Psychology Research and Behavior Management

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Food Intake and Mental Health Among Middle School Students in Shandong Province: A Network Analysis

Yisong Yao[1,*], Baoyi Liao[2,*], Jingjing Feng[2,*], Shiwei Tang[2], Ziyi Zhang[2], Dajun Yang[2], Xinrui Yin[2], Jiahong Xie[2], Ludan Yang[3], Wenwen Yin[3]

[1]Department of Otorhinolaryngology, Head and Neck Surgery, Yantai Yuhuangding Hospital Qingdao University, Yantai, People's Republic of China; [2]Sichuan Primary Health Care Research Center, North Sichuan Medical College, Nanchong, People's Republic of China; [3]Science and Technology College of Hubei University of Arts and Science, Hubei University of Arts and Science, Xiangyang, People's Republic of China

*These authors contributed equally to this work

Correspondence: Wenwen Yin, Science and Technology College of Hubei University of Arts and Science, Xiangyang, People's Republic of China, Email 460921982@qq.com

Purpose: A network analysis model was used to investigate the network structure linking food intake and mental health among middle school students in Shandong Province from a specific symptom perspective.

Methods: A total of 6179 middle school students aged 11–18 years in Shandong Province were included in the study. The modified Chinese Diet Quality Questionnaire (DQQ) and Symptom Check List 90 (SCL-90) were used to estimate the status of food intake and mental health, respectively. Network analysis was performed to explore the potential associations between food intake and mental health.

Results: The symptom with the highest strength was "Frequency of eating eggs in the last week (FI-9)". "Obsessive compulsive (SCL-2)" was the symptom with the highest bridge strength. "Obsessive compulsive (SCL-2)" and "Frequency of eating eggs in the last week (FI-9)" were the most strongly related (weight=0.09).

Conclusion: From a network analysis perspective, this study identified complex pathways of correlations between specific food intake such as eggs, fruits and the appearance of abnormal psychological symptoms such as anxiety, depressive, and obsessive-compulsive symptoms in middle school students. In the future, medical professionals may adopt appropriate interventions based on the centrality index and bridging centrality indicators identified in this study to effectively reduce the comorbidity of eating issues and poor mental health status in middle school students.

Keywords: food intake, middle school students, network analysis, mental health

Introduction

Adolescents are predisposed to the development of mental disorders.[1] Mental disorders are defined as conditions that result in impaired cognitive, emotional, behavioral, or volitional function, with varying degrees of impairment, including depression, anxiety, and obsessive-compulsive disorder, etc. According to the latest statistics, 252 million adolescents worldwide suffered from mental disorders in 2021, with a prevalence rate of 9.5%, accounting for 13% of the health burden in this age group.[2,3] The repercussions of the Covid-19 epidemic pandemic, in conjunction with unique academic pressures, social expectations, and cultural contexts, which collectively influence their mental health, have made adolescents among China a specific target population that cannot be overlooked.[4,5] The age-standardized prevalence of mental disorders among Chinese adolescents has been documented to be as high as 8.9%.[6] Mental disorders have become a leading cause of disability-adjusted life-years in Chinese adolescents, especially middle school students, ranking third after other major causes.[6] Consequently, there is important to investigate the factors that may influence the mental health of middle school students in China.

Received: 8 June 2025
Accepted: 21 August 2025
Published: 1 September 2025

A body of research has indicated that food intake represent a significant modifiable factor in the context of adolescents' mental health.[7] Decrease in the consumption of vegetables, fruits and frequent consumption of high-fat, high-sugar, high-sodium fast foods are associated with a notable elevation in the risk of depression and anxiety among adolescents.[8,9] A multitude of cross-sectional and prospective meta-analyses have further demonstrated that increased intake of ultra-processed, casual and ready-to-eat foods are associated with a subsequent risk of adverse mental health outcomes such as depression, anxiety and perceived stress.[10,11] Additionally, lower vegetable and oily fish intake, higher intake of high-sugar foods can also predict higher obsessive-compulsive symptoms.[12] Furthermore, it has been hypothesized that distinct food intake patterns may also influence personality traits and the risk of psychological symptoms among adolescents. For instance, adolescents who adhere to a Mediterranean diet are less likely to experience depressive symptoms.[13,14]

Differences in food intake lead to changes in nutrient intake (such as zinc, omega-3 fatty acids, magnesium, folate, copper, and manganese), which may contribute to the development of psychological symptoms such as anxiety or depressive symptoms.[15,16] Poor dietary habits that activate inflammation in the body are also important triggers for depressive symptoms.[17] Causing by excessive consumption of fatty and high-sugar foods, obesity is also often associated with dysregulated stress responses.[17] In addition, aberrant food intake behaviors frequently engender sentiments of guilt, discomfort, even low self-esteem and body image problems, which can not only influence the subjective experience of eating but also interact with negative emotions and pathological behaviors, thereby establishing a detrimental cycle that can ultimately result in various mental illnesses. Certain emotional temperaments (such as depressive or anxious temperaments) can also exacerbate the cycle.[18–20]

However, the majority of current explorations of the relationship between food intake and mental health among middle school students have been limited to one-on-one surveys and lack a more systematic assessment, while truly ignored a fine-grained understanding of the symptomatic level of the relationship between the two. Network analysis methods, grounded in graph theory, have emerged as a promising framework for elucidating the intricate interplay among multiple factors. These methods facilitate the construction of network diagrams, thereby enabling the identification of both core symptoms and the interconnections among symptom clusters.[21] The present study aims to utilize a graph theory-based network analysis method to examine the association between food intake and mental health among middle school students in Shandong Province, with a view to providing a theoretical basis for specific food intake and mental health among middle school students and guidance for further mechanistic studies. Based on this, this study proposed the hypothesis that.

H1: Food intake was associated with mental health of middle school students from Shandong Province.

Research Participants and Methods

Participants

The data for this study were primarily obtained from the Shandong University Database of Youth Health in Population Health Data Archive.[22] The database under scrutiny surveyed the health and health-related behaviors of 99,327 middle school students from 186 schools in 17 cities in Shandong Province. The sampling method employed was probability proportionate to size sampling to the total number of school years, namely 2015/2016, 2016/2017, 2017/2018, and 2020/2021. More detailed survey protocols was in previous literature.[23] The sample for this study was primarily drawn from the database for the 2020–2021 school year, in which 11,063 students were recruited. Following the exclusion of illogical samples and samples with missing food intake information, a total of 6179 participants were included in this study. Prior to participating in the survey, teachers, parents and students completed consent forms. The study was approved by the Ethics Committee of Shandong University (20180517). One of the authors was granted authorization to utilize the dataset in accordance with the stipulated regulations.

Measurements

General Socio-Demographic Characteristics

The general socio-demographic characteristics included gender, year of birth, ethnicity, family residential area, and parents' level of education.

Food Intake

In this study, we assessed the food intake content using the modified Chinese Diet Quality Questionnaire (DQQ), which has been shown to be a reliable instrument for evaluating the eating quality of children and adolescents in China.[23,24] DQQ comprises 29 food groups. Combined with previous literature and taking into account the fact that Shandong residents are less inclined to consume cheese products and cereals, we deleted cereal and cheese intake.[24] Consequently, the final version of the DQQ comprised 17 items, with individuals being asked to report the frequency of consumption of each food type during the previous week. Responses were then categorized into five levels, with a scale ranging from 1 to 5 representing "0 times", "1–2 times", "about once every two days", "about once a day", and "more than once a day". In this study, the Cronbach's α coefficient was 0.886.

Mental Health

In this study, we assessed mental health using Symptom Check List 90 (SCL-90), which is an instrument designed to screen for a wide range of mental problems.[25] SCL-90 comprises 90 entries and encompasses the following 10 psychological symptom traits: somatization (SCL-1), obsessive compulsive (SCL-2), interpersonal sensitivity (SCL-3), depression (SCL-4), anxiety (SCL-5), hostility (SCL-6), phobic anxiety (SCL-7), paranoid ideation (SCL-8), psychoticism (SCL-9), and other (SCL-10). The scale utilizes a Likert-5 scale, with 1–5 representing "not at all" to "extremely". The total score ranges from 90 to 450, with higher scores indicating more severe mental health problems in the past week. A total score surpassing 160 suggests the presence of a substantial mental health concern for the participants.[26] In this study, the Cronbach's α coefficient was 0.897.

Statistical Analyses

Statistical analyses were performed using SPSS 26.0. Network analyses were performed in R 4.2.2 (https://mirrors.ustc.edu.co.uk/CRAN/), including network construction, network estimation, network accuracy, and stability analysis. In this study SCL-1 to SCL-10 sequentially denoted the network nodes (nodes) corresponding to the 10 psychological symptom traits of the SCL-90, and the 17 entries of the DQQ were denoted by FI-1 to FI-17.

The R-qgraph (version 1.9.2) package was utilized for network visualization. Within the network, each node denoted a symptom, with edges representing the relationships between symptoms. The estimation of edge weighted within the network was achieved through the implementation of a graphical lasso model, which was optimized using the Extended Bayesian Information Criterion (EBIC).[27] The thickness of the edges in the network was indicative of the strength of the relationship between two nodes. The thickness of the edges was indicative of the strength of the relationship between the corresponding nodes. The correlation between nodes was indicated by the color of the edges (blue for positive correlation and red dashed line for negative correlation). The adjustment parameter was set to 0.5.

The centrality function in R-qgraph (version 1.9.2) was utilized to calculate the centrality indices: strength, closeness, betweenness, and expected influence (EI) to assess the importance of each node in the network.[28] Given the presence of both positive and negative correlations in the network analysis of this study, when strength, closeness, and betweenness were not sensitive, bridge expected influence (BEI) was not introduced in this study.[29] R-networktools (version 1.5.0) was used to calculate bridge centrality indices, including bridge strength, bridge betweenness, and bridge closeness. Bridging centrality was an extension of the centrality index, which was used to identify bridging nodes in the network.[30] Bridge centrality measured the role of a node in linking its network to other networks, assessing the strength and direction of a node's connections to other nodes.[31] In addition, the predictability of each node was evaluated using the R-mgm (version 1.2–13) software package. Nodes with high predictability were susceptible to the influence of nearby nodes.[29,31] In this study, centrality measures were reported as standardized values (z-scores). Bridging centrality was an extension of the centrality index, which was used to identify bridging nodes in the network.

To examine whether the accuracy of network estimation was affected by sample changes and whether the centrality index of the network structure was stable, the stability and accuracy of the network model were assessed using R-bootnet (version 1.5), where the Correlation Stability Coefficient (CS-C) was calculated to assess the stability of the network model.[32] A CS-C value above 0.25 is considered acceptable, and greater than 0.5 indicates good stability, with larger values indicating better stability.[33]

The Network Comparison Test (NCT) was performed using the R software Network Comparison Test package (version 1.5) to assess the differences in network structure between food intake and mental health among middle school students of various genders.[34] To ensure the reliability of the network edge weights, 95% confidence intervals (95% CI) were generated for each edge weight using a non-parametric bootstrap method. A narrower 95% CI signifies a higher degree of network edge weight accuracy.

Results

Participant Characteristics

A total of 6179 middle school students were included in this study. Of these, 2865 (46.4%) were males; 1531 (24.8%) were countryside. See Table 1 for details.

The mean total SCL-90 scale score was 138.40 ± 52.569, and the mean scores of the ten dimension scores ranged from 8.82 to 20.39; the detection rate of SCL-90-positive symptoms (total score > 160) was 27.9%. The mean, standard deviation, strength, closeness, betweenness, expected influence and predictability of all psychological symptoms are specified in Tables 2 and 3.

Network Structure

The symptom network of psychological symptoms and food intake in middle school students was shown in Figure 1. Among them, "Frequency of eating green leafy vegetables in the last week (FI-1)" and "Frequency of eating red and orange vegetables

Table 1 Demographic Characteristics of the Participants

Characteristics	N(%)
Gender	
Male	2865(46.4)
Female	3314(53.6)
Year of birth	
1998–2003	2261(36.6)
2004–2011	3709(60.0)
Unknown	209(3.4)
Ethnicity	
Han	6062(98.1)
Other	117(1.9)
Family residential area	
City/county center	2693(43.6)
Remote urban or urban-rural areas of the city/county	428(6.9)
City and countryside	1349(21.8)
Other cities/counties	178(2.9)
Countryside	1531(24.8)
Mother's education level	
Junior high and below	3732(60.4)
Secondary Vocational and High School	1556(25.2)
Specialist and above	891(14.4)
Father's education level	
Junior high and below	3255(52.7)
Secondary Vocational and High School	1813(29.3)
Specialist and above	1111(18.0)
Mental health	
Normal(<160)	4455(72.1)
Mild abnormality(160~225)	1287(20.8)
Marked abnormality(226~315)	369(6.0)
Serious abnormality(>315)	68(1.1)

Table 2 Descriptive Statistics of ten Psychological Symptoms

Node	Items	Scores (Mean ± Standard Deviation)	Strength[a]	Closeness[a]	Betweenness[a]	Expectedinfluence[a]	Predictability[b]
SCL-1	Somatization	17.28±6.842	−0.450	−0.517	−0.284	−0.738	0.776
SCL-2	Obsessive compulsive	17.69±6.862	−0.777	−0.449	−0.638	−0.713	0.811
SCL-3	Interpersonal sensitivity	14.62±6.169	0.969	0.731	1.135	0.694	0.872
SCL-4	Depression	20.39±8.817	0.770	0.550	−0.284	0.849	0.879
SCL-5	Anxiety	15.34±6.509	1.682	1.718	1.844	1.769	0.889
SCL-6	Hostility	8.82±3.800	−0.958	−1.362	−0.993	−0.896	0.765
SCL-7	Phobic anxiety	10.14±4.324	−1.659	−1.373	−0.993	−1.603	0.707
SCL-8	Paranoid ideation	8.90±3.674	0.307	0.972	1.135	0.381	0.847
SCL-9	Psychoticism	14.62±5.822	0.235	−0.036	−0.638	0.308	0.856
SCL-10	Other	10.90±4.481	−0.120	−0.234	−0.284	−0.050	0.808

Notes: [a]Standardized z-scores were used for use across all groups. [b]An index in network analysis, which indicates the extant of one nodes is affected by other nodes.

Table 3 Descriptive Statistics of Psychological Symptoms and Food Intake in Adolescents

Node	Items	Scores (Mean ± Standard Deviation)	Strength[a]	Closeness[a]	Betweenness[a]	Expected influence[a]	Predictability[b]
SCL-1	Somatization	17.28±6.842	−0.842	−1.015	−0.532	−1.056	0.779
SCL-2	Obsessive compulsive	17.69±6.862	−0.016	1.063	2.347	−0.417	0.819
SCL-3	Interpersonal sensitivity	14.62±6.169	0.665	0.232	0.165	1.271	0.874
SCL-4	Depression	20.39±8.817	0.165	−0.127	−0.532	1.292	0.880
SCL-5	Anxiety	15.34±6.509	1.076	−0.638	−0.392	2.202	0.889
SCL-6	Hostility	8.82±3.800	−1.511	−1.469	−0.579	−1.252	0.767
SCL-7	Phobic anxiety	10.14±4.324	−2.132	−1.135	−0.579	−1.565	0.711
SCL-8	Paranoid ideation	8.90±3.674	−0.101	−0.733	−0.181	0.354	0.848
SCL-9	Psychoticism	14.62±5.822	−0.340	−1.399	−0.556	0.442	0.856
SCL-10	Other	10.90±4.481	−0.807	−0.572	−0.275	0.307	0.808
FI-1	Frequency of eating green leafy vegetables in the last week	2.08±1.005	0.719	−0.143	−0.415	−0.510	0.465
FI-2	Frequency of eating red and orange vegetables in the last week	2.67±1.113	0.682	0.383	−0.134	0.995	0.546
FI-3	Frequency of eating potatoes in the last week	2.87±1.125	−1.648	−0.248	−0.579	−0.736	0.400
FI-4	Frequency of eating tubers in the last week	2.55±1.065	−0.415	−0.491	−0.579	0.190	0.474
FI-5	Frequency of eating fruits in the last week	3.29±1.208	1.099	1.558	0.662	0.942	0.543
FI-6	Frequency of eating soy products in the last week	2.34±1.133	−0.144	−0.624	−0.415	−1.006	0.375
FI-7	Frequency of eating fresh meats in the last week	2.91±1.125	−0.014	0.518	−0.462	0.734	0.495
FI-8	Frequency of eating seafood in the last week	2.47±1.079	0.989	1.098	0.029	−0.184	0.385
FI-9	Frequency of eating eggs in the last week	3.60±1.178	2.333	2.922	3.752	0.815	0.507
FI-10	Frequency of eating dairy in the last week	2.48±1.072	−0.876	−0.299	−0.579	−0.630	0.349

(*Continued*)

Table 3 (Continued).

Node	Items	Scores (Mean ± Standard Deviation)	Strength[a]	Closeness[a]	Betweenness[a]	Expected influence[a]	Predictability[b]
FI-11	Frequency of eating processed meats in the last week	2.35±1.094	−0.055	−0.396	−0.298	0.002	0.376
FI-12	Frequency of eating instant noodles in the last week	3.14±1.119	−0.496	−0.382	−0.251	−0.309	0.361
FI-13	Frequency of eating fast food in the last week	3.82±1.092	−0.362	0.435	−0.111	−2.217	0.394
FI-14	Frequency of eating sugared beverages in the last week	4.11±1.044	1.656	1.646	1.200	0.867	0.542
FI-15	Frequency of eating sugared or salted snacks or desserts in the last week	3.85±1.079	0.740	0.510	−0.064	0.577	0.568
FI-16	Frequency of eating fried foods in the last week	3.60±1.067	−0.045	−0.302	−0.579	−0.356	0.512
FI-17	Frequency of eating soy and meat in the last week	3.72±1.022	−0.320	−0.390	−0.509	−0.751	0.479

Notes: [a]Standardized z-scores were used for use across all groups. [b]An index in network analysis, which indicates the extant of one nodes is affected by other nodes.

in the last week (FI-2)" were the most strongly connected (weight=0.389), followed by "Frequency of eating fried foods in the last week (FI-16)" and "Frequency of eating soy and meat in the last week (FI-17)" and "Frequency of eating sugared or salted snacks or desserts in the last week (FI-15)". The marginal weights between the two were are roughly the same, 0.345 and 0.335, respectively. Within the relationship between psychological symptoms and food intake in middle school students,

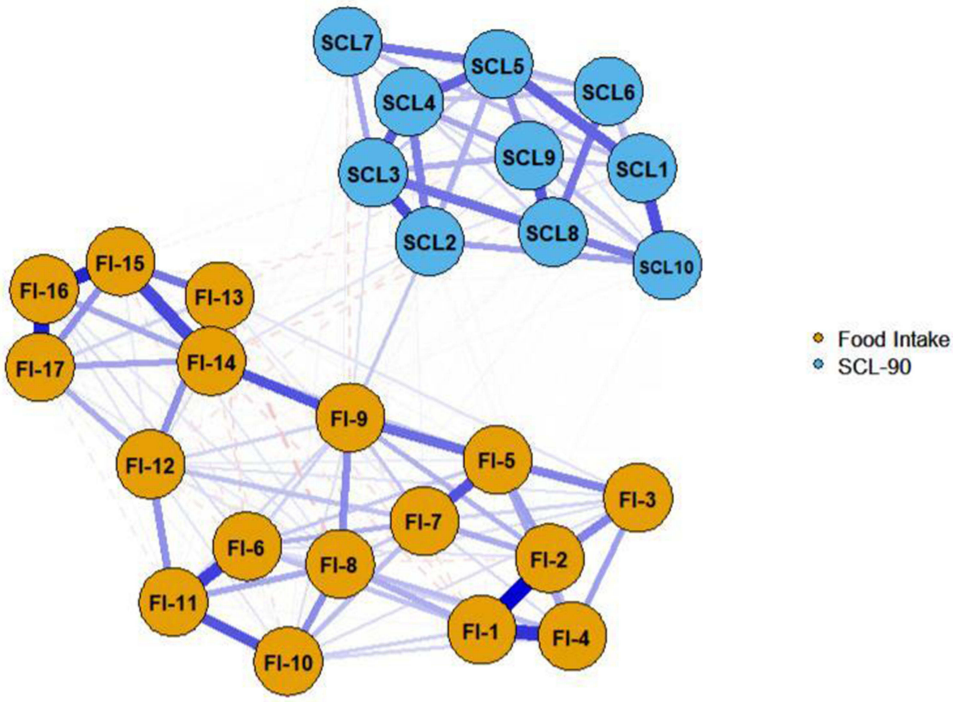

Figure 1 Symptom network of psychological symptoms and food intake in adolescents.

"Obsessive compulsive (SCL-2)" and "Frequency of eating eggs in the last week (FI-9)" were the most closely related (weight=0.09). This was followed by "Phobic anxiety (SCL-7)" and "Frequency of eating eggs in the last week (FI-9)" (weight=0.049). Symptom network connections were mainly centered on the ten psychological symptoms of the SCL-90 and the dimensions of food intake, such as "Obsessive compulsive (SCL-2)" and "Interpersonal sensitivity (SCL-3)", "Frequency of eating green leafy vegetables in the last week (FI-1)" versus "Frequency of eating red and orange vegetables last week (FI-2)". We made another symptom network diagram for the ten psychological symptoms of the SCL-90 to explore the effects of different psychological traits further, and the results were shown in Figure 2.

Centrality and Bridge Centrality

In the symptom network of psychological symptoms and food intake in middle school students, the node "Frequency of eating eggs in the last week" (FI-9) showed the highest strength, closeness, and betweenness, 2.332, 2.921, and 3.752, followed by "Frequency of eating fruit in the last week (FI-5)" and "Obsessive compulsive (SCL-2)". The highest expected influence was "Anxiety (SCL-5)", followed by "Depression (SCL-4)" and "Interpersonal sensitivity (SCL-3)". In the bridging network of psychological symptoms and food intake in middle school students, "Obsessive compulsive (SCL-2)" and "Frequency of eating eggs in the last week (FI-9)" were the most apparent bridge symptoms. The symptom with the highest bridge strength (ie, left panel) was "Obsessive compulsive (SCL-2)", followed by "Frequency of eating eggs in the last week (FI-9)", "Somatization (SCL-1)", and "Phobic anxiety (SCL-7)". See Figures 3 and 4 for details.

Network Accuracy and Stability

The stability of edge weights was tested by bootstrapping. After bootstrapping 1000 times, the symptom network shows high stability and accuracy. The relatively narrow 95% confidence interval range indicates that the estimation of edge weights in the network is relatively accurate and credible. And the structure of the network in this study was also more stable. In addition, the results of the non-parametric bootstrap analysis show that most of the comparisons between edge weights and centrality metrics are statistically significant. See Supplementary Figures 1–7 for details.

Network Comparisons

The results of the study showed no significant differences in network structure and overall strength across symptom networks for males and females (M = 0.109, $P = 0.063$; S = 0.207, $P = 0.516$), indicating a high degree of similarity between the networks being compared. See Figures 5, 6 and Supplementary Figures 8–11 for details.

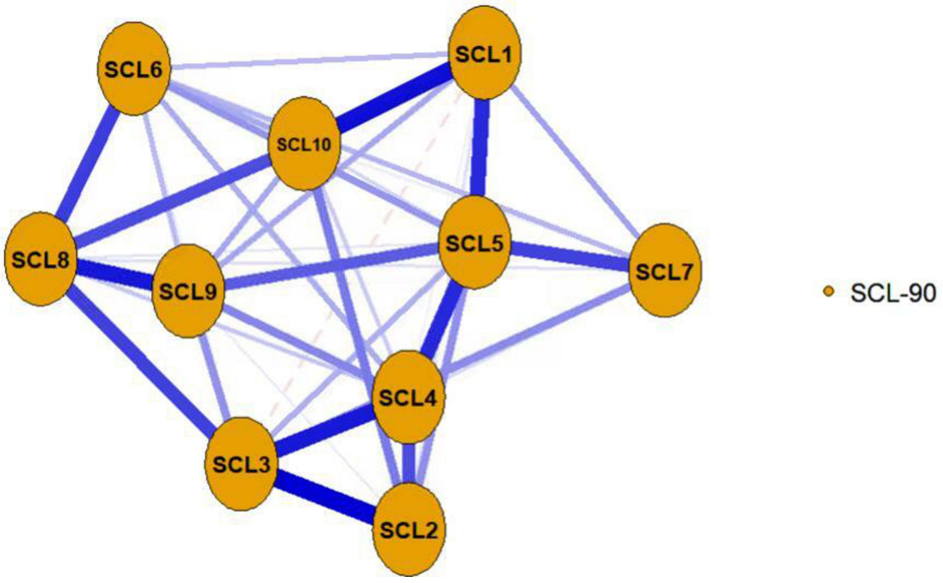

Figure 2 Symptom networks for the ten psychological symptoms in the SCL-90.

https://doi.org/10.2147/PRBM.S537043

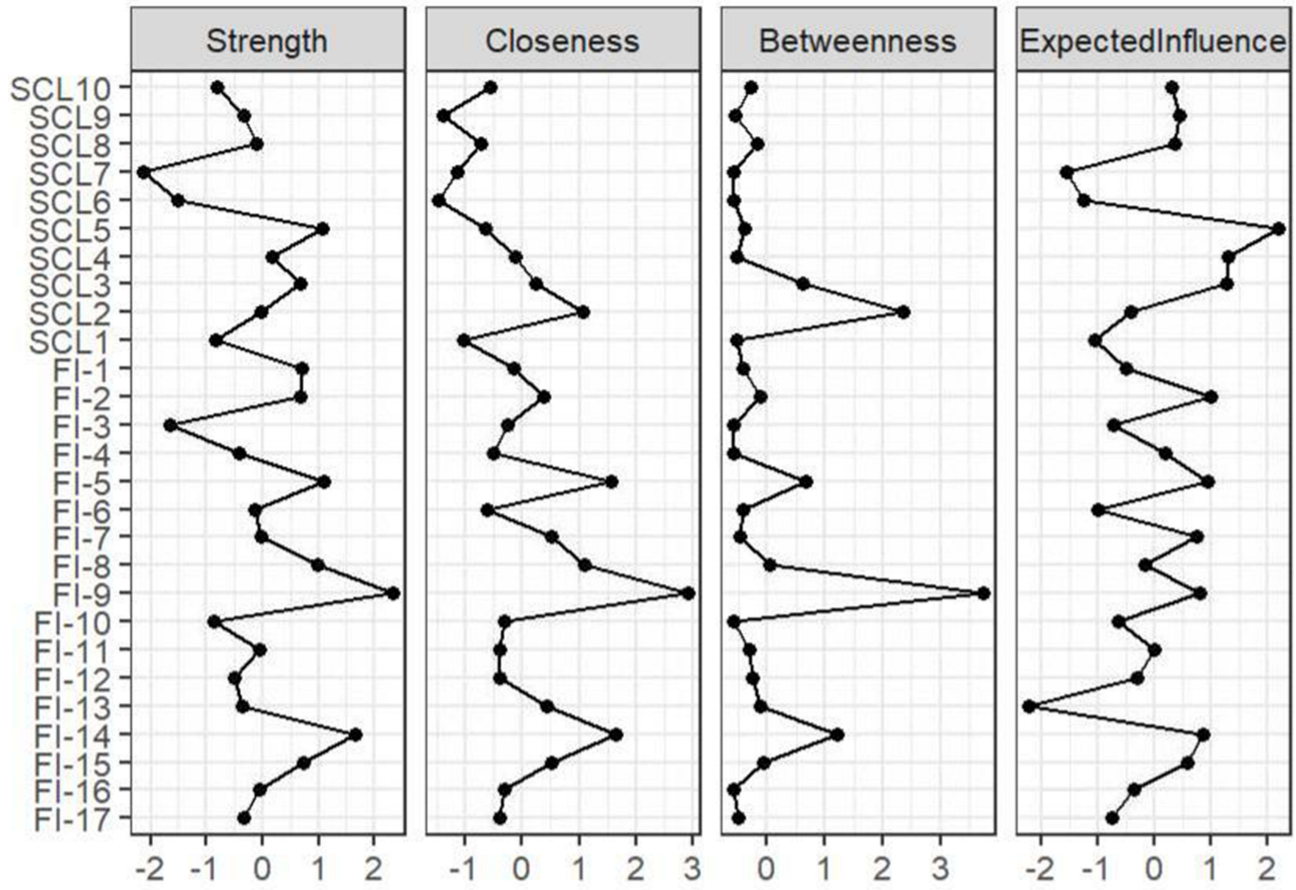

Figure 3 Centrality indicators of psychological symptoms and food intake in adolescents.

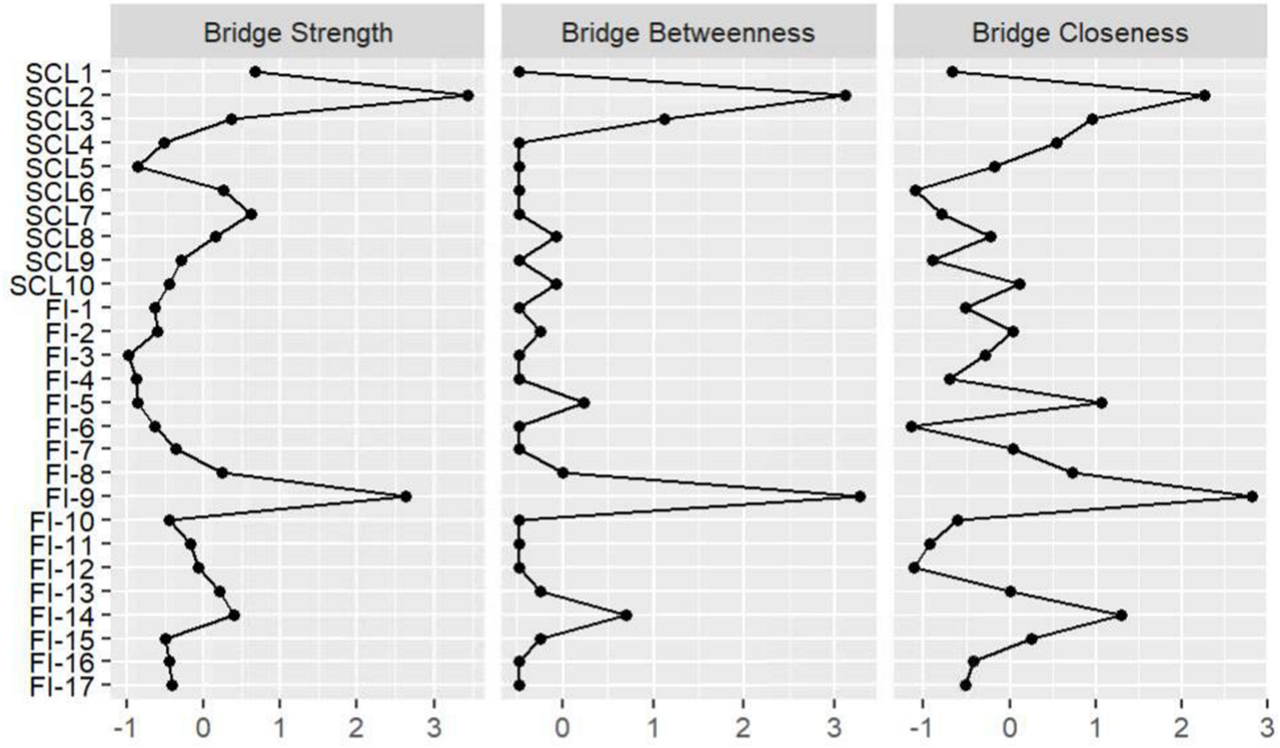

Figure 4 Indicators of bridging centrality of psychological symptoms and food intake in adolescents.

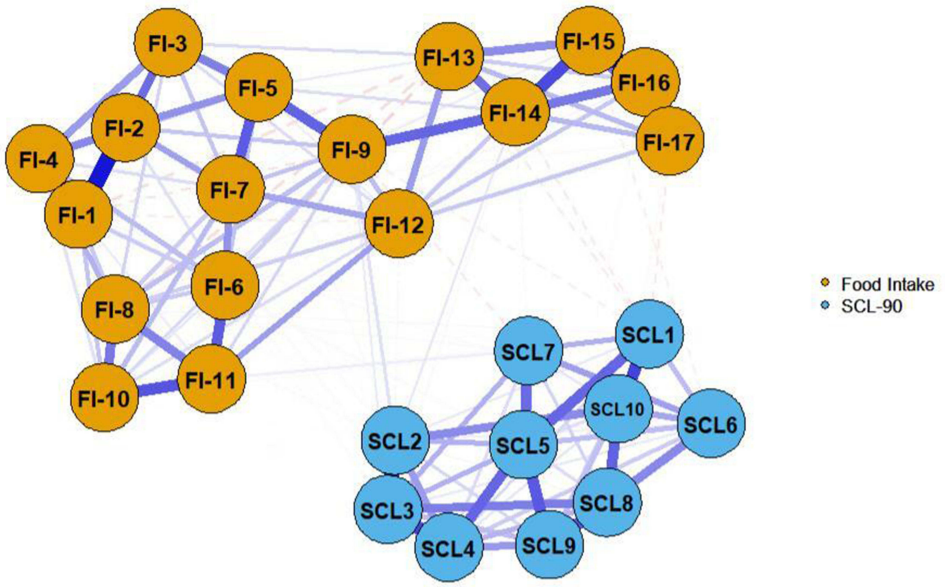

Figure 5 Symptom network for psychological symptoms and food intake (males).

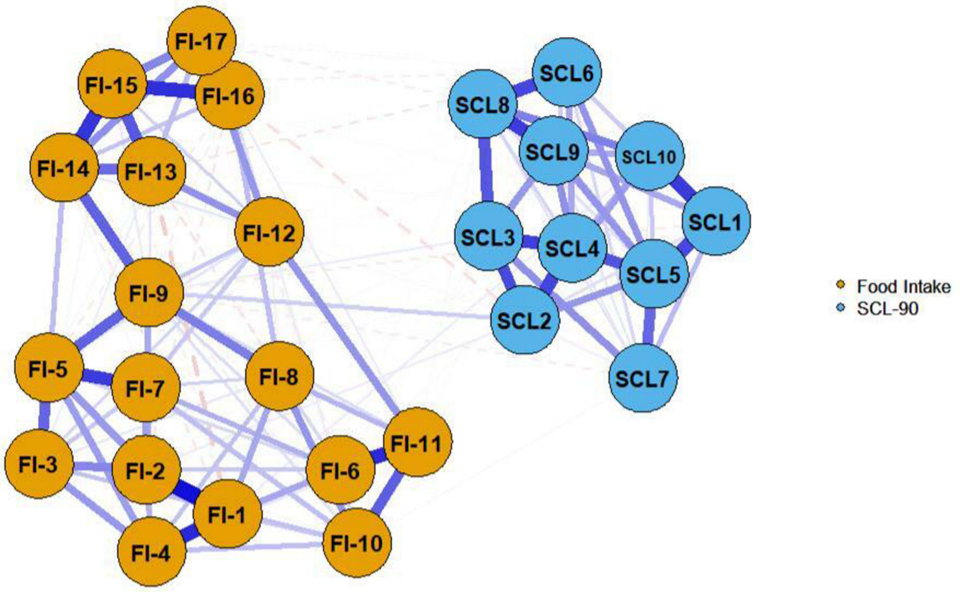

Figure 6 Symptom network of psychological symptoms and food intake (females).

Discussion

A large body of previous research has confirmed the association between food intake and mental health.[35–37] Building on this foundation, the present study adopted a network analysis approach to explore the complex and interconnected relationships between food intake and psychological symptoms among adolescents. The intention of network analysis is not to present the traditional odds ratios, but rather to identify connections between a myriad of variables. In our networks, "Frequency of eating eggs in the last week" was centrally located in both unadjusted and adjusted networks and either directly or indirectly connected with mental health and other food intake behaviors in a sample of adolescents from the Shandong Province. We found a small but positive association between obsessive-compulsive symptoms and "Frequency of eating eggs" score. Additionally, anxiety symptoms and obsessive-compulsive symptoms were inversely

https://doi.org/10.2147/PRBM.S537043

linked by egg intake. Contrary to previous findings,[38–40] we did not find associations between vegetable intake or and symptoms of depression and anxiety or a relationship between depressive symptoms scores and other psychological symptoms. This discrepancy may be attributed to the self-reported nature of the current survey, where potential cross-cultural variations in the conceptualization of "vegetables" between Eastern and Western populations could have influenced the results. Additionally, traditional Chinese culinary practices predominantly employ stir-frying and pan-frying methods for vegetable preparation, which may alter the nutritional properties and functional efficacy of vegetables compared to raw or steamed preparations commonly emphasized in Western dietary patterns. However, these results should be interpreted with caution, given the limitations of our study design and the possibility of reverse causality. Future studies should incorporate objective assessment methods, including biomarker analysis, to obtain more precise measurements of dietary intake. This approach will enable a more rigorous investigation of the mechanisms through which specific dietary components influence overall mental health via targeted psychological symptoms. History of mental health symptoms and physiological health may likewise influence daily dietary choices, BMI, and adolescent's ability to adjust to the nutrient demands of growth and development.[40] Our study adopts a comprehensive dietary pattern approach rather than examining isolated nutrients, investigating how habitual food intake may influence overall mental health status through its effects on specific psychological symptom domains. This paradigm enables more precise dietary modification strategies for adolescents, ultimately facilitating holistic mental health improvement.

Characteristics of Food Intake in Adolescents

When exploring the additional role of food intake in mental health problems among adolescents, their interplay warrants diligent detangling. Strategically, we used food intake frequency to reflect various food intake to explore how they might relate to adolescents' mental health. In the current food intake network structure, the variables ranked by descending edge weight are frequency of eating vegetables in the last week, frequency of eating fried in the last week, frequency of eating soy and meat in the last week, and frequency of eating snacks or desserts with added sugar or salt in the last week. Contrary to previous survey findings,[41,42] adolescents in the current study reported a higher average frequency of consuming processed and pre-packaged foods compared to fresh foods such as fruits and vegetables. This dietary pattern may be attributed to multiple factors. On the one hand, adolescents' eating behaviors are often influenced by parental or school regulations. During weekdays, many adolescents are required to bring meals from home or eat in school canteens.[43] These meals typically consist of pre-packaged or processed foods due to their convenience in storage and reheating. Concurrently, convenience emerges as a predominant motivational factor in adolescents' food selection behaviors, which may partially account for their heightened consumption of processed and pre-prepared food products.[44] On the other hand, the consumption of sugar-fat mixtures and sugar-sweetened beverages can lead to rapid increases in blood glucose levels, which in turn elicit pleasurable sensations.[45] Adolescents are particularly vulnerable to these rewarding effects, making such foods especially difficult for them to resist.[46] High sugar/fat foods hyperstimulate the mesolimbic dopamine pathway, particularly the nucleus accumbens, reinforcing compulsive eating behaviors.[47] The adolescent brain shows heightened dopaminergic sensitivity, increasing susceptibility to addictive-like eating patterns.[48] Meanwhile, sugar transiently suppresses cortisol, offering stress relief.[49] Emotional factors exert a measurable impact on food selection and consumption behaviors among adolescents,[44] this will increase the frequency of eating among teenagers who are under great academic pressure. Previous studies have shown that specific unhealthy dietary patterns can negatively impact physical health; for example, high sugar intake is a known risk factor for the development of diabetes.[37] In the bridging network of psychiatric symptoms and food intake in adolescents, "obsessive-compulsive symptoms (SCL-2)" and "frequency of eating eggs in the last week (FI-9)" were the most apparent bridge symptoms. This has not been identified in previous research.[41] At the same time, no gender differences were observed among adolescents in Shandong within the framework of this neural network model.

The Relationship Between Atypical Eating Behaviors and Psychological Symptoms

In the current network structure, we identified a relationship between egg intake and obsessive-compulsive symptoms, anxiety symptoms, and depressive symptoms. Additionally, fruit intake was found to be associated with "anxiety symptoms", "depressive symptoms" and "interpersonal sensitivity". Consistent with previous study,[50] these four symptoms play a crucial role in the

activation and maintenance of the pathological network of mental health. In other words, the intake of eggs and fruits is associated with a complex relationship with the mental health of adolescents.

The physiological mechanisms underlying the impact of egg and fruit intake on mental health are rather complex. They can be explained roughly from the following aspects. On the one hand, eggs are rich in choline, a precursor for acetylcholine (ACh) and phospholipids, critical for memory, learning, and mood regulation.[50] The adolescent brain has heightened synaptic plasticity, increasing choline demand; deficiency may impair cognition or mood stability.[51] On the other hand, eggs contain tryptophan, a precursor for serotonin (5-HT), which promotes emotional stability and reduces the risk of anxiety symptoms and depressive symptoms.[52] Meanwhile, choline in eggs is a precursor for acetylcholine (ACh), which modulates basal ganglia function. Obsessive-compulsive symptoms is linked to dysregulation in basal ganglia-cortical circuits, and choline supplementation might stabilize these pathways.[53] Meanwhile, vitamin D in egg yolk may reduce neuroinflammation and modulate BDNF, potentially correcting Obsessive-compulsive symptoms-related circuit dysfunction.[54] In some studies, the vitamin D levels of patients with obsessive-compulsive symptoms are lower than those of the general population. Some studies show that fruit intake is related to mental health conditions.[38,55,56] The adolescent brain has high oxidative metabolic activity, fruits are rich in polyphenols and vitamins, which reduce oxidative stress in the hippocampus.[57] Therefore, fruits can protect the cognitive functions of teenagers whose brains have high oxidative metabolic activity. Folate in citrus fruits aids homocysteine (a neurotoxin) breakdown; elevated levels are linked to depressive symptoms and cognitive decline.[58] Magnesium in fruits modulate NMDA receptors (preventing glutamate overexcitation) and neuronal resting potential, alleviating anxiety and insomnia.[59]

Furthermore, both obsessive-compulsive symptoms and rigid eating behaviors may be influenced by temperamental predispositions or internalized guilt associated with food intake. Our findings potentially extend beyond mere nutritional effects, suggesting underlying vulnerabilities in emotional processing and behavioral regulation. Specifically, the results indicate that dietary patterns may modulate overall mental health status through their effects on specific psychological symptom clusters. While our network analysis revealed significant associations between psychological symptoms and specific dietary patterns, these relationships may be partially mediated by latent temperamental characteristics and internalized food-related guilt,[19,20] consistent with established findings in adolescent populations.[60] Future studies should assess these psychological constructs to clarify whether the observed links are direct or mediated by latent emotional regulation mechanisms.

There is still several limitations in this study. First, this was a cross-sectional study that was unable to determine a causal relationship between food intake and mental health. Therefore, in the future, we need to design longitudinal cohort studies that can elucidate causal relationships. Second, frequency of intake of a particular food cannot fully summarize food intake. In the future, food intake should be assessed more comprehensively, including the amount of food intake and the frequency of food intake. Third, the current study primarily relied on self-assessment questionnaires, potentially introducing recall bias or response bias. We propose that future research endeavors develop more comprehensive assessment tools.

Conclusion

This study applied network analysis to identify core symptoms and bridge symptoms in the network of food intake and mental health among middle school students in Shandong Province. Daily food choices affect the psychological symptoms of middle school students. The intake of key foods, such as eggs and fruits, may be associated with the appearance of abnormal psychological symptoms such as anxiety, depression, and obsessive-compulsive symptoms in middle school students. Through this study, we found that there may be vulnerable nodes or treatment targets in students' mental health. Food intake behavior may serve as a behavioral marker of psychological distress or regulatory difficulties. Intervening in students' abnormal eating behaviors may improve their abnormal mental health status.

Ethical

Prior to participating in the survey, teachers, parents and students completed consent forms. The study was approved by the Ethics Committee of Shandong University (20180517). One of the authors was granted authorization to utilize the dataset in accordance with the stipulated regulations.

According to Article 32, Items 1 and 2 of the "Ethical Review Measures for Life Science and Medical Research Involving Human Subjects" issued on February 18, 2023, in China:

1. Item 1: Research involving human subjects that only uses de-identified data from public databases and does not involve direct information related to individuals may generally be exempt from ethical review.
2. Item 2: If the research data come from a project that has obtained informed consent and the use of the data conforms to the scope of the original informed consent, it may also be considered exempt from ethical review.

Therefore, our research meets the criteria outlined above and can be exempt from further ethical review.

Acknowledgments

We would like to express our sincere gratitude to the Population Health Data Archive for providing valuable data, which can be accessed at https://www.ncmi.cn./index.html.

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.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Piao J, Huang Y, Han C, et al. Alarming changes in the global burden of mental disorders in children and adolescents from 1990 to 2019: a systematic analysis for the global burden of disease study. *Eur Child Adolesc Psychiatry*. 2022;31(11):1827–1845. doi:10.1007/s00787-022-02040-4
2. GBD 2021 Diseases and Injuries Collaborators. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the global burden of disease study 2021. *Lancet*. 2024;403(10440):2133–2161. doi:10.1016/S0140-6736(24)00757-8
3. World Health Organization. Adolescent mental health [homepage on the Internet] Geneva: World Health Organization. 2021. Available from: https://www.who.int/news-room/fact-sheets/detail/adolescent-mental-health. Accessed April 26, 2025.
4. Santomauro DF, Mantilla Herrera AM, Shadid J, COVID-19 Mental Disorders Collaborators. Global prevalence and burden of depressive and anxiety disorders in 204 countries and territories in 2020 due to the COVID-19 pandemic. *Lancet*. 2021;398(10312):1700–1712. doi:10.1016/S0140-6736(21)02143-7
5. Mudunna C, Weerasinghe M, Tran T, et al. Nature, prevalence and determinants of mental health problems experienced by adolescents in south Asia: a systematic review. *Lancet Reg Health Southeast Asia*. 2025;33:100532. doi:10.1016/j.lansea.2025.100532
6. Dong W, Liu Y, Bai R, Zhang L, Zhou M. The prevalence and associated disability burden of mental disorders in children and adolescents in China: a systematic analysis of data from the global burden of disease study. *Lancet Reg Health West Pac*. 2025;55:101486. doi:10.1016/j.lanwpc.2025.101486
7. Skinner J, Jebeile H, Burrows T. Food addiction and mental health in adolescents: a systematic review. *Lancet Child Adolesc Health*. 2021;5(10):751–766. doi:10.1016/S2352-4642(21)00126-7
8. Liu MW, Chen QT, Towne SD Jr, et al. Fruit and vegetable intake in relation to depressive and anxiety symptoms among adolescents in 25 low- and middle-income countries. *J Affect Disord*. 2020;261:172–180. doi:10.1016/j.jad.2019.10.007
9. Tang WK, Lee JC. Association of fast-food intake with depressive and anxiety symptoms among young adults: a pilot study. *Nutrients*. 2024;16(19):3317. doi:10.3390/nu16193317
10. Lane MM, Gamage E, Travica N, et al. Ultra-processed food consumption and mental health: a systematic review and meta-analysis of observational studies. *Nutrients*. 2022;14(13):2568. doi:10.3390/nu14132568
11. Liu C, Xie B, Chou CP, et al. Perceived stress, depression and food consumption frequency in the college students of China Seven Cities. *Physiol Behav*. 2007;92(4):748–754. doi:10.1016/j.physbeh.2007.05.068
12. Brierley ME, Albertella L, Christensen E, et al. Lifestyle risk factors for obsessive-compulsive symptoms and related phenomena: what should lifestyle interventions target? *Aust N Z J Psychiatry*. 2023;57(3):379–390. doi:10.1177/00048674221085923
13. Dalnoki L, Hurks PPM, Gubbels JS, Eussen SJPM, Mommers M, Thijs C. Exploring the relationship of dietary intake with inattention, hyperactivity, and impulsivity, beyond ADHD. *J Atten Disord*. 2025;29(1):70–79. doi:10.1177/10870547241293946
14. Alfaro-González S, Garrido-Miguel M, Martínez-Vizcaíno V, López-Gil JF. Mediterranean dietary pattern and psychosocial health problems in spanish adolescents: the EHDLA study. *Nutrients*. 2023;15(13):2905. doi:10.3390/nu15132905

15. Jacka FN, Maes M, Pasco JA, Williams LJ, Berk M. Nutrient intakes and the common mental disorders in women. *J Affect Disord*. 2012;141(1):79–85. doi:10.1016/j.jad.2012.02.018
16. Nakamura M, Miura A, Nagahata T, Shibata Y, Okada E, Ojima T. Low zinc, copper, and manganese intake is associated with depression and anxiety symptoms in the Japanese working population: findings from the eating habit and well-being study. *Nutrients*. 2019;11(4):847. doi:10.3390/nu11040847
17. Kiecolt-Glaser JK, Derry HM, Fagundes CP. Inflammation: depression fans the flames and feasts on the heat. *Am J Psychiatry*. 2015;172(11):1075–1091. doi:10.1176/appi.ajp.2015.15020152
18. Chu DT, Minh Nguyet NT, Nga VT, et al. An update on obesity: mental consequences and psychological interventions. *Diabetes Metab Syndr*. 2019;13(1):155–160. doi:10.1016/j.dsx.2018.07.015
19. Raffone F, Atripaldi D, Barone E, et al. Exploring the role of guilt in eating disorders: a pilot study. *Clin Pract*. 2025;15(3):56. doi:10.3390/clinpract15030056
20. Favaretto E, Bedani F, Brancati GE, et al. Synthesising 30 years of clinical experience and scientific insight on affective temperaments in psychiatric disorders: state of the art. *J Affect Disord*. 2024;362:406–415. doi:10.1016/j.jad.2024.07.011
21. Borsboom D, Cramer AO. Network analysis: an integrative approach to the structure of psychopathology. *Annu Rev Clin Psychol*. 2013;9:91–121. doi:10.1146/annurev-clinpsy-050212-185608
22. Shandong University Database of Youth Health. Population health data archive[homepage on the Internet]. Available from: https://www.ncmi.cn/phda/dataDetails.do?id=CSTR:17970.11.A0031.202107.209.V1.0. Accessed July 19, 2022.
23. Zhang SF, Luo W, Dong XS, et al. A dataset on the status quo of health and health-related behaviors of chinese youth: a longitudinal large-scale survey in the secondary school students of Shandong Province. *Chin Med Sci J*. 2022;37(1):60–66. doi:10.24920/004051
24. Wang H, Herforth AW, Xi B, Zou Z. Validation of the diet quality questionnaire in Chinese children and adolescents and relationship with pediatric overweight and obesity. *Nutrients*. 2022;14(17):3551. doi:10.3390/nu14173551
25. Yu Y, Wan C, Huebner ES, Zhao X, Zeng W, Shang L. Psychometric properties of the symptom check list 90 (SCL-90) for Chinese undergraduate students. *J Ment Health*. 2019;28(2):213–219. doi:10.1080/09638237.2018.1521939
26. Zhuang SM, Chen F. Chinese adolescents and youth with methamphetamine dependence: prevalence and concurrent psychological problems. *Nurs Res*. 2016;65(2):117–124. doi:10.1097/NNR.0000000000000141
27. Mei Q, Li C, Yin Y, Wang Q, Wang Q, Deng G. The relationship between the psychological stress of adolescents in school and the prevalence of chronic low back pain: a cross-sectional study in China. *Child Adolesc Psychiatr Ment Health*. 2019;13:24. doi:10.1186/s13034-019-0283-2
28. Liu R, Chen X, Qi H, et al. Network analysis of depressive and anxiety symptoms in adolescents during and after the COVID-19 outbreak peak. *J Affect Disord*. 2022;301:463–471. doi:10.1016/j.jad.2021.12.137
29. Robinaugh DJ, Millner AJ, McNally RJ. Identifying highly influential nodes in the complicated grief network. *J Abnorm Psychol*. 2016;125(6):747–757. doi:10.1037/abn0000181
30. Jones PJ, Ma R, McNally RJ. Bridge centrality: a network approach to understanding comorbidity. *Multivariate Behav Res*. 2021;56(2):353–367. doi:10.1080/00273171.2019.1614898
31. Foygel R, Drton M. Extended Bayesian information criteria for Gaussian graphical models. *Adv Neural Inf Process Syst*. 2010;23:604–612.
32. Onnela JP, Saramäki J, Hyvönen J, et al. Structure and tie strengths in mobile communication networks. *Proc Natl Acad Sci U S A*. 2007;104(18):7332–7336. doi:10.1073/pnas.0610245104
33. Bai W, Cai H, Liu S, et al. Anxiety and depressive symptoms in college students during the late stage of the COVID-19 outbreak: a network approach. *Transl Psychiatry*. 2021;11(1):638. doi:10.1038/s41398-021-01738-4
34. Ding L, Ren X, Sun Y, Yu C, Li G, Wang C. Network analysis of association between problematic social network use and alexithymia in freshmen. *Psychol Res Behav Manag*. 2024;17:3503–3514. doi:10.2147/PRBM.S472799
35. Arab A, Karimi E, Garaulet M, Scheer FAJL. Social jetlag and dietary intake: a systematic review. *Sleep Med Rev*. 2023;71:101820. doi:10.1016/j.smrv.2023.101820
36. Muth AK, Park SQ. The impact of dietary macronutrient intake on cognitive function and the brain. *Clin Nutr*. 2021;40(6):3999–4010. doi:10.1016/j.clnu.2021.04.043
37. Dakanalis A, Mentzelou M, Papadopoulou SK, et al. The association of emotional eating with overweight/obesity, depression, anxiety/stress, and dietary patterns: a review of the current clinical evidence. *Nutrients*. 2023;15(5):1173. doi:10.3390/nu15051173
38. Głąbska D, Guzek D, Groele B, Gutkowska K. Fruit and vegetables intake in adolescents and mental health: a systematic review. *Rocz Panstw Zakl Hig*. 2020;71(1):15–25. doi:10.32394/rpzh.2019.0097
39. Chen H, Cao Z, Hou Y, Yang H, Wang X, Xu C. The associations of dietary patterns with depressive and anxiety symptoms: a prospective study. *BMC Med*. 2023;21(1):307. doi:10.1186/s12916-023-03019-x
40. Guzek D, Głąbska D, Groele B, Gutkowska K. Role of fruit and vegetables for the mental health of children: a systematic review. *Rocz Panstw Zakl Hig*. 2020;71(1):5–13. doi:10.32394/rpzh.2019.0096
41. Lassale C, Batty GD, Baghdadli A, et al. Healthy dietary indices and risk of depressive outcomes: a systematic review and meta-analysis of observational studies. *Mol Psychiatry*. 2019;24(7):965–986. doi:10.1038/s41380-018-0237-8
42. Ge L, Sadeghirad B, Ball GDC, et al. Comparison of dietary macronutrient patterns of 14 popular named dietary programmes for weight and cardiovascular risk factor reduction in adults: systematic review and network meta-analysis of randomised trials [published correction appears in BMJ. 2020 Aug 5;370:m3095. doi: 10.1136/bmj.m3095.]. *BMJ*. 2020;369:m696. doi:10.1136/bmj.m696
43. Yang C, Pan X, Zhao Y, Wang X, Wang Z, Ren X. Snacking behaviour and nutrients intake among 11–16 years-old students from two different boarding system schools. *Heliyon*. 2023;9(3):e14517. doi:10.1016/j.heliyon.2023.e14517
44. Konttinen H, Halmesvaara O, Fogelholm M, Saarijärvi H, Nevalainen J, Erkkola M. Sociodemographic differences in motives for food selection: results from the LoCard cross-sectional survey. *Int J Behav Nutr Phys Act*. 2021;18(1):71. doi:10.1186/s12966-021-01139-2
45. Ludwig DS, Ebbeling CB. The carbohydrate-insulin model of obesity: beyond "calories in, calories out". *JAMA Intern Med*. 2018;178(8):1098–1103. doi:10.1001/jamainternmed.2018.2933
46. Reichelt AC. Adolescent maturational transitions in the prefrontal cortex and dopamine signaling as a risk factor for the development of obesity and high fat/high sugar diet induced cognitive deficits. *Front Behav Neurosci*. 2016;10:189. doi:10.3389/fnbeh.2016.00189

47. DiFeliceantonio AG, Coppin G, Rigoux L, et al. Supra-additive effects of combining fat and carbohydrate on food reward. *Cell Metab*. 2018;28(1):33–44.e3. doi:10.1016/j.cmet.2018.05.018
48. Lin WC, Liu C, Kosillo P, et al. Transient food insecurity during the juvenile-adolescent period affects adult weight, cognitive flexibility, and dopamine neurobiology. *Curr Biol*. 2022;32(17):3690–3703.e5. doi:10.1016/j.cub.2022.06.089
49. Mor A, Kayacan Y, Ipekoglu G, Arslanoglu E. Effect of carbohydrate-electrolyte consumption on insulin, cortisol hormones and blood glucose after high-intensity exercise. *Arch Physiol Biochem*. 2019;125(4):344–350. doi:10.1080/13813455.2018.1465098
50. Borsboom D. A network theory of mental disorders. *World Psychiatry*. 2017;16(1):5–13. doi:10.1002/wps.20375
51. Bragg MG, Prado EL, Caswell BL, et al. The association between plasma choline, growth and neurodevelopment among Malawian children aged 6–15 months enroled in an egg intervention trial. *Matern Child Nutr*. 2023;19(2):e13471. doi:10.1111/mcn.13471
52. Peganova S, Hirche F, Eder K. Requirement of tryptophan in relation to the supply of large neutral amino acids in laying hens. *Poult Sci*. 2003;82(5):815–822. doi:10.1093/ps/82.5.815
53. Obeid R, Karlsson T. Choline - a scoping review for nordic nutrition recommendations 2023. *Food Nutr Res*. 2023;67:10.29219/fnr.v67.10359. doi:10.29219/fnr.v67.10359
54. Quialheiro A, Moreira JD, Xavier AJ, Peres MA, Peres MA. The association between vitamin D and BDNF on cognition in older adults in Southern Brazil. *Rev Saude Publica*. 2023;56:109. doi:10.11606/s1518-8787.2022056004134
55. Kakutani N, Yokota T, Fukushima A, et al. Impact of citrus fruit intake on the mental health of patients with chronic heart failure. *J Cardiol*. 2022;79(6):719–726. doi:10.1016/j.jjcc.2021.12.004
56. Dabravolskaj J, Marozoff S, Maximova K, Campbell S, Veugelers PJ. Relationship between fruit and vegetables intake and common mental disorders in youth: a systematic review. *Public Health Rev*. 2022;43:1604686. doi:10.3389/phrs.2022.1604686
57. Li L, Li WJ, Zheng XR, et al. Eriodictyol ameliorates cognitive dysfunction in APP/PS1 mice by inhibiting ferroptosis via vitamin D receptor-mediated Nrf2 activation. *Mol Med*. 2022;28(1):11. doi:10.1186/s10020-022-00442-3
58. Galluzzi S, Marizzoni M, Gatti E, et al. Citrus supplementation in subjective cognitive decline: results of a 36-week, randomized, placebo-controlled trial. *Nutr J*. 2024;23(1):135. doi:10.1186/s12937-024-01039-8
59. Boyle NB, Lawton C, Dye L. The effects of magnesium supplementation on subjective anxiety and stress-a systematic review. *Nutrients*. 2017;9(5):429. doi:10.3390/nu9050429
60. Daly AN, Kearney JM, O'Sullivan EJ. The underlying role of food guilt in adolescent food choice: a potential conceptual model for adolescent food choice negotiations under circumstances of conscious internal conflict. *Appetite*. 2024;192:107094. doi:10.1016/j.appet.2023.107094