

Associations Between Sleep Duration, Sleep Quality, and Depressive Symptoms: Evidence from Medical Graduate Students in China

Hong He¹, Yanlin Zeng¹, Zhibing Chen², Min Wu², Yan Wang¹

¹The First Affiliated Hospital, Sun Yat-Sen University, Guangzhou, 510080, People's Republic of China; ²Department of Medical Statistics, School of Public Health and Research Center for Health Information, Sun Yat-Sen University, Guangzhou, 510080, People's Republic of China

Correspondence: Yan Wang, The First Affiliated Hospital, Health Management Center, Sun Yat-sen University, Guangzhou, 510080, People's Republic of China, Email wangy68@mail.sysu.edu.cn

Objective: This study aims to explore the independent and combined effects of sleep duration and sleep quality on depressive symptoms in the medical graduate student population, utilizing causal inference methods, in order to provide more informative evidence to support mental health interventions in this group.

Methods: A cross-sectional study was conducted among 2591 medical graduate students from Sun Yat-sen University in Guangdong, China. Participants completed self-administered questionnaires, including the Center for Epidemiological Survey Depression Scale (CES-D) for depressive symptoms and the Pittsburgh Sleep Quality Index (PSQI) scale for sleep quality. Sleep duration was categorized based on hours of sleep per night. A causal inference approach using inverse probability weighting (IPW) was employed to evaluate the relationship between sleep factors and depression risk.

Results: Individuals sleeping less than 7 hours had a 1.65-fold higher depression risk (95% CI: 1.26–2.14), while those sleeping ≥ 9 hours had a 0.67-fold lower risk (95% CI: 0.47–0.95). High sleep quality reduced depression risk. In the low sleep quality group, short sleep increased depression risk by 1.40-fold (95% CI: 1.02–1.94), while long sleep decreased it by 0.66-fold (95% CI: 0.45–0.97). In the high sleep quality group, sleeping 8–9 hours increased depression risk by 1.80-fold (95% CI: 1.10–2.95) compared to 7–8 hours. Sensitivity analyses confirmed the robustness of these findings across different IPW models.

Conclusion: Both sleep duration and quality are significantly associated with depressive symptoms among medical graduate students. These findings may support targeted interventions that improving sleep hygiene, particularly for those with low sleep quality, while also emphasizing the importance of maintaining an optimal sleep duration of 7–8 hours for those with high-quality sleep.

Keywords: depression, sleep duration, sleep quality, medical graduate students, causal inference

Introduction

Depression is a common psychological disorder and has become a major public health issue globally, severely threatening the health of individuals, families, and society,¹ particularly prominent in medical student populations.² Research indicates that approximately 30% of university students are affected by depression, with medical students facing a higher risk due to the unique academic pressures and clinical rotation burdens they experience.^{3,4} At the same time, sleep, as a key modifiable lifestyle factor, has increasingly gained attention in recent years. However, a recent meta-analysis showed that poor sleep quality was common among medical students,⁵ and evidence from medical students in Anhui, China, also emphasized the prevalence of sleep problems.⁴

Numerous studies have demonstrated a strong association between abnormal sleep parameters and depressive symptoms, but the findings remain controversial. Some studies support a U-shaped association, whereby both sleep deprivation (typically defined as <6 hours) and excessive sleep (usually >9 hours) may increase the risk of depression.^{6,7} In contrast, other studies have failed to observe a significant link between prolonged sleep and depressive symptoms,⁸ and some have even indicated that sleep duration may not be a stable predictor of depression, with subjective sleep quality emerging as a more consistent indicator.^{9,10} Recent research has further emphasized the potential bidirectional relationship between sleep disturbances and depression.^{5,11} On one hand, sleep deprivation may disrupt hypothalamic–

pituitary–adrenal (HPA) axis regulation,¹² leading to abnormal cortisol secretion and increased vulnerability to depression.¹³ In addition, poor sleep quality may alter functional connectivity between the prefrontal cortex and the amygdala, thereby compromising emotional regulation and executive functioning.^{14,15} On the other hand, depression itself may be characterized by sleep architecture disturbances, including insomnia and hypersomnia,⁵ potentially contributing to a vicious cycle between poor sleep and depressive symptoms.

These inconsistent findings may stem from the difficulty of disentangling the directionality of the sleep–depression relationship and the inadequate adjustment for confounding variables in conventional cross-sectional studies.¹⁶ Traditional observational designs often fall short in establishing causal inferences, which limits the interpretability of their conclusions.^{17,18} In response to this challenge, recent advances in causal inference methodology have enabled researchers to approximate the conditions of randomized controlled trials by statistically balancing covariates across exposure levels, thereby improving the robustness and credibility of causal claims derived from observational data.¹⁹ In addition, although some studies have explored the individual effects of sleep duration and sleep quality on depressive symptoms, there is currently a lack of in-depth research on their combined impact, because medical graduate students may face both insufficient sleep duration and poor sleep quality simultaneously.

Therefore, this study aims to explore the independent and combined effects of sleep duration and sleep quality on depressive symptoms in the medical graduate student population based on an inverse probability weighted (IPW) logistic regression model by adjusting the covariate distributions of the exposed and non-exposed groups to minimize the effects of confounders, providing a more precise scientific basis for mental health interventions targeted at this group.

Methods

Study Population

The study was a cross-sectional study conducted in September 2024 at Sun Yat-sen University in Guangdong Province, China. All first-year medical graduate students who participated in the entrance physical examination were invited to take part in the study, including master's and doctoral students in clinical medicine, preventive medicine, dentistry, and nursing. The survey was distributed electronically, and participants who agreed to take part completed a self-administered structured questionnaire, which included basic demographic information, lifestyle behaviors, health-related variables, the Center for Epidemiological Survey Depression Scale (CES-D), and the Pittsburgh Sleep Quality Index (PSQI). To improve the authenticity and response rate of the survey, in this survey, the CES-D scale and the PSQI scale were combined into one questionnaire for on-site concentrated investigation. The collected questionnaires will be re-examined on the same day. Those filled out randomly or with missing values greater than 5% will be discarded. A total of 32 participants were excluded from the review stage due to insufficient or incomplete responses. Ultimately, 2591 participants with complete data were included in the analysis (Figure 1).

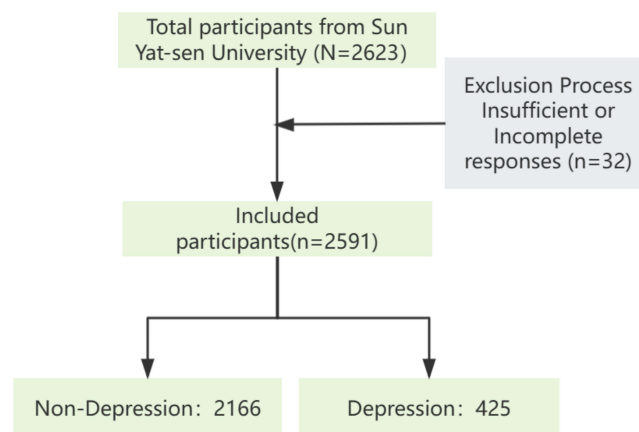


Figure 1 Flowchart of participant inclusion and exclusion.

Measures

Assessment of Sleep-Related Variables

The PSQI scale²⁰ was used to assess individuals' sleep quality over the past month. The scale consists of seven components: sleep duration, subjective sleep quality, sleep latency, sleep efficiency, sleep disturbance, use of sleeping medications, and daytime dysfunction, with each component scoring 0 to 3. Therefore, the global PSQI score ranges from 0 to 21, with higher scores indicating poorer sleep quality,²¹ and the cut-off point for poor sleep quality is 7.²² This value is well-supported by previous research and has been shown to effectively identify individuals with significant sleep disturbances. Participants were stratified into two groups based on their PSQI score to examine the relationship between sleep duration and depression risk across different levels of sleep quality. High sleep quality was defined as a PSQI score of 7 or below, while low sleep quality was defined as a PSQI score above 7. The PSQI is widely used both in China and internationally for screening sleep disorders, and its Chinese version has been shown to be reliable in Chinese populations.^{23–25} The Cronbach's alpha for the PSQI scale was 0.73.

Nighttime sleep duration was defined as the actual hours of sleep at night using PSQI, calculated from participant-reported bedtime and morning wake time. Sleep duration was subsequently categorized as <6h, 6–6.9h, 7–7.9h, 8–8.9h, and \geq 9h following a standard approach.²⁶ Generally, 7–8h is considered as the optimal sleep duration.²⁷

Assessment of Depressive Symptoms

Depression was measured using the 10-items CES-D scale.²⁸ A 4-point Likert scale was used to evaluate the frequency of symptoms during the preceding week, with the following response options: 0 (little or no time <1 day), 1 (some or little time 1–2 days), 2 (occasional or moderate time 3–4 days), and 3 (most or all time 5–7 days). Two of the 10 items, which measure positive emotions, were reverse-coded. Total scores ranged from 0 to 30, with a score \geq 10 indicating clinically relevant depressive symptoms.²⁹ The Cronbach's alpha for the CES-D scale was 0.79.

Measurement of Covariates

According to the results of previous literature, confounding factors included demographic variables, lifestyle behaviors, and health-related factors. Demographics included gender (male and female), age (in years), and educational level (Master's and PhD students). Lifestyle behaviors included drinking (yes or no), smoking (yes or no), physical activity level (none, 1–4 times per month, or more than 4 times per month), water intake (\leq 400 mL/day, 400–800 mL/day, 800–1200 mL/day, 1200–2000 mL/day, or >2000 mL/day). Health-related factors included history of hypertension (yes or no), and history of diabetes (yes or no). Variables that exhibited significant differences ($P < 0.05$) in baseline characteristics will be included in the model to minimize potential bias.

Statistical Analysis

Logistic regression model with IPW were used to assess the association between sleep duration and depression risk. We calculated odds ratio (OR) and corresponding confidence interval (CI) for the interquartile range (IQR) increase in sleep duration concentrations. The basic idea of IPW was to emulate a randomized controlled trial, creating a pseudo-population to balance potential confounding effects efficiently. In this study, we constructed three weighting methods based on a linear model (LM), a generalized estimating equation (GEE) or a Extreme Gradient Boosting, XGBoost.^{30–32} Each model was selected for its strengths: LM for simplicity and interpretability, GEE for accounting for correlations within clustered data, and XGBoost for modeling complex, non-linear relationships. Using these three methods allowed us to test the consistency of our findings across different model assumptions and weighting strategies. We calculated a generalized propensity score (GPS) by regressing exposure to potential confounders and developed stabilized inverse probability weights based on the inverse ratio of GPS to ensure a balanced confounding effect across exposure groups.³³ Covariate balance in the weighted pseudo-population was assessed by the average absolute correlation (AC), with AC < 0.1 indicating good confounder balance.¹⁹ Based on the optimal balance of confounders ([Supplementary Figure S1](#)), we evaluated the relationship of sleep duration and sleep quality and depression risk using XGB-IPWs as the final model.

This study utilized a sequential modeling strategy. Model 1 was a crude logistic model for sleep duration or sleep quality and depression. Based on Model 1, Model 2 was further adjusted for the covariates. Model 3 was based on Model

2 refitted with the XGB-IPW causal inference approach and was employed as the primary model. In addition, we conducted a stratified analysis of the results from the primary model to explore the effect of sleep duration on depression modification across different sleep qualities. The statistical significance of these sleep qualities was assessed using a two-sample *z*-test. Finally, we conducted sensitivity analysis comparing the results of different IPW weighting methods with those of the primary model to evaluate the robustness of the results. We considered a two-side $P < 0.05$ as statistically significant. We accomplished all analyses using R software (version 4.3.0, R Core Team, 2022).

Results

Descriptive Statistics

The descriptive statistics of the sample are summarized in Table 1. Among the participants, 425 (16.4%) had high CESD-10 scores. The average age was approximately 23.5 years, with 55% of the participants being male and 83% being master’s students. A total of 1042 participants (40.22%) reported sleeping between 7 and 8 hours per night. The average total score on the PSQI was 6, with 1540 students (59.44%) having good sleep quality and 1051 students (40.56%) having poor sleep quality. Participants with higher CESD-10 scores were more likely to be younger, hold a master’s degree, consume alcohol, have low water intake, engage in low physical activity. Both shorter sleep duration and poor sleep quality were associated with higher CESD-10 scores. A complete list of population characteristics is shown in the [Supplementary Table S1](#).

Associations of Residential Sleep Duration with Depression in All Participants

Figure 2 shows an association between sleep duration and depression risk in different models. After fully adjusting for confounders, every 1 IQR increase in sleep duration was associated with a 0.83-fold reduction in the risk of developing depression (OR: 0.83, 95% CI:0.76–0.91). For every 1 IQR increase in PSQI score, the risk of depression increased 5.75 times (95% CI:4.76–6.99).

Table 1 Baseline Characteristics of the Study Participants

Characteristics		Total	Depression		p
		(n=2591)	No (n=2166)	Yes (n=425)	
Age, M (SD)		23.5 (3.32)	23.6 (3.41)	23.1 (2.73)	<0.001
Gender, n (%)	Male	1435 (55.38%)	977 (45.11%)	179 (42.12%)	0.280
	Female	1156 (44.62%)	1189 (54.89%)	246 (57.88%)	
Education, n (%)	Master’s	2149 (82.94%)	1780 (82.18%)	369 (86.82%)	0.024
	Doctoral	442 (17.06%)	386 (17.82%)	56 (13.18%)	
Water Intake, n (%)	>2000 mL/day	314 (12.12%)	273 (12.60%)	41 (9.65%)	0.025
	~2000 mL/day	682 (26.32%)	585 (27.01%)	97 (22.82%)	
	~1200 mL/day	793 (30.61%)	662 (30.56%)	131 (30.82%)	
	~800 mL/day	587 (22.66%)	477 (22.02%)	110 (25.88%)	
	<=400 mL/day	215 (8.30%)	169 (7.80%)	46 (10.82%)	
Drinking status, n (%)	No	2214 (85.45%)	1868 (86.24%)	346 (81.41%)	0.012
	Yes	377 (14.55%)	298 (13.76%)	79 (18.59%)	
Physical activity, n (%)	None	388 (14.97%)	300 (13.85%)	88 (20.71%)	<0.001
	1-4times/month	1292 (49.86%)	1095 (50.55%)	197 (46.35%)	
	>4times/month	911 (35.16%)	771 (35.60%)	140 (32.94%)	
Sleep duration, n (%)	~8hours	1042 (40.22%)	873 (40.30%)	169 (39.76%)	<0.001
	<7hours	512 (19.76%)	383 (17.68%)	129 (30.35%)	
	~9hours	672 (25.94%)	589 (27.19%)	83 (19.53%)	
	≥9hours	365 (14.09%)	321 (14.82%)	44 (10.35%)	
PSQI Score		6.03 (3.24)	5.45 (2.87)	8.97 (3.43)	
Sleep quality, n (%)	Good	1540 (59.44%)	1439 (66.44%)	101 (23.76%)	<0.001
	Poor	1051 (40.56%)	727 (33.56%)	324 (76.24%)	

Abbreviations: M, Mean; SD, Standard Deviation.

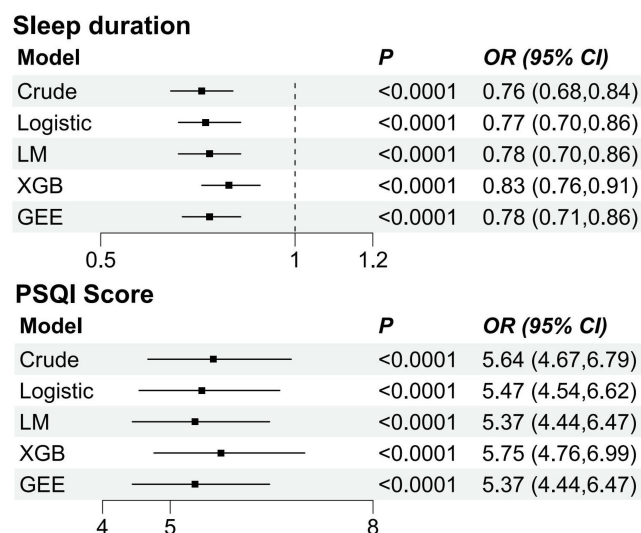


Figure 2 Associations between per IQR increasing in sleep duration and PSQI score and depression in different models.

Notes: The IQR for sleep duration is 1.0 hour. The IQR for sleep quality is 5. All models adjust for age, drinking status, educational level, physical activity and water intake.

After categorizing sleep duration, we found that shorter sleep duration (<7 hours) was associated with an increased risk of depression across all models (see Table 2). Specifically, compared to individuals with a sleep duration of 7–8 hours, those who slept less than 7 hours had a 1.65-fold increased risk of depression (OR: 1.65, 95% CI: 1.26–2.14), while those with long sleep duration (≥ 9 hours) exhibited a 0.67-fold reduced risk of depression (95% CI: 0.47–0.95). Individuals with low sleep quality demonstrated a 5.93-fold higher risk of depression (OR: 5.93, 95% CI: 4.67–7.49). In addition, we found a significant interaction between sleep quality and sleep duration.

Association Between Sleep Duration and Depression in Different Sleep Quality Participants

Table 3 presents the association between sleep duration and depression across different sleep quality groups. In the high sleep quality group, in Model 1 and Model 2, although the OR showed a risk effect in both the long sleep duration group and the 7–8 hour sleep duration group, there was no statistical significance. In Model 3, individuals with a sleep duration of 8–9 hours had a 1.80 times higher risk of depression than those with a sleep duration of 7–8 hours (OR: 1.80, 95% CI: 1.10–2.95).

In the low sleep quality group, the results of Model 3 found that the risk of depression in individuals in the group with sleep duration less than 7 hours increased by 1.40 times compared with the group with sleep duration of 7–8 hours (OR:

Table 2 Associations of Residential Sleep Duration and Sleep Quality with Depression in All Participants

Variables		n	Model 1	Model 2	Model 3
			95% CI	95% CI	95% CI
Sleep duration, hours	7-8	1042			
	<7	512	1.73 (1.34,2.25) *	1.67 (1.28,2.16) *	1.65 (1.26,2.14) *
	8-9	672	0.73 (0.55,0.97)	0.74 (0.55,0.98)	0.77 (0.58,1.02)
	≥ 9	365	0.70 (0.50,1.01)	0.73 (0.51,1.05)	0.67 (0.47,0.95)
Sleep quality	Good	1540			
	Poor	1051	6.36 (4.99,8.08) *	6.11 (4.79,7.78) *	5.93 (4.67,7.49) *
Sleep duration \times Sleep quality			-	-	0.0224 ^a

Notes: Model 1: a crude model; Model 2: further adjusted for age, drinking, education, physical activity and water intake; Model 3: based on Model 2 refitted by inverse probability weight. Interaction terms were denoted by “ \times ”. *: $p < 0.05$. a: p value.

Table 3 The Association Between Sleep Duration and Depression Across Different Sleep Quality Groups

	Model 1	<i>p</i>	Model 2	<i>p</i>	Model 3	<i>p</i>
	OR (95% CI)		OR (95% CI)		OR (95% CI)	
Sleep duration ^a						
7-8						
<7	1.17(0.62,2.22)	0.6280	1.13(0.59,2.14)	0.7261	1.31(0.68,2.55)	0.4208
8-9	1.40(0.87,2.27)	0.1634	1.39(0.85,2.25)	0.1886	1.80(1.10,2.95)	0.0189
≥9	1.07(0.57,2.00)	0.8305	1.05(0.56,1.98)	0.8840	1.16(0.62,2.18)	0.6430
Sleep duration ^b						
7-8						
<7	1.36(1.00,1.86)	0.0483	1.34(0.98,1.83)	0.0656	1.40(1.02,1.94)	0.0375
8-9	0.66(0.45,0.97)	0.0326	0.64(0.44,0.96)	0.0288	0.62(0.41,0.93)	0.0198
≥9	0.71(0.45,1.13)	0.1524	0.72(0.45,1.15)	0.1690	0.61(0.38,0.96)	0.0344

Notes: Model 1: a crude model; Model 2: further adjusted for age, drinking, education, physical activity and water intake; Model 3: based on Model 2 refitted by inverse probability weight. ^aParticipants with good sleep quality; ^bParticipants with poor sleep quality.

1.40, 95% CI: 1.02–1.94). The results of Model 1, Model 2 and Model 3 revealed that individuals with a sleep duration of 8–9 hours had a reduced risk of depression by approximately 0.66, 0.64 and 0.62 times, respectively (OR: 0.66, 95% CI: 0.45–0.97; OR: 0.64, 95% CI: 0.44–0.96; OR: 0.62, 95% CI: 0.41–0.93).

Sensitive Analysis

The results of the sensitivity analyses are shown in [Supplementary Table S2](#). We found that the results remained consistent across logistic regression models utilizing three different inverse probability weights (ie, LM, XGB, and GEE). [Supplementary Table S1](#) presents the associations per interquartile range (IQR) increase in sleep duration and depression in different models under LM and GEE weighting methods across different populations.

Discussion

This study, based on self-reported data from medical graduate students in China, found that both longer sleep duration and high sleep quality were significantly associated with a reduction in depressive symptoms. Further stratified analyses emphasized the critical role of sleep quality in moderating the relationship between sleep duration and depression. These findings underscore the importance of tailoring sleep intervention strategies to individual differences in sleep quality to more effectively alleviate depressive symptoms.

This study highlights the importance of healthy sleep behaviors on depression among medical graduate students. Consistent with previous studies,^{34,35} sleep deprivation was significantly associated with increased risk of depression. While prior studies have suggested a potential U-shaped relationship between sleep duration and depression,^{17,36,37} these mainly focused on middle-aged populations and may not apply to graduate medical students, who commonly experience insufficient sleep due to demanding schedules and nighttime duties.³⁸ Sleep quality also emerged as a key independent factor associated with depression, aligning with recent findings.^{9,10} Several mechanistic studies have suggested that high-quality sleep may reduce cortisol levels by inhibiting HPA axis overactivation and enhance prefrontal-amygdala neuromodulation, thereby improving mood regulation and alleviating depressive symptoms.^{12,14} Notably, depression itself can disrupt sleep architecture, such as by prolonging sleep latency and reducing slow-wave sleep,⁵ suggesting a possible bidirectional relationship. Although this cross-sectional study cannot establish causality, it reinforces the strong association between sleep and depression and adds new population-based evidence to this area.

Further stratified analyses indicated that sleep quality plays a key moderating role in the relationship between sleep duration and depression, reflecting differential pathways between individual sleep needs and emotional well-being. For individuals with low sleep quality, extending sleep duration was negatively associated with depression. Recent studies have shown that prolonged sleep duration improves mood regulation by elevating the proportion of slow-wave sleep³⁹ and mitigates the risk of depression by reducing inflammatory factors such as IL-6.⁴⁰ In contrast, excessive sleep was positively associated with depression in individuals with high sleep quality. Some studies have suggested that prolonged sleep duration was significantly associated with daytime functional decline, low mood, and cognitive sluggishness, which may be linked to fluctuations in neurotransmitter levels (such as dopamine and serotonin).¹⁷ Another study indicated that excessive sleep duration could weaken the restorative functions of sleep by increasing sleep fragmentation or reducing the proportion of deep sleep, thereby negatively impacting mental health.⁴¹ In addition, such divergent pathways may also be further influenced by individual characteristics,⁴² such as chronotype (morningness/eveningness preference)⁴³ or differences in stress-coping capacity.⁴⁴

This study also provides implications for medical education and health management practices. Depression among medical students not only affects their personal mental and physical well-being but may also impair future clinical judgment and the quality of patient care.^{45,46} Therefore, it is recommended that medical schools optimize course schedules and clinical rotations to reduce nighttime workload and incorporate systematic sleep hygiene education into the curriculum.⁴⁷ Existing research has shown that cognitive behavioral therapy, mindfulness training, and digital interventions can effectively improve sleep quality and emotional well-being among student populations.^{48,49} Low-cost, self-guided intervention modules—such as online screening tools, personalized sleep-wake feedback, and group-based cognitive support—are suggested to be integrated into campus health promotion systems, though their effectiveness warrants further investigation in future studies.

This study utilized advanced causal inference methods to explore the potential association between sleep duration, sleep quality, and the risk of depression. It is also one of the few studies specifically focusing on the unique population of medical graduate students. Despite the novelty and strengths of the research, there are still several limitations. First, the study only included newly enrolled students, which may not fully represent the entire population of graduate students, particularly those in higher years facing graduation and employment pressures. Therefore, future studies should expand the sample range to enhance the generalizability of the findings. Second, all sleep data were collected by self-report and lacked objective measures (eg, somatic dynamographs), which may be subject to recall bias and lacks objectivity. Third, although IPW reduces confounding bias, it still does not fully conclusively prove the existence of causality because it is an observational study. Fourth, although the PSQI instrument captures multiple components of sleep quality (such as sleep latency and sleep efficiency), this study focused primarily on sleep duration and global sleep quality due to the predefined scope and space limitations. Future analyses are needed to examine other PSQI components, which may also have important implications for depressive symptoms. Lastly, this study did not investigate potential mediating mechanisms, such as emotional regulation, self-perception, or impaired social functioning, which may play significant roles in the relationship between sleep duration, sleep quality, and depression. Consequently, future research could further consider exploring this complex relationship from multidimensional perspectives, including psychosocial factors and neurobiological mechanisms.

Conclusion

This study found that sleep duration and quality are significantly associated with depressive symptoms among medical graduate students. The association between sleep duration and depression varied by sleep quality, underscoring the importance of Targeted strategies when designing interventions. While based on cross-sectional data, the use of causal inference methods strengthens the validity of the observed associations and provides a basis for future longitudinal or interventional research.

Data Sharing Statement

The data can be shared by the corresponding author upon reasonable request.

Ethical and Institutional Review Board

The present study was approved by the Clinical Research and Laboratory Animal Ethics Committee, Sun Yat-sen University (Approval Number: 2022 - 024). The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2013. The need for informed consent was waived by the ethics review board due to the anonymized nature of the study. To ensure confidentiality, all patient data were de-identified prior to analysis, with personal identifiers removed and replaced by unique codes. Access to raw data was restricted to authorized researchers only, and data were stored in a password-protected encrypted database.

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Author Contributions

Hong He and Yanlin Zeng: Conceptualization, Methodology, Software, Writing – Original Draft, Writing – Review & Editing. Zhibing Chen and Min Wu: Formal Analysis, Writing – Reviewing and Editing. Yan Wang: Conceptualization, Project Administration, Writing – Review & Editing. All authors have approved the final version of the manuscript. 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; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no conflict of interest.

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