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Dietary Micronutrient Intake and Its Associations with Memory Function, Mental Health, and Sleep Quality among Medical University Students: A Network Analysis

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Abstract

Objective: Micronutrient deficiencies among university students may adversely influence their sleep quality, mental health, and memory function. The overarching purpose of this study was to evaluate the associations between dietary micronutrient intake and memory performance, mental health, and sleep quality among medical university students.
Method: This was a cross-sectional study conducted on a sample of 985 university students. The Food Frequency Questionnaire, Prospective & Retrospective Memory Questionnaire, Depression, Anxiety and Stress Scale-21, and Pittsburgh Sleep Quality Inventory were used to assess dietary intake, memory function, mental health, and sleep quality, respectively. An undirected network was constructed via the EBICglasso model, and a directed acyclic graph was developed employing a Bayesian network.
Results: The average age of the students was 22.44 ± 1.95 years. Among these participants, 500 (50.76%) were female and 485 (49.24%) were male. Assessments showed that 485 (49.20%) participants had depression symptoms, 490 (49.70%) had anxiety symptoms, 620 (62.90%) had stress, and 535 (54.30%) experienced sleep disturbances based on the cut-off scores of the questionnaires. Network analyses identified zinc, magnesium, B-group vitamins, vitamin D, and vitamin C as central nodes related to mental health, memory function, and sleep quality.
Conclusion: Zinc, magnesium, vitamin B2, vitamin D, and vitamin C emerged as key micronutrients associated with mental health, memory function, and sleep quality. These micronutrients represent promising targets for future clinical studies.

Key words: *Diet; Memory; Mental Health; Prevalence; Sleep Quality; Students*

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Depression, anxiety, and stress, as well as sleep disturbances, are prevalent among university students. These conditions can impair cognitive functions such as concentration, attention, and memory performance, particularly working memory, and are linked to reduced academic performance among this population. Working memory is a form of short-term memory vital for students' learning efficacy and test performance (1-4). Moreover, lifestyle factors, such as diet quality, physical activity, and sleep hygiene, along with other factors like social support, academic pressure, financial stress, and parental separation, influence the mental health of undergraduates (5). However, university students often face challenges in adhering to a well-balanced diet that incorporates healthy fats, fruits, vegetables, and whole grains. Financial constraints, time pressures, and adjustment to new living environments often lead to increased consumption of calorie-rich, low-nutrient foods (Westernized dietary patterns). Consequently, students may suffer from deficiencies in essential micronutrients, including vitamins and minerals, which may negatively impact both their mental health and academic performance (6).

Westernized dietary habits have resulted in an excessive intake of macronutrients alongside relative micronutrient deficiencies. Micronutrients, including vitamins and minerals, are necessary for cognitive abilities, mental well-being, and healthy sleep. Recent studies highlight the importance of specific micronutrients, such as zinc, magnesium, iron, and vitamins D, E, C, B3, B6, B9, and B12, in supporting cognitive function, mental health, and sleep quality (7-10). Vitamin D affects mental health through neurotransmitter regulation, anti-inflammatory action, immune modulation, neuroprotective effects, and hypothalamic-pituitary-adrenal axis regulation, as well as by regulating sleep-wake and circadian rhythms. Zinc also contributes to neurotransmitter coordination, neurogenesis, and antioxidant activity (7, 8). The B-group vitamins (thiamine, B1; riboflavin, B2; niacin, B3; pantothenic acid, B5; pyridoxine, B6; biotin, B7; folate, B9; and cyanocobalamin, B12) are vital for preserving optimal brain performance and supporting the production of neurotransmitters (11). Notably, vitamins B12 and B6 are crucial for neurotransmitter synthesis, particularly of dopamine and serotonin (7, 9). Furthermore, vitamin B3 is involved in cellular signaling and energy metabolism (9). Deficiency of vitamins B6, B9, and B12 can elevate homocysteine levels, leading to a higher risk of cerebrovascular disease and mental disorders (7, 10). Additionally, antioxidants such as vitamins E and C contribute to the reduction of oxidative stress, which can negatively impact brain health (7, 8, 10). Lastly, magnesium positively affects the reduction of neuroinflammation (10).

Understanding the complex association between micronutrient intake and mental and brain health is essential for recognizing how diet can influence university students' mental well-being and memory performance. To explore these connections, network analysis offers a powerful approach to examine how different variables relate to each other (12). Applying network analysis enables a detailed investigation of how dietary micronutrient intake interacts with mental health, sleep quality, and memory performance among medical students. This technique also highlights the key variables that play major roles within the network, which may be targeted in clinical interventions (12). Accordingly, the current study was designed to evaluate the associations between dietary micronutrient intake and memory function, sleep quality, and mental health, with a specific focus on depression, anxiety, and stress symptoms among university students by applying undirected and Bayesian network methods.

Materials and Methods

Ethical Considerations

This study (Grant Number: 96000895) was conducted following the guidelines of and after approval from the ethical committee of Kerman University of Medical Science (IR.KMU.REC.1396.2190). Participation was voluntary, with the study's purpose and methods clearly explained. Students received detailed instructions to respond to the questionnaires accurately. All participants provided signed informed consent and were assured that their information would remain confidential.

Study Design and Participants

This cross-sectional study, conducted between February 2022 and October 2022, followed convenience-based sampling, recruiting students (aged 18-25 years) enrolled at Kerman University of Medical Sciences. The students with medical conditions, incomplete Food Frequency Questionnaires ($\geq$ 70 items left unanswered), or implausible daily energy intakes (< 800 or > 4200 kcal, which may indicate errors in dietary reporting, inaccurate measurements, or unusual eating patterns (13)) were excluded from this study.

Data Collection and Measurements

The participants' demographic characteristics (age, gender, academic discipline, marital status, and place of residence) were recorded. Also, their anthropometric parameters, namely height, weight, hip and waist circumferences, and body mass index (BMI; measured as the ratio of body weight and height in units of kg/m^2) were recorded by a trained researcher involved in this study.

In this study, the validated Persian versions of self-reported questionnaires, including the Prospective and Retrospective Memory Questionnaire (PRMQ), Depression, Anxiety and Stress Scale-21 (DASS-21), Pittsburgh Sleep Quality Inventory (PSQI) and Food Frequency Questionnaire (FFQ), were used to assess memory function, mental health, sleep quality, and dietary intake, respectively. The validity and reliability of all the questionnaires in Persian have been reported in previous studies (14-17). The students were asked to complete these four questionnaires during the study.

The PRMQ is a 16-element questionnaire comprising two sub-scales, each with eight items: Prospective Memory and Retrospective Memory. Each question is required to be answered on a 5-point Likert scale from 5 (always) to 1 (never). Higher scores represent a greater degree of memory failures in everyday life (16).

The DASS‑21 is composed of 21 elements divided into three sub-scales (seven items each) to assess depression, anxiety, and stress levels. Items are to be responded to on a Likert scale with scores ranging between 0 (not applicable to the respondent) and 3 (highly applicable to the respondent). Higher scores represent a greater degree of depression, anxiety, and stress symptoms (15). The scores for each subscale are doubled to match the cut-off scores of the more validated DASS-42. The cut-off scores for identifying clinical depression, anxiety, and stress are 10 or higher, 8 or higher, and 15 or higher, respectively (18).

The PSQI has 19 inquiries divided into seven categories in order to evaluate sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction. Higher scores are associated with more sleep disturbances. Participants with scores above 5 are considered poor sleepers (17).

The FFQ, a 168‑item semi‑quantitative questionnaire, is among the most common methods to evaluate dietary food and nutrition intake annually. The Persian version of the FFQ is comprised of food items with standard serving sizes that Iranians usually consume. Participants provided estimates of food consumption frequency over the past year, classified as daily, weekly, monthly, or yearly. The reported frequency and consumed portion size for each food were converted to daily intake and grams using household measures, respectively (14). Nutritionist-IV Software modified for Iranian foods (v 7.0; N-Squared Computing, Salem, OR, USA) was utilized for analysis of the information obtained from the FFQ, and the mean intake of energy and nutrients was calculated by this software as well (19). Afterwards, the Index of Nutritional Quality (INQ) for each micronutrient was calculated as the ratio of the daily amount of nutrient consumed per 1000 kcal received to the recommended dietary allowance (RDA) of that nutrient per 1000 kcal received (20). Micronutrients including calcium, iron, magnesium, selenium, zinc, vitamins A, B1, B2, B3, B5, B6, B7, B9, B12, C, D, and E were used to calculate the INQs. Although the majority of vitamin D is produced through the skin via sunlight exposure, in many Muslim countries, cultural and clothing factors, such as wearing the hijab, limit sun exposure, making dietary intake a more significant source. Therefore, vitamin D dietary intake was taken into account in the analyses (21).

Data Analysis

The data obtained from the participants were analyzed using SPSS version 20 software. The Kolmogorov-Smirnov test was applied to assess normality. The independent samples t-test or Mann-Whitney U test was conducted to examine the differences in the quantitative data between male and female groups based on the normality of the data. The Chi-square test was employed to compare the categorical variables. A P-value of less than 0.05 was considered statistically significant.

Network Analysis

For this study, two types of networks were constructed: an undirected network to identify the strongest associations and central variables among micronutrients and health outcomes, and a Bayesian network to explore possible directional associations among micronutrient intake, memory function, sleep, and psychological well-being. Demographic data, BMI, psychological factors, and the INQs of the micronutrients were included in the network analyses.

Undirected Network Analysis

This network is designed using the Extended Bayesian Information Criterion Graphical Lasso (EBICglasso) model and is represented as an undirected graph. In this framework, nodes symbolize variables, while edges depict conditional dependencies among them. The edges vary in thickness and color to reflect the strength and polarity of relationships. A thicker edge signifies a stronger connection, with red edges indicating negative associations and blue edges denoting positive ones. To determine the nodes with the highest degree centrality within the network, the centrality index known as "strength" is calculated. This metric represents the sum of the absolute weights of edges directly linked to a node. Nodes exhibiting the highest strength are regarded as central, indicating stronger statistical connections with other variables within the system (12). Importantly, high strength centrality reflects statistical connectivity within the network and does not imply clinical or biological importance.

To evaluate the network stability, the case-dropping bootstrap procedure was employed. A correlation stability coefficient (CS-C) greater than 0.5 indicated high stability. Nonparametric bootstrapping, using 1,000 bootstrap samples, was conducted to assess the accuracy of the estimated network edges. The EBICglasso model was estimated with a tuning parameter (γ) set to 0.5, as recommended in previous studies, to balance sparsity and accurate edge estimation. The undirected network was visualized using the packages "qgraph" and "bootnet" in R software (version 4.3.0).

Bayesian Network Analysis

The Bayesian network is used to develop a directed acyclic graph (DAG) that assesses probabilistic dependencies among variables. In this framework, nodes represent variables, while directed edges illustrate the conditional associations between them. Variables positioned at the top of the DAG are identified as having greater conditional relevance (12). The DAG was performed using the "bnlearn" package with the Hill-climbing algorithm in R software (version 4.3.0), on the basis of conditional dependencies between pairs of variables.

Results

Overall, 985 students participated in the study. The mean age of the students was 22.44 ± 1.95 years. The sample consisted of 500 (50.76%) females and 485 (49.24%) males. The academic disciplines of the participants included pharmacy (280; 28.43%), medicine (300; 30.46%), dentistry (180; 18.27%), and paramedicine (225; 22.84%). Table 1 presents the demographic and anthropometric characteristics, macronutrient intakes, and psychological factors of the participants. There were significant differences in the anthropometric characteristics and macronutrient intakes between the two genders. However, the analyses revealed no significant differences in DASS-21, PRMQ, and PSQI scores between the male and female students.

The psychological assessment indicated that 485 participants (49.20%) experienced depression symptoms, 490 (49.70%) suffered from anxiety symptoms, and 620 (62.90%) reported stress. Furthermore, 535 participants (54.30%) experienced sleep disturbances.

The mean intake and INQ for each micronutrient of the participants are shown in Table 2. The female students had significantly higher INQ values for vitamins A, D, E, C, B2, and B3, zinc, and magnesium. Conversely, the INQs for vitamins B5 and B12, folate, calcium, and iron were significantly higher in the male participants. Additionally, the mean daily intakes of micronutrients, including vitamins A (838.63 ± 55.44 µg), D (2.30 ± 1.18 µg), B12 (1.95 ± 1.05 µg), folate (381.12 ± 144.20 µg) and selenium (39.30 ± 14.20 µg) for males and vitamins A (609.19 ± 459.19 µg), D (1.96 ± 1.25 µg), B2 (0.99 ± 0.38 mg), B5 (4.51 ± 1.68 mg), B12 (1.03 ± 0.68 µg), folate (247.60 ± 106.79 µg), biotin (27.95 ± 13.39 µg), calcium (704.81 ± 265.18 mg), iron (15.70 ± 7.01 mg) and selenium (25.86 ± 13.99 µg) for females, were lower than the RDI.

Figure 1 illustrates the relationships between demographic variables, micronutrients, and psychological factors, including anxiety, depression, stress, memory impairments, and sleep problems. A strong cluster of micronutrients, particularly B vitamins, zinc, magnesium, and biotin, was observed. Gender showed a significant negative relationship with iron (r = -0.85), indicating lower iron levels in females. Age revealed non-significant associations with psychological variables, except for stress (r = 0.48). BMI and marital status demonstrated weak associations with psychological factors. Stress and anxiety symptom were positively correlated (r = 0.56), and both variables exhibited moderate negative associations with micronutrients, particularly vitamins B, and E. Depression symptom had significant positive associations with both stress (r = 0.65) and anxiety symptoms (r = 0.54), reflecting their known psychological interdependence. Sleep problems exhibited strong positive associations with depression symptom (r = 0.41), anxiety symptom (r = 0.43), and stress (r = 0.40). It also presented a weak negative correlation with certain micronutrients such as vitamins B and D. Memory impairments showed moderate positive associations with psychological factors and weak associations with the micronutrients.

The centrality plot (Figure 2) presents the relative importance of nodes based on the strength of their connections within the network. Zinc exhibited the highest strength, indicating its prominent role in connecting with other variables in the network. B vitamins, especially B2, and magnesium, were also identified as central nodes in the network. Vitamin D and vitamin C closely followed, highlighting their relevance within the network structure. The case‑dropping bootstrap procedure indicated a CS‑C of 0.67, exceeding the recommended threshold of 0.5 and confirming that the estimated centrality measures were stable and reliable.

The DAG provides a structured representation of the relationships between variables (Figure 3). As observed, magnesium served as a central node, connecting biotin to iron and zinc, which were further related to psychological factors. B vitamins were involved in multiple pathways, emphasizing their crucial role.

Table 1. The Demographic and Anthropometric Characteristics, Macronutrient Intakes and Psychologic Factors of the Medical University Students

Variable	WQ	Male (N=485) N (%) or Mean ± SD	Female (N=500) N (%) or Mean ± SD	[a] P-value
Marital status				
Married	105 (10.66%)	45 (9.28%)	60 (12.00%)	0.536
Single	880 (89.34%)	440 (90.72%)	440 (88.00%)	
Place of residence				
Home	495 (50.25%)	210(43.30%)	285 (57.00%)	0.064
Dormitory	490 (49.75%)	275 (56.70%)	215 (43.00%)	
Age	22.44 ± 1.95	22.38 ± 1.97	22.49 ± 1.95	0.614
Body mass index (kg/m^2)	23.06 ± 3.78	24.85 ± 3.82	21.33 ± 2.82	0.0001
Waist circumference (cm)	86.05 ± 11.67	92.91 ± 11.10	79.47 ± 7.78	0.0001
Hip circumference (cm)	98.48 ± 8.30	101.77 ± 9.12	95.33 ± 5.93	0.0001
Energy (kcal/day)	3554.19 ± 1648.63	4157.28 ± 1406.96	2969.20 ± 2969.20	0.0001
Carbohydrate (g/day)	315.59 ± 234.88	384.31 ± 245.58	248.94 ± 204.01	0.0001
Protein (g/day)	133.62 ± 73.59	163.69 ± 72.05	104.46 ± 62.80	0.0001
Fat (g/day)	139.35 ± 51.18	164.68 ± 45.25	114.78 ± 44.29	0.0001
Prospective and Retrospective Memory Questionnaire	34.73 ± 7.59	34.76 ± 7.25	34.69 ± 7.95	0.855
Depression Subscale	9.89 ± 7.29	8.97 ± 6.51	10.78 ± 7.90	0.136
Anxiety Subscale	8.30 ± 5.84	8.21 ± 5.37	8.40 ± 6.30	0.812
Stress Subscale	16.14 ± 7.85	15.51 ± 7.55	16.76 ± 8.13	0.333
Pittsburgh Sleep Quality Inventory	6.04 ± 2.92	6.10 ± 2.62	5.98 ± 3.20	0.411

[a] Based on chi-square or Independent samples t-test or Mann-Whitney U test

Table 2. The Mean Intake and Index of Nutritional Quality for Micronutrients of the Medical University Students

Micronutrients	Overall (Mean ± SD)	Overall INQ (Mean ± SD)	Male INQ (Mean ± SD)	Female INQ (Mean ± SD	[a] P-value
Vitamin A (µg/d)	722.16 ± 520.42	0.55 ± 0.39	0.46 ± 0.27	0.64 ± 0.46	0.01
Vitamin C (µg/d)	117.27 ± 43.99	0.96 ± 0.60	0.70 ± 0.28	1.21 ± 0.70	0.0001
Vitamin D (µg/d)	2.13 ± 1.22	0.09 ± 0.06	0.08 ± 0.05	0.1 ± 0.07	0.097
Vitamin E (µg/d)	17.72 ± 7.07	0.73 ± 0.32	0.66 ± 0.23	0.80 ± 0.38	0.008
Vitamin B_1 (mg/d)	1.53 ± 0.70	0.79 ± 0.26	0.77 ± 0.26	0.81 ± 0.25	0.982
Vitamin B_2 (mg/d)	1.23 ± 0.54	0.61 ± 0.18	0.57 ± 0.17	0.65 ± 0.18	0.011
Vitamin B_3 (mg/d)	23.76 ± 9.21	0.96 ± 0.28	0.88 ± 0.27	1.04 ± 0.27	0.0001
Vitamin B_5 (mg/d)	5.82 ± 2.26	0.68 ± 0.16	0.72 ± 0.15	0.64 ± 0.15	0.0001
Vitamin B_6 (mg/d)	1.56 ± 0.61	0.72 ± 0.26	0.73 ± 0.29	0.71 ± 0.22	0.734
Vitamin B_{12} (µg/d)	1.48 ± 0.99	0.36 ± 0.22	0.42 ± 0.23	0.31 ± 0.21	0.0001
Folate (µg/d)	313.34 ± 142.91	0.46 ± 0.17	0.48 ± 0.18	0.45 ± 0.16	0.038
Biotin (µg/d)	32.18 ± 13.72	0.63 ± 0.21	0.61 ± 0.17	0.66 ± 0.24	0.068
Calcium (mg/d)	894.02 ± 344.39	0.66 ± 0.16	0.68 ± 0.14	0.63 ± 0.17	0.001
Iron (mg/d)	20.34 ± 9.10	1.07 ± 0.51	1.54 ± 0.25	0.61 ± 0.17	0.0001
Magnesium (mg/d)	389.99 ± 160.99	0.65 ± 0.22	0.54 ± 0.15	0.75 ± 0.23	0.0001
Zinc (mg/d)	13.91 ± 5.86	0.87 ± 0.24	0.78 ± 0.19	0.95 ± 0.25	0.0001
Selenium (µg/d)	32.48 ± 15.58	0.32 ± 0.11	0.33 ± 0.10	0.31 ± 0.12	0.115

INQ: Index of Nutritional Quality
[a] Based on Mann-Whitney U test

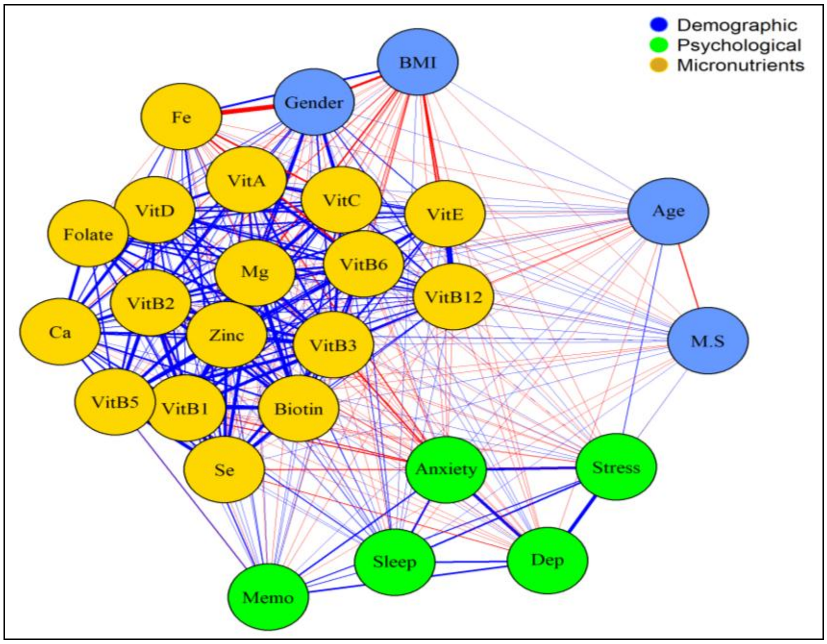

Figure 1. The Undirected Network of Micronutrients, Demographic Variables and Psychological Factors

MS: Marital status, Dep: Depression, Memo: Memory, BMI: Body mass index, Fe: Iron, Mg: Magnesium, Ca: Calcium, VitA: Vitamin A, VitC: Vitamin C, VitD: Vitamin D, VitE: Vitamin E, VitB1: Vitamin B_1, VitB2: Vitamin B_2, VitB3: Vitamin B_3, VitB5: Vitamin B_5, VitB6: Vitamin B_6, VitB12: Vitamin B_{12}

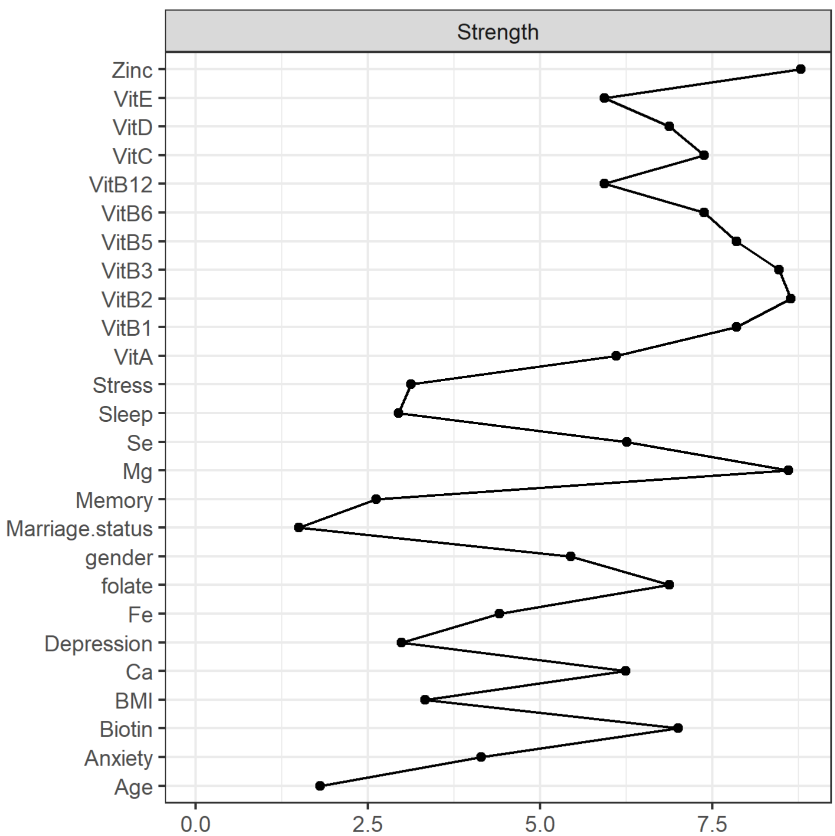

Figure 2. The Central Nodes of the Network of Micronutrients, Demographic Variables and Psychological Factors

BMI: Body mass index, Fe: Iron, Mg: Magnesium, Ca: Calcium, VitA: Vitamin A, VitC: Vitamin C, VitD: Vitamin D, VitE: Vitamin E, VitB1: Vitamin B_1, VitB2: Vitamin B_2, VitB3: Vitamin B_3, VitB5: Vitamin B_5, VitB6: Vitamin B_6, VitB12: Vitamin B_{12}

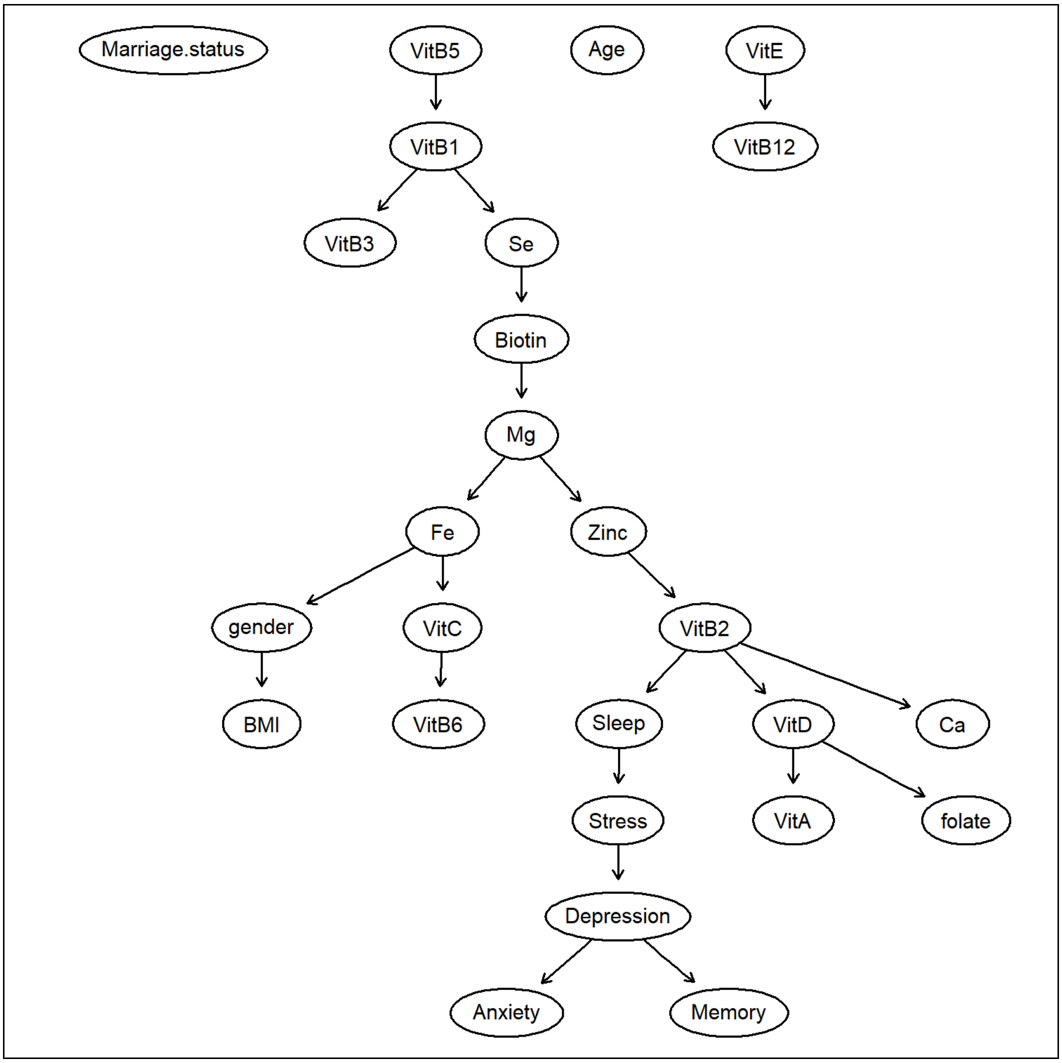

Figure 3. The Bayesian Network of Micronutrients, Demographic Variables and Psychological Factors

BMI: Body mass index, Fe: Iron, Mg: Magnesium, Ca: Calcium, VitA: Vitamin A, VitC: Vitamin C, VitD: Vitamin D, VitE: Vitamin E, VitB1: Vitamin B1, VitB2: Vitamin B2, VitB3: Vitamin B3, VitB5: Vitamin B5, VitB6: Vitamin B6, VitB12: Vitamin B12

Discussion

In the current study, network analysis identified zinc as the most central micronutrient, followed by B vitamins (especially B2), magnesium, vitamin D, and vitamin C, all of which played key roles in the network structure. Based on their centrality in the network, these micronutrients show notable associations with memory, sleep, and mental health.

Many studies have reported that a healthy diet (rich in fruits, vegetables, and fish) could improve sleep quality, cognitive function, and symptoms of anxiety and depression in university students (22-24). These studies focused on food types rather than specific micronutrients. However, some studies have examined the effects of the intake of several micronutrients on mental health, sleep quality, and memory function in different populations. It should be noted that most studies on cognitive function have focused on elderly and pediatric populations (25, 26). Below, several studies relevant to this subject are discussed.

Hajianfar et al. conducted a cross-sectional research study among Iranian female students and reported an inverse relationship between dietary zinc intake and anxiety, depression, and sleep problems (27). In another study, it was reported that the undergraduate students with a daily vitamin B2 intake below the RDI exhibited statistically significantly higher levels of anxiety (28). Furthermore, a study conducted by Mahdavifar et al. on the general Iranian population indicated that a high dietary intake of B vitamins, particularly vitamin B7, was linked to reduced levels of depression, anxiety, and stress-related symptoms (11). Moreover, Arabshahi et al. found that dietary vitamin D intake was significantly related to reduced risks of anxiety and sleep disorders among healthy Iranian athletes; however, no significant relationship was observed for depressive symptoms (29). A study among healthy young women demonstrated significant associations between cognitive performance and dietary intake of calcium, zinc, iron, and vitamins A, B1, and B2. This study also revealed an inverse relationship between cognitive function and depression, anxiety, stress, and sleep disturbance (30). Also, Cansino et al. reported that dietary intake of specific micronutrients such as vitamins E, B3, and B6 had a beneficial impact on memory function across the adult lifespan (9). Moreover, O'Connor et al. concluded that maintaining optimal intake of micronutrients such as vitamin D and B vitamins throughout life is crucial for preserving cognitive health during aging (31) Furthermore, suboptimal (i.e., below the RDA) micronutrient intake is prevalent among the general population and can directly affect energy levels, cognitive function, and overall well-being (32). In the present study, it was found that that the mean daily intake of many minerals and vitamins such as calcium, selenium, iron, folate, biotin, and vitamins B2, B5 and B12, A, and D was below the RDI, which might lead to insufficient micronutrient consumption among the students. Similarly, previous studies in Asia have shown insufficient intake of micronutrients such as calcium, iron, and vitamins A, C, B1, B2, and B3 among university students (33, 34).

All the mentioned studies highlight the critical role of a proper diet and adequate intake of micronutrients in promoting mental health, sleep quality, and memory performance in young populations, especially university students, for whom maintaining a healthy and balanced diet remains a major challenge (6). The variations in findings across the reviewed studies and the current study may arise from differences in population characteristics, dietary habits, lifestyles, assessment tools, statistical analysis methods, and confounding factors.

Regarding the central micronutrients in the present study, special attention should be given to antioxidants such as zinc and vitamin C, which protect the brain from oxidative stress that may lead to mental disorders, sleep disturbances, and memory impairment (7, 8, 10, 31). Zinc supports neurogenesis within the brain and is vital for neural stem cell proliferation and tissue differentiation. Consequently, it is crucial for maintaining memory performance (7). Additionally, the roles of B vitamins in maintaining homocysteine levels within the normal range, in the synthesis and modulation of neurotransmitters, and in the integration of myelin sheath and axons in the brain should be considered (8, 11, 30, 35). Notably, vitamin B2 may enhance cognitive function by exerting antioxidant and anti-inflammatory effects (36). The association of vitamin B2 with mental health might be explained by its role in forming the coenzymes flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD), which serve as vital rate limiting factors in numerous enzymatic reactions in the cells, including those involved in the metabolism of fatty acids in brain lipids, processes necessary for maintaining brain health (37). Although the specific mechanisms underlying the relationship between magnesium and brain health are not yet fully understood, evidence suggests that magnesium may attenuate neuroinflammation, reduce oxidative stress, block NMDA receptor activity, limit excessive calcium influx, preserve myelin sheaths and myelinated axons, and influence the release and metabolism of neurotransmitters (10, 38, 39). These mechanisms help explain why certain micronutrients were identified as central in the network analysis of this study.

Data acquired from the current study also showed a notably high prevalence of depression symptoms, anxiety symptoms, stress, and sleep disturbance among the university students, which was expected, as reported in previous studies using the similar questionnaires (1, 2, 5). It should be noted that these prevalence estimates were derived from the established DASS 21 and PSQI cut off scores validated in Iranian populations and reflect symptom level screening rather than clinical diagnoses. Furthermore, sleep disturbances appear to exacerbate anxiety, depression symptom, stress, and memory impairment. The negative effect of mental health issues (depression, anxiety, stress) and sleep disturbance on memory function in the students has also been reported in previous studies (1, 3, 4).

Limitation

One limitation of this study is that it was performed within a single university and a specific population. Additional research involving expanded and varied populations is required to strengthen generalizability. Another limitation was the reliance on participant-reported dietary intake via FFQ, which may have introduced recall bias. In addition, completing several different questionnaires may exhaust students and affect the accuracy of their answers. Moreover, unmeasured confounders such as socioeconomic status, physical activity, genetic predisposition, and micronutrient status (e.g., serum levels) may have influenced the observed networks, and this should be considered in interpreting the results. Furthermore, gender differences may influence dietary micronutrient intake, psychological symptoms, and sleep quality. Although gender was included as a variable in the network model, separate multi-group network analyses were not conducted due to the limited sample size for stable subgroup estimation. Future studies with larger and more balanced samples are recommended to explore gender-specific network structures.

The cross sectional design of this study precludes causal inference; therefore, it is recommended that core micronutrients from both networks, viz., zinc, vitamin B2, and magnesium, be applied in clinical interventional studies to investigate their impacts on mental health, sleep parameters, and memory function in university students.

Conclusion

In summary, this study identified zinc, B vitamins (particularly B2), and magnesium as key micronutrients associated with mental health, sleep quality, and memory function among medical university students. The findings highlight the potential benefits of conducting dietary intervention studies targeting these micronutrients to evaluate their impact on mental health, sleep quality, and memory function.

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Conflict of Interest

None.

Author's Contributions

SP: Investigation, Project administration, Validation, Writing - Original draft. TD and FA: Supervision, Resources, Formal analysis, Writing - Original draft, Writing – review & editing. FD: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Supervision, Validation, Visualization, Writing - Original Draft, Writing – review & editing. All authors read and approved the final manuscript.

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