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The Current Situation Regarding Low-Intensity Physical Activity and Insufficient Sleep Among University Students in China, and Their Impact on Mental Health

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Abstract

Objective: To systematically assess the status of physical activity (PA), sleep, and mental health among college students in China, analyze the factors influencing mental health, and provide a theoretical basis for developing intervention programs to improve college students' mental health.

Method: We used stratified, cluster, and stage sampling methods. We surveyed 49,717 college students from 106 institutions of higher education across 31 provinces, autonomous regions, and municipalities directly under the central government. The

study used an online questionnaire covering students' physical activity behaviors, sleep quality, mental health, health behaviors, and sociodemographic information.

Results: A total of 43,294 valid questionnaires were collected in this survey (a response rate of 87.1%), of which 25,289 were from female students (58.4% of the total). Among college students, 64.7% engaged in low-intensity physical activity (PA); the prevalence of insufficient sleep was 33.2%; the prevalence of poor sleep quality was 20.4%; and the prevalence of high-risk symptoms for depression and anxiety was 8.3% and 3.0%, respectively. Binary logistic regression indicated that high-intensity PA (OR = 0.854) and adequate sleep duration (OR = 0.826) were protective against the onset of depressive symptoms. Adequate sleep duration (OR = 0.985) was a protective factor against the onset of anxiety symptoms. Poor sleep quality was a risk factor for both depressive (OR = 1.156 – 1.373) and anxiety (OR = 2.625 – 6.240) symptoms.

Conclusion: Physical activity among college students is predominantly of low intensity, and the prevalence of insufficient sleep is high. High-intensity physical activity and adequate, high-quality sleep may help alleviate mental health issues among college students, and there appears to be an interactive effect between physical activity and sleep on the alleviation of depressive symptoms. Future research could explore targeted interventions that combine physical activity and sleep behaviors to improve college students' mental health.

Keywords

College students; physical inactivity; sleep; mental health; health promotion

0 Preface

In recent years, the incidence of mental health disorders—particularly depression and anxiety—has risen sharply worldwide. [1, 2]. College students are in the transitional phase from adolescence to adulthood and are susceptible to multiple sources of stress, which can lead to frequent psychological issues; as such, they have become a

key demographic in China that requires urgent attention [3-6]。2In April 2023, the Ministry of Education and 16 other departments jointly issued the “Special Action Plan for Comprehensively Strengthening and Improving Student Mental Health Work in the New Era (2023–2025)” (hereinafter referred to as the “Action Plan”). The Action Plan calls for greater emphasis on student mental health work, stronger mental health monitoring, and mental health assessments. Depression and anxiety are the most common mental health issues among college students.[7].Depression significantly increases the risk of cardiovascular disease and all-cause mortality among college students and is a major factor contributing to years lived with disability and the burden of disease worldwide. [8] A recent study involving more than 1.4 million people shows that a diagnosis of depression at any age is associated with a 1- to 2-fold increased risk of dementia. [8]. In particular, with the increased use of social media in recent years, the prevalence of mental illness and self-harm among young people has also been on the rise [9]. Therefore, interventions targeting risk factors for depression and anxiety are needed to improve college students’ mental health.

Engage in regular, moderate-to-vigorous physical activity（**Moderate-Vigorous intensity PA，MVPA）Not only is it key to preventing noncommunicable diseases**[10]. It also helps maintain mental health, including preventing cognitive decline and symptoms of depression and anxiety [11]. Previous studies have shown that PA deficiency is independently associated with an increased risk of depression and anxiety. [12]. However, 27.5% of adults did not meet the physical activity levels recommended by the World Health Organization in 2010[13], and this situation has shown little improvement over the past decade[11]. In addition to PA, sleep is also an important factor affecting college students' mental health[14, 15]. Research has found that short-term sleep deprivation reduces college students' learning efficiency, impairs cognitive function, and increases reaction time[16, 17]; Chronic sleep deprivation and poor sleep quality are strong risk factors for obesity, diabetes, and peripheral artery disease, among other conditions[18-20]. Previous studies have shown that a lack of physical activity, insufficient sleep duration, and poor sleep quality are independently associated with an increased risk of depression and anxiety. [12, 21-23], yet few studies

have comprehensively examined these risk factors.

1. Theoretical Analysis and Formulation of Research Hypotheses

The Stress Buffering Model provides a compelling explanation for the relationship between PA and mental health [24]. As a proactive coping strategy, PA can enhance an individual's psychological resilience, helping them better cope with life's stresses and thereby mitigate the negative impact of psychological stress on health. In recent years, research on exercise and health promotion has advanced rapidly, and studies on promoting mental health from a behavior change perspective have garnered particular attention from scholars [25]. However, the topics scholars focus on, as well as the research paradigms and statistical strategies they employ, vary, leading to uncertainty, inconsistency, and even contradictions in their conclusions [26]. Furthermore, large-sample epidemiological survey data on physical activity (PA), sleep, and mental health among college students in China remain limited. Accordingly, this study uses an epidemiological survey approach to analyze PA levels, sleep patterns, and mental health status among college students in China. The innovative aspects of this study are, first, its empirical analysis of the current status of physical activity, sleep, and mental health among Chinese college students based on large-scale national data; and, second, its analysis of the interactive effects of PA and sleep on college students' mental health. The study moves beyond previous analyses of single-factor influences on mental health, and its findings will provide data support for future research exploring multivariate, comprehensive interventions for college students' mental health.

Against this backdrop, the primary objectives of this study are: 1) to understand the current levels of PA and sleep patterns among college students in China through a large-sample epidemiological survey paradigm, thereby providing foundational data for scholars conducting research on college students' health behaviors; 2) to explore the prevalence of mental health issues among college students using paper-and-pencil tests, thereby providing data support for the promotion of mental health and the implementation of intervention programs; 3) To validate the associations between

college students' physical activity levels, sleep patterns, and mental health from a mathematical and statistical perspective, thereby providing theoretical support for the development of subsequent intervention strategies based on a behavior change approach. Based on stress model theory, this study proposes the following hypotheses: 1) There is a positive correlation between college students' physical activity levels and their mental health. 2) There is a positive correlation between college students' sleep quality and their mental health. 3) Physical activity and sleep interact to influence college students' mental health, jointly affecting their mental health status.

2 Research Methods

2.1 Data Sources

This survey targets currently enrolled undergraduate students at general higher education institutions in mainland China. The list of general higher education institutions is based on the Ministry of Education's "List of General Higher Education Institutions Nationwide (as of June 15, 2023)" and includes both associate degree and bachelor's degree students; this survey does not include graduate students (master's and doctoral candidates). This study used stratified, cluster, and phased sampling methods to ensure sample representativeness and long-term traceability. The sampling process is as follows: First, we allocated an average of three sampling locations to each province (autonomous region, municipality). Within these, we designated provincial capitals as "Category I" sampling locations, while the remaining prefectures (cities) were classified as "Category II" or "Category III" based on their geographic location and level of socioeconomic development. For municipalities directly under the central government, we primarily used random cluster sampling and also considered the number of sampling sites. Second, the criteria for selecting sampling units included: higher education institutions registered with the Ministry of Education; institutions meeting sampling requirements (age, number of students, grade distribution, etc.); institutions with a designated person responsible for distributing questionnaires and willing to participate in long-term monitoring; and institutions where college students

had returned to campus after the fall semester. Finally, participants were grouped by gender (male, female) and academic year (8 levels), with a minimum sample size of 45 per group. The total sample size for each province (autonomous region, municipality) was 1,080, resulting in an estimated 33,480 valid questionnaires nationwide (minimum sample size). A total of 49,717 questionnaires were ultimately returned. The survey involved 106 universities across 31 provinces, autonomous regions, and municipalities directly under the central government on the Chinese mainland. Trial registration: Not applicable. This cross-sectional observational survey is not a clinical trial[27].

2.2 Variable Settings

The survey covered sociodemographic information, health behaviors, and a series of scales; the average completion time was 5 minutes and 56 seconds. To ensure the quality of the questionnaire analysis, the selected established scales have all passed psychometric validity tests among college students in mainland China and are accompanied by evaluation norms for Chinese college students. Control variables primarily include gender, academic year, institution, and the institution's location (as indicated by the postal code). The institution's location is categorized according to China's geographic regions as "Eastern," "Central," and "Western"[28]. This study included college students' health behaviors as control variables. Research has shown that unhealthy lifestyle habits, such as smoking and drinking, are closely linked to poor sleep quality and mental health issues; both are important confounding factors affecting sleep quality and mental health (depression/anxiety). [29]. Smoking may lead to problems with sleep, such as reduced sleep duration and difficulty falling asleep [30], and may also affect sleep quality by triggering neuroinflammation[31]. A nationwide observational study of 12,637 adults found that alcohol consumption is significantly associated with sleep problems such as poor sleep quality and short sleep duration, and that people who drink are more likely to experience mental health issues such as anxiety and depression [32]. Therefore, this study included smoking and drinking behaviors as control variables to examine the reciprocal relationships among physical activity, sleep, and mental health more clearly. In this study, college students' smoking behaviors were

categorized into three groups—"never smoked," "occasional smoker," and "frequent smoker"—in accordance with the World Health Organization (WHO) definitions of smoking-related terms; drinking behaviors were assessed using the U.S. Youth Risk Behavior Surveillance Survey[33], and drinking behavior was categorized into three groups—"never drank," "drank but never got drunk," and "got drunk"—based on the number of days participants drank alcohol and the number of days they got drunk in the past month, for the purposes of analysis. Table 1 presents the main variables of this study, along with their corresponding measurement methods and scoring rules.

Table1

2.3 Data Analysis Methods

Data were processed using SPSS 25.0 and Excel. (1) First, the data were preprocessed, and valid questionnaires were selected according to the validation criteria; (2) The chi-square test was used to analyze differences among variables in terms of sociodemographic factors and health behaviors, and Cramer's V coefficient (hereinafter referred to as the V coefficient) was used as a measure of association in the analysis of differences. [34]; (3) A binary logistic regression model was used to examine the odds ratio (OR) for the occurrence of mental health issues following exposure to PA and sleep-related factors[35]. In the specific analysis, we controlled for sociodemographic variables such as gender, grade level, age, school, and school location, as well as health behavior variables such as smoking and alcohol consumption.

3. Research Findings

A total of 43,294 valid questionnaires were collected in this survey. The Central Region had the highest response rate, while the Western Region had a lower response rate; the overall response rate met the sampling requirements.

3.1 Current Status of Physical Activity and Sleep Quality Among Chinese College Students

Table 2 summarizes college students' physical activity (PA) levels and sleep patterns. Low-intensity physical activity (LPA) was the predominant form of PA among college students, accounting for 64.7% of the total. Significant differences were observed based on gender (V = 0.322) and school location (V = 0.164). Specifically, the reported rate of LPA was higher among female students (76.6%) than among male students (48.1%); Among the regions where universities are located, the western region had the highest VPA reporting rate at 13.3%, while the central region had the highest LPA reporting rate at 40.8%. The overall reported rate of insufficient sleep among college students was 33.2%, with differences observed under the alcohol consumption variable (V = 0.109); specifically, students who had been intoxicated reported the highest rate of insufficient sleep (40.7%). The overall proportion of college students reporting "poor" sleep quality was 20.4%, with differences observed in reporting rates under the alcohol consumption indicator (V=0.125); among them, students who had "been drunk" reported the highest proportion of "poor" sleep quality (30%).

Table2

3.2 Prevalence of Mental Health Issues Among Chinese College Students

Table3

Table 3 presents a summary of the detection rates for depression and anxiety symptoms among college students. The detection rates for high-risk depression and anxiety symptoms were 8.3% and 3.0%, respectively. Regarding gender differences, there were no significant differences between male and female students in the proportions of those at high risk for depression (V = 0.094) and anxiety (V = 0.062)

symptoms. Regarding differences by academic stage, there were no significant differences in the detection rates of depression (V = 0.013) and anxiety (V = 0.019) among students at different academic stages. Among factors related to the university's location, there was a significant difference in the detection of depressive symptoms (V = 0.121); the detection rate for high-risk depression was highest among college students at universities in the eastern region, at 8.9%. Regarding smoking behavior, differences were observed in the detection of depression and anxiety symptoms among college students based on their smoking habits. Specifically, the proportion of college students at high risk for depression was highest among those who smoked frequently (19.4%, V = 0.189), and the proportion at high risk for anxiety was highest among those who smoked frequently (7.8%, V = 0.135). Regarding drinking behavior, there were differences in the detection rates of depression and anxiety symptoms among college students based on different drinking patterns. Specifically, the proportion of college students at high risk for depression was highest among those who had experienced intoxication (21.5%, V = 0.185), and the proportion at high risk for anxiety was highest among those who had experienced intoxication (11.5%, V = 0.108).

3.3 The Relationship Between Physical Activity, Sleep, and Mental Health Among College Students

Table 4 summarizes the associations between physical activity (PA), sleep, and mental health among college students. In a binary logistic regression analysis with depression diagnosis as the dependent variable, compared with low PA (LPA), very high PA (VPA) (OR = 0.854, 95% CI: 0.816 – 0.954, P = 0.003) was a protective factor against depressive symptoms among college students. Compared with insufficient sleep duration, adequate sleep duration (OR = 0.826, 95% CI: 0.751 – 0.909, P < 0.001) was a protective factor against depressive symptoms among college students, whereas excessive sleep duration (OR = 2.988, 95% CI: 2.276 – 3.275, P < 0.001) was a risk factor for depressive symptoms. Compared with those with very good sleep quality, those with fair (OR = 1.171), average (OR = 1.156), and very poor (OR = 1.373) sleep quality were all risk factors for depressive symptoms. When PA, sleep duration, and

sleep quality were simultaneously included in the regression analysis (Model 4), the protective effects of all three variables increased slightly, indicating an interaction effect between sleep and PA.

In a binary logistic regression analysis with anxiety diagnosis as the dependent variable, the effect of PA on anxiety diagnosis was not statistically significant. Compared with insufficient sleep duration, adequate sleep duration (OR = 0.295, 95% CI: 0.268 – 0.325, P < 0.001) was a protective factor against anxiety symptoms among college students. Compared with those with very good sleep quality, those with fair (OR = 6.240), average (OR = 6.252), and very poor (OR = 2.625) sleep quality were all risk factors for anxiety symptoms. When PA, sleep duration, and sleep quality were simultaneously included in the regression analysis (Model 4), adequate sleep duration remained a protective factor against anxiety symptoms among college students.

table4

4 Discussion

The Chinese government has always attached great importance to the mental health and well-being of its people, keeping their mental health and well-being at the forefront of its concerns at all times. Promoting the physical and mental health and all-around development of students is a major issue of public concern and social focus. As an integral part of overall health, mental health serves as a crucial foundation for personal achievement and happiness. Recently, the topic of student mental health has drawn widespread public attention [5]. College students are in a transitional phase from adolescence to adulthood, a period during which mental health issues are particularly likely to arise. It is important to pay ongoing attention to their mental health and investigate the factors that influence it, so that problems can be identified early and necessary interventions can be implemented. [3, 4]. Using epidemiological survey methods, this study analyzes levels of physical activity and sleep patterns among college students in China and their association with mental health. The presentation of these data will help advance efforts to promote mental health among college students

in China.

4.1 Analysis of the Current Status of Physical Activity Among College Students

The results show that physical activity (PA) levels among college students are predominantly at the low-intensity level (LPA) (64.7%), and that male students engage in more moderate-to-vigorous physical activity (MVPA) than female students. In terms of the global trend of declining physical activity, there is a significant downward trend in PA levels across all population groups worldwide.[36]. This phenomenon is closely linked to changes in human nutrition, transportation, and lifestyle.[37]. According to the results of the Eighth National Survey on Students' Physical Fitness and Health released by China's Ministry of Education in 2021, the rate of college students meeting physical fitness and health standards has still not improved, with the failure rate as high as 30 percent.[38]...Overall, there is a sustained downward trend, which corroborates the findings of this study in terms of the outcomes of PA (physical health). Regarding gender differences, male students engage in more physical activity than female students, consistent with previous findings [39, 40]. College students are in a transitional phase from adolescence to adulthood. Research has found that MVPA levels among both male and female students show an upward trend before the age of 12, but then follow a steady downward trend thereafter. Researchers believe this may be related to the rapid physiological and psychological development that occurs during adolescence [41]. The latest research, however, suggests that sporadic PA (exercise snacks) can also provide health benefits[42]. Against this backdrop of global physical inactivity (PIA), "Any physical activity is beneficial; the more you move, the better; exercise in moderation and within your limits; consistency is key." [43]. Increasing PA among university students is imperative.

4.2 Analysis of College Students' Sleep Patterns

College students' sleep patterns encompass two aspects: sleep duration and sleep quality. Regarding sleep duration, this study found that the overall reported rate of sleep deprivation among college students was 33.2%. Previous studies have reported

inconsistent findings on college students' sleep duration. In China, the reported rate of sleep deprivation among Han Chinese students aged 9 to 18 in 2014 was 77.2%, and this rate increased with age. [28]. According to data from the second follow-up survey (2014) of the China Kadoorie Biobank (CKB) project, the overall reported prevalence of insufficient sleep among adults in China was 25.8%.[44]. In a 2019 study, researchers collected PSQI data from 729 college students at two universities in Anhui and Jiangsu provinces; the results showed that the prevalence of sleep deprivation among college students was 56.2%.[45]. It can be seen that there are variations in the reported rates of sleep deprivation among college students. These variations may reflect differences in measurement tools, the socioeconomic status of participants' locations, and the growth of entertainment and cultural industries in the areas where their schools are located. Overall, however, sleep deprivation among college students is a serious issue, particularly as the prevalence of sleep deprivation has increased with the emergence of new factors such as smartphone addiction and employment pressures [46]. The dangers of sleep deprivation have been widely confirmed by the academic community. A study published in *The Lancet* showed that, compared to students who got a healthy amount of sleep each night, those who slept less than 9 hours per night had smaller brain regions responsible for memory, intelligence, and well-being. Two years later, these differences persisted, suggesting that sleep deprivation causes long-term damage to the brain. Of course, sleep deprivation is also a contributing factor to serious mental health issues such as depression and anxiety, a finding that was confirmed by the results of this study.

The overall prevalence of poor sleep quality among college students was 20.4% (combining the prevalence rates for "fair" and "very poor" sleep quality), and the prevalence was highest among students who smoked or engaged in heavy drinking. Previous studies report considerable variation in rates of poor sleep quality. For example, a 2021 survey using the PSQI scale among 1,220 students of various academic years at four general universities in Jiangsu, Shaanxi, Hubei, and Chongqing, China, found that the rate of poor sleep quality was 13.2%. [47]The China Sleep Research Report (2022) also used the PSQI and found that only 0.36% of college students had poor sleep quality [46]. These findings may be attributed to factors such as sampling

regions, the method of questionnaire completion (e.g., the degree of anonymity), and the cross-cultural application of the PSQI. Furthermore, the prevalence of poor sleep quality is higher among college students who smoke or drink to excess; existing research suggests that health behaviors such as smoking and drinking are major contributors to sleep problems [48]. This study suggests that there may be a “vicious cycle” (a relationship of mutual causality) between college students’ poor sleep quality and unhealthy behaviors such as smoking and drinking. In other words, college students engage in unhealthy behaviors such as smoking and drinking because of their poor sleep quality, and conversely, these unhealthy behaviors lead to sleep disturbances. Of course, whether this “vicious cycle” actually exists requires further empirical testing.

4.3 Analysis of the Current State of Mental Health Among College Students

The results of this study found that the detection rates for high-risk depression and anxiety symptoms among college students were 8.3% and 3.0%, respectively. The detection rate for depression was highest among college students in the eastern region, and there were differences in the detection rates of depression and anxiety among college students based on different health behaviors (smoking and drinking). The *Mental Health Blue Book: Report on the Development of Mental Health Among the Chinese Population (2019–2020)* reported that in 2020, 4.2% of college students were at high risk for depression, and 8.4% were at high risk for anxiety [49]. It can be seen that the detection rate of high-risk depression and anxiety among college students in this study was significantly higher than in 2020. One possible reason is related to the COVID-19 pandemic; for example, a recent study in *The Lancet* showed that survivors of COVID-19 primarily experience symptoms such as fatigue or muscle weakness, difficulty sleeping, anxiety, or depression [50]. This may also relate to the academic and employment pressures faced by today’s college students, as well as their use of social media. It should be noted that each college student’s mental health issues are complex and unique, requiring a careful consideration of various factors, including

personal, family, academic, and social environments. To improve college students' mental health, universities and other relevant departments should strengthen mental health education and counseling services, formulate corresponding policies and measures, and create a positive, supportive, and caring environment for college students' mental health.

4.4 A Discussion on the Protective Effects of Physical Activity and Sleep on Mental Health and Their Mechanisms

The results indicate that physical activity (PA) and high-quality sleep among college students protect mental health. There is broad consensus on the effectiveness of PA-promoting interventions (including recreational exercise or regular physical activity) in improving mental health issues such as depression and anxiety [51-59]...In particular, for adults with mild depression, there is no difference between exercise and medication[60]. These studies will provide foundational evidence for the role of physical activity in promoting mental health. Previous research has explored the use of physical activity (PA) interventions to improve students' mental health; for example, Chen Peijie et al. noted that staying active and engaging in regular PA (primarily leisure-time PA) may help college students recover from mental health issues experienced during periods of isolation caused by major public health crises such as the COVID-19 pandemic. [61]. Regarding sleep as a protective factor for health, the academic community has proposed various explanations[62, 63], but a mature theory has not yet been developed[64]. One possible reason is that longer sleep may reduce time available for health-promoting behaviors (such as physical activity), while further research is needed to determine whether mental health and sleep problems are bidirectionally related. In addition to the individual effects of PA and sleep on college students' mental health, the results of this study also indicate an interactive effect between PA and sleep in protecting against depressive symptoms among college students. This suggests that researchers and clinicians engaged in mental health intervention studies for students may adopt interventions that combine PA and sleep. As previously mentioned, in prospective cohort studies, when examined as individual risk factors,

physical inactivity, insufficient sleep, and poor sleep quality have been associated with an increased risk of depression and anxiety [65-72]. However, few studies have examined how the combination of PA and sleep factors affects mental health[66, 72]. Compared with sleep deprivation occurring on its own, the co-occurrence of sleep deprivation and poor sleep quality is more strongly associated with the development of chronic mental health symptoms [73]. At the same time, physical inactivity and sleep problems often co-occur and exhibit a bidirectional relationship (a vicious cycle in which inactivity leads to sleep problems, and sleep problems affect physical activity). [74, 75]This requires researchers to adequately control for confounding factors when designing single-variable (PA or sleep) intervention studies. Furthermore, Huang et al. noted a time-dependent relationship between PA and sleep: increasing sleep duration may reduce the time available for PA. In particular, current intervention studies based on 24-hour activity patterns have already been validated in the context of health promotion among children and adolescents. [76, 77]... Few studies have focused on college students as the target population. A recent study published in *The Lancet* shows that regular physical activity and healthy sleep are both crucial for preventing cognitive decline. A related commentary notes that a better understanding of the interactions between physical activity and sleep on cognitive health will help inform future lifestyle interventions and reduce the risk of dementia [78]. In light of this, future research designs aimed at promoting and intervening in students' mental health should comprehensively consider physical activity (PA) and sleep factors, and use comprehensive intervention methods to improve students' mental health.

4.5 Innovations and Limitations of This Study

The innovative aspect of this study lies in its empirical analysis of the current status of physical activity, sleep, and mental health among Chinese college students, based on a large-scale national dataset. The study found a synergistic protective effect of VPA and high-quality sleep against depressive symptoms, providing a basis for combined interventions. However, the study also has some limitations. First, this study is a cross-sectional study; therefore, causal inferences cannot be drawn. Second, sleep

and physical activity (PA) were not objectively measured but relied on self-reports, increasing the risk of recall and reporting biases. Furthermore, the study did not collect data on participants' history of mental illness and did not strictly determine whether students suffered from mental health issues such as depression or anxiety; it merely examined their symptoms of depression and anxiety. Finally, there are numerous factors that influence mental health (such as diet and nutrition, social and peer relationships, home environment, socioeconomic status, dormitory environment, screen time, and the built environment) [79-82]. Because of the study's design limitations, this research focused only on factors such as physical activity (PA), sleep, and smoking and alcohol consumption. Despite these limitations, a growing body of research suggests that ensuring adequate sleep and increasing physical activity among students can alleviate or even prevent mental health disorders. Our findings further underscore the need for researchers and clinicians to consider the combined effects of PA and sleep on adolescents' mental health when conducting research and designing interventions. In future studies, we hope to conduct large-scale longitudinal studies analyzing additional factors related to mental health to explore how PA and sleep influence these symptoms.

5. Conclusions and Recommendations

Physical activity among college students is primarily light-intensity, and reported sleep deprivation is high. VPA and adequate, high-quality sleep may help alleviate mental health issues among college students. Using a large-scale epidemiological survey, this study examined current levels of physical activity, sleep patterns, and mental health among college students in China, providing foundational data for scholars researching students' health behaviors. Based on these findings, the study recommends that higher education institutions prioritize students' physical activity, sleep, and mental health. Institutions should develop strategies to increase students' physical activity, optimize sleep environments to support high-quality sleep, and regularly assess students' mental health using scientifically validated measurement tools. For scholars engaged in promoting student mental health, future research should further explore targeted interventions combining PA and sleep behaviors to improve

college students' mental health. Finally, this study urges college students to engage in regular moderate-to-vigorous physical activity (MVPA), refrain from smoking and drinking alcohol, improve the quality of deep slow-wave sleep, and avoid mental health issues.

Abbreviations

PA: Physical activity

MVPA: Moderate-Vigorous intensity Physical Activity

PIA: physical inactivity

LPA: Low-intensity physical activity

MPA: Moderate-intensity physical activity

VPA: Very-high-intensity physical activity

OR: Odds ratio

CI: Confidence interval

IPAQ: International Physical Activity Questionnaire

PSQI: Pittsburgh Sleep Quality Index

CES-D: Center for Epidemiologic Studies Depression Scale

GAD-7：Generalized Anxiety Disorder-7 item scale

CKB: China Kadoorie Biobank

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Authors' contributions

Shan-shan Han and Yi-ran Yao contributed equally to this work as co-first authors.

Shan-shan Han: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing - original draft, Writing - review and editing.

Yi-ran Yao: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing - original draft, Writing - review and editing.

Bo Li: Conceptualization, Methodology, Supervision, Project administration, Writing - review and editing.

Qian-Qian Shao: Conceptualization, Methodology, Supervision, Project administration, Writing review and editing.

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Availability of data and materials

The authors can make the raw data supporting the conclusions of this article available without undue reservation.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki. The Ethics Committee of Nantong University approved this research protocol, and it was registered under approval number 2022(70). This study recruited only adult undergraduate students aged ≥18 years; no participants under 16 years of age were involved, and parental/guardian consent was therefore not required. Before the research and testing began, the researchers obtained informed consent from all study participants.

Informed Consent Statement

Informed consent was obtained from all the subjects involved in the study.

Competing Interests

The authors declare no conflicts of interest.

Consent for publication

Not applicable.

535 # Table

536 **Table 1. List of major variables**

Variable Categories	Variable Name	Measurement Scales	Variable Scoring Rules and Categories
Independent variable			
	Physical Activity	International Physical Activity Questionnaire, IPAQ	Divided into: Vigorous intensity PA (VPA), moderate intensity PA(MPA), Light intensity PA (LPA) [83].
	Sleep Quality	Pittsburgh Sleep Quality Index, PSQI	In the Chinese adult norms for the PSQI, sleep quality is categorized as “very good” (total score ⩽ 5), “fair” (5 < total score ⩽ 10), “average” (11 ⩽ total score < 15), and “very poor” (total score ⩾ 16).[84]Since most studies combine “average” and “very poor” sleep quality into a single category labeled “poor” for discussion, the results on college students’ sleep quality in this study are presented using a four-category classification; however, for regression analysis, a three-category classification (combining “average” and “very poor” from the normative data into “poor” sleep quality) was used to facilitate comparison with the literature.
	Sleep Duration	Pittsburgh Sleep Quality Index (PSQI)	Sleep duration of <7 hours is defined as “insufficient sleep,” 7–9 hours as “adequate sleep,” and ⩾9 hours as “excessive sleep” [85].
Dependent variable			
	Mental Health - Depression	The Center for Epidemiologic Studies Depression Scale (CES-	The CES-D uses 10 as the cutoff score and 17 as the cutoff score for high risk of depression [86]. In this study, the severity

		D）	of depressive symptoms was classified into three categories: “normal,” “low risk,” and “high risk.” In the binary logistic regression analysis, the “high-risk” group identified through the depressive symptom screening was designated as the “detected” group.
	Mental Health—Anxiety	Generalized Anxiety Disorder (GAD-7）	The total score on the GAD-7 ranges from 0 to 21, where 0–4 indicates “no” anxiety, 5–9 indicates “mild” anxiety, 10–14 indicates “moderate” anxiety, and 15–21 indicates “severe” anxiety [49]. In this study, the severity of anxiety symptoms was classified into three categories: “normal,” “low risk,” and “high risk,” with “mild” and “moderate” scores on the GAD-7 scale both categorized as “low risk.” In the binary logistic regression analysis, the “high risk” group identified based on anxiety symptoms was designated as the “detected” group.

Table 2. Physical activity level and sleep status of college students.

Features			Number of people	Physical activity				Sleep Duration				Sleep Patterns				
				Low	Medium	High	Statistic	Shortcomings	Suitable	Too long	Statistic	Great	Not bad	General	Very poo	Statistic
Summary		n	43294	280	1079	44		14375	2340	5517		120	223	77	10	
		%	100	64.	24.9	10.		33.2	54.1	12.7		27.	51.	18.	2.4	
Gender																
	Male	n	18005	865	5860	34	x^2=4	5940	9713	2352	x^2=2.96	513	926	31	41	x^2=5.6
		%	41.6	48.	32.6	19.	502.	33.0	54.0	13.1	1	28.	51.	17.	2.3	05
	Female	n	25289	193	4938	97	58 P<0.	8435	1368	3165	P=0.22 8	696	131	45	60	P=0.13 2
		%	58.4	76.	19.5	3.9	001 V=0	33.4	54.1	12.5	V=0.00 8	27.	51.	18.	2.4	V=0.01 1
Learning Phase																
	First-year	n	24624	155	6513	25		8307	1323	3080		677	128	43	58	
		%	56.9	63.	26.5	10.		33.7	53.8	12.5		27.	52.	17.	2.4	
	Second-year	n	11044	717	2769	10	x^2=1	3680	5989	1375	x^2=26.2	306	564	20	25	x^2=22.
		%	25.5	65.	25.1	9.9	54.8 77	33.3	54.2	12.5	50 P<0.00	27.	51.	18.	2.3	397 P=0.00
	Third-year	n	5912	414	1153	61	P<0. 001	1830	3233	849	1 V=0.02	176	298	10	15	8 V=0.02
		%	13.7	70.	19.5	10.	V=0	31.0	54.7	14.4	5	29.	50.	17.	2.5	3
	Fourth-year	n	1714	112	363	22	.060	558	943	213		484	883	31	33	
		%	4.0	65.	21.2	13.		32.6	55.0	12.4		28.	51.	18.	1.9	
School Location																
	East	n	15061	992	3771	13		4970	8090	2001		419	768	27	38	

Features			Number of people	Physical activity (hours/day)				Sleep Duration				Sleep Patterns				
				Low	Medium	High	Statistic	Shortcomings	Suitable	Too long	Statistic	Great	Not bad	General	Very poo	Statistic
	Middle	%	34.8	65.0	25.0	9.1	x^2=375.630 P<0.001 ***V=0.164***	33.0	53.7	13.3	x^2=13.325 P=0.01 V=0.017	27.0	51.1	18.5	2.6	x^2=13.220 P=0.04 V=0.017
		n	17644	11702	4252	1600		3450	5851	1288		2905	5564	1886	234	
	West	%	40.8	66.2	24.1	9.6		32.6	55.3	12.2		27.4	52.6	17.8	2.2	
		n	10589	6402	2775	1411		5955	9461	2228		4994	9142	3108	395	
		%	24.5	60.5	26.2	13.3		33.8	53.6	12.6		28.3	51.8	17.6	2.3	
Smoking behaviour																
	Never smoked	n	38337	24770	9579	3988		12632	20904	4801		10808	20061	6581	797	
		%	88.6	64.6	25.0	10.4		33.0	54.5	12.5		28.4	52.3	17.2	2.1	
	Occasional smoker	n	2171	1391	548	232	x^2=8.690 P=0.069 V=0.014	720	1142	309	x^2=41.325 P<0.001 V=0.031	574	1093	448	56	x^2=390.235 P<0.001 ***V=0.105***
		%	5.0	64.1	25.2	10.7		33.2	52.6	14.2		26.4	50.4	20.7	2.6	
	Regular smoker	n	2786	1865	671	250		1023	1356	407		623	1241	754	168	
		%	6.4	66.9	24.1	9.0		36.7	48.7	14.6		22.4	44.5	27.1	6.0	
Alcohol Consumption Patterns																
	Has never drunk alcohol	n	21084	13645	5260	2179	x^2=7.122	6685	11440	2959	x^2=208.437	6743	10711	3211	419	x^2=672.242

Features		Number of people	Physical activity				Sleep Duration				Sleep Patterns				
			Low	Medium	High	Statistic	Shortcomings	Suitable	Too long	Statistic	Great	Not bad	General	Very po	Statistic
Have drunk	%	48.7	64.[illegible]	25.0	10.[illegible]	P=0.130 V=0.013	31.7	54.3	14.0	P<0.001 ***V=0.109***	32.[illegible]	50.[illegible]	15.[illegible]	2.0	P<0.001 ***V=0.125***
	n	16839	108[illegible]	4227	17[illegible]		5503	9392	1944		415[illegible]	912[illegible]	31[illegible]	36[illegible]	
Have drunk alcohol, but have never been drunk.	%	38.3	64.3	25.1	10.6		32.7	55.8	11.5		24.7	54.2	19.0	2.2	
Have drunk	n	5371	354[illegible]	1311	51[illegible]		2187	2570	614		119[illegible]	256[illegible]	13[illegible]	23[illegible]	
	%	12.4	66.1	24.4	9.5		40.7	47.9	11.4		22.2	47.7	25.6	4.4	

Table3 Risk of depression and anxiety among college students

Features			Depression				Anxiety			
			Risk-free	**Low risk**	**High Risk**	**Statistical**	**Risk-free**	**Low risk**	**High Risk**	**Statistical**
Overall		n	26082	10539	6673		36824	3584	1248	
		%	60.2	24.3	15.4		88.5	8.5	3	
Gender										
	Male	n	10885	4331	2789	x^2=1.401	15236	1470	506	x^2=45.140
		%	60.5	24.1	15.5	P=0.496	88.5	8.5	2.9	P=0.933
	Female	n	15197	6208	3884	V=0.006	21588	2078	742	V=0.062
		%	60.1	24.5	15.4		88.4	8.5	3.0	
Learning Phase	First-year	n	14830.0	6018.0	3776.0	x^2=5.725	21145	2027	706	x^2=15.063
		%	60	24	15	P=0.455	88.6	8.5	3.0	P<0.001
	Second-year	n	6582.0	2717.0	1745.0	V=0.011	9348	933	324	V=0.019
		%	60	25	16		88.1	8.8	3.1	
	Third-year	n	3628.0	1395.0	889.0		4866	446	167	
		%	61	24	15		88.8	8.1	3.0	
	Fourth-year	n	1042.0	409.0	263.0		1465	142	51	
		%	61	24	15		88.4	8.6	3.1	
School Location	East	n	8880	3748	2433	x^2=120.038	12874	1315	468	x^2=7.5731
		%	59.0	24.9	16.2	P<0.001	87.8	9.0	3.2	P=0.109
	Middle	n	10716	4230	2698	***V=0.150***	14801	1369	493	V=0.013
		%	60.7	24.0	15.3		88.8	8.2	3.0	
	West	n	6486	2561	1542		9149	864	287	
		%	61.3	24.2	14.6		88.8	8.4	2.8	
Smoking Behavior	Never smoked	n	23561	9286	5490	x^2=352.325	33082	2919	985	x^2=310.055
		%	61.5	24.2	14.3	P<0.001	89.4	7.9	2.7	P<0.001
	Occasional smoker	n	1097	585	489	***V=0.164***	2779	428	164	***V=0.135***
		%	50.5	26.9	22.5		82.4	12.7	4.9	
	Regular smoker	n	1424	668	694		963	201	99	
		%	51.1	24.0	24.9		76.2	15.9	7.8	
Alcoh										
Alcohol Consumption Patterns	Never drunk alcohol	n	13297	4812	2975	x^2=482.996	18179	1590	568	x^2=337.331
		%	63.1	22.8	14.1	P<0.001	89.4	7.8	2.8	P<0.001

Have drunk alcohol, but have never been drunk.	n	10179	4243	2417	***V=0.175***	18117	1857	598	***V=0.108***
	%	60.4	25.2	14.4		88.1	9.0	2.9	
Have drunk	n	2606	1484	1281		528	101	82	
	%	48.5	27.6	23.9		74.3	14.2	11.5	

Table4 Correlation analysis of physical activity, sleep and mental health of college students*

Mental Health	Factors	Test Results		Model 1		Model 2		Model 3		Model 4	
		Detection Rate (%)	Statistical values	OR (95% CI)	P	OR (95% CI)	P	OR（95%CI）	P	OR（95%CI）	P
Depression											
	Physical Activity										
	LPA	30.0	x^2=9.438 P<0.001 V=0.104	1.0（ref）						1.0（ref）	
	MPA	25.8		0.997(0.911,1.092)	0.055					0.989(0.906,1.079)	0.098
	VPA	5.3		0.896(0.802,0.932)	<0.001					0.888(0.797,0.989)	0.004
	Sleep Duration[a]										
	Shortcomings	43.9	x^2=4378.383 P<0.001 V=0.346			1.0（ref）				1.0（ref）	
	Suitable	25.9				0.364(0.330,0.402)	<0.001			0.335(0.305,0.367)	<0.001
	Too long	11.1				1.147(1.040,1.265)	0.006			1.120(1.101,1.331)	<0.001
	Sleep Patterns										
	Great	17.8	x^2=2252.368 P<0.001 V=0.248					1.0（ref）		1.0（ref）	
	Not bad	32.4						3.381(2.939,3.890)	<0.001	3.251(2.207,4.305)	<0.001
	General	41.6						4.447(3.981,5.084)	<0.001	4.434(3.359,4.524)	<0.001
	Very poor	34.0						2.407(2.098,2.761)	<0.001	1.728(1.600,1.884)	<0.001

Mental Health	Factors	Test Results		Model 1		Model 2		Model 3		Model 4	
		Detection Rate (%)	Statistical values	OR (95% CI)	P	OR (95% CI)	P	OR（95%CI）	P	OR（95%CI）	P
Anxiety											
	Physical Activity										
	LPA	15.3	x^2=0.126 P=0.939 V=0.002	1.0（ref）						1.0（ref）	
	MPA	15.5		0.994(0.910,1.085)	0.892					1.003(0.915,1.098)	0.956
	VPA	15.3		0.985(0.894,1.085)	0.756					0.994(0.899,1.098)	0.899
	Sleep Duration										
	Shortcomings	26.8	x^2=2095.674 P<0.001 V=0.220			1.0（ref）				1.0（ref）	
	Suitable	9.7				0.295(0.268,0.325)	<0.001			0.334(0.301,0.370)	<0.001
	Too long	9.8				0.985(0.892,1.088)	0.772			0.956(0.863,1.058)	0.382
	Sleep Patterns										
	Great	12.3	x^2=1574.743 P<0.001 V=0.191					1.0（ref）		1.0（ref）	
	Not bad	12.3						6.240(5.455,7.138)	<0.001	3.655(3.176,4.026)	<0.001
	General	25.0						6.252(5.494,7.115)	<0.001	4.459(3.901,5.095)	<0.001
	Very poor	46.6						2.625(2.298,2.999)	<0.001	2.384(2.079,2.733)	<0.001

*In the binary logistic regression analysis, the following variables were controlled for: gender, educational level, school location, smoking

behavior, and drinking behavior. Model 1 included physical activity level; Model 2 included sleep duration; Model 3 included sleep quality; and Model 4 included physical activity level, sleep duration, and sleep quality.

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