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The relationship between physical activity and depression, anxiety, and stress in college students: a mediating effect of diet

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Objective: Previous studies have demonstrated that engaging in physical activity is a vital behavioral element in mitigating experiences of depression, anxiety, and stress. However, the specific mechanisms by which dietary practices and physical activity interact to affect these psychological conditions are not fully understood. Thus, this study aimed to comprehensively examine the relationships between physical activity, diet, and mental health outcomes, specifically depression, anxiety, and stress, among college students and to elucidate the pathways through which these factors interact.

Method: This study analyzed 1,076 college students (18.8 ± 0.8 years old) via the Adult Dietary Behavior Questionnaire (covering eight dimensions), the physical activity scale, and the depression-anxiety-stress scale.

Results: There were significant differences in dietary behavior and physical activity parameters between male and female college students; however, no significant differences were observed in levels of depression, anxiety, or stress. The dimensions of college students' dietary behavior were significantly correlated with symptoms of anxiety, stress, and depression ($p < 0.01$). Higher levels of physical activity were negatively correlated with anxiety, stress, and depression symptoms in college-aged students ($p < 0.01$). Dietary behavior was significantly correlated with college students' physical activity. Through structural equation modeling analysis, our findings revealed that physical activity not only directly reduced depression, stress, and anxiety among college students but also indirectly alleviated them by improving their dietary behaviors. The direct effects of physical activity on depression, anxiety, and stress in college students were greater than the mediating effects of dietary behavior.

Conclusion: Regular physical activity plays a key role in reducing depression, anxiety, and stress among college students, with dietary behavior serving as a mediating factor. Therefore, promoting exercise and healthy eating within university settings is recommended for better mental health. Future research should investigate this relationship across diverse populations to gain valuable insights into mental health interventions.

KEYWORDS

physical activity, emotional overeating, satiety, delayed eating, depression-anxiety-stress

1 Introduction

Depression is the second most common disease globally, affecting approximately 3.8% of the population, or 280 million people, with major depression rates varying from 6 to 18% across cultures (1). Anxiety disorders affect approximately 4.4% of the global population, whereas depression and anxiety together represent 38% of the mental illness burden (2, 3). The risk in individuals with diabetes is approximately 78% higher than that in the general population, and anxiety disorder patients have a 65% higher risk of hypertension (4). The mechanism of depression involves genetic, environmental, and biological factors, with genetics contributing to approximately 37% of the risk (5). Psychosocial factors, including childhood trauma and socioeconomic stress, can increase the risk for adult depression (6, 7). Adolescent mental health disorders in China are estimated to have a prevalence of 8.9%, with anxiety (8.2%) and depression (6.1%) accounting for 22.4% of health loss (8).

1.1 The role of physical activity in depression, anxiety, and stress

Physical activity is widely recognized for improving health, promoting social interaction, enhancing self-efficacy, benefiting mental health, and alleviating depression (9). Physical activity is considered to be an effective method for the treatment of depression, mainly through the regulation of serotonin. Aerobic exercise can promote the release of 5-hydroxytryptamine in the anterior cingulate cortex to relieve depression, pain, and anxiety. These findings provide a biological basis for the application of physical activity in mental health interventions (10). Physical activity influences serotonin release and receptor function, with exercise enhancing 5-HT1A and 5-HT7 receptor activity linked to reduced depressive symptoms (11). Exercise reduces inflammation, regulates the endocrine system, increases serotonin levels, improves mood, and alleviates depression through increased brain-derived neurotrophic factor and neural plasticity (12). Exercise affects depression by regulating neurotransmitters, reducing inflammation, and improving cognition (13, 14). For example, physical activity increases neurotransmitters such as serotonin and dopamine and helps reduce inflammation linked to depression, supporting its role in intervention (15). Increasing physical activity reduces depression and costs in rural elderly individuals and benefits the mental health of young people (16, 17). Physical exercise and social activities can be used to treat and potentially prevent depression (18). Physical exercise is preferred for treating mild to moderate depression and shows better efficacy than antidepressants do, with minimal side effects (19). Exercise is an effective therapy that positively impacts anxiety disorders and alleviates depression and anxiety symptoms in nonclinical populations (20). A survey of 47 countries with 237,964 respondents revealed that low physical activity increases anxiety disorder risk by 1.32 times (21). Moreover, another meta-analysis suggested that there is insufficient clinical evidence that physical activity significantly reduces anxiety disorders (22). This finding indicates that factors beyond physical activity influence depression and anxiety, with research suggesting that the frequency and intensity of activity affect psychological stress. Inactive individuals tend to struggle with stress management, unlike those who engage in exercise (23). Thus, moderate physical activity effectively reduces stress and enhances overall mental health.

Long-term exercise training can reduce sympathetic nervous system sensitivity, with trained individuals showing lower sympathetic activity and catecholamine levels during exercise than untrained individuals do, indicating better stress management (24). Exercise positively impacts psychological and physiological regulation by decreasing catecholamine levels under chronic stress, improving cardiovascular function, and reducing sympathetic nervous system activation (25). Exercise improves mood and cognition by regulating neurotransmitters such as serotonin and dopamine, alleviating depression and anxiety (26). However, current research has focused mainly on adults and patients with chronic diseases but has not focused on college students, who face significant mental health issues during critical development (27, 28).

1.2 The role of diet in depression, anxiety, and stress

Healthier diets enhance exercise's positive effects on mental health, improving self-efficacy and reducing anxiety, whereas malnutrition can diminish exercise enjoyment and affect mental health (29). For example, both the traditional Brazilian diet and olive oil intervention can effectively alleviate anxiety and depression symptoms in severely obese adults (30). In addition, higher dietary quality is negatively correlated with the incidence of severe depression in young people (31). Students who adhere to the Mediterranean diet intake rich fruits, vegetables, and fish, indicating a lower risk of depression. This diet model may have a protective effect on mental health, emphasizing the relationship between eating habits and emotional health (32). The Mediterranean diet is linked to lower anxiety and stress in elderly Australians, but not significantly with depression (33). A negative correlation exists between dietary quality and depression/anxiety symptoms in Chinese adolescents, whereas free sugar intake is positively correlated with these symptoms (34).

Ein et al. (35) demonstrated through a meta-analysis that an 8-week ultralow-calorie diet ($\leq$800 kcal/day), when paired with treatment and exercise, can significantly increase the efficacy of antidepressants (35). Individuals in healthy diet interventions show greater emotional improvement post-aerobic exercise, indicating that good nutrition supports energy and enhances exercise appeal through better psychological states (36). Nutritional improvement reduces depression and anxiety, enhancing the positive mental health impact of exercise (37). Reasonable dietary habits and nutritional support enhance exercise effectiveness and promote neurotransmitter balance. Malnutrition can worsen anxiety and depression, while proper supplementation may alleviate these issues (38). Therefore, good nutrition enhances exercise's psychological benefits and helps establish habits by improving mood and reducing anxiety and depression. Moreover, stress can affect health and quality of life by altering appetite

and diet (39, 40). Good nutrition enhances exercise's psychological benefits and helps establish habits by improving mood and reducing anxiety and depression. Moreover, stress can affect health and quality of life by altering appetite and diet (39, 41). For example, the Mediterranean diet, which is high in antioxidants and healthy fats, reduces stress and anxiety, improving mental health (42, 43). Similarly, a diet high in fruits and vegetables is linked to lower psychological stress, suggesting that healthy eating helps relieve stress (44, 45).

1.3 Relationship between diet and physical activity

A correlation exists between nutrition and physical activity; university students who exercise tend to follow the Mediterranean diet, improving their nutritional quality (46). However, higher stress and negative emotions, along with lower positive emotions, can reduce physical activity in college students. In contrast, increased activity is associated with lower stress and negative emotions, while also promoting healthier eating habits (core features include low fat, low sugar, low salt, high fruit and vegetable intake, and a preference for natural ingredients) (47). Specifically, physical activity can alleviate stress, reduce negative emotions, and enhance positive emotions, whereas a positive mindset encourages more activity. However, Si and Zhang (48) noted that there is no significant mutual influence between healthy eating and stress or emotional levels. In the elderly population, the combination of a healthy diet (adding dairy, egg, and meat) and moderate physical activity has been shown to significantly lower the risk of mild cognitive impairment, highlighting the potential synergistic effects of diet and exercise in preserving cognitive health (48). In addition, the interaction between diet and exercise cannot be ignored when improving athletic performance. For example, athletes adopting a low-carbohydrate, high-fat diet can improve endurance under specific conditions. However, the adaptation process to this dietary pattern is relatively slow (49). Combining exercise with a balanced diet enhances metabolic benefits and promotes overall health (50). In summary, dietary behavior is linked to physical activity and mediates its effects on mental health issues such as depression and anxiety, making its exploration vital for effective intervention strategies.

Although previous studies have explored the positive effects of physical activity and dietary behavior on mental health, there are still research gaps. First, most studies have focused on the independent effects of a single factor (such as only exercise or diet) on depression, anxiety, and stress, and lack a systematic analysis of the interaction between the two factors. Second, existing research has focused primarily on the general population or chronic disease patients, and there is relatively insufficient research on college students, a special group that is in a critical period of psychological development and has a high incidence of mental health problems. Third, the mediating role of diet between physical activity and mental health has not been systematically studied, which limits a comprehensive understanding of intervention mechanisms. Therefore, this study uses a cross-sectional survey with college students to analyze the relationships among physical activity, diet, and mental health via SEM and mediation analysis, with a focus on dietary behavior as a mediator. This study helps deepen the understanding of the intervention mechanism for college students' mental health and provides a theoretical basis and practical guidance for universities to develop scientifically effective, comprehensive "exercise nutrition" intervention strategies.

2 Research participants and methods

2.1 Research participants

In total, 1,388 college students from three universities west of China were investigated anonymously via Questionnaire Star. The exclusion criteria for sample screening were as follows: (I) participants were full-time college students; and (II) participants did not have any sports-related disabilities or movement disorders. To guarantee the utmost reliability of the information, prior to completing each questionnaire, an administrator from our team exclusively addressed respondents' inquiries according to the website's guidelines, refraining from offering any leading suggestions. The administrator emphasized that participants should complete the questionnaire independently and clearly stated that they could not access the data or engage in discussions with others. A total of 312 invalid questionnaires were generated due to conflicting viewpoints or other reasons, and 1,076 were ultimately considered valid questionnaires, with an effective rate of 77.5%.

The subjects in this study met the requirements of the Declaration of Helsinki for human experimentation and were approved by the Academic Ethics Committee of Sichuan University of Arts and Sciences (Approval No. 2023SASULL-001). The collected data do not involve sensitive information such as participant names and phone numbers, and we declare that these data are only used for research purposes.

2.2 Research methods

2.2.1 Population informatics survey

The demographic information collected in this study included age, sex, major, and grade level.

2.2.2 Adult dietary behavior survey questionnaire

The adult eating behavior questionnaire of Sheng et al. (51), which comprises eight dimensions (I. hunger, II. food reactivity, III. emotional overeating, IV. enjoyment of food, V. satiety, VI. emotional eating deficiency, VII. picky eating, and VIII. delayed eating), has been proven to have good reliability and validity in a survey of the Chinese population (51). All the data were measured using a five-point Likert scale, ranging from "strongly disagree" to "strongly agree." Cronbach's alpha coefficient was employed to assess the scale's reliability. In this study, the coefficients of the corresponding factors were as follows: hunger 0.828, food reactivity 0.817, emotional overeating 0.924, food enjoyment 0.833, satiety reactivity 0.637, emotional eating 0.948, food pickiness 0.813, delayed eating 0.933, and overall 0.879, indicating the reliability of the scale in this study.

2.2.3 Physical activity survey

The PARS-3 (52) is used to evaluate college students' physical activity in the previous month. This scale consists of three questions, namely, the intensity of physical activity (what is your physical activity or intensity?), duration (how long do you persist in the intensity of the aforementioned physical activity?), and frequency (how many times have you engaged in the aforementioned physical activity?). The corresponding score ranges from 1 to 5 in terms of physical activity levels = intensity score × (duration score – 1) × frequency score, with a score range of 0–100. The scale is widely used in studies of the Chinese population (53, 54). The Cronbach's alpha coefficient was used to evaluate the scale's reliability. In this study, the Cronbach's alpha coefficient was 0.746. This indicates that the scale is reliable.

2.2.4 Depression–anxiety–stress survey

The depression, anxiety, and stress scale (DASS-21) is employed to assess symptoms of depression, anxiety, and stress (55). An early Chinese study verified the reliability of the Chinese version of the tool (56, 57). The students rated 21 statements, with seven measurement questions for each assessed structure (depression, anxiety, and pressure symptoms). All data were measured via a five-point Likert scale, ranging from "strongly disagree" to "strongly agree." Cronbach's alpha coefficient was employed to assess the scale's reliability. In this study, the Cronbach's alpha coefficients for depression, anxiety, and stress were 0.906, 0.943, and 0.956, respectively, indicating that the scale is reliable.

2.2.5 Data processing

The data analysis was conducted using SPSS 27.0 and Amos 23.0 statistical software. Cronbach's alpha was used to evaluate the reliability of the questionnaire, an independent sample t-test was used to analyze the differences in dietary behavior, physical activity, and depression anxiety pressure parameters between male and female college students, the Pearson correlation coefficient was used to measure the relationships between variables, the structural equation measurement model was used to verify the degree of association between variables, and the CMIN/DF, CFI, and RMSEA were used to evaluate the goodness of fit of the model. Differences were considered significant at a p-value of $\leq$0.05.

3 Results

3.1 Basic demographic information

There was no significant difference in age between male and female college students in this survey (18.8 ± 1.0 vs. 18.8 ± 0.7, $p = 0.733$). The proportion of male students is 31.88%, and the proportion of female students is 68.12%. The survey respondents were mainly first-year (44.05%) and second-year university students (44.98%). For specific other information, please refer to Table 1.

TABLE 1 Basic information of the participants.

Items	Sample size	%
Sex		
Male	343	31.88
Female	733	68.12
Major types		
A	358	33.27
B	331	30.76
C	77	7.16
D	83	7.71
E	227	21.30
Grade		
Fresher	474	44.05
Sophomore	484	44.98
Junior	75	6.97
Senior	43	4.00

A: Science and Engineering (Physics, Chemistry, Architecture, Mathematics, and Intelligent Manufacturing); B: Social Sciences (Horse Academy, Foreign Languages, Health and Wellness, and Teacher Education); C: Art (Media, News, Music, and Art); D: Medicine (Clinical, Nursing, and Public Health); E: Physical education.

3.2 Differences in diet, physical activity, and depression, anxiety, and stress between male and female college students

Compared to female college students, male college students scored significantly lower in six dimensions: food reactivity, emotional overeating, enjoyability of food, satiety, picky eating, and delayed eating. There were no significant differences in the other two dimensions of the dietary behavior questionnaire. In terms of physical activity, male college students have significantly greater exercise intensity, duration, and frequency than female college students do, and their total physical activity is also significantly greater than that of female college students. There was no significant difference in depression, anxiety, or stress between male and female college students, as shown in Table 2.

3.3 Relationships among dietary behavior, physical activity, and depression, anxiety, and stress

Through the Pearson correlation analysis, we discovered that the eight dimensions of dietary behavior are positively correlated with depression, anxiety, and stress among college students. Moreover, food enjoyment is inversely related to stress. The level of physical activity is significantly negatively correlated with depression, anxiety, and stress among college students. Among the eight dimensions of dietary behavior, only food reactivity, emotional overeating, satiety, food pickiness, and eating delay are significantly negatively correlated with physical activity levels (the other three dimensions are not correlated with physical activity).

TABLE 2 Differences in dietary behavior, physical activity, depression, anxiety, and stress between male and female college students.

Items	Male (n = 343)	Female (n = 733)	p-value
Hunger	2.9 ± 0.8	2.9 ± 0.8	0.414
Food reactivity	2.9 ± 0.8	3.1 ± 0.9	0.000
Emotional overeating	2.4 ± 1.0	2.7 ± 1.0	0.000
Enjoyability of food	3.9 ± 0.8	4.0 ± 0.8	0.005
Satiety	2.4 ± 0.7	2.7 ± 0.7	0.000
Emotional eating deficiency	2.9 ± 1.1	3.0 ± 1.0	0.103
Picky eating	2.5 ± 0.9	2.7 ± 0.9	0.000
Delayed eating	2.2 ± 0.9	2.4 ± 1.0	0.003
Exercise intensity	3.2 ± 1.3	1.9 ± 1.2	0.000
Exercise duration	4.0 ± 1.2	2.8 ± 1.1	0.000
Exercise frequency	3.4 ± 1.0	2.6 ± 1.0	0.000
Depression	14.9 ± 6.0	15.2 ± 5.5	0.447
Anxiety	16.4 ± 6.9	17.0 ± 6.6	0.212
Stress	14.8 ± 6.3	15.0 ± 6.0	0.576

See Table 3 for details. Regression analysis was conducted on only the five dimensions of dietary behavior, along with physical activity, depression, anxiety, and stress. Three regression models were established for physical activity, dietary behavior, depression, anxiety, and stress in Models 1–3. In Model 1, the order of weights affecting depression was picky eating, physical activity, emotional overeating, and satiety. In Model 2, the weight order that affects anxiety was picky eating, physical activity, food reactivity, and emotional overeating. In Model 3, the weight order that affects stress was emotional overeating, picky eating, and physical activity. The specific relevant parameters are shown in Table 4.

3.4 Path analysis of the influence of physical activity on depression, anxiety, and stress in college students

The structural equation model has high flexibility, applicability, and comprehensiveness in path analysis. It can effectively address potential errors and measurement errors and analyze multiple dependent variables and their complex relationships, providing a comprehensive model fitting evaluation. Therefore, the researchers constructed three structural equation models on the basis of the three regression models. Figure 1 shows that physical activity not only directly affects college students' depression but also mediates depression through dietary behavior (Figure 1). The direct effect of physical activity was −0.143, and the 95% confidence interval was (−0.219, −0.064), $p < 0.01$. The mediating effect was −0.053, and the 95% confidence interval was (−0.133, −0.039), $p < 0.01$. The mediating effect was significant; the direct effect accounted for 66.9%, and the mediating effect accounted for 33.1% (see Table 5). Figure 2 shows that physical activity not only directly affects the anxiety level of college students but is also mediated through dietary behavior (Figure 2). The direct effect of physical activity was −0.141, and the 95% confidence interval was (−0.212, −0.069), $p < 0.01$. The mediating effect was −0.071, and the 95% confidence interval was (−0.084, −0.029), $p < 0.01$. The mediating effect was significant; the direct effect accounted for 72.7%, and the mediating effect accounted for 27.3% (see Table 5). Figure 3 shows that physical activity not only directly affects the stress level of college students but is also mediated through dietary behavior (Figure 3). The direct effect of physical activity was −0.136, and the 95% confidence interval was (−0.204, −0.068), $p < 0.01$. The mediating effect was −0.049, and the 95% confidence interval was (−0.078, −0.027), $p < 0.01$. The mediating effect was significant; the direct effect accounted for 73.5%, and the mediating effect accounted for 26.5% (see Table 5).

4 Discussion

4.1 Main findings of this study

This study revealed significant differences in dietary behavior (food reactivity, emotional overeating, enjoyability of food, satiety, picky eating, and delayed eating) and physical activity between male and female college students. However, no significant differences were observed in depression, anxiety, or stress scores. Physical activity directly influences depression and anxiety levels and mediates these effects through dietary behavior, reducing depression, anxiety, and stress.

4.2 Gender differences in physical activity and dietary behavior

Some men prefer high-intensity exercise, such as strength training, whereas some women prefer low-intensity activities, such as walking and yoga (58, 59). Men have a higher physical activity level than women do and are more likely to meet WHO recommendations (60, 61). Male college students scored higher than female college students did in terms of physical activity intensity, duration, frequency, and level, which aligns with past research (59, 60). Differences among college students stem from biological and sociocultural factors; men favor high-intensity exercise, whereas women prefer low-intensity exercise (58, 59). Traditional beliefs link "masculinity" to physical ability, prompting men to engage in intense exercise, whereas women prefer low-calorie workouts due to beauty standards (58, 60). Men prefer high-energy foods and have limited dietary options (59, 60, 62). Women are more prone to emotional eating, whereas men eat mainly due to hunger, indicating different emotional and physiological mechanisms (59, 63).

Compared to male college students, female college students presented greater food reactivity, emotional overeating, enjoyment of food, satiety, and picky eating, which aligns with the findings of Berge et al. (63) and Lombardo et al. (59). These dietary gender differences may stem from women's heightened sensitivity to food odors and tastes due to estrogen fluctuations, which impact satiety signals (58, 59). Women are more sensitive

TABLE 3 Relationships among dietary behavior, physical activity, depression, anxiety, and pressure among college students.

Items	1	2	3	4	5	6	7	8	9	10	11	12
1 Hunger	1											
2 Food reactivity	0.571**	1										
3 Emotional overeating	0.366**	0.456**	1									
4 Enjoyability of food	0.236**	0.392**	0.213**	1								
5 Satiety	0.287**	0.301**	0.265**	−0.009	1							
6 Emotional eating deficiency	0.069*	0.092*	−0.164**	−0.043	0.279**	1						
7 Picky eating	0.146**	0.172**	0.151**	−0.067*	0.288**	0.217**	1					
8 Delayed eating	0.128**	0.136**	0.154**	−0.076*	0.618**	0.222**	0.287**	1				
9 Physical activity	0.011	−0.076*	−0.141**	−0.004	−0.167**	−0.036	−0.099**	−0.142**	1			
10 Depression	0.131**	0.133**	0.164**	−0.180**	0.192**	0.146**	0.172**	0.163**	−0.146**	1		
11 Anxiety	0.124**	0.164**	0.163**	−0.096*	0.147**	0.163**	0.168**	0.127**	−0.139**	0.772**	1	
12 Stress	0.130**	0.140**	0.192**	−0.150**	0.149**	0.182**	0.182**	0.150**	−0.154**	0.772**	0.807**	1

*$P < 0.05$, **$P < 0.01$.

TABLE 4 Regression equations of dietary behavior, physical activity, depression, anxiety, and stress.

Items	Unstandardized coefficients		Standardized coefficients	*T*	*p*- value
	B	Std. Error	Beta		
Model 1 (vs. Depression)					
Food reactivity	0.234	0.221	0.036	1.056	0.291
Emotional overeating	0.488	0.185	0.089	2.643	0.008
Satiety	0.602	0.300	0.079	2.008	0.045
Picky eating	0.661	0.196	0.105	3.371	0.001
Delayed eating	0.294	0.218	0.051	1.349	0.178
Physical activity	−0.019	0.006	−0.100	−3.322	0.001
Model 2 (vs. Anxiety)					
Food reactivity	0.673	0.263	0.087	2.560	0.011
Emotional overeating	0.514	0.220	0.079	2.342	0.019
Satiety	0.235	0.356	0.026	0.660	0.509
Picky eating	0.834	0.233	0.112	3.578	0.000
Delayed eating	0.272	0.259	0.040	1.051	0.293
Physical activity	−0.023	0.007	−0.100	−3.324	0.001
Model 3 (vs. Stress)					
Food reactivity	0.291	0.235	0.042	1.239	0.216
Emotional overeating	0.743	0.196	0.127	3.786	0.000
Satiety	0.038	0.319	0.005	0.118	0.906
Picky eating	0.822	0.208	0.123	3.945	0.000
Delayed eating	0.436	0.232	0.071	1.883	0.060
Physical activity	−0.023	0.006	−0.110	−3.658	0.000

to leptin, but ghrelin levels fluctuate with emotions, causing emotional eating (59, 63). Women often cope with negative emotions by eating, whereas men prefer exercise or social activities, highlighting gender differences in emotional regulation (58, 59, 63). Future interventions should include mindfulness eating training for women, address "health food" stereotypes with education, and reduce the risk of imbalanced diets resulting from food neophobia.

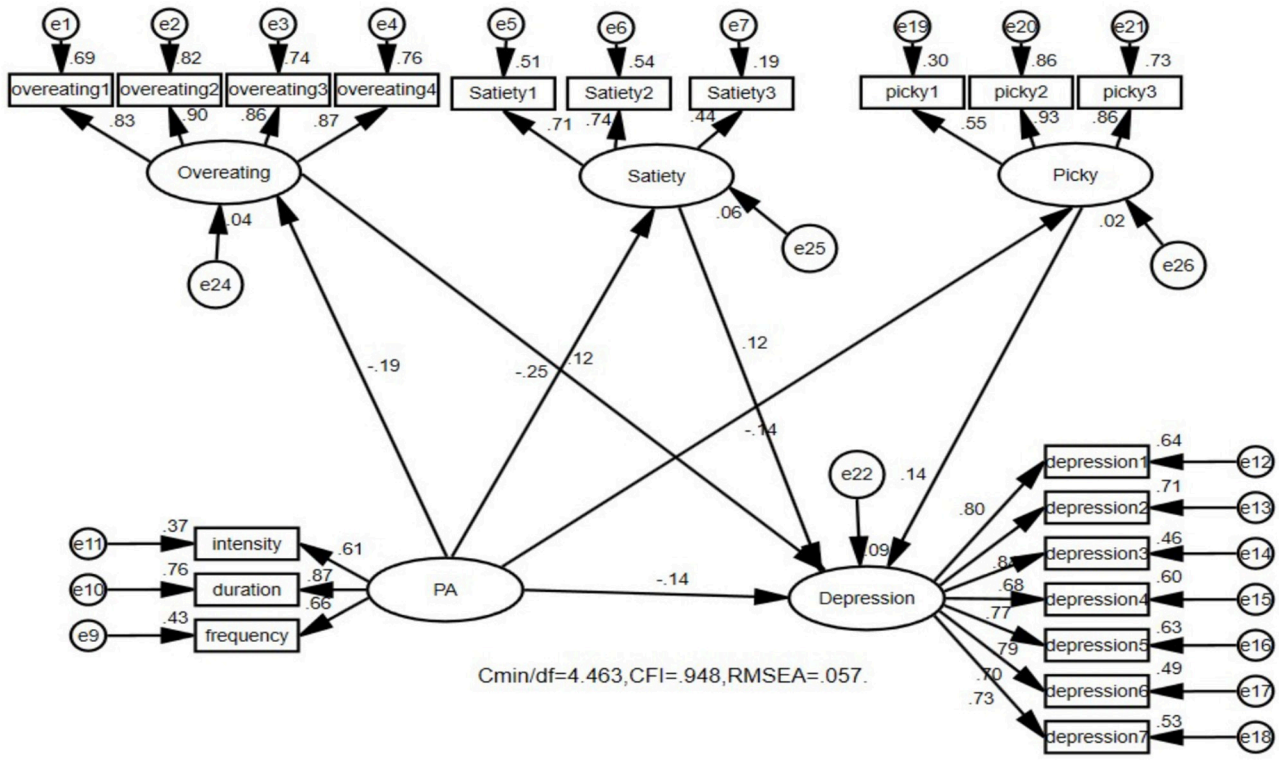

FIGURE 1
Physical activity not only affects college students' depression through a direct mechanism, but also plays a role through mediating effects from overeating, safety, and picky. The model shows a good fitness coefficient. PA, physical activity.

TABLE 5 Path analysis of physical activity and dietary behavior influencing depression, anxiety, and stress.

Effect	Path	Beta	*p*-value	95%CI	
				Low	Upper
Direct effect	PA- Depression	−0.143	0.002	−0.219	−0.064
Indirect effect	PA- DB1-Depression	−0.071	0.001	−0.113	−0.039
Total effect	PA- Depression	−0.214	0.003	−0.275	−0.137
Direct effect	PA- Anxiety	−0.141	0.000	−0.212	−0.069
Indirect effect	PA- DB2- Anxiety	−0.053	0.000	−0.084	−0.029
Total effect	PA- Anxiety	−0.194	0.000	−0.262	−0.124
Direct effect	PA- Stress	−0.136	0.000	−0.204	−0.068
Indirect effect	PA- DB3- Stress	−0.049	0.000	−0.078	−0.027
Total effect	PA- Stress	−0.185	0.000	−0.252	−0.118

DB1 is composed of three intermediaries, namely, overeating, satiety, and picky; DB2 is composed of three intermediaries, namely, overeating, reaction, and pickiness; DB3 is composed of two intermediaries, namely, overeating and picky eating.
PA, physical activity.

4.3 Positive effects of physical activity on depression, anxiety, and stress among college students

Recent reviews have shown that physical activity, including aerobic exercise, strength training, or yoga, effectively alleviates depressive symptoms, comparable to medications or therapy (64, 65). In contrast, dietary interventions can reduce depression in non-clinical and female groups but are ineffective for anxiety, with unclear active ingredients and mechanisms (66). The intake of ultra-processed foods (UPFs) is linked to increased depression risk, indicating a need to reduce ultra-processed foods (UPFs) while increasing exercise (67). Moderate-intensity continuous training and high-intensity interval training (HIIT) (HIIT) have comparable effects, but HIIT is more time-efficient; yoga efficacy depends on frequency and cultural adaptation (68). Overall, physical activity

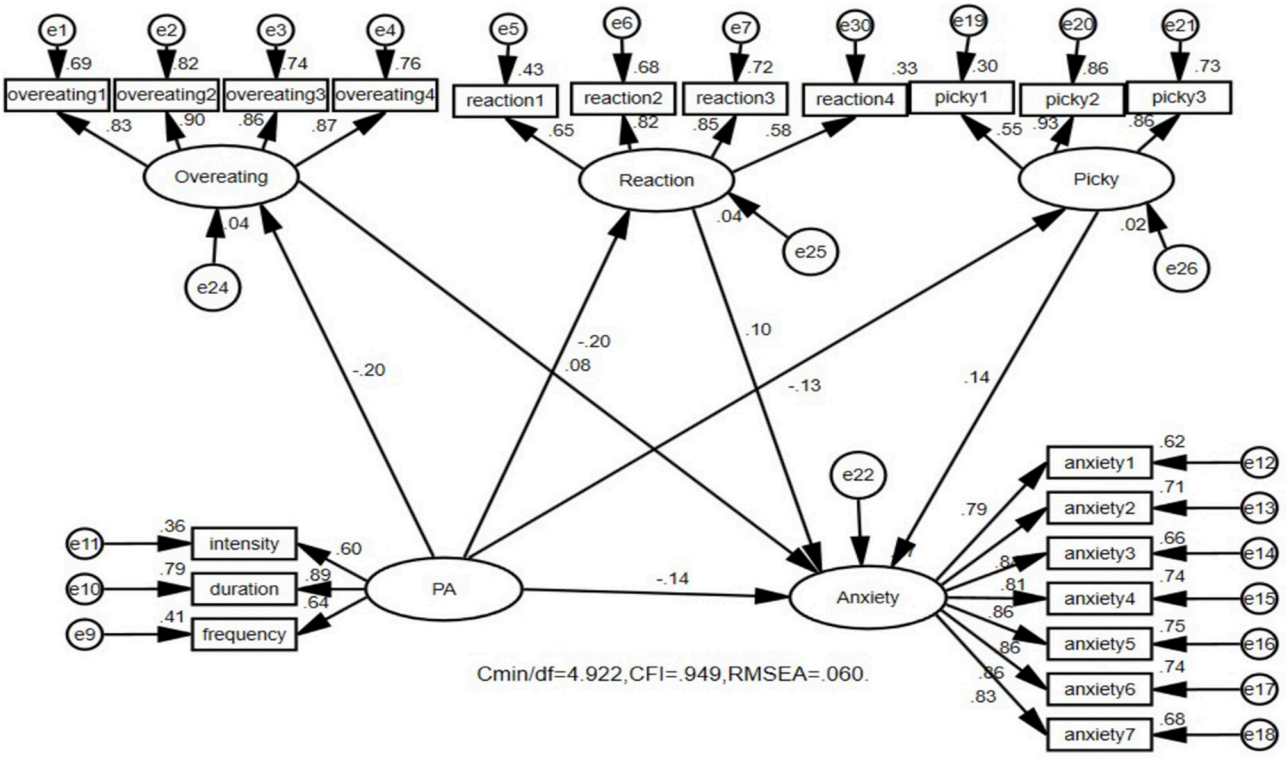

FIGURE 2
Physical activity not only affects college students' depression through a direct mechanism, but also plays a role through mediating effects from overeating, reaction, and picky. The model shows a good fitness coefficient. PA, physical activity.

is recommended for depression prevention and treatment because of its low cost and risk. However, high-quality randomized controlled trials are needed to determine the optimal dosage and personalization.

A negative correlation ($r = -0.139$, $p < 0.01$) between physical activity and anxiety was found in college students, which is consistent with the findings of a recent study in which exercise's antianxiety efficacy was comparable to that of pharmacological treatments or therapy, with no addiction risk or benefits for cardiovascular issues (69). The dose–response relationship suggests that moderate-to-high-intensity aerobic exercise (≥60% VO_2 peak, ≥150 min per week) or high-intensity interval training (HIIT) can significantly reduce state–trait anxiety scores within 2–4 weeks, whereas low-intensity activities (such as yoga) require more extended intervention periods to achieve equivalent results (70). Physical activity significantly affects anxiety disorders more than depression does, indicating that anxiety symptoms may be more sensitive to exercise-induced neurochemical changes. The molecular mechanisms by which exercise mitigates anxiety can be encapsulated by the three interdependent pillars of "monoamine inhibition plasticity" (71–73). The phased release of the dopamine reward system elevates mood and establishes a positive feedback loop that reinforces exercise behavior, further improving adherence to the intervention (74).

This investigation did not reveal a notable association between physical activity and subjective stress levels among college students. Nonetheless, prior research has indicated that exercise may modulate the stress response via a biphasic process characterized by "acute activation and chronic adaptation." Acute high-intensity exercise instantly increases adrenaline and noradrenaline levels, enhancing energy mobilization and alertness (75). However, endurance training reduces peak catecholamine secretion from rest and stress, increasing heart rate variability, indicating synergistic adaptation with lower sympathetic sensitivity and higher parasympathetic tone (24, 76). This adaptive modification is crucial for chronically stressed populations, as regular physical activity can reduce cardiovascular risk by 10%—20%, similar to beta-blockers (25). Therefore, the lack of correlation in cross-sectional studies may be due to low sample pressure or imprecise exercise volume measurement, but not biological pathway failure. Alkhatatbeh et al. (77) confirmed that young adults exhibiting suboptimal sleep quality tend to experience heightened levels of anxiety and depression in comparison to their well-rested counterparts, which is often accompanied by more pronounced musculoskeletal discomfort. Enhancing sleep quality may be a potential intervention to mitigate these adverse symptoms (77). Furthermore, a dose–response relationship exists between deteriorating sleep quality and the intensification of depressive symptoms, wherein poorer sleep correlates with increased severity of depression (78). Sleep disorders not only constitute a significant risk factor for depression but also may intensify preexisting symptoms (79).

Prolonged engagement with electronic devices is recognized as a critical element influencing sleep quality, particularly

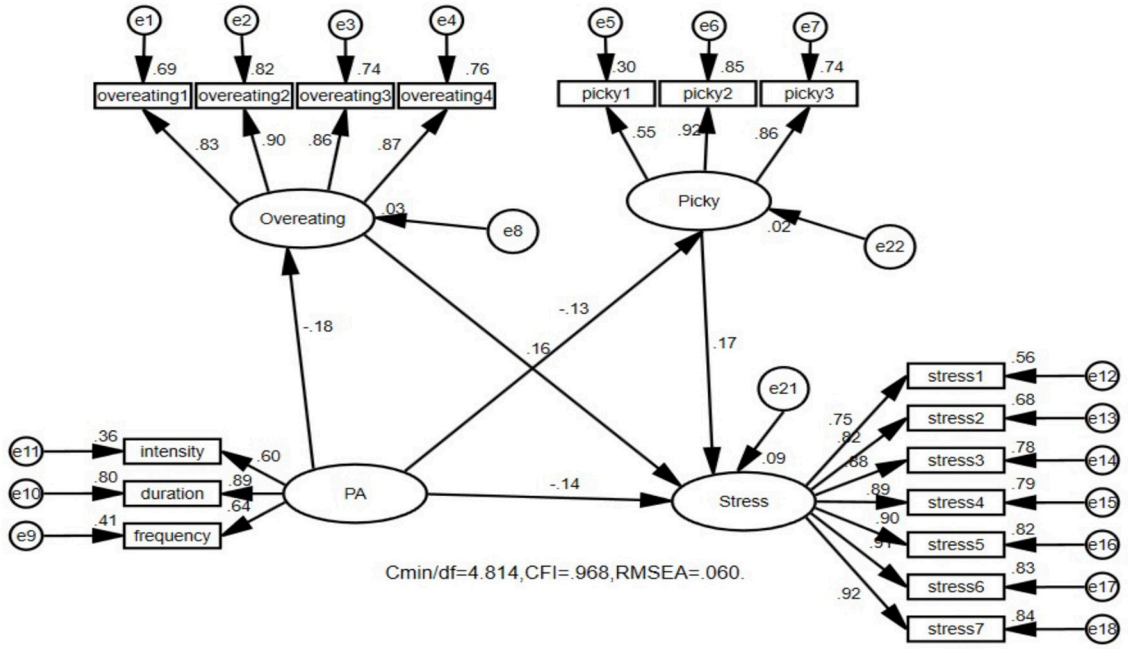

FIGURE 3
Physical activity not only affects college students' depression through a direct mechanism, but also plays a role through mediating effects from overeating and picky. The model shows a good fitness coefficient. PA, physical activity.

among adolescents. Empirical studies have demonstrated a robust correlation between the utilization of electronic devices and the prevalence of sleep disorders (80, 81). Excessive use of smartphones and computers is positively associated with depressive symptoms, revealing a notable increase in the incidence of depression and anxiety among adolescents who engage with these devices for durations exceeding 2 h (82, 83). Moreover, interaction with electronic devices may adversely affect adolescents' social skills and psychological resilience, further aggravating emotional challenges.

4.4 Dietary behavior plays a mediating role in the relationships among physical activity, depression, anxiety, and stress among college students

Numerous studies have demonstrated that engaging in physical exercise serves as a potent strategy for mitigating the risks of anxiety and depression (84–86). Enhanced physical activity significantly reduces anxiety and depression, with prior research showing a strong link between higher activity levels and lower symptoms. Moreover, sleep quality also negatively correlates with both conditions (87). Increased physical activity is linked to better wellbeing and sleep quality, indicating that sleep mediates the relationship between activity and anxiety (88). However, diverse viewpoints persist in this domain; for example, (22) established that there is a lack of sufficient evidence to substantiate the claim that physical activity can effectively avert the onset of anxiety disorders (22).

In this research, we discovered that engaging in physical activity can influence the levels of depression and anxiety among college students, while dietary measures can effectively modulate these conditions. This finding validates previous scholars' views (31, 36) and introduces a novel perspective that dietary habits significantly mediate this relationship. Physical activity regulates energy expenditure, appetite, and ghrelin, reducing emotional eating and mitigating the effects of high sugar on serotonin and dopamine (59). Exercise enhances leptin sensitivity and reduces the risk of depression linked to eating disorders (89). Regular physical activity enhances self-efficacy and reduces stress-related eating behaviors. This change effectively interrupts the vicious cycle characterized by pressure → emotional eating → guilt → anxiety (59, 63). Adverse emotions can lead to unhealthy eating and increased distress, whereas exercise encourages better food choices and emotional control (90). A prior investigation revealed a reciprocal relationship between the quality of sleep and states of depression and anxiety (88). Future studies should assess the relationships among physical activity, diet, sleep, and mental health. Supplementation may reduce inflammation linked to high-fat diets. Changes in the gut microbiota can affect cognition and lead to anxiety or depression (91). These investigations provide new ways to manage depression and anxiety.

Physical activity is crucial for an active lifestyle and significantly reduces stress, especially in college students, who experience lower stress levels with increased exercise (92). This study confirmed that college students' physical activity not only directly affects stress but also exerts its effect through the mediating role of overeating and pickiness. An additional study revealed that physical exercise is a strong stress management strategy that

helps students face challenges and maintain mental wellbeing (93). Physical activity alleviates stress, but the role of dietary habits is often overlooked; nutrition affects both diet quality and mental wellbeing, with studies showing a strong link between diet and mental health, especially under pressure (94). For example, emotional eating involves the use of food to cope with stress, leading to harmful habits and increased psychological distress (95).

Compared to their sedentary peers, students who exercised regularly presented better nutrition and lower stress (92). Dietary improvements can significantly reduce stress, especially in physically active individuals (96). Dietary habits partially mediate the link between physical activity and stress, with improved nutrition, especially more fruits and vegetables, increasing mental wellbeing and reducing anxiety and depression (97). In addition, a nutritious diet positively correlates with increased physical activity, suggesting that better dietary habits can reduce stress levels (96). Gender significantly influences physical activity and stress management, with women seeking social support and men preferring exercise (96). Women seek social support under stress, whereas men relieve tension through physical activity (98). Therefore, the formulation of tailored exercise regimens that consider individual capabilities and preferences can significantly enhance stress management.

4.5 Innovations and limitations of this study

The originality of this study is reflected in the following three points: (I) the initial identification of an absence of substantial gender disparities in the levels of depression, anxiety, and stress among college students. Concurrently, a pronounced gender distinction in dietary habits and physical activity emerges, thereby contesting the conventional reliance on gender stereotypes in mental health interventions; (II) the innovative validation of the impact of physical activity on mental health through direct effects (depression/anxiety) and indirect mediation (dietary behavior), breaking through the previous research framework of single behavioral effects; and (III) the first empirical evidence shows that emotional overeating and food preferences can explain 75% of the variation in stress levels, overturning the notion that physical activity dominates stress regulation and establishing the core position of diet in stress management.

The current investigation serves as a trailblazer in revealing gender-invariant levels of depression, anxiety, and stress while simultaneously revealing gender-specific patterns in dietary habits and physical activity. It establishes direct and indirect pathways (mediated through dietary behaviors) through which physical activity influences mental health. However, the cross-sectional design somewhat constrains the efficacy of causal inference, particularly under the assumption that diet is a mediator between physical activity and psychological and emotional symptoms; it fails to eliminate the potential influences of reverse causality and unmeasured confounding factors on path coefficients. Future investigations should embrace longitudinal or experimental frameworks to elucidate the temporal and causal relationships, augmented by sensitivity analyses of the reverse path model to assess the robustness of the mediation hypothesis. Self-reported data are prone to various biases, including response, comprehension, and recall biases—limitations that could be alleviated by incorporating ecological momentary assessments, wearable technology, and digital food diaries for the continuous, objective tracking of physical activity and nutritional intake. The limited sociocultural diversity of the current sample restricts the generalizability of the findings; therefore, multisite, cross-cultural, and lifespan studies are warranted to evaluate the boundary conditions of the present results. Finally, the simplistic operationalization of diet inhibits the identification of specific foods, nutrients, or dietary patterns that contribute to stress; future research should utilize comprehensive dietary records, biomarkers (such as inflammatory cytokines and gut microbiome profiles), and nutrient databases to develop multifaceted "food–nutrient–metabolome–mood" frameworks, thereby translating our findings into precise, tailored nutritional strategies for the enhancement of mental health.

5 Conclusion

This study systematically evaluated differences in dietary habits, physical exercise, and levels of depression, anxiety, and stress between male and female college students, while exploring the potential impact of dietary habits on the relationship between physical activity and mental health (including depression, anxiety, and stress). The results reveal the complex interaction between students' lifestyles and mental health indicators, providing valuable cross-sectional insights into the mechanisms by which physical exercise and nutrition promote mental health.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Academic Ethics Committee of Sichuan University of Arts and Sciences. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Author contributions

SJ: Data curation, Methodology, Investigation, Writing – original draft, Formal analysis. CC: Supervision, Funding acquisition, Data curation, Writing – original draft, Conceptualization, Writing – review & editing. GL: Investigation,

Data curation, Writing – review & editing. ZJ: Methodology, Formal analysis, Writing – review & editing, Investigation.

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Conflict of interest

The authors declare that this study was conducted without any commercial or financial relationships that could be considered potential conflicts of interest.

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References

1. Andrade L, Caraveo-Anduaga JJ, Berglund P, Bijl RV, De Graaf R, Vollebergh W, et al. The epidemiology of major depressive episodes: results from the International Consortium of Psychiatric Epidemiology (ICPE) Surveys. *Int J Methods Psychiatr Res.* (2003) 12:3–21. doi: 10.1002/mpr.138

2. Liu DL, Yu ZZ, Liu L, Li GH, Li XM, Ruan CY, et al. Socioeconomic disparities in the prevalence of depression and anxiety, and their associations with diabetes in rural southwest China. *BMC Public Health.* (2025) 25:668. doi: 10.1186/s12889-025-21837-x

3. Zhang WY, Nan N, He Y, Zuo HJ, Song XT, Zhang M, et al. Prevalence of depression and anxiety symptoms and their associations with cardiovascular risk factors in coronary patients. *Psychol Health Med.* (2023) 28:1275–87. doi: 10.1080/13548506.2022.2104885

4. Denollet J, Strik JJ, Lousberg R, Honig A. Recognizing increased risk of depressive comorbidity after myocardial infarction: looking for 4 symptoms of anxiety-depression. *Psychother Psychosom.* (2006) 75:346–52. doi: 10.1159/000095440

5. Jindal M, Chhetri A, Ludhiadch A, Singh P, Peer S, Singh J, et al. Neuroimaging genomics a predictor of major depressive disorder (MDD). *Mol Neurobiol.* (2024) 61:3427–40. doi: 10.1007/s12035-023-03775-0

6. Bonk S, Eszlari N, Kirchner K, Gezsi A, Garvert L, Kuokkanen M, et al. Impact of gene-by-trauma interaction in MDD-related multimorbidity clusters. *J Affect Disord.* (2024) 359:382–91. doi: 10.1016/j.jad.2024.05.126

7. Anderson CA, Ruiz J. Depressive symptoms among hispanic adolescents and effect on neonatal outcomes. *Hisp Health Care Int.* (2022) 20:25–32. doi: 10.1177/15404153211003223

8. 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

9. Denche-Zamorano Á, Salas-Gómez D, Parraca JA, Tomas-Carus P, Adsuar JC, Barrios-Fernandez S. Relationship between depression and physical activity frequency in spanish people with low, medium, and high pain levels. *J Pers Med.* (2024) 14:855. doi: 10.3390/jpm14080855

10. Zhou YS, Meng FC, Cui Y, Xiong YL Li XY, Meng FB, et al. Regular aerobic exercise attenuates pain and anxiety in mice by restoring serotonin-modulated synaptic plasticity in the anterior cingulate cortex. *Med Sci Sports Exerc.* (2022) 54:566–81. doi: 10.1249/MSS.0000000000002841

11. Haunhorst S, Bloch W, Ringleb M, Fennen L, Wagner H, Gabriel HHW, et al. Acute effects of heavy resistance exercise on biomarkers of neuroendocrine-immune regulation in healthy adults: a systematic review. *Exerc Immunol Rev.* (2022) 28:36–52. doi: 10.1016/j.exger.2022.111775

12. Maekawa T, Sakitani N, Ryu Y, Takashima A, Murase S, Fink J, et al. Application of passive head motion to generate defined accelerations at the heads of rodents. *J Vis Exp*. (2022). doi: 10.3791/63100-v

13. Lasselin J. Is inflammation-associated depression atypical depression? *Brain Behav Immun.* (2020) 87:193–4. doi: 10.1016/j.bbi.2020.01.008

14. Fan Y, Wang L, Jiang H, Fu Y, Ma Z, Wu X, et al. Depression circuit adaptation in post-stroke depression. *J Affect Disord.* (2023) 336:52–63. doi: 10.1016/j.jad.2023.05.016

15. Romney M, Robinson RF, Boyle J. Mental health pharmacists: increasing necessary mental health service delivery. *Fed Pract.* (2022) 39:106–8. doi: 10.12788/fp.0237

16. Sun X, Zhou M, Huang L, Nuse B. Depressive costs: medical expenditures on depression and depressive symptoms among rural elderly in China. *Public Health.* (2020) 181:141–50. doi: 10.1016/j.puhe.2019.12.011

17. Crawford CM, Fallucco E, Fava M, Ingelfinger J, Scott-Vernaglia S. Depression - screening and treating depression in adolescents. *N Engl J Med.* (2024) 390:e56. doi: 10.1056/NEJMp2400711

18. Pearce M, Garcia L, Abbas A, Strain T, Schuch FB, Golubic R, et al. Association between physical activity and risk of depression: a systematic review and meta-analysis. JAMA Psychiatry. (2022) 79:550–9. doi: 10.1001/jamapsychiatry.2022.0609

19. Carek PJ, Laibstain SE, Carek SM. Exercise for the treatment of depression and anxiety. *Int J Psychiatry Med.* (2011) 41:15–28. doi: 10.2190/PM.41.1.c

20. Rebar AL, Stanton R, Geard D, Short C, Duncan MJ, Vandelanotte C, et al. A meta-meta-analysis of the effect of physical activity on depression and anxiety in non-clinical adult populations. *Health Psychol Rev.* (2015) 9:366–78. doi: 10.1080/17437199.2015.1022901

21. Stubbs B, Koyanagi A, Hallgren M, Firth J, Richards J, Schuch F, et al. Physical activity and anxiety: a perspective from the World Health Survey. *J Affect Disord.* (2017) 208:545–52. doi: 10.1016/j.jad.2016.10.028

22. Moreno-Peral P, Pino-Postigo A, Conejo-Cerón S, Bellón D, Rodríguez-Martín B, Martínez-Vizcaíno V, et al. Effectiveness of physical activity in primary prevention of anxiety: systematic review and meta-analysis of randomized controlled trials. *Int J Environ Res Public Health*. (2022) 19:1813. doi: 10.3390/ijerph19031813

23. Vieira NB, Bandeira PFR, de Sousa DF, Delmondes GA, Júnior JG, Zaia V. Statistical and machine learning modeling of psychological, sociodemographic, and physical activity factors associated with weight regain after bariatric surgery. *Int J Environ Res Public Health*. (2025) 22:904. doi: 10.3390/ijerph22060904

24. Reynolds CA, Minic Z. Chronic pain-associated cardiovascular disease: the role of sympathetic nerve activity. *Int J Mol Sci.* (2023) 24:5378. doi: 10.3390/ijms24065378

25. Hrabalova P, Bohuslavova R, Matejkova K, Papousek F, Sedmera D, Abaffy P, et al. Dysregulation of hypoxia-inducible factor 1α in the sympathetic nervous system accelerates diabetic cardiomyopathy. *Cardiovasc Diabetol.* (2023) 22:88. doi: 10.1186/s12933-023-01824-5

26. Kale MB, Wankhede NL, Goyanka BK, Gupta R, Bishoyi AK, Nathiya D, et al. Unveiling the neurotransmitter symphony: dynamic shifts in neurotransmitter levels during menstruation. *Reprod Sci.* (2025) 32:26–40. doi: 10.1007/s43032-024-01740-3

27. Yu J, Pu F, Yang G, Hao M, Zhang H, Zhang J, et al. Sex-specific association between childhood adversity and accelerated biological aging. *Adv Sci.* (2024) 11:e2309346. doi: 10.1002/advs.202309346

28. Sweeney M, Carpenter L, de Souza S, Caton E, Galloway J, Cope A, et al. Self-management behaviors do not affect remission but mediate between mental health and disease outcomes in a longitudinal study of rheumatoid arthritis. *Rheumatol Int.* (2025) 45:31. doi: 10.1007/s00296-024-05761-8

29. Dinas PC, On Behalf Of The Students Of Module Introduction To Systematic R, Karaventza M, Liakou C, Georgakouli K, Bogdanos D, et al. Combined effects of physical activity and diet on cancer patients: a systematic review and meta-analysis. *Nutrients*. (2024) 16:1749. doi: 10.3390/nu16111749

30. Canheta ABS, Santos A, Souza JD, Silveira EA. Traditional Brazilian diet and extra virgin olive oil reduce symptoms of anxiety and depression in individuals with severe obesity: Randomized clinical trial. *Clin Nutr.* (2021) 40:404–11. doi: 10.1016/j.clnu.2020.05.046

31. Gomes AP, Gonçalves H, Dos Santos Vaz J, Kieling C, Rohde LA, Oliveira IO, et al. Do inflammation and adiposity mediate the association of diet quality with depression and anxiety in young adults? *Clin Nutr.* (2021) 40:2800–8. doi: 10.1016/j.clnu.2021.03.028

32. Morales G, Balboa-Castillo T, Fernández-Rodríguez R, Garrido-Miguel M, Guidoni CM, Sirtoli R, et al. Adherence to the mediterranean diet and depression, anxiety, and stress symptoms in Chilean university students: a cross-sectional study. *Cad Saude Publica.* (2023) 39:e00206722. doi: 10.1590/0102-311xen206722

33. Allcock L, Mantzioris E, Villani A. Adherence to a mediterranean diet is inversely associated with anxiety and stress but not depression: a cross-sectional analysis of community-dwelling older Australians. *Nutrients*. (2024) 16:366. doi: 10.3390/nu16030366

34. Xie X, Li Y, Zhang Y, Lin X, Huang M, Fu H, et al. Associations of diet quality and daily free sugar intake with depressive and anxiety symptoms among Chinese adolescents. *J Affect Disord.* (2024) 350:550–8. doi: 10.1016/j.jad.2024.01.101

35. Ein N, Armstrong B, Vickers K. The effect of a very low calorie diet on subjective depressive symptoms and anxiety: meta-analysis and systematic review. *Int J Obes.* (2019) 43:1444–55. doi: 10.1038/s41366-018-0245-4

36. Kwak S, Shin J, Kim JY. The relationship between self-perceived health and physical activity in the mental health of Korean cancer survivors. *Healthcare.* (2023) 11:1549. doi: 10.3390/healthcare11111549

37. Tian H, Wang Z, Meng Y, Geng L, Lian H, Shi Z, et al. Neural mechanisms underlying cognitive impairment in depression and cognitive benefits of exercise intervention. *Behav Brain Res.* (2025) 476:115218. doi: 10.1016/j.bbr.2024.115218

38. Akinci E, Wieser MO, Vanscheidt S, Diop S, Flasbeck V, Akinci B, et al. Impairments of social interaction in depressive disorder. *Psychiatry Investig.* (2022) 19:178–89. doi: 10.30773/pi.2021.0289

39. Luo Y, Sato Y. Relationships of social support, stress, and health among immigrant Chinese women in Japan: a cross-sectional study using structural equation modeling. *Healthcare.* (2021) 9:258. doi: 10.3390/healthcare9030258

40. Zhang G, Feng W, Zhao L, Zhao X, Li T. The association between physical activity, self-efficacy, stress self-management and mental health among adolescents. *Sci Rep*. (2024) 14:5488. doi: 10.1038/s41598-024-56149-4

41. Castarlenas E, Galán S, Solé E, Roy R, Sánchez-Rodríguez E, Jensen MP, et al. Perceived stress, perceived social support, and global health in adults with chronic pain. *Int J Behav Med.* (2025) 32:92–101. doi: 10.1007/s12529-023-10250-6

42. Edwards JR, Gotschall JW, Clougherty JE, Schinasi LH. Associations of greenspace use and proximity with self-reported physical and mental health outcomes during the COVID-19 pandemic. *PLoS ONE.* (2023) 18:e0280837. doi: 10.1371/journal.pone.0280837

43. van der Veer A, Madern T, van Lenthe FJ. Tunneling, cognitive load and time orientation and their relations with dietary behavior of people experiencing financial scarcity - an AI-assisted scoping review elaborating on scarcity theory. *Int J Behav Nutr Phys Act.* (2024) 21:26. doi: 10.1186/s12966-024-01576-9

44. Huang ZP, Huang F, Liang Q, Liao FZ, Tang CZ, Luo ML, et al. Socioeconomic factors, perceived stress, and social support effect on neonatal nurse burnout in China: a cross-sectional study. *BMC Nurs.* (2023) 22:218. doi: 10.1186/s12912-023-01380-z

45. Sigursteinsdottir H, Rafnsdottir GL. The well-being of primary school teachers during COVID-19. *Int J Environ Res Public Health*. (2022) 19:11177. doi: 10.3390/ijerph191811177

46. Zurita-Ortega F, San Román-Mata S, Chacón-Cuberos R, Castro-Sánchez M, Muros JJ. Adherence to the Mediterranean diet is associated with physical activity, self-concept and sociodemographic factors in university student. *Nutrients*. (2018) 10:966. doi: 10.3390/nu10080966

47. Schultchen D, Reichenberger J, Mittl T, Weh TRM, Smyth JM, Blechert J, et al. Bidirectional relationship of stress and affect with physical activity and healthy eating. *Br J Health Psychol.* (2019) 24:315–33. doi: 10.1111/bjhp.12355

48. Si B, Zhang K. Animal-derived foods, physical activities, and mild cognitive impairment among Chinese older adults: findings from CLHLS (2008-2018). *BMC Public Health.* (2025) 25:2088. doi: 10.1186/s12889-025-23382-z

49. Prins PJ, Noakes TD, Buga A, Gerhart HD, Cobb BM, D'Agostino DP, et al. Carbohydrate ingestion eliminates hypoglycemia and improves endurance exercise performance in triathletes adapted to very low- and high-carbohydrate isocaloric diets. *Am J Physiol Cell Physiol.* (2025) 328:C710–27. doi: 10.1152/ajpcell.00583.2024

50. Amerkamp J, Benli S, Isenmann E, Brinkmann C. Optimizing the lifestyle of patients with type 2 diabetes mellitus - Systematic review on the effects of combined diet-and-exercise interventions. *Nutr Metab Cardiovasc Dis.* (2025) 35:103746. doi: 10.1016/j.numecd.2024.09.016

51. Sheng W, Shaofa N, Guibao Z, Zuxun L. Reliability and validity analysis of adult dietary behavior evaluation scale. *Med Soc.* (2006) 19:4. doi: 10.3870/j.issn.1006-5563.2006.07.008

52. Liang D. Stress level of college students and its relationship with physical exercise. *Chin Ment Health J.* (1994) 8:5–6.

53. Duan X, Wang X, Li X, Li S, Zhong Y, Bu T. Effect of mass sports activity on prosocial behavior: a sequential mediation model of flow trait and subjective wellbeing. *Front Public Health.* (2022) 10:960870. doi: 10.3389/fpubh.2022.960870

54. Zeng M, Chen S, Zhou X, Zhang J, Chen X, Sun J. The relationship between physical exercise and mobile phone addiction among Chinese college students: testing mediation and moderation effects. *Front Psychol.* (2022) 13:1000109. doi: 10.3389/fpsyg.2022.1000109

55. Henry JD, Crawford JR. The short-form version of the Depression Anxiety Stress Scales (DASS-21): construct validity and normative data in a large non-clinical sample. *Br J Clin Psychol.* (2005) 44(Pt 2):227–39. doi: 10.1348/014466505X29657

56. Cao CH, Liao XL, Jiang XY Li XD, Chen IH, Lin CY. Psychometric evaluation of the depression, anxiety, and stress scale-21 (DASS-21) among Chinese primary and middle school teachers. *BMC Psychol.* (2023) 11:209. doi: 10.1186/s40359-023-01242-y

57. Zhang Z, Lin R, Qiu A, Wu H, Wu S, Zhang L, et al. Application of DASS-21 in Chinese students: invariance testing and network analysis. *BMC Public Health.* (2024) 24:2934. doi: 10.1186/s12889-024-20123-6

58. Varì R, Scazzocchio B, D'Amore A, Giovannini C, Gessani S, Masella R. Gender-related differences in lifestyle may affect health status. *Ann Ist Super Sanita.* (2016) 52:158–66. doi: 10.4415/ANN_16_02_06

59. Lombardo M, Feraco A, Armani A, Camajani E, Gorini S, Strollo R, et al. Gender differences in body composition, dietary patterns, and physical activity: insights from a cross-sectional study. *Front Nutr.* (2024) 11:1414217. doi: 10.3389/fnut.2024.1414217

60. Hoteit M, Hallit S, Al Rawas H, Amasha J, Kobeissi F, Fayyad R, et al. Adolescent health in lebanon: exploring alcohol use, dietary patterns, mental health, physical activity, and smoking using the Global School-Based Student Health Survey Approach. *Nutrients.* (2024) 16. doi: 10.3390/nu16213590

61. Liu W, He MZ, Wang Y, Wang Y, Zhou Y, Wu M, et al. Differences in health-related behaviors between middle school, high school, and college students in Jiangsu province, China. *Asia Pac J Clin Nutr.* (2017) 26:731–7. doi: 10.6133/apjcn.072016.06

62. Gong L, Wu T, Zhang L, Lin G, Luo F, Zhang W, et al. The impact of behavioral risks on cardiovascular disease mortality in China between 1990 and 2019. *Heliyon.* (2024) 10:e39706. doi: 10.1016/j.heliyon.2024.e39706

63. Berge JM, Larson N, Bauer KW, Neumark-Sztainer D. Are parents of young children practicing healthy nutrition and physical activity behaviors? *Pediatrics.* (2011) 127:881–7. doi: 10.1542/peds.2010-3218

64. Schuch FB, Stubbs B. The role of exercise in preventing and treating depression. *Curr Sports Med Rep.* (2019) 18:299–304. doi: 10.1249/JSR.0000000000000620

65. Brinsley J, Schuch F, Lederman O, Girard D, Smout M, Immink MA, et al. Effects of yoga on depressive symptoms in people with mental disorders: a systematic review and meta-analysis. *Br J Sports Med.* (2021) 55:992–1000. doi: 10.1136/bjsports-2019-101242

66. Firth J, Marx W, Dash S, Carney R, Teasdale SB, Solmi M, et al. The effects of dietary improvement on symptoms of depression and anxiety: a meta-analysis of randomized controlled trials. *Psychosom Med.* (2019) 81:265–80. doi: 10.1097/PSY.0000000000000673

67. Werneck AO, Steele EM, Delpino FM, Lane MM, Marx W, Jacka FN, et al. Adherence to the ultra-processed dietary pattern and risk of depressive outcomes: findings from the NutriNet Brasil cohort study and an updated systematic review and meta-analysis. *Clin Nutr.* (2024) 43:1190–9. doi: 10.1016/j.clnu.2024.03.028

68. Martland R, Korman N, Firth J, Vancampfort D, Thompson T, Stubbs B. Can high-intensity interval training improve mental health outcomes in the general population and those with physical illnesses? A systematic review and meta-analysis. *Br J Sports Med.* (2022) 56:279–91. doi: 10.1136/bjsports-2021-103984

69. Ma R, Qiao M, Zhou Y, Sun W, Lv Y, Zhou X, et al. The relationship between knowledge, psychological flexibility, anxiety and healthy behaviour in stroke patients: a chain mediation model. *J Clin Nurs.* (2025). doi: 10.1111/jocn.17820

70. Tomiga Y, Tanaka K, Kusuyama J, Takano A, Higaki Y, Anzai K, et al. Exercise training ameliorates carbon tetrachloride-induced liver fibrosis and anxiety-like behaviors. *Am J Physiol Gastrointest Liver Physiol.* (2024) 327:G850–60. doi: 10.1152/ajpgi.00161.2024

71. Warner AK, Iskander L, Allen K, Quatela I, Borrelli H, Sachs BD. The effects of brain serotonin deficiency on the behavioral and neurogenesis-promoting effects of voluntary exercise in tryptophan hydroxylase 2 (R439H) knock-in mice. *Neuropharmacology.* (2024) 258:110082. doi: 10.1016/j.neuropharm.2024.110082

72. Xiao QX, Qin HY, Chen JJ, Fang CL, Wang QL Li QJ, et al. Multi-omics analysis reveals the potential mechanisms underlying long-term exercise-induced enhancement of learning and memory in male mice. *Biogerontology.* (2025) 26:84. doi: 10.1007/s10522-025-10225-y

73. Ebrahimnejad M, Azizi P, Alipour V, Zarrindast MR, Vaseghi S. Complicated role of exercise in modulating memory: a discussion of the mechanisms involved. *Neurochem Res.* (2022) 47:1477–90. doi: 10.1007/s11064-022-03552-w

74. Boecker H, Daamen M, Maurer A, Bodensohn L, Werkhausen J, Lohaus M, et al. Fractional amplitude of low-frequency fluctuations associated with μ-opioid and dopamine receptor distributions in the central nervous system after high-intensity exercise bouts. *Front Neuroimaging.* (2024) 3:1332384. doi: 10.3389/fnimg.2024.1332384

75. Sun W, Lu H, Zhang P, Zeng L, Ye B, Xu Y, et al. Localized propranolol delivery from a copper-loaded hydrogel for enhancing infected burn wound healing via adrenergic β-receptor blockade. *Mater Today Bio.* (2025) 30:101417. doi: 10.1016/j.mtbio.2024.101417

76. Ishii M, Ishiyama G, Ishiyama A, Kato Y, Mochizuki F, Ito Y. Relationship between the onset of ménière's disease and sympathetic hyperactivity. *Front Neurol.* (2022) 13:804777. doi: 10.3389/fneur.2022.804777

77. Alkhatatbeh MJ, Abdul-Razzak KK, Khwaileh HN. Poor sleep quality among young adults: the role of anxiety, depression, musculoskeletal pain, and low dietary calcium intake. *Perspect Psychiatr Care.* (2021) 57:117–28. doi: 10.1111/ppc.12533

78. Um YJ, Kim Y, Chang Y, Jung HS, Cho IY, Jeon SW, et al. Association of changes in sleep duration and quality with incidence of depression: a cohort study. *J Affect Disord.* (2023) 328:64–71. doi: 10.1016/j.jad.2023.02.031

79. Bao C, Wang Y, Le T, Xu L, Tang W, Zou W, et al. Relationship between depressive symptoms and sleep quality and cognitive inhibition ability in prenatal pregnant women. *BMC Psychiatry.* (2023) 23:522. doi: 10.1186/s12888-023-04976-6

80. Bacaro V, Meneo D, Curati S, Buonanno C, De Bartolo P, Riemann D, et al. The impact of COVID-19 on Italian adolescents' sleep and its association with psychological factors. *J Sleep Res.* (2022) 31:e13689. doi: 10.1111/jsr.13689

81. Liu Z, Tang H, Jin Q, Wang G, Yang Z, Chen H, et al. Sleep of preschoolers during the coronavirus disease 2019 (COVID-19) outbreak. *J Sleep Res.* (2021) 30:e13142. doi: 10.1111/jsr.13142

82. Hamshari S, Yaseen S, Zayed M, Dalasha A, Maraqa B, Nazzal Z. Adolescents' electronic devices use during the COVID-19 pandemic and its relationship to anxiety and depression levels: a cross-sectional study. *BMC Psychiatry.* (2024) 24:38. doi: 10.1186/s12888-023-05482-5

83. Amin SM, Mohamed MAE, Metwally El-Sayed M, El-Ashry AM. Nursing in the digital age: the role of nursing in addressing cyberbullying and adolescents mental health. *J Psychiatr Ment Health Nurs.* (2025) 32:57–70. doi: 10.1111/jpm.13085

84. McDowell CP, Dishman RK, Gordon BR, Herring MP. Physical activity and anxiety: a systematic review and meta-analysis of prospective cohort studies. *Am J Prev Med.* (2019) 57:545–56. doi: 10.1016/j.amepre.2019.05.012

85. Schuch FB, Stubbs B, Meyer J, Heissel A, Zech P, Vancampfort D, et al. Physical activity protects from incident anxiety: a meta-analysis of prospective cohort studies. *Depress Anxiety.* (2019) 36:846–58. doi: 10.1002/da.22915

86. Martínez-Moreno A, Ibáñez-Pérez RJ, Cavas-García FF, Cano-Noguera F. The influence of physical activity, anxiety, resilience and engagement on the optimism of older adults. *Int J Environ Res Public Health.* (2020) 17:8284. doi: 10.3390/ijerph17218284

87. Ghrouz AK, Noohu MM, Dilshad Manzar M, Warren Spence D, BaHammam AS, Pandi-Perumal SR. Physical activity and sleep quality in relation to mental health among college students. *Sleep Breath.* (2019) 23:627–34. doi: 10.1007/s11325-019-01780-z

88. Akbari HA, Pourabbas M, Yoosefi M, Briki W, Attaran S, Mansoor H, et al. How physical activity behavior affected well-being, anxiety and sleep quality during COVID-19 restrictions in Iran. *Eur Rev Med Pharmacol Sci.* (2021) 25:7847–57.

89. Liu L, Liu C, Liu X, Yang Y. Summary of the effect of an exercise intervention on antenatal depression and the optimal program: a systematic review and meta-analysis. *BMC Pregnancy Childbirth.* (2023) 23:293. doi: 10.1186/s12884-023-05629-y

90. Amatori S, Donati Zeppa S, Preti A, Gervasi M, Gobbi E, Ferrini F, et al. Dietary habits and psychological states during COVID-19 home isolation in italian college students: the role of physical exercise. *Nutrients.* (2020) 12:3660. doi: 10.3390/nu12123660

91. Lof J, Smits K, Melotte V, Kuil LE. The health effect of probiotics on high-fat diet-induced cognitive impairment, depression and anxiety: a cross-species systematic review. *Neurosci Biobehav Rev.* (2022) 136:104634. doi: 10.1016/j.neubiorev.2022.104634

92. Lepping KM, Bailey CP, Mavredes MN, Faro JM, Napolitano MA. Physical activity, stress, and physically active stress management behaviors among university students with overweight/obesity. *Am J Lifestyle Med.* (2023) 17:601–6. doi: 10.1177/15598276211020688

93. Frömel K, Šafár M, Jakubec L, Groffik D, Žatka R. Academic stress and physical activity in adolescents. *Biomed Res Int.* (2020) 2020:4696592. doi: 10.1155/2020/4696592

94. Wang HX, Cheng L, Yuan X, Lyu JL, Li P, Yan SY, et al. The mediating effect of concurrent changes in dietary behaviors on the associations between intervention and changes in adiposity outcomes: evidence from a cluster-randomized controlled trial. *Nutrients.* (2025) 17:376. doi: 10.3390/nu17030376

95. Chen JL, Doong JY, Tu MJ, Huang SC. Impact of dietary coparenting and parenting strategies on picky eating behaviors in young children. *Nutrients.* (2024) 16:898. doi: 10.3390/nu16060898

96. Brockmann AN, Ross KM. Bidirectional association between stress and physical activity in adults with overweight and obesity. *J Behav Med.* (2020) 43:246–53. doi: 10.1007/s10865-020-00145-2

97. Cao B, Zhao Y, Ren Z, McIntyre RS, Teopiz KM, Gao X, et al. Are physical activities associated with perceived stress? The evidence from the China Health and Nutrition Survey. *Front Public Health.* (2021) 9:697484. doi: 10.3389/fpubh.2021.697484

98. Militello R, Luti S, Gamberi T, Pellegrino A, Modesti A, Modesti PA. Physical activity and oxidative stress in aging. *Antioxidants.* (2024) 13:557. doi: 10.20944/preprints202404.0293.v1