

The Impact of Physical Exercise on Sleep Quality Among College Students: The Chain Mediating Effects of Perceived Stress and Ruminative Thinking

Deyan Liu¹, Yuge Tian¹, Min Liu², Shangjian Yang¹

¹School of Physical Education, Shandong University, Jinan, 250061, People's Republic of China; ²Comprehensive Department, Jinan Mass Sports Development Center, Jinan, 250101, People's Republic of China

Correspondence: Shangjian Yang, School of Physical Education, Shandong University, Jinan, 250061, People's Republic of China, Email yangshangjian@sdu.edu.cn

Purpose: This study aimed to investigate the relationship between physical exercise and sleep quality among college students, focusing on the chain mediating roles of perceived stress and ruminative thinking.

Participants and Methods: A total of 955 college students completed questionnaires, including the Physical Activity Rating Scale (PARS-3), the Pittsburgh Sleep Quality Index (PSQI), the Perceived Stress Scale (PSS), and the Ruminative Thinking Response Scale (RRS). The PROCESS macro Model 6 and Bootstrap methods were used to analyze the mediating effects of perceived stress and ruminative thinking.

Results: (1) Negative correlations were found between physical exercise and sleep quality ($r = -0.361$, $p < 0.01$), perceived stress ($r = -0.393$, $p < 0.01$), and ruminative thinking ($r = -0.503$, $p < 0.01$). Positive correlations existed between sleep quality and perceived stress ($r = 0.477$, $p < 0.01$), as well as between sleep quality and ruminative thinking ($r = 0.549$, $p < 0.01$), and perceived stress and ruminative thinking ($r = 0.550$, $p < 0.01$). (2) Physical exercise significantly impacted college students' sleep quality directly, with an effect size of -0.074 . The relative proportion of indirect effects mediated by perceived stress and ruminative thinking was 20.59%, with individual effect sizes of -0.085 and -0.135 respectively, accounting for 23.89% and 37.93% of the total effect. (3) Additionally, there was a chain mediation effect with an effect size of -0.063 , representing 17.59% of the total effect.

Conclusion: Physical exercise can reduce perceived stress to alleviate ruminative thinking, thereby improving sleep quality. The findings of this study provide a scientific basis for the development of mental health education and intervention strategies in colleges. Colleges should offer diverse physical activities and improve facilities to encourage student participation in exercise. College students should recognize the importance of physical exercise in enhancing sleep quality, actively engage in physical activities, learn psychological adjustment techniques, and cultivate healthy lifestyle habits.

Keywords: physical exercise, sleep quality, perceived stress, ruminative thinking, chain mediation

Introduction

Good sleep is essential for maintaining personal health and improving life quality. Currently, Chinese college students often suffer from short sleep duration and unhealthy sleep patterns.¹ Short-term sleep deprivation can lead to reduced concentration, memory decline, and slower reaction times. Long-term sleep deprivation may trigger anxiety, depression, and even increase the risk of mental disorders.² Therefore, addressing sleep quality issues among college students is significant.

Physical exercise is crucial for improving sleep quality among college students. Recent studies have primarily focused on behavioral patterns or psychological states, such as how exercise influences sleep quality through factors like smartphone addiction, happiness, and loneliness.^{3–5} However, less attention has been paid to cognitive processes. In

recent years, with the intensification of social competition and increased academic pressure, Chinese college students often find themselves in a state of continuous tension.⁶ This persistent stress has led to a gradual increase in perceived stress levels, severely disrupting students' emotional and cognitive functions.⁷ Ruminative thinking causes students to repeatedly dwell on negative events or emotions, intensifying self-doubt and pessimistic expectations for the future, which in turn exacerbates anxiety and depression.⁸ These negative emotions and thought patterns not only impact students' mental health but may also lead to health issues such as sleep disorders and impaired immune system function.⁹

Previous studies have primarily focused on the individual relationships between physical exercise and perceived stress, physical exercise and ruminative thinking, and physical exercise and sleep quality. However, these studies often overlook the interactions among these variables and their complex underlying mechanisms. This study attempts to establish a chain mediation model within an integrated framework to explore the mechanisms by which perceived stress and ruminative thinking mediate the effect of physical exercise on improving sleep quality among college students. This perspective not only extends the existing theoretical framework on how physical exercise enhances sleep quality in college students but also provides important scientific evidence for colleges to design extracurricular physical activity programs and psychological adjustment courses. The findings hold significant theoretical and practical value.

Theoretical Basis and Hypotheses

The Influence of Physical Exercise on Sleep Quality Among College Students

Physical exercise is a vital tool for enhancing both physical and mental health. Numerous studies confirm its effectiveness in improving sleep quality and treating sleep disorders non-pharmacologically.^{10–13} Researchers in China have demonstrated that consistent exercise, such as the Baduanjin routine for 12 weeks, significantly improves sleep quality among college students.¹⁴ Active exercise habits correlate positively with subjective sleep quality improvement, leading to shorter sleep latency and higher sleep quality.¹⁵ Physiologically, exercise helps regulate the body's circadian rhythm, inducing natural drowsiness at specific times of day.¹⁶ Psychologically, it fosters positive motivation, aiding in overcoming sleep disturbances caused by negative mental states.¹⁷

Hypothesis 1: Physical exercise positively influences sleep quality among college students.

The Mediating Effect of Perceived Stress

Perceived stress involves individuals' evaluations of external events and their stress responses. It encompasses not only the events themselves but also personal interpretations of their significance, emphasizing subjective cognitive and emotional reactions rather than just objective stressors.¹⁸

According to the Cognitive Phenomenon Logical Transactional (CPT) model, stress is conceptualized as a dynamic process encompassing both primary and secondary appraisals of a given situation,¹⁹ during the primary appraisal stage, physical exercise helps reduce the perceived severity of external stressors,²⁰ in the secondary appraisal stage, the psychological and physiological benefits of exercise enhance individuals' sense of coping resources, further lowering perceived stress.²¹ The cross-adaptation hypothesis suggests that physical exercise, as a stressor, prompts adaptive mechanisms that enhance resilience and calmness under pressure.²² The antagonistic inhibition hypothesis posits that physical activity alleviates psychological stress based on neuroimmunology.^{23,24} According to the stress-diathesis model, stress events may activate predispositions for depression, leading to sleep disorders.²⁵ Several studies now show that perceived stress can negatively predict sleep quality, ie, the higher the level of perceived stress, the lower the quality of sleep. During the outbreak of COVID-19, insomnia played a mediating role between perceived stress and depression among medical students, and the weaker the individual's resistance to stress, the worse the adaptation to stress, which led to insomnia, sleep anisotropy, and other problems; at the same time, insomnia itself exacerbates the level of perceived stress, which in turn creates a vicious cycle.^{26–32}

Hypothesis 2: Perceived stress plays a mediating role in the impact of physical exercise on sleep quality among college students.

The Mediating Effect of Ruminative Thinking

Ruminative thinking refers to the continuous, cyclical contemplation of causes, processes, consequences, and self-evaluations related to stressful events.³³ It is defined as maladaptive, negatively impacting individuals by trapping them in negative emotions instead of taking action to resolve situations. This repetitive focus intensifies existing negative emotional states, potentially increasing emotional distress and psychological fatigue, affecting daily life and work performance.³⁴

Ruminative thinking is considered a potential vulnerability factor for depression, with moderate-intensity exercise proven effective in treating severe depression.³⁵ Since sleep disorders are core symptoms of depression, ruminative thinking may influence the effect of exercise on sleep quality.³⁶ Cognitive theories of sleep maintenance propose that when individuals perceive sleep disturbances, a series of negative cognitive responses are triggered.³⁷ In addition, several studies have shown that sleep disorders are associated with ruminative thinking that Sebastian Butz found that after a week of “daily self-compassion” intervention, ruminative thinking significantly decreased and sleep quality improved in patients with severe depression.³⁸ Adam J. Guastella concluded that high ruminators had more intrusive thoughts before sleep and poorer sleep quality following stressful events.³⁹

Hypothesis 3: Ruminative thinking plays a mediating role in the impact of physical exercise on sleep quality among college students.

The Chain Mediating Effect of Perceived Stress and Ruminative Thinking

Perceived stress positively influences ruminative thinking. According to Nolen-Hoeksema’s 1987 response style theory, individuals facing pressure may adopt three strategies: ruminative thinking, problem-solving, and distraction.⁴⁰ Under prolonged high-pressure conditions, ruminative thinking becomes a favored approach. Stressful events exacerbate ruminative thinking, evidenced by its mediating role in the relationship between adolescent stress perception and problematic smartphone use.^{41,42} Perceived stress prompts individuals to engage in ruminative thinking, maintaining high cognitive activation, which catalyzes negative emotions and adversely affects sleep quality, exacerbating sleep disorders. Further evidence indicates that ruminative thinking is linked to emotional regulation imbalance, amplifying subjective stress and hindering adaptation and recovery after stressful life events.⁴³ Higher stress levels significantly promote ruminative thinking occurrence; the stronger the stress, the more frequent and severe ruminative thinking becomes.⁴⁴

Hypothesis 4: Perceived stress and Ruminative thinking play a chain mediating role in the impact of physical exercise on sleep quality among college students.

In summary, this study introduces perceived stress and ruminative thinking into research on the relationship between physical exercise and sleep quality among college students for the first time, constructing a chain mediation model (Figure 1).

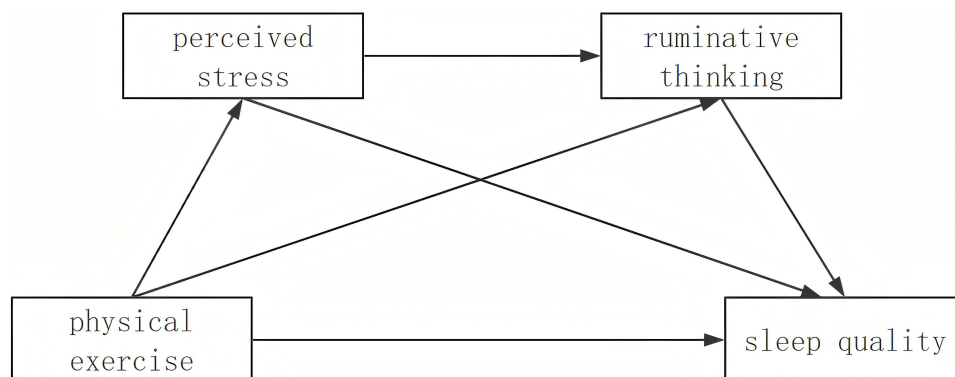


Figure 1 Chain mediation hypothesis model of physical exercise, perceived stress, ruminative thinking, and sleep quality.

Notes: This figure presents the hypothesized relationships among physical exercise, perceived stress, ruminative thinking, and sleep quality. The arrows indicate the direction of influence.

Materials and Methods

Participants

This study is a cross-sectional research aimed at assessing the relationships between physical exercise, perceived stress, ruminative thinking, and sleep quality at a specific point in time. This study used convenience sampling, surveying college students in Shandong Province, China via Wenjuanxing. All methods were conducted in accordance with the Declaration of Helsinki-Ethical Principles for Medical Research Involving Human Subjects and other relevant laws, regulations and ethical norms. I have conducted the STROBE checklist of cross-sectional studies. The studies involving humans were approved by the Ethics Committee of Shandong University. Informed consent was obtained from the all participants. Prior to filling out the survey questionnaire, we thoroughly introduce to the participants the purpose of our research and our confidentiality policy. Out of 1059 questionnaires distributed, 955 valid responses were obtained after removing invalid ones due to irregular answering patterns or excessively short completion times, yielding a 90.1% valid return rate. The sample included 480 males and 475 females, with 630 undergraduates (66%), 183 postgraduates (19%), 18 doctoral students (2%), and 124 students with associate degrees or lower (13%). Participants' ages ranged from 18 to 26 years ($M \pm SD$ 21.19 \pm 2.122).

Measures

Physical Activity Rating Scale (PARS-3)

This study used the Physical Activity Rating Scale (PARS-3), a revised version of the Physical Activity Rating Scale (PARS-3) by Chinese scholar Liang Deqing, to assess participants' physical activity levels.⁴⁵ This scale focuses on intensity, frequency, and duration, quantified on a five-point Likert scale. The formula "exercise volume = frequency \times (duration - 1) \times intensity" is applied, with scores ≤ 19 indicating low exercise volume, 20–42 moderate volume, and ≥ 43 high volume. The Cronbach's alpha coefficient is 0.793, indicating good reliability.

Pittsburgh Sleep Quality Index (PSQI)

The PSQI is widely recognized as a reliable tool for sleep assessment.⁴⁶ Adapted by Liu Xianchen et al for Chinese populations, it accurately evaluates college students' sleep quality.⁴⁷ Comprising seven factors and 18 questions, each rated from 0 to 3 based on severity, higher total scores indicate poorer sleep quality. A score above 7 signifies significant sleep disorders.⁴⁸ The Cronbach's alpha coefficient is 0.853, indicating good reliability.

Perceived Stress Scale (PPS)

The Chinese version of the Perceived Stress Scale, revised by Yang Tingzhong et al, contains 14 items scored on a five-point Likert scale.⁴⁹ Reverse scoring applies to questions 4, 5, 6, 7, 9, 10, and 13. Higher total scores indicate greater perceived stress intensity. The Cronbach's alpha coefficient is 0.904, indicating good reliability.

Ruminative Response Scale (RRS)

The RRS, originally developed by Nolen-Hoeksema and Morrow and adapted for China by Han Xiuyu and Yang Hongfei, includes 22 items divided into symptom ruminative thinking, intrusive thinking, and reflective pondering dimensions.⁷ Using a four-point Likert scale, higher scores suggest a stronger tendency towards ruminative thinking. The Cronbach's alpha coefficient is 0.965, indicating good reliability.

Results

Control and Examination of Common Method Bias

The data collected in this study were derived from questionnaire surveys, which may introduce the risk of common method bias. To mitigate this potential bias, reverse-coded items were incorporated into the questionnaire to detect and reduce mechanical responses from participants. Additionally, the order of questions was randomized to prevent patterned responses. Harman's single-factor test was conducted to assess the presence of common method bias. The results indicated that five factors had eigenvalues greater than 1, with the first factor accounting for 34.787% of the variance,

which is below the critical threshold of 40%.⁵⁰ Based on these findings, it can be concluded that the data collected in this study were not significantly affected by common method bias, ensuring a high level of data reliability.

Descriptive Statistics and Correlation Analysis

The mean values, standard deviations, and descriptive statistics along with correlation analyses for the variables involved in the present study are illustrated in Table 1. Physical exercise showed a significant negative correlation with sleep quality ($r = -0.361$, $p < 0.01$), perceived stress ($r = -0.393$, $p < 0.01$), and ruminative thinking ($r = -0.503$, $p < 0.01$). Conversely, sleep quality exhibited a significant positive correlation with perceived stress ($r = 0.477$, $p < 0.01$) and ruminative thinking ($r = 0.549$, $p < 0.01$). Likewise, perceived stress was significantly and positively correlated with ruminative thinking ($r = 0.550$, $p < 0.01$).

The Mediation Effect Test

In this study, physical exercise served as the independent variable, sleep quality as the dependent variable, and perceived stress and ruminative thinking as mediating variables. Demographic variables such as gender, age, and degree were controlled to minimize confounding effects and enhance the explanatory power of the model. Using SPSS 26.0 and the PROCESS 4.1 plugin, the chain mediation effects of perceived stress and ruminative thinking in the relationship between physical exercise and sleep quality were tested. Model 6 was chosen, and bootstrapping was performed 5000 times while calculating the 95% confidence interval. The results are shown in Table 2: Physical exercise significantly negatively influenced college students' sleep quality ($\beta = -0.357$, $p < 0.001$), indicating that the higher the level of physical exercise, the better the sleep quality (since a higher total score on the sleep quality index represents poorer sleep quality). Physical exercise also significantly negatively affected perceived stress ($\beta = -0.392$,

Table 1 Descriptive Statistics and Correlation Analysis of Variables

Variable	M	SD	PE	SQ	PS	RT
PE	25.37	24.692	I			
SQ	6.43	4.043	-0.361**	I		
PS	37.46	13.277	-0.393**	0.477**	I	
RT	48.75	18.303	-0.503**	0.549**	0.550**	I

Notes: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Abbreviations: PE, physical exercise; SQ, sleep quality; PS, perceived stress; RT, ruminative thinking.

Table 2 Mediated Effects of Perceived Stress and Ruminative Thinking Regression Models

Variable	SQ		PS		RT		SQ	
	β	t	β	t	β	t	β	t
Gender	-0.186	-3.065**	-0.148	-2.472*	0.101	1.976*	-0.169	-3.180**
Age	0.007	0.496***	0.010	0.681	0.018	1.509	-0.004	-0.282
Degree	-0.128	-4.402	-0.131	-4.557***	-0.028	-1.134	-0.068	-2.649**
PE	-0.357	-11.772***	-0.392	-13.098***	-0.352	-12.726***	-0.074	-2.367*
PS					0.416	15.078***	0.218	6.826***
RT							0.385	11.426***
R	0.395		0.422		0.637		0.601	
R ²	0.156		0.178		0.405		0.362	
F	44.011***		51.395***		129.317***		89.452***	

Notes: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Abbreviations: PE, physical exercise; SQ, sleep quality; PS, perceived stress; RT, ruminative thinking.

Table 3 Mediating Effects of Perceived Stress and Ruminative Thinking

Path	Effect	Boot SE	Boot 95% CI Lower Limit	Boot 95% CI Upper Limit	Relative Mediation Effect
PE→PS→SQ (Ind1)	-0.085	0.014	-0.113	-0.057	23.89%
PE→RT→SQ (Ind2)	-0.135	0.015	-0.165	-0.109	37.93%
PE→PS→RT→SQ (Ind3)	-0.063	0.009	-0.082	-0.046	17.59%
Total indirect effect	-0.284	0.020	-0.032	-0.246	79.41%
Direct effect	-0.074	0.031	-0.134	-0.013	20.59%
Total effect	-0.357	0.030	-0.417	-0.297	100.00%
C1 (Ind1-Ind2)	0.050	0.022	0.007	0.094	14.03%
C2 (Ind1-Ind3)	-0.023	0.019	-0.058	0.016	6.30%
C3 (Ind2-Ind3)	-0.073	0.016	-0.103	-0.042	20.36%

Abbreviations: PE, physical exercise; SQ, sleep quality; PS, perceived stress; RT, ruminative thinking.

$p < 0.001$) and ruminative thinking ($\beta = -0.352$, $p < 0.001$). Perceived stress had a significant positive impact on ruminative thinking ($\beta = 0.416$, $p < 0.001$) and sleep quality ($\beta = 0.218$, $p < 0.001$); similarly, ruminative thinking had a significant positive impact on sleep quality ($\beta = 0.385$, $p < 0.001$).

Based on the content shown in Table 3, the direct effect of physical exercise on sleep quality among college students is -0.074 , with a relative mediating effect ratio of 20.59%. The Bootstrap 95% confidence interval does not include zero (LLCL = -0.134 , ULCL = -0.013), indicating that appropriate physical exercise can significantly improve sleep quality among college students. Subsequently, the mediating roles of perceived stress and ruminative thinking were separately tested in the relationship between physical exercise and sleep quality among college students.

Perceived stress has an indirect effect of -0.085 in the impact of physical exercise on sleep quality among college students. Its Bootstrap 95% confidence interval ranges from LLCL = -0.113 to ULCL = -0.057 , which does not contain zero, with a relative mediating effect ratio of 23.89%. This suggests that perceived stress plays a significant mediating role in the impact of physical exercise on sleep quality among college students, and that college students can reduce their level of perceived stress and thus improve their sleep quality through appropriate physical exercise.

Ruminative thinking has an indirect effect of -0.135 in the influence of physical exercise on sleep quality among college students. Its Bootstrap 95% confidence interval ranges from LLCL = -0.165 to ULCL = -0.109 , which does not contain zero, with a relative mediating effect ratio of 37.93%. This indicates that ruminative thinking has an independent mediating effect in the process of physical exercise influencing sleep quality among college students, and that this effect is significant. College students can reduce the degree of ruminative thinking and thus improve sleep quality through appropriate physical exercise.

Finally, the chain mediation effect of perceived stress and ruminative thinking in the impact of physical exercise on sleep quality among college students was tested. The indirect effect of the serial mediation path (physical exercise → perceived stress → ruminative thinking → sleep quality among college students) is -0.063 , with a relative mediating effect ratio of 17.59%. Its Bootstrap 95% confidence interval ranges from LLCL = -0.082 to ULCL = -0.046 , which does not contain zero, suggesting that perceived stress and ruminative thinking play a chain mediation role in the impact of physical exercise on sleep quality among college students. Based on the above analysis results, a serial mediation model diagram for the impact of physical exercise on sleep quality among college students (Figure 2) was constructed.

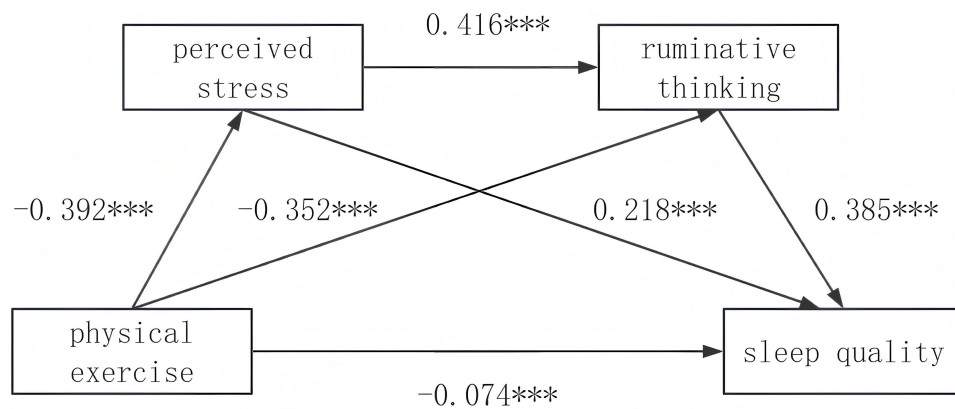


Figure 2 Path Analysis of the Chain Mediation Model.

Notes: This figure displays the results of the path analysis testing the chain mediation model. ***indicates statistical significance at $p < 0.001$.

Discussion

The scales used in this study are retrospective tools designed to reflect participants' recent states. For example, the PARS-3 scale asks participants to recall their physical exercise habits over the past month, while the PSQI scale measures sleep quality during the previous month. Furthermore, the scales used in this study have been widely employed in other short-term studies and have demonstrated reliable results.^{7,45,46,49,51} Therefore, the time frame of the current study is capable of capturing the immediate effects of physical exercise on sleep quality, as well as the mediating role of psychological factors.

Impact of Physical Exercise on Sleep Quality Among College Students

The study controlled for demographic variables such as gender, age, and degree, examined the influence of physical exercise on sleep quality and analyzed the serial mediating effects of perceived stress and ruminative thinking. It was found that physical exercise and sleep quality exhibit a significant negative correlation. However, it should be noted that the scoring criteria of the PSQI used in this study indicate that higher scores represent poorer sleep quality, while lower scores actually reflect better sleep conditions. Thus, the inverse association observed between physical exercise and sleep quality is, in fact, indicative of a positive impact. Hence, Hypothesis H1 is supported.

Regular and moderate physical exercise not only enhances physical health but also optimizes sleep quality effectively. Kong Haijun's meta-analysis revealed that physical exercise has a positive and significant therapeutic effect on sleep disorders among college students. Practices such as fitness Qigong, aerobics, Tai Chi, aerobic exercises, and yoga have been proven to significantly decrease the total score of the PSQI, thereby improving sleep quality among college students.⁵² Part of this effect is attributed to the positive impact of physical exercise on melatonin secretion patterns. Melatonin, an important hormone in the human body, is regulated by light exposure and circadian rhythms. Regular and moderate physical activities, particularly those conducted during the day, can promote melatonin secretion at night, enhancing nocturnal sleepiness and facilitating the onset of sleep. Long-term adherence to physical exercise can significantly improve the regularity and stability of melatonin secretion, contributing to the establishment and maintenance of a healthy and stable sleep-wake cycle.⁵³

Mediating Role of Perceived Stress

The study findings indicate that physical exercise can affect sleep quality among college students through the mediating effect of perceived stress. Therefore, Hypothesis H2: Perceived stress mediates the effect of physical exercise on sleep quality among college students, is confirmed.

Physical exercise, as a positive lifestyle intervention, has been widely studied and recognized for its beneficial impact on mental health and sleep quality. Its mechanisms are complex and multifaceted, encompassing physiological, psychological, and sociological domains. Physical exercise triggers the release of various neurotransmitters with

psychological regulatory functions, including endorphins, serotonin, and dopamine.⁵⁴ The endorphin hypothesis proposes that when exercise intensity reaches a certain threshold, it increases endorphin levels in the body.⁵⁵ Endorphins, natural painkillers, significantly enhance feelings of happiness and relaxation; serotonin plays a crucial role in mood stabilization and sleep regulation; and dopamine, known as the “happiness hormone” is vital for the generation of pleasure and maintenance of motivation.⁵⁴ The synergistic action of these neurotransmitters not only effectively alleviates stress and anxiety but also contributes to improved sleep quality. Engaging in physical exercise temporarily removes individuals from daily stressors, providing a positive and energy-consuming activity. By expending energy and focusing attention on physical activity, it effectively reduces excessive focus on stressful events and promotes the reallocation of psychological resources.⁵⁶ Team sports or group fitness activities offer opportunities for social interaction. Under the drive of shared goals, supportive networks are established among participants, which positively impacts stress reduction and sleep improvement.⁵⁵

Mediating Role of Ruminative Thinking

The study results demonstrate that physical exercise can influence sleep quality among college students through the mediating effect of ruminative thinking. Therefore, Hypothesis H3: ruminative thinking mediates the effect of physical exercise on sleep quality among college students, is confirmed.

Research has revealed the efficacy of mind-body training (Mental and physical training, MAP), which combines relaxation techniques like meditation with regular aerobic exercise, in regulating ruminative thinking and positively impacting mental health.⁵⁷ Participation in physical exercise effectively diminishes persistent negative emotions, significantly reducing the degree of ruminative thinking, which is critical for mental health enhancement. For college students, who often face multiple pressures from academics and social interactions, leading to overthinking and anxiety, which in turn affects sleep quality, regular physical activities such as running, swimming, or team sports help balance hormonal levels within the body. Specifically, they lower cortisol concentrations (a stress hormone) and increase levels of serotonin and dopamine, the “happiness hormone”.⁵⁴ These changes alleviate symptoms of anxiety and depression, helping individuals detach from negative emotions and ceaseless self-reflection, fundamentally alleviating sleep disorders caused by high levels of ruminative thinking. This not only boosts daytime energy and academic efficiency among college students but also enhances overall mental health and quality of life.

The Chain Mediation Path of Perceived Stress and Ruminative Thinking

The study finds that physical exercise influences sleep quality among college students through the serial mediating effects of perceived stress and ruminative thinking. Therefore, Hypothesis H4: Perceived stress and ruminative thinking serially mediate the effect of physical exercise on sleep quality among college students, is supported.

In exploring the biological mechanisms underlying depression, dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis is considered a central pathology closely associated with the development of depression. Both perceived stress and ruminative thinking are seen as potential factors in the onset and exacerbation of depression.²⁵ Adopting an active lifestyle involving physical exercise has been shown to mitigate the HPA axis’ exaggerated response to acute stress and enhance its recovery capacity, potentially interrupting or alleviating depression triggered by perceived stress and ruminative thinking.^{58,59} When individuals encounter stressful events, they often fall into a state of ruminative thinking, and if this occurs close to bedtime, it delays the onset of sleep and degrades sleep quality.⁷ Relevant studies point out that ruminative thinking induced by stress keeps individuals in a state of heightened cognitive alertness, which not only fails to assist them in effectively coping with stressors but also triggers a series of negative emotions, such as anxiety and panic. These negative emotions, in turn, exacerbate sleep disorders, forming a vicious cycle.^{31,60} Physical exercise reduces perceived stress, thereby inhibiting ruminative thinking and ultimately improving sleep quality. LaRocque and Harkness, through a randomized controlled trial, demonstrated that both aerobic exercise and various styles of yoga significantly decrease perceived stress and ruminative thinking, even rivaling the effectiveness of medication alone.⁶¹

This study includes gender, age, and degree as control variables. However, previous research has suggested that males and females may differ in emotional responses, stress management, or sleep patterns. These differences may influence sleep quality or perceived stress through physiological, psychological, or socio-cultural factors.^{62,63} For example, females

may be more prone to perceiving higher levels of stress or are more likely to experience anxiety and depression, factors that could impact their sleep quality.^{64,65} With increasing age and academic progression, individuals may face greater academic pressure and societal expectations,^{66,67} which could intensify the frequency of ruminative thinking and negatively affect sleep quality. Future research will refine the experimental procedures, increase and diversify the sample size, and employ stratified analysis or interaction effect analysis to further explore how these variables interact and influence the relationship between physical exercise, perceived stress, ruminative thinking, and sleep quality.

Practical Implications

Physical exercise can reduce perceived stress, alleviate ruminative thinking, and thereby improve sleep quality. Therefore, college students should be encouraged to actively engage in physical exercise as an essential part of a healthy lifestyle. This requires collaborative efforts from the government, schools, and individuals.

The government should develop relevant policies and plans based on research findings to promote the establishment of a comprehensive physical exercise system and mental health support system in colleges. Policies could be introduced to require colleges to increase the proportion of physical education courses, ensuring students receive regular physical exercise. Additionally, the government should encourage colleges to establish counseling centers to provide more mental health support, such as regular mental health screenings and counseling services. The government could also support colleges in organizing diverse stress-relief activities, including Mental Health Awareness Months, meditation and yoga courses, and relaxation workshops, to help students reduce academic pressure and anxiety.

Colleges and educational institutions should inspire student participation by offering a variety of physical activities and well-equipped sports facilities. Schools can organize campus sports events, club sports competitions, or fitness classes, such as aerobics, badminton, and football, to raise awareness about the importance of physical exercise. At the same time, the availability and flexibility of sports facilities should be ensured, allowing students to exercise at their convenience.

For individual college students, recognizing the importance of physical exercise in relieving stress, reducing ruminative thinking, and improving sleep quality can motivate them to participate in physical activities and adopt positive psychological adjustment strategies. Students can reduce academic and life stress by engaging in regular running or participating in group sports. Additionally, by attending counseling courses, meditation, or yoga, they can cultivate good psychological regulation abilities, further enhancing their self-management skills. This not only improves their overall health but also helps them develop positive lifestyle habits and a healthy way of living, laying a solid foundation for their future health.

Limitations of the Study

However, this study has certain limitations. First, the use of questionnaires to measure sleep quality may introduce potential biases and limitations in objectivity. To more comprehensively capture sleep patterns, future research could consider incorporating objective physiological measurement tools, such as polysomnography and electroencephalography, to provide more reliable physiological evidence, thereby enhancing the accuracy and reliability of the findings.

Second, due to the cross-sectional design of this study, which aimed to assess the relationships between physical exercise, perceived stress, ruminative thinking, and sleep quality at a specific point in time, it is difficult to explore the causal mechanisms between physical activity and sleep quality in depth. Additionally, this study analyzed the relationship between physical exercise and sleep quality through retrospective questionnaires, but this design cannot capture the long-term cumulative effects of physical exercise. Future research could adopt a longitudinal design or intervention studies to track changes in individuals' physical activity levels and sleep quality over time, in order to more fully elucidate the causal relationship and underlying mechanisms.

Third, this study only examined the mediating roles of perceived stress and ruminative thinking in the relationship between physical exercise and sleep quality among college students. Other variables, such as social support, psychological resilience, and mindfulness, may also play a significant role. Future research should incorporate more relevant psychological and social factors for a comprehensive analysis. In this study, demographic variables such as gender, age, and degree were included as control variables, but their effects were not explored in depth. Future studies will further

optimize the experimental design, expand and diversify the sample size, and employ stratified or interaction effect analysis to explore the potential moderating or mediating roles of gender, age, and degree in the relationship between physical exercise, perceived stress, ruminative thinking, and sleep quality, thus providing more comprehensive support for the research conclusions.

Conclusion

This study found that, first, there are significant correlations among physical exercise, perceived stress, ruminative thinking, and sleep quality. Second, physical exercise significantly negatively predicts sleep quality in college students. Finally, perceived stress and ruminative thinking not only serve as simple mediators in the relationship between physical exercise and sleep quality, but also exert a chain-mediated effect on sleep quality through perceived stress and ruminative thinking, meaning that improving sleep quality can be achieved by reducing perceived stress and controlling ruminative thinking. This research finding also provides a scientific basis for the design of mental health education and intervention strategies in colleges. Colleges should encourage students to actively engage in physical exercise by offering a variety of sports activities (such as sports events and fitness classes) and providing well-equipped sports facilities. College students, in turn, should recognize the important role of physical exercise in improving sleep, actively participate in exercise, and learn psychological adjustment techniques (such as meditation and yoga) to alleviate stress, reduce ruminative thinking, and thereby improve sleep quality.

Data Sharing Statement

Due to the restrictive conditions of data provision, they cannot be shared publicly. For details, please contact the author directly.

Ethical Approval and Consent to Participate

This study was approved by the Ethics Committee of Shandong University. All research procedures were conducted in accordance with the ethical guidelines outlined in the Declaration of Helsinki. All participants in the survey provided informed consent and voluntarily agreed to participate in the study.

Acknowledgment

We extend our gratitude to all the participants for their dedication and hard work in contributing to our research study.

Author Contributions

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

Disclosure

The authors declare no competing interests in this work.

References

1. Li L, Wang YY, Wang SB, et al. Sleep duration and sleep patterns in Chinese university students: a comprehensive meta-analysis. *J Clin Sleep Med*. 2017;13(10):1153–1162. doi:10.5664/jcsm.6760
2. Ping T, Chenghong W. Correlation between sleep quality and health condition of college students. *China J Health Psychol*. 2010;18(02):181–184. doi:10.13342/j.cnki.cjhp.2010.02.056
3. Xue X *The Relationship between Physical Exercise and Sleep Quality among College Students in Xi'an in the Post-Epidemic Era —The Chain Mediation Role of Mobile Phone Dependence and Anxiety* [Master's thesis]. Xi'an Physical Education University; 2023. Available from: <https://link.cnki.net/doi/10.27401/d.cnki.gxatc.2023.000273>. Accessed February 20, 2025.
4. Chaoyi H. *Study on the Relationship between Physical Activity, Subjective Wellbeing and Sleep Quality between College Students—Take the Undergraduates of Soochow University as an Example* [Master's thesis]. Soochow University; 2021. Available from: <https://link.cnki.net/doi/10.27351/d.cnki.gszhu.2021.003863>. Accessed February 20, 2025

5. Wang P, Wang XC. Effect of time management training on anxiety, depression, and sleep quality. *Iranian J Public Health*. 2018;47(12):1822–1831.
6. Junhui S, Jie S, Lei F. The effect of increased after-school exercise time on self-efficacy, perceived stress and improvement of academic performance of medical students. *China Higher Med Educ*. 2022;2022(09):17–18.
7. Dan Z, Xueqing H, Qinxue L. Stress and sleep quality among undergraduate students: chain mediating effects of rumination and resilience. *J Psychol Sci*. 2021;44(01):90–96. doi:10.16719/j.cnki.1671-6981.20210113
8. Baolin D, Lijuan M. Core beliefs, deliberate rumination and exercise adherence of undergraduate: the moderated mediating effect of exercise atmosphere. *J Tianjin Univ Sport*. 2018;33(05):441–447. doi:10.13297/j.cnki.issn1005-0000.2018.05.011
9. Qiong L, Meng L, Xing-yu C, Jia-ning Y. Negative rumination and sleep quality of college students: the role of negative emotion and bedtime procrastination. *Chin J Clin Psychol*. 2024;32(01):203–206. doi:10.16128/j.cnki.1005-3611.2024.01.037
10. Kredlow MA, Capozzoli MC, Hearon BA, Calkins AW, Otto MW. The effects of physical activity on sleep: a meta-analytic review. *J Behav Med*. 2015;38(3):427–449. doi:10.1007/s10865-015-9617-6
11. Haigang J The effects of physical activity, perceived stress, and negative emotions on college students' sleep quality: a moderated chain-mediated model. Master's thesis. Tianjin University of Sport; 2023. Available from: <https://link.cnki.net/doi/10.27364/d.cnki.gtty.2023.000221>. Accessed February 20, 2025.
12. Chennaoui M, Arnal PJ, Sauvet F, Léger D. Sleep and exercise: a reciprocal issue?. *Sleep Med Rev*. 2015;20:59–72. doi:10.1016/j.smrv.2014.06.008
13. Yosiaki S, Ogawa M, Kawada T, Suzuki S, Duki MIZ. Afternoon exercise improves the quality of night sleep: a case study observed by EEG and self-rating scale. *Journal of Occupational Health*. 1998;40(1):37–43. doi:10.1539/joh.40.37
14. YuSheng S *Influence of The Baduanjin on Psychological Health ofunderclassman in a University of TCM* [Doctoral dissertation]. Fujian University of Chinese Medicine; 2014. Available from: https://kns.cnki.net/kcms2/article/abstract?v=0rU-DchPsvETFQP8TLFUtEN9zpystELvAhX2IHQqcJVg2UNOOwFeCFYqU4Dmla0KEepVvYjmsGOZgayt1Qe5rw87W1yTKw7BTME-cFXn3TzXt11O1vOk1tJJgamAaNHkpyppCA4b9w_nk7nEVnKvZFGCQzPgSc4qVFX5ydH1s=&uniplatform=NZKPT&language=CHS. Accessed February 20, 2025
15. Kai-hua C, Xiao-yan W. Study of the relevance between the physical exercise and the mood and the sleep conditions. *Chin J School Health*. 2015;36(05):715–717. doi:10.16835/j.cnki.1000-9817.2015.05.023
16. Buxton OM, Lee CW, M L-B, Turek FW, Van Cauter E. Exercise elicits phase shifts and acute alterations of melatonin that vary with circadian phase. *Am J Physiol-Regulatory Integr Comparat Physiol*. 2003;284(3):R714–R724. doi:10.1152/ajpregu.00355.2002
17. Khazaie H, Norouzi E, Rezaie L, Safari-Faramani R. Effect of physical activity on sleep quality in patients with major depression disorder: a systematic review and meta-analysis of randomized controlled trials. *Current Psychol*. 2023;42(33):28846–28856. doi:10.1007/s12144-022-03810-8
18. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. *J Health Soc Behav*. 1983;24(4):385–396. doi:10.2307/2136404
19. Lazarus RS, Folkman S. Cognitive Theories of Stress and the Issue of Circularity. In: Appley MH, Trumbull R, editors. *Dynamics of Stress: Physiological, Psychological and Social Perspectives*. Springer US; 1986:63–80.
20. Peluso MA, Guerra de Andrade LH. Physical activity and mental health: the association between exercise and mood. *Clinics*. 2005;60(1):61–70. doi:10.1590/s1807-59322005000100012
21. Biddle SJ, Asare M. Physical activity and mental health in children and adolescents: a review of reviews. *Br J Sports Med*. 2011;45(11):886–895. doi:10.1136/bjsports-2011-090185
22. Sothmann MS, Buckworth J, Claytor RP, Cox RH, White-Welkley JE, Dishman RK. Exercise training and the cross-stressor adaptation hypothesis. *Exercise Sport Sci Rev*. 1996;24:267–287. doi:10.1249/00003677-199600240-00011
23. Aiguo C, Jun Y. Medium load sports training effects on psychological stressed rat apoptosis stress mechanism. *J Wuhan Sports Univ*. 2007; (05):43–49. doi:10.15930/j.cnki.wtxb.2007.05.011
24. Hu L, Lidong F, Qingxia J, Ruonan W. How physical exercise alleviates psychosocial stress—the integration of cross stress adaptation and antagonistic stress inhibition. *China Sport Sci*. 2023;43(10):73–81. doi:10.16469/j.css.202310008
25. Xiaofan Y, Xiaojie W, Yuanyuan X, Chen X, Li P, Min L. Relationship between perceived stress and insomnia in recruits: chain-mediated effects of brooding and depression. *J Army Med Univ*. 2022;44(18):1887–1892. doi:10.16016/j.2097-0927.202203144
26. Liu Z, Liu RX, Zhang Y, et al. Association between perceived stress and depression among medical students during the outbreak of COVID-19: the mediating role of insomnia. *J Affective Disorders*. 2021;292:89–94. doi:10.1016/j.jad.2021.05.028
27. Lo Martire V, Berteotti C, Zoccoli G, Bastianini S. Improving sleep to improve stress resilience. *Current Sleep Med Rep*. 2024;10:23–33. doi:10.1007/s40675-024-00274-z
28. Xin-yu L, Xin-yi W, Hai-de C, Ling-feng G, Wei-jian L. Relationship between perceived stress and perceived sleep quality: a dual-stage moderated mediation model among university students. *Chin J Clin Psychol*. 2019;27(02):351–355. doi:10.16128/j.cnki.1005-3611.2019.02.029
29. Yongliang Q, Hongjuan W. The mediating role of family care in perceived stress, self-perceived aging, and sleep quality among elderly migraineurs in Changchun City, China. *Chin J Gerontol*. 2021;41(12):2654–2657.
30. Yong-chuang L, Li-na G, Kun L. Mediating effect of sleep quality between depression among the community-dwelling elderly and perceived stress. *Modern Prevent Med*. 2016;43(08):1425–1428.
31. Yuwei Y, Mingyan L, Xiangdong T, Rongmao L. On the stressors and its phenomenological relationship with sleep quality. *Adv Psychol Sci*. 2010;18(10):1537–1547.
32. Hai-Yan Z, Guo-Peng L, Ping L, Hong-Ling Y. Relationship between prenatal maternal stress and sleep quality in pregnant women: Mediating effect of psychological distress. *Chin Mental Health J*. 2016;30(12):896–900.
33. Mu LS, Xiu H, Hongfei Y. A review of rumination research abroad. *Chin J Appl Psychol*. 2009;15(01):90–96.
34. Nolenhoeksema S. Responses to depression and their effects on the duration of depressive episodes. *J Abnormal Psychol*. 1991;100(4):569–582. doi:10.1037/0021-843x.100.4.569
35. Blumenthal JA, Babyak MA, Moore KA, et al. Effects of exercise training on older patients with major depression. *Arch Internal Med*. 1999;159 (19):2349–2356. doi:10.1001/archinte.159.19.2349
36. Singh NA, Clements KM, Fiatarone MA. A randomized controlled trial of progressive resistance training in depressed elders. *J Gerontol Series a-Biol Sci Med Sci*. 1997;52(1):M27–M35. doi:10.1093/gerona/52A.1.M27
37. Yibo J, Fang L, Wenjing S. Cognitive models of insomnia: a lecture. *Chin Mental Health J*. 2011;25(07):496–499.

38. Butz S, Stahlberg D. Can self-compassion improve sleep quality via reduced rumination? *Self Identity*. 2018;17(6):666–686. doi:10.1080/15298868.2018.1456482
39. Guastella AJ, Moulds ML. The impact of rumination on sleep quality following a stressful life event. *Personality Individual Diff*. 2007;42(6):1151–1162. doi:10.1016/j.paid.2006.04.028
40. Nolenhoeksema S, Parker LE, Larson J. Ruminative coping with depressed mood following loss. *J Personality Soc Psychol*. 1994;67(1):92–104. doi:10.1037/0022-3514.67.1.92
41. Yunfeng C, Yongzhi J, Zheng M. Stress perception and problematic smartphone use in adolescents: the role of rumination and emotion regulation. *Psychology*. 2022;10(12):731–739. doi:10.16842/j.cnki.issn2095-5588.2022.12.004
42. Wenyan M, Dawei H, Peng G. Relationship between stressful life events and suicidal ideation among higher vocational college students during COVID-19: The chain mediating effect of rumination and depression. *China J Health Psychol*. 2022;30(07):1037–1042. doi:10.13342/j.cnki.cjhp.2022.07.017
43. Liu Y *The Relationships Among Perceived Stress, Rumination and Depression in High School Students and Intervention Research* [Master's thesis]. Central China Normal University; 2022. Available from: <https://link.cnki.net/doi/10.27159/d.cnki.ghzs.2022.000375>. Accessed February 20, 2025
44. Guangshen D *Stress and Depressed Mood in College Students - The Mediating and Regulatory Role of Automatic Thought and Rumination* [Master's thesis]. Shanghai Normal University; 2020. Available from: <https://link.cnki.net/doi/10.27312/d.cnki.gshsu.2020.000555>. Accessed February 20, 2025
45. Deqing L. Stress level of college students and its relationship with physical exercise. *Chin Mental Health J*. 1994;8(1):5–6.
46. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index - A new instrument for psychiatric practice and research. *Psych Res*. 1989;28(2):193–213. doi:10.1016/0165-1781(89)90047-4
47. Yang J, Zhou L, Xiaodan Z. Relationship between daily physical activity and sleep quality among college students. *Chin J School Health*. 2021;42(07):1047–1051. doi:10.16835/j.cnki.1000-9817.2021.07.020
48. Xianchen L, Maogin T. Reliability and validity of the Pittsburgh Sleep Quality Index. *Chin J Psych*. 1996;29(2):103–107.
49. Tingzhong Y, Hanteng H. An epidemiological study on stress among urban residents in social transition period. *Chin J Epidemiol*. 2003;24(9):11–15.
50. Dandan T, Zhonglin W. Common methodology bias testing: issues and recommendations. *J Psychol Sci*. 2020;43(01):215–223. doi:10.16719/j.cnki.1671-6981.20200130
51. Mu L, Zhou Y, Jamal GC, et al. Insomnia mediates the effect of perceived stress on emotional symptoms during the first wave of the COVID-19 pandemic in China. *J Affect Disord*. 2023;323:770–777. doi:10.1016/j.jad.2022.12.033
52. Hai-jun K, Ya-li Z, Qiu-bao Y, Zhao-yue L, Feng-hua W. Meta analysis of the intervention effect of physical exercise on sleep quality and state of mind of Chinese college students. *Sports Res Educ*. 2019;34(05):85–91. doi:10.16207/j.cnki.2095-235x.2019.05.016
53. Vgontzas AN, Zoumakis M, Bixler EO, et al. Impaired nighttime sleep in healthy old versus young adults is associated with elevated plasma interleukin-6 and cortisol levels: physiologic and therapeutic implications. *J Clin Endocrinol Metabol*. 2003;88(5):2087–2095. doi:10.1210/jc.2002-021176
54. Schultchen D, Reichenberger J, Mittl T, et al. Bidirectional relationship of stress and affect with physical activity and healthy eating. *British J Health Psychol*. 2019;24(2):315–333. doi:10.1111/bjhp.12355
55. Chunlei Z, Shouwei Z, Kunpeng X. Influence of exercise intervention on college students'. *Psychol Pressure*. 2016;42(04):103–108. doi:10.15942/j.jcsu.2016.04.018
56. Yong W, Jing-tao W, Xiao-lin Z, Jun H. Leisure physical exercise and the developmental trajectory of sleep quality in college students: based on parallel latent growth modeling. *J Guangzhou Sport Univ*. 2023;43(06):82–94. doi:10.13830/j.cnki.cn44-1129/g8.2023.06.10
57. Alderman BL, Olson RL, Brush CJ, Shors TJ. MAP training: combining meditation and aerobic exercise reduces depression and rumination while enhancing synchronized brain activity. *Transl Psych*. 2016;6e726. doi:10.1038/tp.2015.225
58. Puterman E, O'Donovan A, Adler NE, et al. Physical activity moderates effects of stressor-induced rumination on cortisol reactivity. *Psychosom Med*. 2011;73(7):604–611. doi:10.1097/PSY.0b013e318229e1e0
59. Tan Q. A review of the relationship between depression and rumination. *Adv Psychol*. 2023;13(12):5703–5709. doi:10.12677/AP.2023.1312724
60. Mei Y *Relationship among Sleep Dysfunctional Beliefs, Rumination and Sleep Quality in College School Students* [Master's thesis]. Fujian Normal University; 2013. Available from: https://kns.cnki.net/kcms2/article/abstract?v=0rU-DchPsvY7ypifMlcXnf9rbSO0yywtIPkEEXZhDn0gFTivpvXvB3yTX5jABJVuu9KluueQ1gx78XFuVqhQUR7RMxpVZF3N6KEP6hkSCoTzEwgRL-1JgR_hVF_6GwLLkYy6SEYRvnlYKxKFFcifkpjP1_Rp&uniplatform=NZKPT&language=CHS. Accessed February 20, 2025
61. La Rocque CL, Mazurka R, Stuckless TJR, Pyke K, Harkness KL. Randomized controlled trial of Bikram yoga and aerobic exercise for depression in women: efficacy and stress-based mechanisms. *J Affective Disorders*. 2021;280:457–466. doi:10.1016/j.jad.2020.10.067
62. Zhang M, Zhang J, Zhang F, Zhang L, Feng D. Prevalence of psychological distress and the effects of resilience and perceived social support among Chinese college students: does gender make a difference? *Psychiatry Res*. 2018;267:409–413. doi:10.1016/j.psychres.2018.06.038
63. Feizi A, Aliyari R, Roohafza H. Association of perceived stress with stressful life events, lifestyle and sociodemographic factors: a large-scale community-based study using logistic quantile regression. *Comput Mathematical Methods Med*. 2012;2012:151865. doi:10.1155/2012/151865
64. Faravelli C, Alessandra Scarpato M, Castellini G, Lo Sauro C. Gender differences in depression and anxiety: the role of age. *Psychiatry Res*. 2013;210(3):1301–1303. doi:10.1016/j.psychres.2013.09.027
65. Graves BS, Hall ME, Dias-Karch C, Haischer MH, Apter C. Gender differences in perceived stress and coping among college students. *PLoS One*. 2021;16(8):e0255634. doi:10.1371/journal.pone.0255634
66. Chao M, Yanyun W, Junjun F, Xin Z. The impact of different types of academic stress on subcomponents of executive function in high school students of different grades. *Acta Psychologica Sinica*. 2025;57(01):18–35. doi:10.3724/SP.J.1041.2025.0018
67. Guanren Z, Wenwen C, Shengchao B. Correlation between academic stress and extracurricular physical exercise among college students. *Chin J School Health*. 2023;44(07):991–994+999. doi:10.16835/j.cnki.1000-9817.2023.07.007

Psychology Research and Behavior Management

Dovepress
Taylor & Francis Group

Publish your work in this journal

Psychology Research and Behavior Management is an international, peer-reviewed, open access journal focusing on the science of psychology and its application in behavior management to develop improved outcomes in the clinical, educational, sports and business arenas. Specific topics covered in the journal include: Neuroscience, memory and decision making; Behavior modification and management; Clinical applications; Business and sports performance management; Social and developmental studies; Animal studies. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit <http://www.dovepress.com/testimonials.php> to read real quotes from published authors.

Submit your manuscript here: <https://www.dovepress.com/psychology-research-and-behavior-management-journal>