RESEARCH

Open Access

The impact of lifestyle sports on the sleep quality of depressed high school students in Jiangsu Province, China: based on cross-sectional study

Xianghe Chen[1*†], Yuxin Yang[1], Jianbo Hu[1], Shengjie Jin[1†], Pengcheng Lu[1†], Xinyu Zeng[1], Xiaoyan Yi[1], Rongbin Yin[2*] and Chenghao Zhong[1]

Abstract

Objective Lifestyle sports refer to the stable forms and behavioral characteristics formed by individuals or groups of individuals who regularly and consciously participate in sports activities, which are divided into six dimensions: joviality type, challenge type, health type, beauty type, study type, and society type. High school students have a high prevalence of depression, and lifestyle sports are important factors affecting depression and depression-induced sleep quality problems. This paper intends to investigate the relationship between the six dimensions of lifestyle sports and the sleep quality of depressed high school students.

Methods In 129 high schools in 13 cities of Jiangsu Province, approximately 300 male and female students were selected for a questionnaire survey in each high school via the Lifestyle Sports Scale, the Self-rating Depression Scale (SDS), and the Pittsburgh Sleep Quality Index Scale (PSQI), and a stratified random sampling method was used. A total of 40,000 questionnaires were distributed, and 32,974 questionnaires were valid. The mediation model of depression between lifestyle sports and sleep quality was constructed via the Model4 model and other models in the SPSS macro program Process4.0. From the 32,974 valid questionnaires, 14,943 depressed high school students (SDS ≥ 53) were screened out, and structural equation modeling of the relationships between the six dimensions of lifestyle sports and the sleep quality of depressed high school students has been established via AMOS 28.0.

Results (1) Lifestyle sports significantly and positively predicted depression ($P < 0.001$), positively predicted sleep quality ($P < 0.001$), and depression significantly and positively predicted sleep quality ($P < 0.001$), and depression significantly mediated the relationship between high school students' lifestyle sports and sleep quality ($\beta = 0.004$, accounting for 29.91% of the total effect value). (2) The joviality type, challenge type, health type, beauty type, study

---

†Xianghe Chen, Yuxin Yang and Jianbo Hu contributed equally to this work.

*Correspondence:
Xianghe Chen
huashixh@163.com
Rongbin Yin
yrb@suda.edu.cn
Full list of author information is available at the end of the article

type and society type of lifestyle sports significantly and positively predicted sleep quality in depressed high school students ($P < 0.01$), with the correlation coefficients between joviality type ($\beta = 0.75$, $P < 0.01$) and study type ($\beta = 0.75$, $P < 0.01$) of lifestyle sports and the sleep quality of depressed high school students being the largest.

Conclusion Depression significantly mediated the relationship between lifestyle sports and sleep quality in high school students. All six dimensions of lifestyle sports are significantly positively correlated with sleep quality in depressed high school students, with the strongest correlations for the joviality type and study type.

Keywords Lifestyle sports, High school students, Depression, Sleep quality, Exercise

Introduction

Depression occurrence is the result of the dynamic interactions of various factors. Analyses from physiological, external, environmental, and macro social development perspectives reveal that significant hormonal fluctuations, low physical activity levels, and high academic pressures can all induce low spirits in high school students, resulting in a high incidence of depression [1, 2]. The "Chinese National Mental Health Development Report" has noted that between 2009 and 2020, approximately 40% of high school students were diagnosed with depression, with a staggering 12.5% being severe cases [3]. The high incidence of depression has led to widespread concerns from the state and society due to resulting issues such as aversion to school, dropout, and high suicide risk. In 2021, the Ministry of Education included depression screening in student health check-ups, and the "14th Five-Year Plan (2021–2025) for National Economic and Social Development of the People's Republic of China" clearly stipulates the need to strengthen the prevention and treatment of psychological issues such as depression in high school students. This study is closely integrated with China's national policies and actual situation, adopts an interdisciplinary perspective, breaks through the limitations of traditional single factor analysis, and aims to implement the requirements of the prevention and treatment of mental health problems in high school students, showing the policy orientation and practical application value of the research.

Depression can lead to significant decreases in sleep duration, quality, and chronotype in individuals, and decreased sleep quality can exacerbate depression [4]. This study focused on exploring the impact of depression on sleep quality. On the basis of the environment–behavior theory, the negative effect of depression on sleep quality is caused by the interaction of multiple factors, such as gene expression, hormones, and the social environment. For example, the down-regulation of the sleep factor CLOCK leads to biological rhythm disorders [5], sleep-wake rhythm disorders induced by reduced melatonin secretion [6, 7], and greater environmental stress (such as academic pressure) in students with depression [8]. A study investigated 516 students from three junior high schools in Tokyo has reported that the prevalence of depressive sleep disorders was 17.064 times greater than that of non-depressed junior high school students and resulted in abnormal sleep structure (sleep duration, quality, and chronotype) [9]. Up to now, there has been no similar comprehensive research report on senior high school students. This study fills the gap in the field of research on senior high school students, and provides a new perspective and basis for in-depth understanding of the relationship between depression and sleep quality in senior high school students.

Lifestyle sports refer to the stable form and behavioral characteristics formed by individuals or groups of individuals who participate in sports activities regularly and consciously and can be divided into six forms of expression: joviality type, challenge type, health type, beauty type, study type, and society type [10]. Joviality type refers to a lifestyle in which individuals participate in physical activities on the basis of the principles of free choice, moderation, and moderation, with a focus on physical and mental pleasure and relaxation. The challenge type refers to enjoying stimulating and challenging sports activities and gaining satisfaction and a sense of achievement in the process of intense and exciting sports. Health type refers to the concern for one's own physical health status, and participation in physical activity is aimed mainly at maintaining one's physical health. The beauty type refers to a lifestyle-oriented towards self-management of body shape and improvement in appearance. Study type refers to a lifestyle that focuses on physical activity for continuous learning and growth with the goal of acquiring and consolidating sports knowledge. Society type refers to a lifestyle in which individuals participate in sports through conscious participation and precise control to achieve personal health, social interaction, cultural experience, or the pursuit of certain social goals and other diverse purposes [11, 12]. Lifestyle sports include not only physical exercise but also all activities related to sports, which promote the physical and mental health of high school students from multiple perspectives [13]. The self-efficacy theory proposed by Bandura suggests that lifestyle sports as a stable and regular task can lead to positive changes in one's psychological state and improve self-efficacy to improve depressed mood [14]. To understand the impact of rural secondary school

students' lifestyle sports on their physical and mental health, a study from China has investigated 1,825 people using the Applied Mental Health Symptom Self-Assessment Scale and the Lifestyle Sports Scale for Secondary School Students and has reported that the detection rate of depression in rural high school students in northwestern Anhui Province who did not have good lifestyle sports was significantly greater [15]. Although this study compared the gap in depression detection rates among high school students with different lifestyle sports, it lacked an analysis of the relationship between the two. There are six types of lifestyle sports, namely, joviality type, challenge type, health type, beauty type, study type, and society type, and joviality and health are significantly and positively associated with college students' depression [16]. This study has used college students as subjects and has had a small sample size (1950 [17] and 483 [18]), and there has been a dearth of research or paucity of data regarding the relationship between lifestyle sports and depression.

Physical exercise is an important method to improve sleep quality in depressed patients, and 8 weeks of aerobic exercise significantly improves sleep quality in depressed patients, but the individual effect is not significant [19, 20]. These findings suggest that exercise improves sleep quality decline in depressed patients in the long-term cumulative effect. Comparing the effects of multiple types of exercise on sleep quality in depressed patients is a current research hotspot. A meta-analysis has revealed that both aerobic exercise and resistance exercise significantly improve the sleep quality of depressed adolescents and that resistance exercise has the largest effect size; meditation exercise had a significant effect on the sleep quality of depressed older adults, whereas other types of exercise are not significant [21]. These findings suggest that different types of exercise should be used for depressed patients in different age groups. In addition to empirical studies, two mediation effect analyses from China have confirmed the mediating role of sleep quality in the relationship between physical activity and depression in college students and old people [22, 23], and depression positively predicts sleep quality [24]. Studies have confirmed that lifestyle sports are a more comprehensive way to improve mental health in depressed patients [13, 25–27], but studies have yet to be conducted exploring the relationship between lifestyle sports and its six dimensions with sleep quality in depressed high school students have yet to be conducted.

In summary, this study intends to investigate the relationships between the six dimensions of lifestyle sports and the sleep quality of depressed high school students, and the following specific research hypotheses were proposed.

Hypothesis 1 Depression positively predicts sleep quality in high school students.

Hypothesis 2 Lifestyle sports positively predict depression in high school students.

Hypothesis 3 Lifestyle sports positively predict sleep quality in high school students.

Hypothesis 4 Depression mediates the relationship between lifestyle, sports, and sleep quality in high school students.

Hypothesis 5 Six dimensions of lifestyle sports positively predict sleep quality in depressed high school students.

Methods

Study design and population

This study utilized a cross-sectional analytical survey with a stratified, multistage, cluster sampling method [28]. Initially, 8–12 representative high schools were selected from each of the 13 cities in Jiangsu Province, considering factors like school level and urban-rural distinctions, between September 2020 and September 2022. This resulted in 129 high schools participating. Systematic sampling was used to distribute 40,000 paper-based questionnaires, completed on-site. Inclusion criteria were (1) voluntary participation with written consent; (2) enrollment in ordinary high schools; and (3) ages 14–19. Exclusion criteria included (1) questionnaires completed in under 180 s; and (2) incomplete questionnaires. The Ethics Committee of the College of Nursing, Yangzhou University (code: YZUHL2020018) approved and supervised the study. Participants were informed about the study, signed consent forms, and confidentiality was maintained. Incomplete questionnaires and those failing manual validation were excluded, and students with depressive moods (SDS ≥ 53) were identified for further analysis.

Sample size

In our study, the sample size was initially calculated using the Charles Kirkland formula, which suggested surveying approximately 1,066 students. However, to ensure more comprehensive data, we expanded this number to 40,000. We targeted high school students from 129 high schools across 13 cities in Jiangsu province, selecting around 300 students from each school. The cities covered the entire province, aligning with our focus on high school students in Jiangsu. We employed stratified random sampling to choose the high schools, considering education level, school level, and urban-rural distribution, ensuring a representative sample of diverse educational environments and socioeconomic backgrounds. Within each

school, classes from Grades 10, Grade 11, and Grade 12 were randomly selected, and all students in these classes were surveyed to maintain randomness and capture a balanced view of the student experience. By surveying entire classes, we aimed to accurately represent the student population at each school, thus providing a more accurate representation of the cities and the province as a whole. The systematic sampling method was used for the final selection of samples, and the distribution, completion, and collection of the 40,000 paper questionnaires were conducted on-site.

Instruments and measurements

(1) Lifestyle sports Scale

To satisfy the purpose of this study, it was combined with the lifestyle sports questionnaire in the Handbook of Assessment of Psychological Scales Commonly Used in Sports Science by Zhang Liwei and Mao Zhixiong [29]. Dan Yujin's 'Development and application of lifestyle sports scale for secondary school students' [30] and Karageorghis 'Lifestyle sports scale' [31] were revised to compile a preliminary scale for high school students' lifestyle sports. The scale consists of two dimensions, self-needs and social expansion, six factors, and 30 items: health, society, beauty, challenge, study, and joviality. Among them, health refers to paying attention to one's own physical health status and participating in sports activities mainly to maintain physical health, and its main influencing factors are physical and mental status and health outlook; it consists of 4, 10, 16, 22, 28. Society type refers to liking social communicative sports activities, achieving the purpose of communicating with others through common activities with others, caring about sports and cultural activities, and making a wide range of friendships. Society type refers to those who like to participate in group sports activities; it was composed of 5, 11, 17, 23, and 29. Beauty type refers to those who are concerned about others or their own cognitive evaluation of their own physical appearance and are concerned about their satisfaction with their bodies and personal management of their bodies; it was composed of 6, 12, 18, 24, and 30. Challenge type refers to those who like stimulating and challenging sports activities and who like to obtain satisfaction from the intense and exciting process of sports. Study type refers to participation in sports activities to master and consolidate sports methods and skills, to improve one's own sports ability and other aspects of ability, or to better learn other aspects of knowledge, purposeful exercise, which was composed of 3, 9, 15, 21, and 27. Joviality type refers to being in a good mood, being able to feel the beauty or pleasurable enjoyment in participating in sports activities, and enjoying participating

in dynamic, moderately or mildly strenuous activities, which can improve one's mood and maintain a good state of mind; it consists of 1, 7, 13, 19, and 25. When a 5-point Likert score was used, the higher the total score of an individual's scale was, the higher the level of his/her corresponding dimension. the higher. The Cronbach's alpha coefficient for this scale is 0.86.

(2) Self-rating Depression Scale (SDS)

For the purpose of this study, the scale was revised with reference to the studies of William W.K. Zung [32] and Mingyuan Zhang [33]. The scale contains 20 items rated via a four-point Likert-type scale, with 10 items worded negatively (presence of symptoms) and 10 items worded positively (absence of symptoms). Positive items are scored inversely. For each item, the respondent rates whether the item occurred 1 = a little of the time, 2 = some of the time, 3 = a good part of the time, or 4 = most of the time. The positive scores of all the items are summed to obtain the total raw score, which is then multiplied by 1.25 to convert it into the standard score, with the scale ranging from "25 to 100." According to the Chinese norm [34], a score of "<53" is considered normal, "53–59" indicates mild depression, "60–69" indicates moderate depression, and a score of "70" or above indicates severe depression. The Cronbach's alpha coefficient for this scale is 0.91.

(3) Pittsburgh Sleep Quality Index Scale (PSQI)

For the purpose of this study, the scale developed by Daniel J. Buysse [35] was used, and the Chinese version of the scale revised by Liu Xianchen et al. [36] was used. The scale consists of 18 self-assessment items and 7 components (sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction). The component scores range from 0 (no difficulty) to 3 (severe difficulty), and each part is added together to produce a global score ranging from 0 to 21. The higher the PSQI score is, the worse the sleep quality. A PSQI score of <3 was defined as good sleep quality, a PSQI score of 3–7 was defined as intermediate sleep quality, and a PSQI score >7 was defined as sleep quality problems [37]. The Cronbach's alpha coefficient for this index is 0.89.

Before conducting the survey for this study, we re-validated the revised scale's reliability and validity to ensure its reliability and effectiveness. We performed a reliability analysis on the revised scale using SPSS 27.0. We performed a reliability analysis on the revised scale, and the Cronbach's alpha obtained all exceeded the threshold of 0.7. This indicates that the scale has good reliability and confirms its applicability in this study's sample.

Table 1 Demographic characteristics of the participants(*N* = 32974)

Characteristics		N	%
Grade	10	10,974	33.3
	11	9841	29.8
	12	12,159	36.9
Class type	Humanities	11,123	33.7
	Science	18,578	56.3
	Arts	1941	5.9
	Sports	1332	4.1
Gender	Male	16,896	51.2
	Female	16,078	48.8
Age	14–15	3233	9.8
	16–17	25,857	78.4
	18–19	3884	11.8
Residential area	Urban	14,610	44.3
	Rural	18,364	55.7
An only child	Yes	15,158	46
	No	17,816	54
Residency	Home	21,145	64.1
	Dormitory	10,010	30.4
	Lodge or trusteeship	1819	5.5
Family structures	Two-parent	29,591	89.7
	Single-parent	2251	6.8
	Reconstituted	1132	3.5

Statistical analysis

First, high school students were analyzed to explore the relationships among the three variables of lifestyle sports, depression, and sleep quality. Based on the above mediation theory, depressed high school students were then analyzed to explore the relationships between the six dimensions of lifestyle sports and the sleep quality of depressed high school students.

IBM SPSS and SPSS AMOS software were used to analyze the data. The characteristics of the 32,974 high school students were described by Harman's one-way test and descriptive statistics (mean, standard deviation) to detect common method bias. Descriptive analysis and Pearson correlation analysis were used to explore the relationship between sports lifestyle and depression and sleep quality. PROCESS was used to construct and test the mediation model of depression, and the structural equation model (SEM) was established to reveal the relationship between physical education lifestyle and its six dimensions and sleep quality scores of high school students with depression. ADF method was used to analyze the SEM, and NFI, GFI, TLI, IFI, RMSEA and other indexes were used to evaluate the fitting of the model. Given the large sample size, the Bollen-Stine method was used to correct standard errors and test statistics to account for deviations from normality. The two-tailed p-values at the 0.05 level were considered statistically significant.

Table 2 Correlation analysis among major variables(*N* = 32974)

Variable	M ± SD	1	2	3
1 Lifestyle sports	85.30 ± 20.09	1.000		
2 Depression	50.21 ± 11.55	0.095**	1.000	
3 Sleep quality	5.55 ± 2.90	0.081**	0.263**	1.000

Note: **means *P* < 0.01. M: Mean, SD: Standard deviation

Results

Common method deviation test

The Harman one-way test was used to check for common method bias problems in this study [38], and the results revealed a total of two factors with eigenvalues greater than 1, with a maximum factor variance explained of 36.36% (< 40%), and no factors with excessive explanatory power, so there were no serious common method bias problems with the data of this study.

Demographic characteristics of the participants

In this study, 129 high schools in 13 cities in Jiangsu Province were surveyed, with a total of 40,000 questionnaires distributed, 36,573 recovered (91.4% recovery rate), and 32,974 valid questionnaires (90.2%validity rate). The grade, class type, gender, age, urban-rural distribution, only child, mode of residence, and family structure of the obtained samples all conformed to the demographic characteristics. The demographic characteristics of the participants were as follows (Table 1): 32,974 high school students; 10,974 (33.3%) were in Grade 10 high school; 9,841 (29.8%) were in Grade 11 high school; and 12,159 (36.9%) were in Grade 12 high school. There were 16,896 (51.2%) males and 16,078 (48.8%) females, and the mean age was 16.55 ± 0.873 years. Age stratification revealed that there were 3,233 high school students aged 14–15 years (9.8%), 25,857 high school students aged 16–17 years (78.4%), and 3,884 high school students aged 18–19 years (11.8%), of whom 18,578 were enrolled in science classes (56.3%), 11,123 in humanities (33.7%), 1,941 in art classes (5.9%), and 1,332 in sports classes (4.1%). In terms of place of residence, there were 18,364 (55.7%) in rural areas and 14,610 (44.3%) in urban areas, of whom 15,158 (46%) were only children and 17,816 (54%) were not. In terms of mode of residence, 21,145 (64.1%) lived at home, 10,010 (30.4%) in dormitory areas, and 1,819 (30.4%) lived on lodging or trusteeship. In terms of family structure, there were 29,591 (89.7%) two-parent families, 2,251 (6.8%) single-parent families, and 1,132 (3.5%) reconstituted families.

Correlation analysis of lifestyle sports, depression, and sleep quality scores among high school students

Pearson's correlation analysis revealed (Table 2) that lifestyle sports were significantly and positively correlated with depression (*r* = 0.095, *P* < 0.01) and that lifestyle sports were significantly and positively correlated with

Table 3 Data for the analysis of mediating effect of lifestyle sports on sleep quality and depression

Dredictor variable	Outcome variable	R	R²	SE	t	β	P	F
Lifestyle sports	Sleep quality	0.081	0.007	0.001	14.802	0.012	< 0.001	$F(1,32974) = 219.111, P = 0.0001$
Lifestyle sports	Depression	0.095	0.009	0.003	17.280	0.055	< 0.001	$F(1,32974) = 298.587, P = 0.0001$
Lifestyle sports	Sleep quality	0.269	0.072	0.001	10.675	0.008	< 0.001	$F(2,32974) = 1282.253, P = 0.0001$
Depression				0.001	48.269	0.065	< 0.001	

Note: SE: Standard error.

Table 4 Bootstrap test results for mediation effect

Effect	Standardised effect size	Boot 95% CI	Effect ratio
Total effect	0.012	[0.010, 0.013]	100%
Direct effect	0.008	[0.007, 0.010]	70.09%
Mediating effect	0.004	[0.003, 0.004]	29.91%

sleep quality ($r = 0.081$, $P < 0.01$). Depression was significantly positively correlated with sleep quality ($r = 0.263$, $P < 0.01$).

Mediating effect test for depression between lifestyle sports and sleep quality in high school students

The correlations among lifestyle sports, depression, and sleep quality were significant and met the prerequisites for the mediation test. Using lifestyle sports as the independent variable, depression as the mediator variable, and sleep quality score as the dependent variable, mediated effects analyses were conducted via the Model 4 model in the SPSS macro program Process 4.1. The mediated effects analysis revealed (Table 3) that lifestyle sports significantly and positively predicted sleep quality ($\beta = 0.012$, $t = 14.802$, $P < 0.001$) and remained significantly and positively predictive of sleep quality with the addition of the mediating variable (depression) ($\beta = 0.008$, $t = 10.675$, $P < 0.001$). Lifestyle sports significantly positively predicted depression ($\beta = 0.055$, $t = 17.280$, $P < 0.001$), and depression significantly positively predicted sleep quality ($\beta = 0.065$, $t = 48.269$, $P < 0.001$). The results of the Bootstrap method used to test the mediating effect (Table 4) revealed that the total effect of lifestyle sports on sleep quality was 0.012, the direct effect was 0.008 (70.09% of the total effect ratio), and the mediating effect was 0.004 (29.91% of the total effect ratio).

The Bootstrap method was used to construct confidence intervals for the mediating effects. The mediation model constructed in this study was tested, 95% confidence intervals for the effect values were estimated, and the study samples were repetitively sampled 5000 times. The results revealed that the direct effect of lifestyle sports on sleep quality scores, the indirect effect with depression as the mediating pathway, and the total effect of all three factors were significant, and the 95% confidence intervals did not contain 0. Therefore, the direct and indirect effects were significant, and a mediating effect of depression was established (Fig. 1).

Correlations between lifestyle sports and sleep quality in depressed high school students

To further validate the associations between the six dimensions of lifestyle sports and the sleep quality of depressed high school students, high school students with depressed moods (SDS ≥ 53) were screened from 32,974 valid questionnaires, totaling 14,943. Among them, 5,636 grade 10 students, 4,910 grade 11 students, 4,397 grade 12 students, 7,460 male students and 7483 female students were included. Next, we took depressed high school students as the research subjects. The results of Pearson's bivariate correlation analysis of the six dimensions of lifestyle sports with sleep quality showed (Table 5) that joviality, challenge, health, beauty, study and society type of lifestyle sports were significantly and positively correlated with sleep quality (all $p < 0.01$).
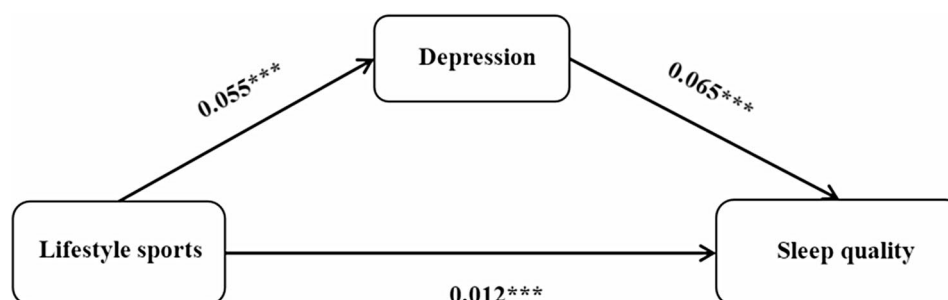

Fig. 1 Moderated mediation model of depression between lifestyle sports and sleep quality. *Note*: *** means $P < 0.001$

Table 5 Correlation analysis between variables (*N* = 14943)

Variable	M ± SD	1	2	3	4	5	6	7
1 Sleep quality	6.25 ± 3.097	1.000						
2 Joviality type	12.93 ± 4.946	0.069**	1.000					
3 Challenge type	17.3 ± 5.197	0.065**	0.419**	1.000				
4 Health type	11.85 ± 4.905	0.047**	0.488**	0.200**	1.000			
5 Beauty type	14.59 ± 5.175	0.030**	0.210**	0.226**	0.244**	1.000		
6 Study type	15.54 ± 4.898	0.099**	0.480**	0.480**	0.420**	0.274**	1.000	
7 Society type	14.41 ± 5.003	0.075**	0.465**	0.332**	0.348**	0.290**	0.450**	1.000

Note: **means *P* < 0.01. M: Mean, SD: Standard deviation.
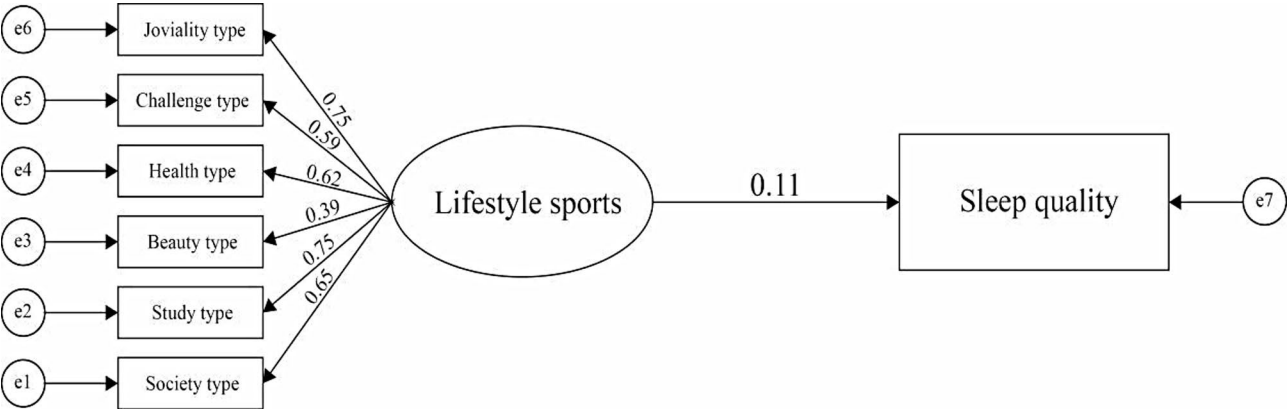

Fig. 2 Structural equation model of six dimensions of lifestyle sports and sleep quality

Table 6 Hypothesis testing of model regression coefficients

Path	b	β	SE	CR	P
Lifestyle sports → Joviality type	1	0.75			0.002
Lifestyle sports → Challenge type	0.824	0.59	0.012	68.412	0.002
Lifestyle sports → Health type	0.812	0.62	0.011	71.788	0.002
Lifestyle sports → Beauty type	0.551	0.39	0.013	41.655	0.001
Lifestyle sports → Study type	0.991	0.75	0.012	84.677	0.002
Lifestyle sports → Society type	0.871	0.65	0.012	73.318	0.002
Lifestyle sports → Sleep quality	0.092	0.11	0.008	11.931	0.001

Note: SE: Standard Error; CR: Critical Ratio.

Construction and testing of structural equation models of lifestyle sports and sleep quality among depressed high school students

The structural equation model was used to test the path relationships among the variables (Fig. 2), and the fit indices of the model were as follows: $x^2/df = 1.011$, RMSEA = 0.001, NFI = 0.998, IFI = 1.000, TLI = 1.000, and CFI = 1.000. All the fit metrics were within the standard range, indicating that the model was well-fitted. Hypothesis testing of model regression coefficients Model regression coefficient hypothesis tests revealed the following (Table 6): (1) Lifestyle sports significantly and positively predicted sleep quality ($\beta = 0.11$, $P < 0.01$). (2) Joviality ($\beta = 0.75$, $P < 0.01$), challenge ($\beta = 0.59$, $P < 0.01$), health ($\beta = 0.62$, $P < 0.01$), beauty ($\beta = 0.39$, $P < 0.01$), study ($\beta = 0.75$, $P < 0.01$) and society ($\beta = 0.65$, $P < 0.01$) all had

significant positive correlations with sleep quality, with the largest correlation coefficients for Joviality and Study.

Discussion

This study explored the relationships between lifestyle sports, depression, and sleep quality in high school students. It found that depression significantly predicts poor sleep quality, confirming Hypothesis H1. High academic pressure worsens depression, impacting sleep through negative memory bias and cognitive dysfunction. Depressive rumination and inflammatory responses further degrade sleep quality. A significant correlation between lifestyle sports and depression supports Hypothesis H2. Unlike studies on college or diabetic populations, this research used a 'Lifestyle Sports Scale' for high schoolers, showing that lifestyle sports reduce HPA axis activation and boost 5-HT secretion, improving depression through self-efficacy and self-esteem. Lifestyle sports also predict better sleep quality by lowering cortisol and enhancing mental resilience, confirming Hypothesis H3. Depression mediates the relationship between lifestyle sports and sleep quality, supporting Hypothesis H4. Students engaging in lifestyle sports experience increased enjoyment and stress resilience, improving sleep quality by shifting focus from negative thoughts. The study also identified that joviality and study dimensions of lifestyle sports most strongly correlate with improved sleep in depressed students, supporting Hypothesis H5. These findings

highlight the important role of lifestyle sports in influencing depression and sleep quality among high school students, offering valuable insights for interventions aimed at enhancing adolescent mental health through physical activity.

In the present study, we found that depression significantly and positively predicted sleep quality among high school students, aligning with previous research [9]. Two studies from China explore the relationship between depression and sleep quality in high school students and report that depression significantly and positively predicts sleep quality in high school students [39, 40]. External environmental factors such as high study pressure can lead to the occurrence of depression in high school students, which in turn affects sleep [41]. For this reason, high negative memory bias levels in depressed mood mediate the positive moderating effects of depression on sleep quality [42]. Cognitive abilities such as attentional shifting, memory-biased processing, and executive functioning are significantly reduced in depressed high school students, and high school students with heightened negative memory bias remember more negative information, persistently focusing on their depressed negative mood and poor sleep quality [43]. Increased depressive rumination leads to sleep overthinking in high school students, resulting in sleep disorders such as slow and shallow sleep onset [44]. Furthermore, upregulated expression of serum inflammatory factors (IL-1β and TNF-α) in depressed patients also leads to decreased sleep quality [45, 46].

Building on these findings, we examined the correlation between lifestyle sports and depression scores, discovering a significant positive relationship with lifestyle sports predicting depression. In previous studies, most of the subjects were college students and type 2 diabetic patients, and few high school students were included. Moreover, the present study was conducted to evaluate the physical lifestyle of high school students using the 'Lifestyle sports scale', which is superior to previous studies that used weekly exercise frequency, time, intensity, and the number of exercises to rate lifestyle sports [15]. Analysis of the neuroendocrine hypothesis reveals that lifestyle sports significantly suppressed HPA axis activation and promoted 5-HT secretion to improve depression, and the suppression of the HPA axis was caused by a reduction in cortisol and adrenocorticotropic hormone-releasing factor during exercise [47]. From the perspective of psychological mechanisms, lifestyle sports significantly improve self-efficacy and individual self-esteem and facilitate distraction from negative thoughts in high school students, thus improving depression [48–50].

Continuing our analysis, we confirmed that lifestyle sports positively predicted sleep quality in high school students, consistent with previous research [51]. This finding indicates that the better their lifestyle is, the greater their sleep quality. This can be analyzed in terms of physiology, psychology, and the interactions between the two: (1) Sleep disorders lead to an increase in the secretion of hormones such as cortisol, whereas lifestyle sports significantly inhibit cortisol secretion, which reduces the perceived stress of high school students, decreases the individual's susceptibility to the external environment, and improves sleep quality [52, 53]. (2) Lower levels of lifestyle sports lead to increased activation of the amygdala, which controls emotions, bipolar disorders in the thalamus, and hippocampal structural atrophy and neuronal regeneration insufficiency, inhibiting the functional connectivity network of the dorsolateral prefrontal and limbic brain regions in the middle frontal pole region [54], and higher individual vulnerability traits can lead to greater exposure to negative emotions in high school students. (3) Lifestyle sports are significantly and positively correlated with mental toughness and self-control, and the above psychological factors positively predicted sleep quality. The study confirmed that increased mental toughness enhances high school student's ability to cope with external environmental disturbances [55], and the strength model of self-control suggests that lifestyle sports is significantly and positively associated with self-control, the theory of bedtime procrastination suggests that students with weak self-control are vulnerable to disturbances from external things, resulting in sleep deprivation, sleep fatigue, and other problems [56].

Furthermore, our study reveals that depression significantly mediates the relationship between lifestyle sports and sleep quality. The cognitive-behavioral hypothesis of 'behavior, emotion, and cognition' suggests that emotion mediates the regulation between behavior and cognition and that lifestyle sports, as an independent predictor of depressive mood, significantly improve high school students' own sense of enjoyment, self-esteem, and resistance to stress [57, 58], which helps diverts individuals' attention from negative thinking. Facilitating high school students to disengage from unpleasant, stressful, anxious, and painful somatic complaints [59, 60] and, in turn, improves the biological changes in circadian rhythms and sleep homeostatic balance, shortens the time prebedtime, and relieves anxiety prebedtime [61]. Furthermore, physical exercise significantly changes lifestyle sports, and high school students' depressed mood is significantly improved at the same time as 5-HT secretion increases in the body, which in turn improves central nervous system function and alleviates anxiety; reduced cortisol secretion increases melatonin secretion and inhibits the activation of the HPA axis, which improves the role of the circadian rhythm of sleep-wakefulness [62, 63].

In a further exploration of these relationships, we constructed a structural equation model that highlights the positive correlation between the six dimensions of lifestyle sports and the sleep quality of depressed high school students. Joviality, study, health, challenge, beauty, and society type of lifestyle sports were all significantly and positively

correlated with the sleep quality of depressed high school students, with joviality type and study type having the highest correlation. A joviality type of lifestyle sports can improve prebedtime anxiety, shorten the time to sleep, and improve the sleep quality of depressed high school students by improving their positive social psychology and increasing their social behaviors [64]. From the perspective of physiological psychology, joviality type of lifestyle sports upregulates 5-HT expression and binds to 5-HT receptors in the nucleus accumbens and hippocampus, activates the projection loop of the nucleus accumbens-hippocampus pathway [65, 66], reduces depressive mood while causing a decrease in rapid eye movement sleep and an increase in slow-wave sleep, and improves sleep quality [67, 68]. Depressed high school students can significantly improve their sleep by learning sports knowledge and skills to divert their attention. Social learning theory suggests that depressed high school students observe the positive attitudes and healthy lifestyles of their peers in physical education and that obtaining social support can change their behaviours and thinking, alleviate depression and promote sleep [69]. It also improves sleep quality by enhancing self-efficacy and optimising cognitive patterns in depressed high school students [70]. In stress adaptation theory, moderate physical challenges can help increase mental toughness, effectively cope with stress, and reduce depression-induced sleep disturbances in depressed students [71]. Challenge type of lifestyle sports can improve sleep quality by enhancing positive coping strategies and increasing awareness and control of the body in depressed high school students [72, 73]. Self-determination theory states that satisfying depressed high school students' sense of autonomy, competence, and belonging increases their intrinsic motivation, enhances motivation for life, and improves sleep quality [74]. These findings suggest that fitness-based factors significantly positively predicted sleep quality in this study and that regular physical activities positively affected sleep quality by regulating body physiology, such as promoting endocrine balance, increasing endorphin secretion, and alleviating depression [75]. By improving the body shape and appearance of depressed high school students, a beauty type of lifestyle sports can increase their satisfaction with their body shape, thereby positively affecting their mental health. By engaging in beauty-type lifestyle sports, depressed high school students can not only increase their sense of control over their body shape but also improve their sense of self-efficacy and psychological resilience, which can help improve sleep quality [76]. Society type of lifestyle sports emphasizes the function of sports activities in terms of social aspects, and social support theory suggests that social support is crucial for reducing depressive symptoms and improving sleep quality and that depressed high school students gain emotional support and a sense of belonging, relieve stress, and enhance sleep quality in society type of lifestyle sports [77, 78]. In addition, by participating in socially orientated physical activities, depressed high school students are able to experience a sense of achievement and self-efficacy, which helps to improve their depressive mood and sleep quality [79].

The present study revealed the mediating relationship of depression between lifestyle sports and sleep quality in high school students and verified the positive effects of the six dimensions of lifestyle sports on sleep quality in depressed high school students. In the context of the high prevalence of depression in high school students, the above findings provide a theoretical basis for the use of physical exercise to prevent and control depression and its triggers in high school students, as well as a solid scientific basis for the development of precise exercise prescriptions to improve depressive symptoms and sleep quality in depressed high school students. However, this study has several limitations: (1) This study reflects only the situation of high school students' depression and other variables at one point in time and lacks a tracking survey for multiple points in time within a certain period of time to explore the trend of change. (2) There are fewer current relevant studies and this study investigated only high school students in Jiangsu Province. If different populations of adolescents in different cultures throughout China or around the world could be investigated, it would be more meaningful for the government, schools, and others to formulate policies related to preventing and controlling the high incidence of depression among adolescents. (3) This study is only a cross-sectional study and lacks a longitudinal intervention study, which, in turn, makes the findings more convincing.

Conclusions

Depression was a significant mediator between lifestyle sports and sleep quality in high school students, and all six dimensions of lifestyle sports were significantly and positively correlated with sleep quality in depressed high school students, with the greatest correlations having been found for joviality type and study type. In addition, in the future, the specific mechanisms of lifestyle sports to improve depression or sleep quality can be explored in depth, including physiological, psychological, and neurobiological dimensions, in order to reveal more comprehensively their intrinsic connections and principles of action and to provide a more targeted and effective strategic basis for the promotion of physical and mental health of high school students.

Abbreviations

SDS	Self-rating Depression Scale
PSQI	Pittsburgh Sleep Quality Index Scale
M	Mean
SD	Standard deviation
SEM	Structural Equation Modelling
ADF	Asymptotically Distribution-Free
NFI	Standardised Fit Index
GFI	Goodness of Fit Index
TLI	Tucker Lewis Index
IFI	Incremental

Chen *et al. BMC Public Health*   (2025) 25:1114

Page 10 of 12

RMSEA	Approximation
IL-1β	Interleukin − 1 beta
TNF-α	Tumor Necrosis Factor - alpha
HPA	Hypothalamus Pituitary Adrenal
5-HT	5 - Hydroxytryptamine

Data availability
(1) Data Sources and Access: Although the data are not publicly available, we ensure that, upon reasonable request, the data are available with the necessary approvals.
(2) Data format and supporting files: Data will be provided in an appropriate format with supporting files to aid understanding and use, including data dictionaries and associated codes.
(3) Restrictions and permissions: The use of data is restricted by ethics committee and institutional policies and will be used in accordance with relevant permissions after obtaining necessary approvals.
(4) Raw data: Raw data supporting the conclusions of this article will be provided by the authors without undue restrictions.
(5) Contact Information: If you have any questions or need further information, please feel free to contact me or the corresponding author (Professor Xianghe Chen, huashixh@163.com).

Declarations

Ethics approval and consent to participate
The study designed was approved by the Ethics Committee of School of Nursing, Yangzhou University (Approval Code: YZUHL2020018). We have obtained informed consent from the school teachers, students and their parents.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]College of Physical Education, Yangzhou University, Yangzhou 225127, China
[2]Physical Education and Sports School of Soochow University, Soochow 215021, China

References
1. Blankenstein NE, Telzer EH, Do KT, van Duijvenvoorde ACK, Crone EA. Behavioral and neural pathways supporting the development of prosocial and risk-taking behavior across adolescence. Child Dev. 2020;91(3):e665–81.
2. Yu XQ, Zhang YL, Yu GL. Prevalence of mental health problems among senior high school students in mainland of China from 2010 to 2020: a meta-analysis. Adv Psychol Sci. 2022;30(5):978–90.
3. Fu XL, Zhang K, Chen XF, Chen ZY. Report on national mental health development in China (2019–2020). Beijing: Social Sciences Academic Press (CHINA); 2021.
4. Guo C, Tomson G, Keller C, Söderqvist F. Prevalence and correlates of positive mental health in Chinese adolescents. BMC Public Health. 2018;18(1):263.
5. Gyorik D, Eszlari N, Gal Z. Every night and every morn: Effect of variation in CLOCK gene on depression depends on exposure to early and recent stress. Front Psychiatry. 2021;12:687487.
6. Jin WQ, Han DM, Wang GH, Li GP, Jiang F. Application of melatonin in children's sleep research and its measurement methods. Chin J Child Health Care. 2021;29(5):506–9.
7. Satyanarayanan SK, Su H, Lin YW, Su KP. Circadian rhythm and melatonin in the treatment of depression. Curr Pharm Design. 2018;24(22):2549–55.
8. Lin ZT, Zhang KT, Huang ZP, He XY, Ye WB, Li LP. Relationship of anxiety, stress and psychological distress with sleep quality in college students during COVID-19 outbreak. South China J Prev Med. 2021;47(4):499–502.
9. Kaneita Y, Yokoyama E, Harano S, Tamaki T, Suzuki H, Munezawa T, Nakajima H, Asai T, Ohida T. Associations between sleep disturbance and mental health status: a longitudinal study of Japanese junior high school students. Sleep Med. 2009;10(7):780–6.
10. Li WC, Xiao HY. Definition of concept of sports lifestyle and its categorical structures. J Shanghai Univ Sport. 2010;34(3):33–7.
11. Yang J, Ni XH, Tang L. Differences of gender role in choosing sports lifestyle of undergraduate students. J Wuhan Sports Univ. 2017;51(03):94–100.
12. Lin Y, Zhou H. The relationship between sports lifestyle and body self-esteem of students in medical colleges and universities. China J Health Psychol. 2018;26(5):782–5.
13. Moeijes J, van Busschbach JT, Bosscher RJ, Twisk JWR. Sports participation and health-related quality of life: a longitudinal observational study in children. Qual Life Res. 2019;28(9):2453–69.
14. Chen N, Zhang J, Wang Z. Effects of middle-aged and elderly people's self-efficacy on health promotion behaviors: mediating effects of sports participation. Front Psychol. 2023;13:889063.
15. Zhang L, Ding YL. Upon the influences of sport lifestyle on the mental and physical health of rural senior middle school students of China-A research conducted in the northwest of Anhui Province. Sports Sci. 2009;30(4):46–50.
16. Gong YX. The study of the relationship between the lifestyle sports and mental health among the college students in Jinan city. Shandong Sport University; 2020.
17. Li H. Analysis on influence factors of physical exercise on college students' mental health. J North China Inst Aerosp Eng. 2015;25(3):57–9.
18. Demirtas O. The effect of sports education on university students' healthy lifestyle behavior. Apuntes Universitarios. 2021;12:108–21.
19. Brupbacher G, Zander-Schellenberg T, Straus D, Porschke H, Infanger D, Gerber M, von Känel R, Schmidt-Trucksäss A. The acute effects of aerobic exercise on sleep in patients with unipolar depression: a randomized controlled trial. Sleep. 2021;44(11):zsab177.
20. Ji C, Yang J, Lin L, Chen S. Physical exercise ameliorates anxiety, depression and sleep quality in college students: experimental evidence from exercise intensity and frequency. Behav Sci (Basel). 2022;12(3):61.
21. Brupbacher G, Gerger H, Wechsler M, Zander-Schellenberg T, Straus D, Porschke H, Gerber M, von Känel R, Schmidt-Trucksäss A. The effects of aerobic, resistance, and meditative movement exercise on sleep in individuals with depression: protocol for a systematic review and network meta-analysis. Syst Reviews. 2019;8(1):105.
22. Li JC, Chen MB, Song PY. Analysis of the chain mediating effect between physical exercise and depression in college students. Teach Learn New Curriculum. 2022;146(14):20–2.
23. Liu HZ. The effects of physical exercise on sleep quality, anxiety and depression of college students. Shanghai University of Sport; 2020.
24. Yin R, Li L, Xu L, Sui W, Niu M, Xu R, Srirat C. Correction to: Association between depression and sleep quality in patients with systemic lupus erythematosus: a systematic review and metaanalysis. Sleep Breath. 2022;26(1):443.
25. Pearce M, Garcia L, Abbas A. Association between Physical Activity and Risk of Depression: a systematic review and Meta-analysis. JAMA Psychiatry. 2022;79(6):550–9.
26. Wang X, Arafa A, Liu K, Eshak ES, Hu Y, Dong JY. Combined healthy lifestyle and depressive symptoms: a meta-analysis of observational studies. J Affect Disord. 2021;289:144–50.
27. Heissel A, Heinen D, Brokmeier LL. Exercise as medicine for depressive symptoms? A systematic review and meta-analysis with meta-regression. Br J Sports Med. 2023;57(16):1049–57.

28. Zhang LC, Gao F, Lu JY, Tao YY, Zhang WJ. Debate on sports research methods: Problem review and application specification of randomization principle in sports science experiment design. J Tianjin Univ Sport. 2024;39(1):36–41.

29. Zhang LW, Mao ZX. Evaluation manual of psychological scales commonly used in sports science, 2nd edn. Beijing Sport University Press; 2004.

30. Dan YJ. Development and application of middle school student sport lifestyle scale. Beijing Sport University; 2015.

31. Karageorghis CI, Vencato MM, Chatzisarantis NL, Carron AV. Development and initial validation of the brunel lifestyle physical activity questionnaire. Br J Sports Med. 2005;39(5):e23.

32. Zung WW. A self-rating depression scale. Arch Gen Psychiatry. 1965;12:63–70.

33. Zhang MY. Psychiatric rating scales manual, 2nd edn. Hunan Science and Technology; 1998. pp. 39–42.

34. Wang CF, Cai ZH, Xu Q. The self-rating depression scale (SDS) was used to evaluate 1340 normal subjects. Chin J Nerv Mental Dis. 1986;5:267–8.

35. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The pittsburgh sleep quality index: a new instrument for psychiatric practice and research. Psychiatry Res. 1988;28(2):193–213.

36. Liu XC, Tang MQ, Hu L, Wang AZ, Wu HX, Zhao GF, Gao HN, Li WS. Reliability and validity of the pittsburgh sleep quality index. Chin J Psychiatry. 1996;2:103–7.

37. Jiang GF, Guo F, Huang Z, Chen ZY. Relation of sleep quality to negative life events and personality in adolescents. Chin Mental Health J. 2013;27(3):220–3.

38. Xu JS, Tang LQ. The relationship between physical exercise and problematic internet use in college students: the chain-mediated role of self-control and loneliness. BMC Public Health. 2024;24(1):1719.

39. Zhang X, Dou Z, Yang F, Luo L, Yang J. Exploring the relationship between sleep patterns and depression among Chinese middle school students: a focus on sleep quality vs. sleep duration. Front Public Health. 2024;12:1383884.

40. He Y, Chen SS, Xie GD, Chen LR, Zhang TT, Yuan MY, Li YH, Chang JJ, Su PY. Bidirectional associations among school bullying, depressive symptoms and sleep problems in adolescents: a cross-lagged longitudinal approach. J Affect Disord. 2022;298(Pt A):590–8.

41. Ma ZY, Su ZQ, Zhang DJ. The application of the theory ofdiathesis-stressin childhood: a longitudinal study. Chin J Clin Psychol. 2018;26(5):960–5.

42. Jiang Y, Jiang T, Xu LT, Ding L. Relationship of depression and sleep quality, diseases and general characteristics. World J Psychiatry. 2022;12(5):722–38.

43. Fossati P. Is major depression a cognitive disorder? Revue Neurologique (Paris). 2018;74(4):212–5.

44. Wang T, Li M, Xu S, Xiang A, Xu X, Wang H. The relationship between sleep quality and depression: critical roles of reflective and brooding rumination and sleep-related cognition. Psychol Health Med. 2023;28(4):955–63.

45. Thompson KI, Chau M, Lorenzetti MS, Hill LD, Fins AI, Tartar JL. Acute sleep deprivation disrupts emotion, cognition, inflammation, and cortisol in young healthy adults. Front Behav Neurosci. 2022;16:945661.

46. Xia L, Zhang P, Niu JW, et al. Relationships between a range of inflammatory biomarkers and subjective sleep quality in chronic insomnia patients: a clinical study. Nat Sci Sleep. 2021;13:1419–28.

47. Wang YJ, Lin JY, Xie T, Wu EM, Lei Q. Mechanism and future prospect of exercise in the treatment of adolescent depression. J Psychol Sci. 2021;44(5):1208–15.

48. Biddle SJ, Asare M. Physical activity and mental health in children and adolescents: a review of reviews. Br J Sports Med. 2011;45(11):886–95.

49. Tang S, Chen H, Wang L, Lu T, Yan J. The relationship between physical exercise and negative emotions in college students in the post-epidemic era: the mediating role of emotion regulation self-efficacy. Int J Environ Res Public Health. 2022;19(19):12166.

50. Qin GY, Han SS, Zhang YS, Ye YP, Xu CY. Effect of physical exercise on negative emotions in Chinese university students: the mediating effect of self-efficacy. Heliyon. 2024;10(17):e37194.

51. Dong ZW. Influence of daily lifestyle on health integrity self-assessment of Zhoushan high school students: an analysis of the relationship between lifestyle sports and health integrity self-assessment. Sport. 2014;80(1):62–4.

52. Petrowski K, Schmalbach B, Stalder T. Morning and evening type: the cortisol awakening response in a sleep laboratory. Psychoneuroendocrinology. 2020;112:104519.

53. Ren ZH, Zhao ZY, Yu XL, Zhao CX, Zhang L, Lin YZ, Zhang W. Testosterone and aggressive behavior in juvenile offenders with antisocial tendency: the mediation effect of hostile attention bias and the moderation effect of cortisol. Acta Physiol Sinica. 2022;52(11):1288–300.

54. Wang ZF, Li ZX, Li H, Jiang B, Niu Y, Li BQ, Xue HH. Research progress on the neuromechanism of exercise interventions for depression. Progress Physiological Sci. 2022;53(6):433–9.

55. Jahangard L, Rahmani A, Haghighi M, Ahmadpanah M, Sadeghi Bahmani D, Soltanian AR, Shirzadi S, Bajoghli H, Gerber M, Holsboer-Trachsler E, Brand S. Always look on the Bright side of life! - higher hypomania scores are associated with higher mental toughness, increased physical activity, and lower symptoms of depression and lower sleep complaints. Front Psychol. 2017;8:2130.

56. Ye N, Wang L, Zhang L, Sun XJ. The mediating effect of self-control on the relationship between physical activity and sleep quality among undergraduates: based on daily diary study. Chin J Appl Psychol. 2023;29(1):89–96.

57. Kandola A, Ashdown-Franks G, Hendrikse J, Sabiston CM, Stubbs B. Physical activity and depression: towards understanding the antidepressant mechanisms of physical activity. Neurosci Biobehav Rev. 2019;107:525–39.

58. Wei X, Lai Z, Tan Z, Ou Z, Feng X, Xu G, Ai D. The effect of physical activity on depression in university students: the mediating role of self-esteem and positive psychological capital. Front Psychol. 2024;15:1485641.

59. Recchia F, Bernal JDK, Fong DY, Wong SHS, Chung PK, Chan DKC, Capio CM, Yu CCW, Wong SWS, Sit CHP, Chen YJ, Thompson WR, Siu PM. Physical activity interventions to alleviate depressive symptoms in children and adolescents: a systematic review and meta-analysis. JAMA Pediatr. 2023;177(2):132–40.

60. Pearce M, Garcia L, Abbas A, Strain T, Schuch FB, Golubic R, Kelly P, Khan S, Utukuri M, Laird Y, Mok A, Smith A, Tainio M, Brage S, Woodcock J. Association between physical activity and risk of depression: a systematic review and meta-analysis. JAMA Psychiatry. 2022;79(6):550–9.

61. Owens JA, Weiss MR. Insufficient sleep in adolescents: causes and consequences. Minerva Pediatr. 2017;69(4):326–36.

62. Grima NA, Rajaratnam SMW, Mansfield D, McKenzie D, Ponsford JL. Poorer sleep quality predicts melatonin response in patients with traumatic brain injury: findings from a randomized controlled trial. J Clin Sleep Med. 2021;17(8):1545–51.

63. Tuft C, Matar E, Menczel Schrire Z, Grunstein RR, Yee BJ, Hoyos CM. Current insights into the risks of using melatonin as a treatment for sleep disorders in older adults. Clin Interv Aging. 2023;18:49–59.

64. Wang YP, Li RY, Pan JH, Wang XN, Liang QL, Chen DY, Chen XJ. The effect of positive psychological intervention on recurrent depressive disorder in adolescents. J Med Theory Pract. 2022;35(8):1411–4.

65. Chen XY, Li YF, Xu CX, Qiao HF. Research progress on effect mechanism of acupuncture intervention on depression in central 5-HT system. Chin Archives Traditional Chin Med. 2022;40(7):150–4.

66. Li C, Meng F, Garza JC, Liu J, Lei Y, Kirov SA, Guo M, Lu XY. Modulation of depression-related behaviors by adiponectin AdipoR1 receptors in 5-HT neurons. Mol Psychiatry. 2021;26(8):4205–20.

67. Xiao M, Xie K, Yuan L, Wang J, Liu X, Chen Z. Effects of Huolisu oral solution on depression-like behavior in rats: neurotransmitter and HPA axis. Front Pharmacol. 2022;13:893283.

68. Sourbron J, Lagae L. Serotonin receptors in epilepsy: novel treatment targets? Epilepsia Open. 2022;7(2):231–46.

69. Neziroglu F, Khemlani-Patel S, Veale D. Social learning theory and cognitive behavioral models of body dysmorphic disorder. Body Image. 2008;5(1):28–38.

70. Su Y, Wang SB, Zheng H, Tan WY, Li X, Huang ZH, Hou CL, Jia FJ. The role of anxiety and depression in the relationship between physical activity and sleep quality: a serial multiple mediation model. J Affect Disord. 2021;290:219–26.

71. Bursnall P. The relationship between physical activity and depressive symptoms in adolescents: a systematic review. Worldviews Evidence-Based Nurs. 2014;11(6):376–82.

72. Ames ME, Leadbeater BJ. Depressive symptom trajectories and physical health: persistence of problems from adolescence to young adulthood. J Affect Disord. 2018;240:121–9.

73. Leone M, Lalande D, Thériault L, Kalinova É, Fortin A. Effects of an exercise program on the physiological, biological and psychological profiles in patients with mood disorders: a pilot study. Int J Psychiatry Clin Pract. 2018;22(4):268–73.

74. Tao K, Liu W, Xiong S, Ken L, Zeng N, Peng Q, Yan X, Wang J, Wu Y, Lei M, Li X, Gao Z. Associations between self-determined motivation, accelerometer-determined physical activity, and quality of life in Chinese college students. Int J Environ Res Public Health. 2019;16(16):2941.

75. Li Q. Study on the effect of Yijinjing on depression in college students: evidence from functional near infrared spectroscopy. Wuhan Sports University; 2024.

76. Yan HM, Huang P, Chen R, Wang YC. The relationship between physical activity and mental health of middle school students: the chain mediating role of negative emotions and self-efficacy. Front Psychol. 2024;15:1415448.

77. Gunuc S, Koylu EO. Investigation of the relationships between Beck depression/anxiety scores and neuropsychological tests scores with lifestyle behaviors in the context of neuroplasticity and neurogenesis approach. Neuroscience. 2023;516:62–74.

78. Zou L, Wang T, Herold F, Ludyga S, Liu W, Zhang Y, Healy S, Zhang Z, Kuang J, Taylor A, Kramer AF, Chen S, Tremblay MS, Hossain MM. Associations between sedentary behavior and negative emotions in adolescents during home confinement: mediating role of social support and sleep quality. Int J Clin Health Psychol. 2023;23(1):100337.

79. Wang YW, Zhou YH. The relationship research between physical activity level and social physical anxiety in high school students: the mediating role of body self-esteem. Adv Psychol. 2024;14(3):59–67.

Publisher's note