MINH
MALAHAYATI INTERNATIONAL JOURNAL OF NURSING AND HEALTH SCIENCE
ISSN 2620-9152 (Print)
ISSN 2621-4083 (Online)
DOI: 10.33024

Nomor: 79/E/KPT/2023

ARTICLE INFORMATION
Received: May, 2, 2026
Revised: July, 6, 2026
Available online: July, 13, 2026
at : https://e-jurnal.iphorr.com/index.php/minh

Sleep duration, sleep quality, and academic functioning among public health students at a university in North Sulawesi

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Abstract

Background: Sleep is a fundamental biological need and is one of the main determinants of physical health, cognitive function, and psychosocial well-being. In young adults, including students, sleep patterns often undergo changes due to academic demands, lifestyle, and environmental factors, consequently, insufficient sleep duration and poor sleep quality are common health problems among university students. Neurophysiological mechanisms that link sleep to learning and memory capacity have been widely explained: certain sleep phases support memory consolidation and information processing critical for short- and long-term learning.
Purpose: To examine the associations of sleep duration and sleep quality with academic functioning, while assessing academic stress as a potential mediator and physical activity as a potential confounder.
Method: An observational study with a cross-sectional approach was employed to evaluate the relationship between sleep duration and sleep quality with the academic function of students at a single time point, taking into account the role of academic stress and health behavior based on the Directed Acyclic Graph (DAG) causal framework and reported in accordance with STROBE guidelines.
Results: The relationship between sleep duration and sleep quality with academic function differs according to the type of indicator, where sleep quality is positively associated with motivation to learn (subjective indicators), but does not show significant association with GPA as an objective indicator after multivariate analysis. In addition, there was no meaningful link between sleep and academic stress, and physical activity was not proven to be the main potential confounder that explains sleep relation to objective academic achievement. Overall, sleep has a stronger association on the subjective aspects of academic experience than objective results, and academic stress does not act as a significant mediator, so relationship between sleep and academic functioning are complex and nonlinear.
Conclusion: Overall, sleep duration and sleep quality have a stronger association on the subjective aspects of academic functioning such as motivation to learn than objective achievement (GPA), without a significant role of academic stress as mediator or physical activity as the main potential confounder, so that the relationship is complex and nonlinear.

Keywords: Academic Function; Academic Stress; Directed Acyclic Graph; Learning Motivation; Sleep Duration; Sleep Quality; University Student.

DOI: https://doi.org/10.33024/minh.v9i4.3145

INTRODUCTION

Sleep is a fundamental biological need and is one of the main determinants of physical health, cognitive function, and psychosocial well-being. In young adults, including college students, sleep patterns often change due to academic demands, lifestyle, and environmental factors, making both sleep duration and quality disturbances a common health issue (Bjørnnes, Torbjørnsen, Valeberg, Sparboe-Nilsen, Sandbekken, Almendingen, & Grov, 2021; Chaput, Gray, Poitras, Carson, Gruber, Olds, & Tremblay, 2020). The neurophysiological mechanisms linking sleep with learning and memory capacity have been widely explained: certain sleep phases support memory consolidation and information processing critical for short-term and long-term learning (Brodt, Inostroza, Niethart, & Born, 2023; Paller, Creery, & Schechtman, 2020). Sleep deprivation can impact cognitive functions such as decreased concentration and attention, impaired short-term memory, slower reaction times, and reduced decision-making ability (Walker, 2017). Therefore, chronic sleep disturbances or sleep insufficiency in students have the potential to disrupt cognitive processes that form the basis of academic functioning.

Globally, various studies indicate a high prevalence of sleep disturbances among the student population. A meta-analysis by (Binjabr, Alalawi, Alzahrani, Albalawi, Hamzah, Ibrahim, Buali, Husni, BaHammam, Vitiello, & Jahrami, 2023) of 90 studies from 37 countries involving a total of 100,602 medical students found that about 55.4% of students experienced sleep disturbances. This indicates that more than half of health students worldwide sleep with suboptimal duration or quality. The study also showed that the Southeast Asian region, which includes Indonesia, has a prevalence of sleep disturbances of 58.7% with conditions showing symptoms of insomnia, poor sleep quality, inadequate sleep duration, daytime dysfunction, and circadian rhythm disturbances.

In a study conducted on students in Indonesia involving 245 medical students from the University of Udayana's class of 2021, it was found that 58% of students had adequate sleep duration, while 42% had insufficient sleep duration. In addition, it was also found that 80% of students had good sleep quality, and 20% had poor sleep quality (Primadani, Utami, Widyadharma, & Adnyana, 2025).

Academic functioning is a multidimensional construct that includes learning behaviors, learning motivation, cognitive processes such as attention and working memory, as well as objective academic outcomes such as the cumulative grade point average (GPA). An approach that considers academic functioning as the primary outcome is more appropriate for studies of student populations compared to measuring a single concentration ability, because academic functioning represents both process aspects (motivation, engagement) and outcomes (GPA) that are relevant for education policy and campus health promotion (Bandura, 1997; Pintrich & De Groot, 1990). In addition, subjective indicators such as learning motivation can be more sensitive to temporary condition changes (such as the quality of the previous night's sleep) compared to the cumulative GPA, so both complement each other in understanding the mechanisms of sleep effects on academic performance (Gallego-Gómez, González-Moro, González-Moro, Vera-Catalán, Balanza, Simonelli-Muñoz, & Rivera-Caravaca, 2021).

Recent empirical studies on the student population consistently show a relationship between sleep aspects (duration, quality, irregularity) and academic indicators, although the results are heterogeneous depending on the measurement methods and study context (Bjørnnes et al., 2021; Memon, Gupta, Crowther, Ferguson, Tuckwell, & Vincent, 2021). Some studies report that sleep duration below the recommended range (usually <7 hours) and poor sleep quality are associated with lower GPA or a risk of poor academic performance, while other studies find more evident effects on subjective indicators such as motivation, academic fatigue, or engagement (Gallego-Go´mez et al., 2021; Toscano-Hermoso, Arbinaga, Fernández-Ozcorta, Gómez-Salgado, & Ruiz-Frutos, 2020). Moreover, evidence regarding the mechanism, namely whether the association of sleep on academic performance is mediated by academic stress, emotion regulation, or changes in specific cognitive capacities, is still inconclusive, and few studies have tested formal mediation with an explicit causal approach (Pascoe, Hetrick, & Parker, 2020; VanderWeele, 2015).

The main empirical gaps that still need to be filled include several aspects. First, most studies are cross-sectional and highly heterogeneous in sleep

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measurement (self-report versus actigraphy), so causal inference is limited and generalization is difficult (Bjørnnes et al., 2021). Second, many studies focus on one type of outcome (such as GPA) without assessing process indicators like motivation and study duration, even though different causal pathways may affect process indicators and outcomes in different ways. Third, evidence from the Indonesian context, particularly in eastern regions such as North Sulawesi, is relatively limited; differences in academic culture, sleep patterns, and social support can affect the patterns of the sleep-academic function relationship. Fourth, the role of physical activity as an upstream determinant factor that can function as a confounder or moderator is often only measured to a limited extent, even though physical activity also affects sleep quality and emotion regulation (Memon et al., 2021; Ye, Jia, Zhang, & Guo, 2022). Therefore, research that examines the relationship between sleep duration and quality with academic function while also considering academic stress and health behaviors (such as physical activity) will provide important contributions to the literature and policy applications.

This study aims to fill several of these gaps by combining several methodological advantages. Conceptually, the study adopts an explicit causal framework based on Directed Acyclic Graphs (DAG) to determine an adequate set of adjustments and avoid overadjustment or collider control that could introduce bias (Hernán & Robins, 2020). Operationally, the research uses multiple indicators of academic function (learning motivation, study duration, performance perception, and GPA), allowing differentiation of effects on proximal versus distal outcomes. In terms of population, the study was conducted among students at a university in North Sulawesi, thereby adding evidence from a regional context that is underrepresented in the international literature. A formal mediation approach (causal mediation analysis) is used to examine the role of academic stress as a mediator, and physical activity is included as a key adjustment variable based on the DAG identification so that estimates of total and direct effects become more informative for policy purposes.

Practically and scientifically, this study is expected to have several important contributions. First, scientifically, this study adds empirical evidence regarding the effects of sleep on various dimensions of academic functioning in the Indonesian context, thus helping to answer whether international findings are generalizable. Second, methodologically, the use of DAGs and causal mediation improves the accuracy of inference compared to ordinary correlational analysis, so the results can be more credible for the purpose of campus policy recommendations. Third, the results that identify which dimensions of academic functioning are most sensitive to changes in sleep (such as motivation vs GPA) can guide more targeted interventions — for example, sleep hygiene programs designed to increase engagement and learning motivation, or structured exercise strategies that improve sleep quality and cognitive capacity. Fourth, from an ethical and feasibility standpoint, sleep- and physical activity-based interventions for university students are relatively safe, scalable, and in line with health promotion principles in higher education institutions.

In brief, this study is scientifically relevant because it integrates cognitive theory and recent sleep literature, relevant to policy because it focuses on outcomes that have practical significance for educational institutions, methodologically feasible because it utilizes DAGs and causal mediation techniques, and feasible and ethical given that the data collection method is an online survey and the variables measured do not require risky interventions. Thus, it is expected that the research results will provide new insights into how sleep duration and quality relate to students' academic functioning in the local context, as well as evidence-based health promotion policy recommendations.

RESEARCH METHOD

This was a cross-sectional observational study was employed to evaluate the relationship between sleep duration and sleep quality and students' academic performance at a single point in time, taking into account the role of academic stress and health behaviors based on the Directed Acyclic Graph (DAG) causal framework. This study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies (Ghaferi, Schwartz, & Pawlik, 2021; Von Elm, Altman, Egger, Pocock, Gøtzsche, & Vandenbroucke, 2007).

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This study was conducted among active students at a university in North Sulawesi Province, Indonesia. The target population for this study is all active students at the Faculty of Public Health, Sam Ratulangi University in Manado, North Sulawesi. The accessible population consists of active students at the Faculty of Public Health, Sam Ratulangi University, during the odd semester of the 2025/2026 academic year who meet the inclusion criteria and have access to the online questionnaire during the data collection period.

The inclusion criteria are being an active student at the time of data collection, willing to participate voluntarily and provide electronic informed consent, and completing the questionnaire in full. The exclusion criteria are respondents with incomplete data on the main variables and respondents who completed the questionnaire more than once. Finally, 256 respondents met the criteria and were included in this study.

The variables analyzed in this study are: (1) Sleep duration: average hours of sleep per night over the past week; (2) Sleep quality: perceived sleep quality over the past week. Measured using an ordinal scale, academic functioning includes the indicators (3) motivation to study at home, (4) average hours spent studying at home, (5) Perceived academic performance compared to peers, (6) most recent cumulative grade point average (GPA). The mediator variable is (7) academic stress: encompassing perceptions of academic pressure and the frequency of disruptions to learning activities due to academic stress, as well as the confounding variables (8) number of days of physical activity and (9) duration of exercise in minutes

Data were collected using an online questionnaire via Google Forms. The form was made available for completion beginning in early September 2025. The data collection period ended on December 31, 2025. The instruments used in this study were electronic devices such as computers/laptops, the statistical software R version 4.5.2, Google Forms for collecting data from students, and Microsoft Excel as an initial tool for data processing.

The data analysis in this study consisted of descriptive analysis to examine the characteristics of the respondents; bivariate analysis to examine the relationship between sleep duration and sleep quality and each indicator of academic functioning, analyzed using Spearman's rank correlation; and multivariate analysis and DAG-based analysis to estimate the total association of sleep duration and sleep quality on academic functioning while controlling for confounding variables according to the DAG. To evaluate the role of academic stress as a mediator, a mediation analysis was conducted using a stepwise regression approach.

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RESEARCH RESULTS

Table 1. Characteristics of the Respondents (N = 256)

Variables	Results	
	(n/%)	Median (IQR)
Age	—	20.0 (19.0–21.0)
Gender		
Female	223/87.11	—
Male	33/12.89	—
Year of Admission		
2021 (Semester 9)	22/8.59	—
2022 (Semester 7)	40/15.63	—
2023 (Semester 5)	94/36.72	—
2024 (Semester 3)	100/39.06	—
Academic Functioning		
Most Recent GPA (0-4)		3.9 (3.8–3.9)
Study Hours/day		3 (2.0–4.0)
Motivation to Learn (1-10)		6 (5.0–7.0)
Academic Performance (1-10)		6 (5.0–7.0)
Sleep Quality and Sleep Duration		
Perceived Sleep Quality (1-10)		5 (4.0–7.0)
Sleep Duration (hours)		6 (5.0–7.0)
Academic Stress and Health Behaviors		
Academic Stress Level (1-10)		6 (5.0–8.0)
Frequency of Academic Stress (1-10)		6 (5.0–7.0)
Physical Activity (days/week)		3 (2.0–5.0)
Duration of Exercise (minutes)		25 (15.0–30.0)

Table 1 summarizes the demographic profile and research variables of the study population. The median age of respondents was 20 years (IQR 19–21), with a predominance of females (87.1%). The distribution of admission years reflected academic heterogeneity, with 39.1% enrolled in the third semester and 36.7% in the fifth semester. Indicators of academic functioning, serving as proxies for long-term cognitive capacity, revealed a median GPA of 3.9 (IQR 3.8–3.9), a median of 3 hours of home study per day (IQR 2–4), and median scores of 6 (on a 1–10 scale) for both learning motivation and perceived academic performance. Sleep-related variables indicated a median subjective sleep quality score of 5 (IQR 4–7) and an average sleep duration of 6 hours per night (IQR 5–7). Academic stress markers demonstrated moderate levels of disturbance, with both intensity and frequency yielding median values of 6 (scale 1–10). Health behavior indicators showed that respondents engaged in moderate-to-vigorous physical activity for a median of 3 days per week, with an average exercise duration of approximately 25 minutes per day.

Table 2. Correlation Matrix of Academic Functioning (GPA, Study Hours and Motivation, Academic Performance) and Perceived Sleep Quality and Sleep Duration.

	Academic Function			Sleep	
	Study Hours	Motivation	Performance	Quality	Duration
GPA	0.07	-0.01	**0.18**	-0.08	**-0.20**
Study Hours		**0.27**	**0.13**	0.01	-0.05
Motivation			**0.38**	**0.34**	**0.13**
Performance				**0.25**	0.07
				Quality	**0.53**

NOTE: The r value is the Spearman rank correlation coefficient. Bold figures, $p < 0.05$.

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Table 2 presents the bivariate correlations between academic function indicators (GPA, study hours, learning motivation, and perceived relative performance) and sleep status markers (subjective sleep quality and average nightly sleep duration). Overall, GPA demonstrated a weak negative association with sleep variables, with a Spearman coefficient of –0.20 for GPA and sleep duration. Non-GPA indicators, particularly learning motivation, exhibited weak but statistically significant positive correlations with perceived sleep quality ($r \approx 0.34$, $p < 0.001$) and sleep duration ($r \approx 0.13$, $p = 0.033$). Learning motivation was also weakly yet significantly correlated with study hours ($r \approx 0.27$, $p < 0.001$) and perceived academic performance ($r \approx 0.38$, $p < 0.001$), although no significant association was observed between GPA and learning motivation. Regarding sleep indicators, perceived sleep quality was moderately correlated with sleep duration ($r \approx 0.53$, $p < 0.001$).

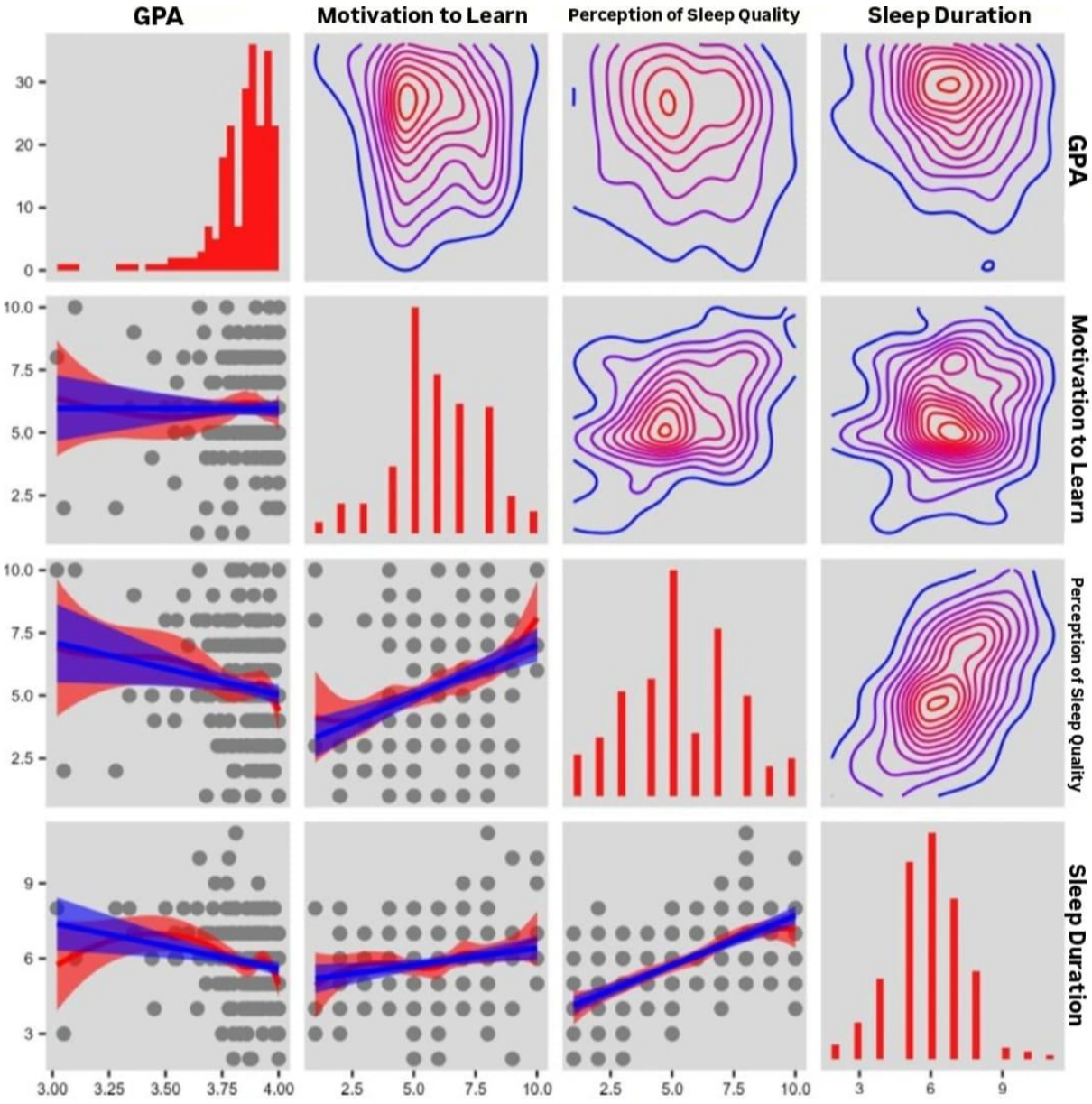


Figure 1. Scatter Plot of the Relationship between Grade Point Average (GPA), Motivation to Learn, Sleep Quality, and Sleep Duration.

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Figure 1 provides a visualization of the findings in Table 2. Two other academic function indicators, namely performance perception and study hours, are no longer displayed because they have a significant positive correlation with learning motivation as described above. For the sake of parsimony, subsequent analyses only used GPA and learning motivation as indicators of academic function. The scatter plot illustrates a fairly clear positive linear relationship between sleep quality perception and sleep duration, as well as between these two variables and study motivation. Figure 1 further provides a visual indication that the relationship between GPA and both sleep quality perception and sleep duration tends to be negative and non-linear. Individual heterogeneity is quite evident in the data distribution in the bivariate graphs of GPA and the two sleep status indicator variables.

Table 3. Multivariate Model and DAG-Based Causal Mediation Analysis for GPA Outcome

Model	Exposure	Estimate	95% CI	*p-value*
Total	Sleep Duration	-0,02	(-0,04−0,00)	0,095
	Sleep Quality Perception	0,00	(-0,01−0,02)	0,624
Mediator	Sleep Duration	-0,02	(-0,04−0,00)	0,095
	Sleep Quality Perception	0,00	(-0,01−0,02)	0,624
Direct Effect	Sleep Duration	-0,02	(-0,04−0,00)	0,095
	Sleep Quality Perception	0,00	(-0,01−0,02)	0,624

Causal Mediation Analysis (CMA)

Effect	Estimate	95% CI	*p-value*
ACME	< 0,001	(-0,002−0,002)	0,974
ADE	0,005	(-0,015−0,027)	0,562
Total	0,005	(-0,015−0,027)	0,570
Prop. Mediated	-0,009	(-0,779−0,755)	0,948

NOTE: CI (Confidence Interval), ACME (Average Causal Mediation Effect), ADE (Average Direct Effect)

Table 3 presents the results of the series of DAG-based modeling for the GPA outcome. The total model, which estimates the combined association of sleep duration and sleep quality perception on GPA, shows small coefficients and does not reach significance at α = 0.05; the estimate for sleep duration is -0.02 per hour of sleep (95% CI -0.04 to 0.00; p = 0.095), while sleep quality perception shows an estimate close to zero (p = 0.624). The mediator model (sleep → academic stress) shows estimation patterns consistent with the total model, and the direct effect model (including the academic stress mediator in the outcome model) does not reveal substantive changes in the sleep coefficients. Causal mediation analysis for GPA (bottom part of Table 3) provides an estimate of the ACME (average causal mediation effect) that is nearly zero and not significant, while the ADE (average direct effect) is also not significant. The proportion of the mediated effect is close to zero with a wide confidence interval that includes zero. Thus, there is no strong evidence that sleep duration and perceived sleep quality have a adjusted association on the GPA in the study sample; the research data also do not support mediation of this relationship by academic stress.

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Table 4. Multivariate Models and DAG-Based Causal Mediation Analysis for the Outcome of Learning Motivation

Model	Exposure	Estimate	95% CI	*p-value*
Total	Sleep Duration	-0,02	(-0,04−0,00)	0,095
	Sleep Quality Perception	0,00	(-0,01−0,02)	0,624
Mediator	Sleep Duration	-0,02	(-0,04−0,00)	0,095
	Sleep Quality Perception	0,00	(-0,01−0,02)	0,624
Direct Effect	Sleep Duration	-0,02	(-0,04−0,00)	0,095
	Sleep Quality Perception	0,00	(-0,01−0,02)	0,624

Causal Mediation Analysis (CMA)

Effect	Estimate	95% CI	*p-value*
ACME	< 0,001	(-0,009−0,014)	0,946
ADE	0,302	(0,157−0,445)	< 0,001
Total	0,302	(0,157−0,439)	< 0,001
Prop. Mediated	0,001	(-0,028−0,052)	0,946

NOTE: CI (Confidence Interval), ACME (Average Causal Mediation Effect), ADE (Average Direct Effect)

Table 4 presents the results of DAG-based modeling for the learning motivation outcome. The multivariate model again shows small and non-significant values for the total association of sleep duration (effect estimate -0.02; 95% CI between -0.04 and 0.00; p = 0.095). For sleep quality perception, the total effect estimate is not even different from zero. However, causal mediation analysis produces important findings: Although the ACME effect estimate is not significant (close to zero), ADE or the controlled direct association of sleep duration and quality on learning motivation appears statistically significant (effect estimate 0.302 and 95% CI 0.157–0.445; p < 0.001), as does the total effect (effect estimate 0.302 and 95% CI 0.157–0.439; p < 0.001). The interpretation is that most of the relationship between the length and sleep quality and learning motivation is not due to the pathway through academic stress, but rather a direct effect.

DISCUSSION

The results of this study reveal several important findings that contribute to our understanding of the relationship between sleep and academic performance in students. First, descriptive data indicate that the majority of student respondents experience suboptimal sleep duration, around 6 hours per night, which is below the recommended 7-9 hours for young adult populations (Hirshkowitz, Whiton, Albert, Alessi, Bruni, DonCarlos, & Hillard, 2015). Students' perceived sleep quality also tends to be at a moderate level with a median of 5 on a 1-10 scale, indicating that most students consider their sleep quality unsatisfactory. These findings are consistent with previous studies that reported a high prevalence of sleep problems among students globally (Gaultney, 2010; Lund, Reider, Whiting, & Prichard, 2010).

Second, bivariate analysis revealed different patterns of association between sleep variables and various indicators of academic function. For the Grade Point Average (GPA), which is an objective indicator of long-term academic performance, a weak negative relationship with sleep duration was found. This finding differs from initial predictions and the dominant literature, where previous studies generally reported a positive relationship between sleep duration and academic achievement (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010; Okano, Kaczmarzyk, Dave, Gabrieli, & Grossman, 2019). In contrast, subjective indicators of academic function such as learning motivation showed a significant positive correlation with perceived sleep quality and, to a weaker degree, with sleep duration. These findings differ from previous research, in which earlier studies reported a negative relationship between sleep quality and learning motivation (Nugroho, Rasimin, & Harahap, 2024). This indicates that although sleep may not directly affect academic performance as reflected in

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GPA, better sleep is associated with subjective aspects of the learning process such as motivation and perception of one's own academic performance.

Third, multivariate analysis based on DAG designed to estimate the adjusted association of sleep on academic function showed results that did not support the main hypothesis of the study. After controlling for confounding variables according to the DAG framework (physical activity), there was no strong evidence that sleep duration or perceived sleep quality causally affects students' GPA in this sample. The mediation model testing the role of academic stress as an indirect pathway also did not yield evidence of significant mediation. ACME values were close to zero with wide confidence intervals, indicating that academic stress does not mediate the relationship between sleep and GPA in the population studied. The results of this study are in line with the dominant literature, where previous research generally reported no relationship between sleep quality and academic achievement (Amelia, Harsa, & Siana, 2022; Sarfriyanda, Karim, & Dewi, 2015; Yekti & Rambe, 2017).

Fourth, different results were found when learning motivation was used as the outcome in the mediation analysis. Although the total association of sleep duration and quality on learning motivation was not statistically significant, the mediation analysis revealed a significant direct effect (ADE). In other words, after separating the pathway through academic stress, there is a direct relationship between sleep characteristics and students' learning motivation. This finding indicates that sleep can influence learning motivation through mechanisms that do not involve academic stress as a mediator.

Significance of Findings in the Context of Public Health Theory and Practice

Research findings, from the perspective of public health theory, highlight the importance of distinguishing between different dimensions of academic function when evaluating health impacts on students. GPA, as an objective and cumulative measure of academic achievement, reflects long-term learning outcomes influenced by various complex factors including basic cognitive abilities, learning strategies, social support, and other non-cognitive factors (Richardson, Abraham, & Bond, 2012). On the other hand, learning motivation and perceived academic performance are more dynamic constructs and more sensitive to current psychological and physiological states, including sleep quality and duration (Walker, 2009).

The results showing that sleep has a direct effect on learning motivation but not on GPA have important implications for public health interventions on campus. This suggests that sleep health promotion programs may be more effective in improving aspects of the learning process such as motivation, engagement, and subjective well-being compared to enhancing objective academic outcomes in the short term. From a public health perspective, increasing learning motivation and subjective well-being remains a highly valuable outcome, as this contributes to the overall quality of life of students and may have long-term effects on mental health and future academic success.

The lack of significant mediation by academic stress also provides important theoretical insights. In the literature, academic stress is often hypothesized as a key mediator in the relationship between sleep deprivation and decreased academic functioning (Lund et al., 2010; Yan, Lin, Su, & Liu, 2018). The theoretical model states that sleep deprivation increases stress reactivity, which then disrupts learning ability and academic performance. However, the findings of this study indicate that in the population studied, this pathway may not be as significant as anticipated, or there may be other more dominant mechanisms that have not been measured in this study.

Consistency of Findings with the Literature

The research results show a complex pattern when compared with the existing literature. Some aspects of the research results are consistent with previous studies, while other aspects show differences that need to be explored further.

Regarding the prevalence of sleep problems, the finding that the majority of students sleep less than 7 hours per night is highly consistent with the global literature. A comprehensive meta-analysis involving students from various countries reported that the average sleep duration of students ranges from 6-7 hours per night, with a high prevalence of poor sleep quality (Lund et al., 2010). Research in Ethiopia also reported a similar pattern, with the majority of students experiencing suboptimal sleep quality based on the

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Pittsburgh Sleep Quality Index (PSQI) (Lemma, Berhane, Worku, Gelaye, & Williams, 2014).

However, the finding of a negative relationship between sleep duration and GPA is an unusual finding and differs from the majority of the literature. Most observational and experimental studies show that longer sleep duration and better sleep quality are associated with higher academic achievement (Curcio, Ferrara, & De Gennaro, 2006; Dewald et al., 2010; Okano et al., 2019). For example, a previous study using objective activity measurement tools found that sleep duration, sleep quality, and sleep consistency together explained almost 25% of the variance in students' academic achievement (Okano et al., 2019). However, it is important to note that some studies also report inconsistent findings or do not find a significant relationship between sleep and academic achievement (Alotaibi, Alosaimi, Alajlan, & Bin Abdulrahman, 2020; Zailinawati, Teng, Chung, Teow, Lee, & Jagmohni, 2009).

Several explanations can be proposed for this difference. First, heterogeneity in the student population may play an important role. Students with very high GPAs (as seen in this study, with a median GPA of 3.9) may have different profiles in terms of learning strategies and time management compared to a more heterogeneous student population. Some high-achieving students may sacrifice sleep for additional study time, creating a negative relationship between sleep duration and GPA, even though this is not optimal for long-term health (Curcio et al., 2006). Second, the cross-sectional design of this study does not allow for establishing the direction of causality. Students with higher academic demands (which may correlate with higher GPAs) may experience more pressure to reduce sleep, creating a negative correlation that does not reflect the actual causal relationship.

The finding that perceived sleep quality is more strongly correlated with learning motivation than with GPA is consistent with research emphasizing the role of sleep in affective and motivational regulation (Pilcher & Walters, 1997; Walker, 2009). Neuroscience research shows that sleep deprivation significantly affects the limbic system and prefrontal cortex, brain areas involved in emotion and motivation regulation (Walker, 2009). Therefore, it is reasonable that sleep quality has a more direct impact on subjective aspects of academic functioning such as motivation compared to objective outcomes like GPA, which accumulate over a long period of time.

Regarding the role of physical activity, the finding that physical activity needs to be controlled as a confounder in the relationship between sleep and academic performance is consistent with the literature indicating a bidirectional relationship between physical activity and sleep quality (Kline, 2014; Kredlow, Capozzoli, Hearon, Calkins, & Otto, 2015). Research shows that regular physical activity can improve sleep quality, while better sleep can also enhance motivation and the ability to engage in physical activity (Memon et al., 2021; Wunsch, Kasten, & Fuchs, 2017). However, in this study, after controlling for physical activity, the relationship between sleep and GPA remained non-significant, indicating that this confounder is not the main explanation for the unexpected findings.

Novelty of Findings

This study provides several novel contributions to the existing literature on the relationship between sleep and students' academic functioning. First, it is one of the few studies in Indonesia that uses an explicit causal framework based on DAG to evaluate the relationship between sleep and academic functioning. The use of DAG allows for a more rigorous identification of confounding variables that need to be controlled and causal pathways that need to be tested, addressing some methodological limitations of previous observational studies that used simple correlational analyses.

Second, this study explicitly distinguishes between various dimensions of academic functioning - objective (GPA) versus subjective (learning motivation, performance perception) - and shows that sleep may have differential impacts on these dimensions. Most previous studies tended to use a single measure of academic functioning, either GPA or exam scores, without considering the more subjective but equally important aspects of the learning process. The finding that sleep has a direct effect on learning motivation but not on GPA provides new insights into the mechanisms through which sleep influences students' academic experiences.

Third, this study uses formal mediation analysis to examine the role of academic stress as a mechanism linking sleep with academic functioning. Although many previous studies theoretically mention stress as

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a potential mediator, only a few have conducted formal statistical testing of this mediation hypothesis (Lund et al., 2010; Wallace, Boynton, & Lytle, 2017). The finding that academic stress does not mediate the relationship between sleep and GPA in this sample challenges the common assumptions in the literature and suggests that alternative mechanisms may need to be explored in future research.

Fourth, this study provides important contextual data from the student population in Eastern Indonesia, particularly in North Sulawesi. Most research on sleep and student academic functioning has been conducted in Western countries or in urban areas of Western Indonesia. Data from different regional contexts can help identify whether the patterns of the relationship between sleep and academic functioning are universal or influenced by contextual factors such as academic culture, social norms about sleep, and academic pressures specific to certain institutions.

Research Strength

This study has several methodological strengths that need to be noted. First, the use of a DAG framework to inform the analytic design is a major strength. DAG allows researchers to make explicit the causal assumptions underlying the study and to identify appropriate analytic strategies to estimate adjusted association from observational data (Greenland, Pearl, & Robins, 1999; Hernán & Robins, 2020). This approach is more rigorous compared to conventional correlational or multiple regression analyses that do not consider the causal structure underlying the variables being studied.

Second, this study uses multiple indicators to measure academic functioning, which provides a more comprehensive picture of how sleep affects various aspects of students' academic experiences. The use of both objective measures (GPA) and subjective measures (learning motivation, performance perception) allows for the identification of differential effect patterns that might be missed if only one indicator is used.

Third, the relatively large sample size (N = 256) provides adequate statistical power to detect significant effects if they exist. Although some effects may be small, this sample size allows for relatively stable estimation of regression coefficients and confidence intervals.

Fourth, this study follows the STROBE reporting guidelines for observational studies (Von Elm et al., 2007), which enhance the transparency and reproducibility of the research. This includes a clear description of the study population, data collection methods, and analytical procedures.

Research Limitations

Although having several strengths, this study also has limitations that need to be considered in the interpretation of the findings. First and most fundamental, the cross-sectional design of this study limits the ability to establish definitive causal relationships between sleep and academic function (Hassan, Alqahtani, Alshahrani, Alhefzy, Alharthi, Alharbi, & Alqahtani, 2025; Wang & Bíró, 2021). While the use of DAGs and mediation analysis provides a framework for causal inference from observational data, the cross-sectional design cannot fully address issues of reverse causation or unmeasured confounding. For example, students with heavier academic workloads may have less sleep, but heavier academic workloads may also reflect more challenging courses taken by students with higher academic abilities. Without longitudinal data, it is difficult to separate these effects.

Second, all data in this study were collected through self-report, which is susceptible to various biases including recall bias and social desirability bias. Self-reported sleep duration and quality may not fully accurately reflect objective sleep parameters as measured by actigraphy or polysomnography (Lauderdale, Knutson, Yan, Liu, & Rathouz, 2008). Some studies indicate that individuals tend to overestimate their sleep duration when using self-report (Okano et al., 2019). The use of objective measures such as sleep trackers or actigraphy in future research will provide more accurate data on sleep parameters.

Third, although this study measures several indicators of academic function, operationalizing academic function as a proxy for concentration ability may be too broad and not specific enough. Concentration ability is a complex cognitive construct that is ideally measured with standardized neurocognitive tests. The use of proxies such as learning motivation and GPA, although practically relevant, may not directly reflect the cognitive abilities that are the theoretical focus of the study.

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Fourth, this study was conducted at a single institution (FKM-UNSRAT) which may have unique characteristics in terms of academic culture, workload, and student composition. This limits the generalizability of the findings to students at other institutions or in different fields of study. Public health students may have higher knowledge and awareness of the importance of sleep compared to students in other fields, which can influence the pattern of the relationship between sleep and academic function.

Fifth, although DAGs are used to identify confounding variables, there is a possibility of residual confounding from variables that are not measured or included in the model. Factors such as socioeconomic status, mental health conditions (e.g., depression, anxiety), caffeine or other substance use that affects sleep, and the quality of the sleep environment were not measured in this study but may influence both sleep and academic function (Curcio et al., 2006; Lund et al., 2010).

Sixth, the measurement of academic stress in this study used a simple scale that might not capture all relevant dimensions of academic stress. Academic stress is a multidimensional construct that includes various sources of stress (e.g., workload, exam pressure, concerns about academic future) and various manifestations (cognitive, emotional, physiological) (Lund et al., 2010). A more comprehensive measurement of academic stress might yield different results in the mediation analysis.

Finally, data were collected during a specific academic period (September-December 2025), and students' sleep patterns and academic functioning may vary depending on the semester phase (e.g., the beginning of the semester versus exam periods). A longitudinal study that tracks students throughout the semester or academic year would provide a better understanding of the temporal dynamics of the relationship between sleep and academic functioning.

Implications for Future Research

The findings of this study indicate several important directions for future research. First, longitudinal studies are needed that track students over time to understand the temporal and dynamic relationship between sleep and academic functioning. A longitudinal design will allow for addressing some limitations of cross-sectional designs and provide stronger evidence regarding the direction of causality (Dewald et al., 2010; Wang & Bíró, 2021).

Second, future research should integrate objective measurements of sleep parameters (e.g., actigraphy, sleep tracking devices) with self-reports to reduce measurement bias and improve the accuracy of sleep data (Okano et al., 2019). The combination of objective and subjective measurements will provide a more comprehensive picture of students' sleep patterns.

Third, future research needs to explore alternative mechanisms that might link sleep with academic functioning beyond academic stress. Potential mechanisms that can be explored include specific cognitive functions (e.g., working memory, attention, executive function), emotion regulation, and other motivational variables (Pilcher & Walters, 1997; Walker, 2009). The use of standardized neurocognitive tests will provide a better understanding of specific aspects of cognitive function affected by sleep.

Fourth, future research should consider measuring and analyzing potential moderator variables that may influence the strength of the relationship between sleep and academic functioning. Potential moderators include chronotype (individual sleep time preference), resilience, self-regulation, and social support (Du, Zan, Cho, Fenton, Hsiao, Hsiao, & Tucker, 2020; Alotaibi et al., 2020). Understanding this moderator can help identify subgroups of students who may be more vulnerable to the negative effects of sleep deprivation.

Fifth, given the differences in outcome patterns for GPA versus study motivation, future research should continue to use multiple indicators of academic functioning and explore whether sleep interventions have differential impacts on these various outcomes. This will also help identify which outcomes are most responsive to interventions and therefore should be the main target of campus sleep health promotion programs.

Sixth, research in various institutional and regional contexts in Indonesia is needed to understand whether the findings of this study can be generalized or whether there are significant contextual variations. Comparisons among students in different fields of study, academic levels, and types of institutions will provide a richer understanding of the heterogeneity in the sleep-academic function relationship.

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Implications for Practice and Policy

Although this study did not find a strong causal relationship between sleep and GPA, the findings on the relationship between sleep and learning motivation still have important practical implications for health promotion on campus. First, the research results suggest that programs designed to increase the duration and quality of students' sleep may be beneficial for improving subjective well-being and learning motivation, even though the impact on objective academic achievement may not be immediately visible or may take longer to manifest.

Second, the high prevalence of insufficient sleep duration (median 6 hours per night) among the students studied indicates the need for targeted public health interventions to promote better sleep hygiene. Interventions that have been shown to be effective include education about the importance of sleep, cognitive-behavioral therapy for insomnia (CBT-I), and modifications to the campus environment to support better sleep (e.g., class schedules that are not too early, adequate rest areas) (Brown, Buboltz & Soper, 2006; Hershner & Chervin, 2014).

Third, higher education institutions need to consider sleep as an integral component of student wellness programs. Currently, many campus health programs focus on nutrition, physical activity, and mental health, but sleep is often overlooked or only receives minimal attention. Integrating sleep health promotion into comprehensive wellness programs can help create a culture that better supports adequate sleep among students.

Fourth, the finding that sleep has a direct effect on learning motivation indicates that academic support programs for students who struggle with motivation should consider assessing and addressing sleep problems as part of their intervention. Academic advisors and student counselors can be trained to ask about sleep patterns and refer students with significant sleep issues to appropriate health services.

Fifth, considering that this study found that most students do not get enough sleep, institutional policies that could be considered include avoiding scheduling classes or exams very early in the morning, providing flexibility in deadlines to accommodate sleep needs, and creating awareness campaigns that normalize adequate sleep as an important health priority, rather than as a sign of laziness or lack of academic dedication (Hershner & Chervin, 2014).

In a broader context, the findings of this study underscore the importance of a holistic approach to student health and success that recognizes that academic achievement is only one dimension of student experience and well-being. Even if sleep does not directly improve GPA, its impact on motivation, mood, and overall health still makes promoting healthy sleep an important public health priority on campus.

between sleep and academic function is complex, nonlinear, and likely involves other unmeasured causal mechanisms.

CONCLUSION

The findings of this study indicate the presence of heterogeneity in the association between sleep duration and quality with academic function, depending on the type of indicators used, where sleep quality has a statistically significant positive association with learning motivation as a subjective outcome, but does not show an independent association with GPA after controlling for confounding variables in a multivariate model. Furthermore, no evidence of a significant association was found between sleep parameters and academic stress, and physical activity was not identified as a major confounder that substantially affects the estimation of the relationship between sleep and objective academic achievement. Overall, the effects of sleep appear to be more dominant in the subjective domain of academic function and are not mediated by academic stress, indicating that the relationship

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