	When the phone has not rung for a while, my mind will start to drift to the idea that the phone has a missed call;	withdrawal symptoms
PMPU7	I feel like I need to spend more time on my phone to be satisfied;	need for satisfaction
PMPU8	When I hallucinate my cell phone ringing or vibrating, I always subconsciously pull it out to check;	withdrawal symptoms
PMPU9	Because of my cell phone use, I usually have less time for leisure activities;	excessive use
PMPU10	I have dreams about smartphones from time to time;	frequent mobile phone-related dreams
PMPU11	Not checking my phone for messages or leaving it on for a while can make me anxious;	loss of control
PMPU12	Using my phone directly affects my studies or productivity;	Jeopardizes learning or productivity
PMPU13	I would be overwhelmed without my cell phone.	loss of control

most strongly connected (strength = 0.31), followed by PMPU5 and PMPU7 (strength = 0.26). Overall, middle school students' mental health and problematic mobile phone use were strongly connected, with the strongest connection between MH7 and PMPU5 (strength = 0.08), followed by MH7 and PMPU13 (strength = 0.07). The results of the

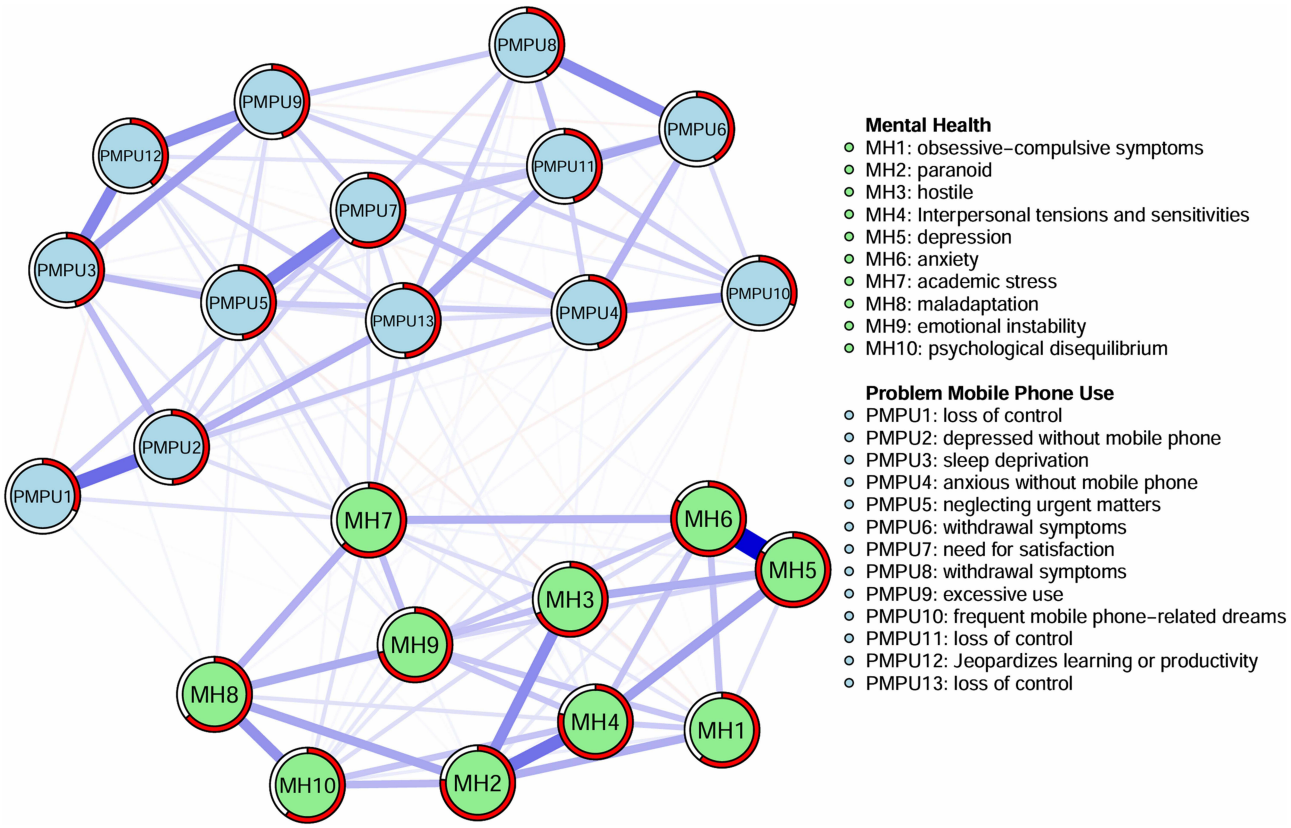

Figure 1 Network estimates of mental health and problematic mobile phone use among middle school students.
Note: The blue solid line represents positive correlation, the red solid line represents negative correlation, and the thickness of the line indicates the degree of correlation. The ring around the node is called the predicted value, and more red parts means more parts of the node can be explained by all the other nodes in the network.

predictability analyses showed (Table 1) that the average predictability value of the network structure of secondary school students' mental health and problematic mobile phone use was 0.56, with the three nodes with the highest predictability values being MH6 (0.835), MH5 (0.833), and MH4 (0.786).

The results of the centering measures (Table 1, Figure 2) indicated that PMPU7 (EI = 1.732), MH6 (EI = 1.385) and MH2 (EI = 1.201) were the core symptoms of the network structure, and that interventions on the core symptoms could alleviate the level of psychological well-being and problematic mobile phone use among middle school students. MH7 (bEI = 0.312), MH10 (bEI = 0.128), and PMPU2 (bEI = 0.122) are bridge symptoms of the network structure, indicating that they are bridging nodes in the network of middle school students' mental health and problematic mobile phone use, with academic stress (MH7) and psychological imbalance (MH0) being linked to problematic mobile phone use through the item "Feeling frustrated without my cell phone (when I try to cut back or use my cell phone, I feel depressed, frustrated, or grumpy)". In this study, we assessed the stability of the network structure centrality index by calculating the correlation stability coefficient CS, which was 0.75 and 0.67 for the EI and bEI, respectively, suggesting strong stability of the results for the network structure core symptom and bridge symptom (Figure 3). Through the nonparametric Bootstrapped test for edge weights, the results showed that the 95% confidence intervals of the edge weights were narrower, indicating that the 95% confidence intervals of the Bootstrapped sampling set and the original dataset overlapped well, which indicated that the assessment of the edge weights was accurate.

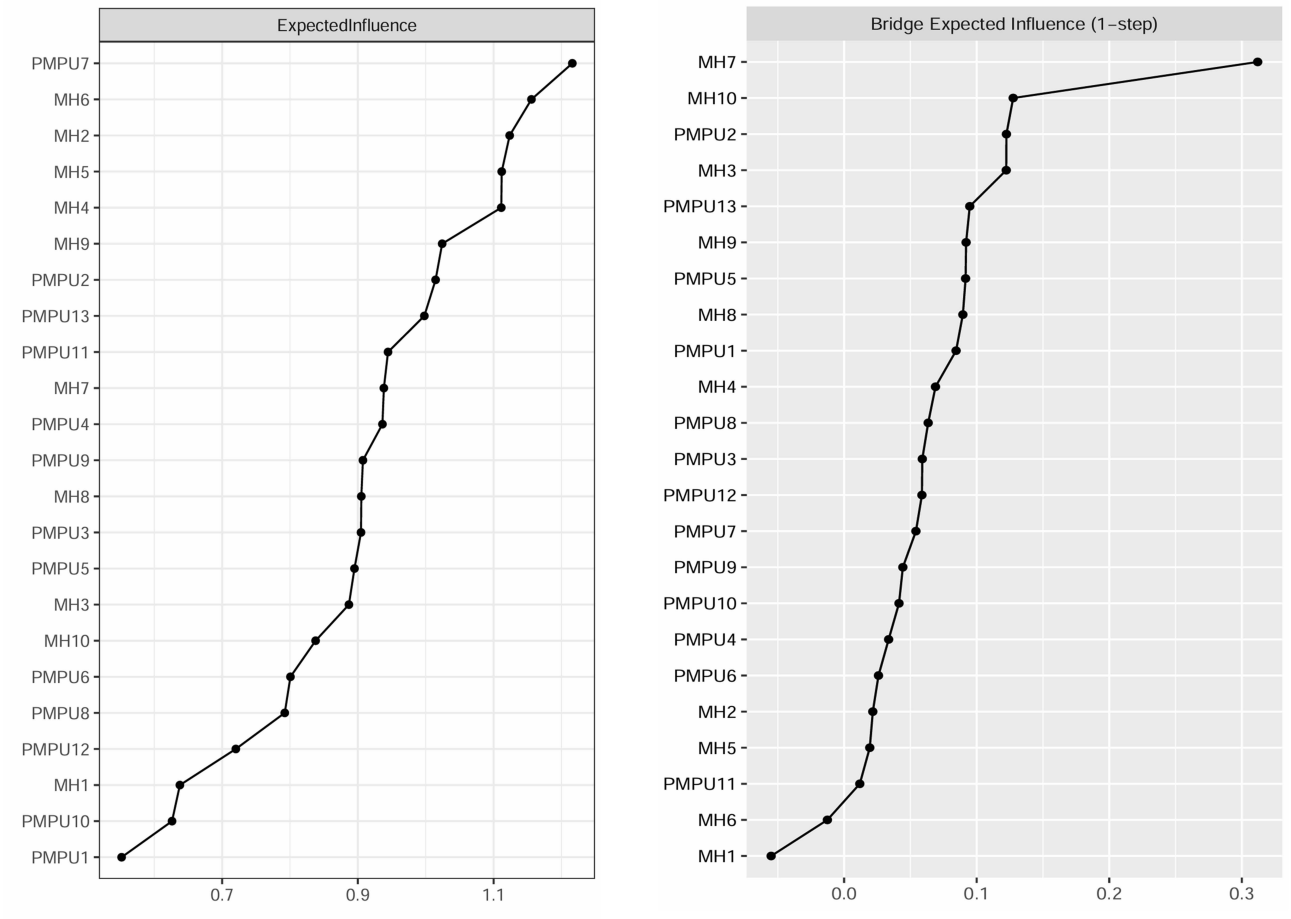

Figure 2 Centrality measurements of network nodes (left) and predicted values of bridge symptoms (right).

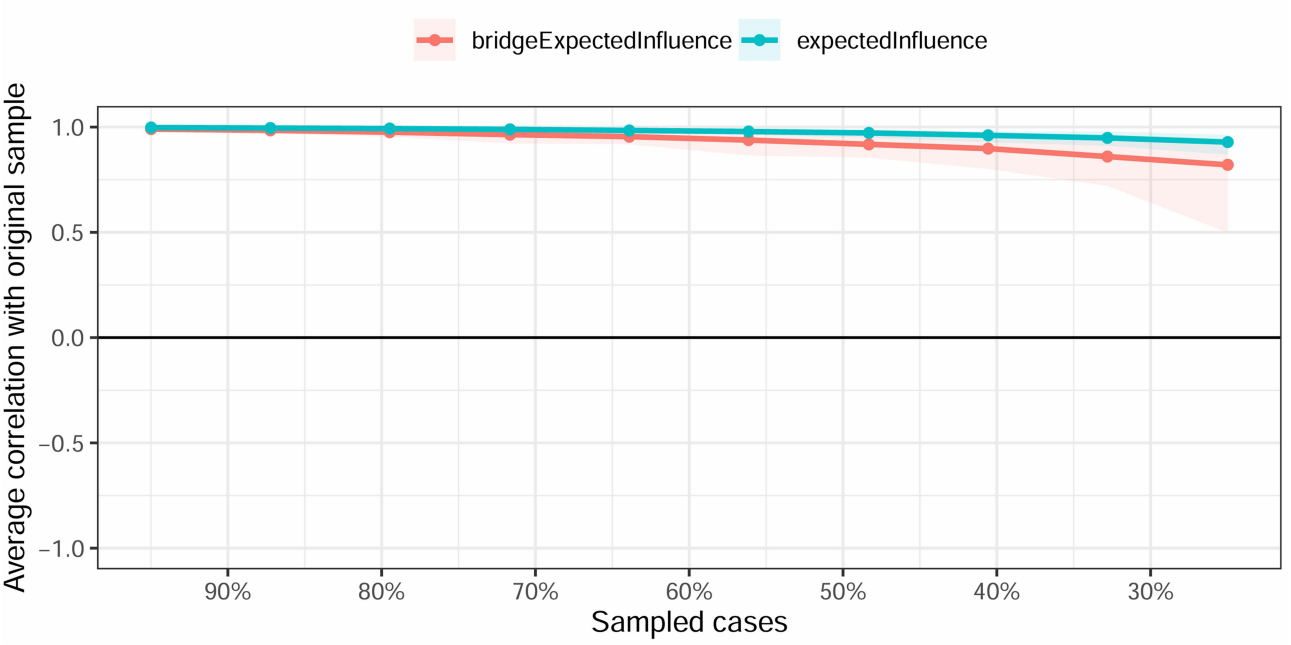

Figure 3 Estimating the stability of the network structure using the case-drop subset bootstrap approach.
Note: The x-axis represents the percentage of cases using the original sample. the y-axis shows the average correlation between the centrality index of the original network and the re-estimated network index.

Discussion

In this study, the network structure of middle school students' mental health and problematic mobile phone use was constructed through network analysis techniques to explore the relationship between the dimensions of middle school students' mental health and the items of the self-rating questionnaire for adolescent problematic mobile phone use.

In this study, middle school students' mental health was strongly associated with problematic mobile phone use, with the highest side weights being academic stress (MH7) and "I would sometimes rather play with my cell phone than deal with some other more pressing matters" (PMPU5), followed by academic stress (MH7) and "I would feel overwhelmed without my cell phone" (PMPU13). Consistent with existing research, perceived academic stress positively predicts problematic mobile phone use in middle school students,[22] and the stronger the sense of academic stress, the more likely the individual is to experience problematic mobile phone use. Middle school students have heavy academic tasks, and they can regulate their stress by using their phones to listen to music, chat, and play games, and studies have shown that perceived stress is a risk factor for problematic mobile phone use among middle school students.[8,11] As smartphones are easily available and simple to operate, middle school students with poor emotional regulation and low self-control are prone to feeling anxiety and intense academic stress,[23] and are more inclined to choose 'fast' regulation (excessive use of smartphones) rather than 'slow' regulation (exercise, reading, and meditation, etc)., which in turn leads to problematic cell phone use.

The core symptoms of the mental health and problematic mobile phone use network of middle school students were "I feel like I need to spend more time on my cell phone to be satisfied" (PMPU7), anxiety (MH6), and depression (MH2). In this study, middle school students who presented with problematic mobile phone use wanted to derive satisfaction from excessive cell phone use, which is consistent with existing studies. Shunsen et al showed that persistent overuse was a core symptom of the network structure of problematic mobile phone use,[24] and Jingjing et al showed that the inability to reduce the amount of time spent using the cell phone was a core symptom of the network structure of cell phone addiction and anxiety symptoms in rural Chinese adolescents.[25] These middle school students are often characterized by high loneliness, low well-being, poor self-control, and low due diligence,[26,27] and they have difficulty in resisting the temptation of smartphones and are unable to successfully engage in emotional regulation and self-control,[28,29] which in turn predisposes them to uncontrolled smartphone use. Studies have shown that emotional regulation and self-control play a key role in the development, persistence, remission, and relapse of problematic mobile phone use.[28,30] Therefore, training and improving middle school students' emotional regulation and self-control and reducing their time spent on cell phone use can maximize the alleviation and improvement of problematic cell phone use and enhance the mental health of middle school students. The other two core symptoms of mental health and problematic mobile phone use networks among middle school students are anxiety and depression, and studies have found that the severity of anxiety and depression is associated with increased levels of problematic smartphone use,[31] and that boredom tendency and fear of missing out (FOMO) have a chain mediating role between depression and anxiety and problematic smartphone use.[32] Middle school students who overuse smartphones that bring rich stimulation and experiences tend to get bored and irritated easily when faced with insipid books, and then involuntarily make themselves feel better by using their phones. Research has shown that in the network structure of problematic mobile phone use and depression and anxiety, "withdrawal" is the bridge symptom between depression, anxiety and problematic mobile phone use,[33] and middle school students who develop problematic mobile phone use are prone to "loss of control".[34] Once they stop using smartphones, they feel irritable and depressed, which shows that depression and anxiety are closely related to problematic mobile phone use. Therefore, reducing the time of phone use and improving anxiety and depression can directly affect the mental health of middle school students and the network of problematic mobile phone use, thus reducing the occurrence of problematic mobile phone use and improving the mental health of middle school students.

The bridge symptoms connecting middle school students' mental health and problematic mobile phone use in this study were feelings of academic stress (MH7), psychological disequilibrium (MH10), and "When I attempt to reduce or stop using my phone, I feel frustrated, depressed or short-tempered" (PMPU2), with middle school students high in feelings of academic stress and psychological disequilibrium were linked to problematic mobile phone use through depression without a phone. Feelings of academic stress reflect problems such as middle school students feeling burdened by studying, fearing teacher questions, hating doing homework, hating school, and fearing and hating tests. Studies have

shown that academic performance and learning efficacy are influential factors in the positive experiences of middle school students,[35] and middle school students who perceive excessive academic stress may escape reality by using phones.[11,36] Therefore, once their phones are removed, middle school students experience both the frustration of losing their cell phones and the anxiety of facing their studies and exams, and the level of psychological conflict increases. Psychological disequilibrium reflects middle school students' feeling that their teachers and parents are unfair to them, and that they are sad that their classmates have better grades than they do. Middle school students who perceive low social support are prone to a sense of unfairness, and the sense of unfairness based on social comparison can become a sense of relative deprivation,[37,38] and studies have shown that social support and relative deprivation mediate the relationship between negative life events and phone dependence,[39] and that middle school students who have low social support and high sense of unfairness are prone to more severe problematic mobile phone use when faced with negative life events.[40] Therefore, helping middle school students regulate and cope with academic stress and improving their social support levels can reduce the severity of problematic mobile phone use.

Conclusion

The core symptoms of middle school students' mental health and problematic mobile phone use network are spending more time playing with phones in order to be satisfied, anxiety, and depression, and middle school students' mental health and problematic mobile phone use network are linked through academic stress, psychological disequilibrium, and "depression without cell phones". Reducing the time spent on phone use and improving anxiety and depression can improve the mental health of middle school students and reduce the incidence of problematic cell phone use; helping middle school students to adjust to the stress of studying and improving their level of social support can reduce the severity of problematic mobile phone use.

Limitations and Perspectives

There are several limitations of this study that should be considered. First, the use of cross-sectional data and static networks in this study does not provide dynamic information and causal relationships between variables. Therefore, a longitudinal study could be conducted with the expectation of analyzing and comparing the network structure of middle school students' mental health and problematic mobile phone use at different points in time. Second, this study only explored the relationship between middle school students' mental health and problematic mobile phone use, ignoring the influence of personality, family, and other factors on problematic mobile phone use. Third, this study did not classify problematic mobile phone use, and there are differences in the treatments taken for different types of problematic cell phone use,[27] which can be further refined in the future with a view to providing ideas and methods for intervening in different types problematic cell phone use.

Data Sharing Statement

All data generated or analyzed during this study are included in this published article.

Ethics Approval and Consent to Participate

In this study, all methods were performed in accordance with the relevant guidelines and regulations. This survey protocol had been verified and approved by Xiamen Xiangyue Hospital Ethics Committee (approval number: 2019-KY -016). And written informed consents had been obtained from all the included participants.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests in this work.

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