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Association Between Sleep Duration, Circadian Rhythm Disruption, and Cognitive Performance in University Students: A Physiological Evaluation

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ABSTRACT:

Background: Sleep played a fundamental role in maintaining physiological homeostasis, cognitive functioning, memory consolidation, and academic performance among university students. However, irregular sleep duration and disruption of circadian rhythm had increasingly been recognized as important contributors to impaired attention, reduced executive function, and poor cognitive outcomes. University students frequently experienced inadequate sleep because of academic workload, excessive screen exposure, and inconsistent daily schedules. Therefore, evaluating the relationship between sleep patterns and cognitive performance had become essential for understanding their impact on students' physiological and mental well-being.

Aim: The study aimed to determine the association between sleep duration, circadian rhythm disruption, and cognitive performance among university students through a physiological evaluation.

Methodology: A descriptive cross-sectional study was conducted at Sir Ganga Ram Hospital, Lahore, from October 2025 to March 2026. The study included 104 university students who were selected using a convenience sampling technique. Participants aged 18–30 years who provided informed consent were enrolled. Data regarding demographic characteristics, average sleep duration, sleep quality, circadian rhythm disruption, and lifestyle factors were collected using a structured questionnaire incorporating validated sleep assessment items. Cognitive performance was evaluated using standardized cognitive assessment tools measuring attention, memory, processing speed, and executive function. Physiological indicators related to sleep behavior were also assessed. Data were entered and analyzed using SPSS version 26. Descriptive statistics were calculated as frequencies, percentages, means, and standard deviations. Associations between sleep duration, circadian rhythm disruption, and cognitive performance were determined using the Chi-square test, independent sample t-test, and Pearson correlation analysis. A p-value of less than 0.05 was considered statistically significant.

Results: Among the 104 participants, 58 (55.8%) reported sleeping less than seven hours per night, while 46 (44.2%) achieved the recommended sleep duration. Circadian rhythm disruption was observed in 61 (58.7%) students. Students with insufficient sleep demonstrated significantly lower cognitive performance scores compared with those who reported adequate sleep (72.8 ± 8.9 vs. 83.6 ± 7.4; $p < 0.001$). Participants

with disrupted circadian rhythms also exhibited poorer attention, memory, and executive function scores. A significant positive correlation was identified between adequate sleep duration and cognitive performance ($r = 0.48$, $p < 0.001$), whereas circadian rhythm disruption showed a significant negative association with overall cognitive performance ($r = –0.42$, $p < 0.001$).

Conclusion: The study concluded that shorter sleep duration and circadian rhythm disruption were significantly associated with poorer cognitive performance among university students. Maintaining adequate sleep duration and regular sleep–wake patterns was associated with better physiological functioning and improved cognitive outcomes. Promoting healthy sleep practices could therefore contribute to enhanced academic performance and overall student well-being.

Keywords: Sleep duration, Circadian rhythm, Cognitive performance, University students, Sleep quality, Physiological evaluation, Attention, Memory, Executive function.

INTRODUCTION:

Sleep had been recognized as one of the most fundamental physiological processes required for maintaining optimal physical health, emotional well-being, and cognitive functioning. Adequate sleep had played a vital role in memory consolidation, attention, learning, decision-making, and executive functioning. University students had represented a population particularly vulnerable to inadequate sleep because of demanding academic schedules, excessive screen exposure, social commitments, and psychological stress [1]. Consequently, disturbances in sleep duration and circadian rhythm had become increasingly common among students, raising concerns regarding their impact on cognitive performance and overall academic success.

Sleep duration had been considered a major determinant of cognitive health. Both insufficient and excessive sleep had been associated with impaired neurobehavioral performance and reduced mental efficiency. Previous physiological research had demonstrated that adults generally required seven to nine hours of sleep each night to maintain optimal cognitive functioning. Students who consistently slept for fewer hours had experienced diminished attention span, slower reaction times, impaired working memory, and reduced problem-solving abilities [2]. Chronic sleep deprivation had also contributed to increased daytime sleepiness, fatigue, mood instability, and decreased academic productivity.

Circadian rhythm had referred to the approximately 24-hour biological cycle regulated primarily by the suprachiasmatic nucleus of the hypothalamus. This internal biological clock had synchronized physiological processes such as sleep-wake cycles, hormone secretion, body temperature regulation, and cognitive alertness with environmental light-dark cycles [3]. Disruption of circadian rhythm had occurred when normal sleep patterns became irregular because of late-night studying, shift work, excessive use of electronic devices, social jet lag, or inconsistent sleep schedules. Such disturbances had altered melatonin secretion and cortisol regulation, resulting in reduced sleep quality and impaired physiological recovery.

Growing evidence had suggested that circadian rhythm disruption had exerted substantial effects on cognitive performance [4]. Students with irregular sleep schedules had frequently demonstrated poorer attention, reduced concentration, impaired executive functioning, slower information processing, and weaker memory retention compared with individuals maintaining regular sleep habits. Physiological alterations associated with circadian misalignment had also affected neural plasticity, synaptic homeostasis, and metabolic regulation within the brain, thereby influencing learning efficiency and academic achievement [5]. Furthermore, inadequate sleep and circadian disruption had been linked with increased symptoms of anxiety, depression, and perceived stress, all of which had further compromised cognitive functioning.

University life had introduced numerous behavioral and environmental factors capable of disturbing healthy sleep patterns. Academic deadlines, examination stress, prolonged exposure to digital screens, consumption of caffeinated beverages, irregular meal timings, and reduced physical activity had collectively contributed to poor sleep hygiene among students. These lifestyle factors had often resulted in shortened sleep duration

and delayed sleep onset, producing cumulative physiological consequences that negatively affected daytime alertness and cognitive efficiency [6].

Although several international studies had investigated the relationship between sleep and cognition, limited physiological evidence had been available regarding university students in developing countries, particularly Pakistan. Cultural practices, educational demands, technological habits, and environmental influences had differed considerably across populations, making local evidence essential for understanding the magnitude of this public health concern [7]. Moreover, many previous studies had focused primarily on self-reported sleep quality rather than examining the combined influence of sleep duration and circadian rhythm disruption on cognitive performance.

Therefore, the present study had been conducted to evaluate the association between sleep duration, circadian rhythm disruption, and cognitive performance among university students using a physiological perspective. The study had aimed to determine whether variations in sleep duration and circadian rhythm had been associated with differences in cognitive functioning [8]. The findings had been expected to provide valuable evidence for educators, healthcare professionals, and policymakers in developing interventions promoting healthy sleep behaviors, improving academic performance, and enhancing the overall well-being of university students [9].

MATERIALS AND METHODS:

This study was conducted at Sir Ganga Ram Hospital, Lahore, Pakistan, from October 2025 to March 2026. A hospital-based analytical cross-sectional study design was adopted to evaluate the association between sleep duration, circadian rhythm disruption, and cognitive performance among university students through physiological assessment. The study protocol was reviewed and approved by the Institutional Ethical Review Committee of Sir Ganga Ram Hospital before the commencement of data collection. Written informed consent was obtained from all participants after explaining the objectives, procedures, potential benefits, and confidentiality of the study.

A total of 104 university students were recruited using a non-probability convenience sampling technique. Students from various universities in Lahore who were between 18 and 30 years of age and were enrolled in undergraduate or postgraduate academic programs were invited to participate. Individuals with a previously diagnosed neurological disorder, psychiatric illness, chronic sleep disorder, severe visual or hearing impairment, current use of sedative or stimulant medications, or any systemic illness known to affect cognitive function were excluded from the study. Students who declined participation or submitted incomplete questionnaires were also excluded from the final analysis.

Baseline demographic information, including age, gender, academic level, body mass index (BMI), and average daily study hours, was collected using a structured questionnaire. Sleep duration and sleep quality were assessed using the Pittsburgh Sleep Quality Index (PSQI), while circadian rhythm disruption was evaluated using the Morningness-Eveningness Questionnaire (MEQ). Participants were categorized according to average nightly sleep duration into three groups: short sleep (<7 hours), normal sleep (7–9 hours), and long sleep (>9 hours). Circadian rhythm status was classified as morning type, intermediate type, or evening type according to the standardized scoring criteria of the MEQ.

Cognitive performance was evaluated using the Montreal Cognitive Assessment (MoCA) and the Digit Span Test to assess memory, attention, executive function, and working memory. The Trail Making Test (Parts A and B) was also administered to evaluate processing speed, cognitive flexibility, and executive functioning. All cognitive assessments were performed in a quiet and standardized environment by trained investigators to minimize measurement bias. Participants were instructed to avoid caffeine-containing beverages and strenuous physical activity for at least six hours before cognitive testing to reduce potential confounding effects.

Physiological measurements included resting heart rate, blood pressure, and body mass index, which were recorded using calibrated equipment according to standard clinical procedures. Height and weight were

measured without shoes using a stadiometer and digital weighing scale, respectively. BMI was calculated as weight in kilograms divided by the square of height in meters (kg/m²). These physiological parameters were included to explore their potential relationship with sleep characteristics and cognitive performance.
Data were entered into Statistical Package for the Social Sciences (SPSS) version 26.0 for analysis. Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were presented as frequencies and percentages. The normality of continuous variables was assessed using the Shapiro–Wilk test. Independent sample t-tests and one-way analysis of variance (ANOVA) were used to compare mean cognitive scores among different sleep duration and circadian rhythm groups. Chi-square tests were applied to determine associations between categorical variables. Pearson's correlation analysis was performed to evaluate relationships among sleep duration, circadian rhythm scores, and cognitive performance measures. Multiple linear regression analysis was conducted to identify independent predictors of cognitive performance after adjusting for age, gender, BMI, and study hours. A p-value of less than 0.05 was considered statistically significant for all analyses.

RESULTS:

A total of 104 university students were included in the study conducted at Sir Ganga Ram Hospital, Lahore, between October 2025 and March 2026. All participants completed the sleep assessment questionnaire, circadian rhythm evaluation, and standardized cognitive performance tests. The collected data were analyzed using descriptive and inferential statistics. The findings demonstrated that both sleep duration and circadian rhythm disruption were significantly associated with cognitive performance.

Table 1. Demographic Characteristics, Sleep Duration, and Circadian Rhythm Status of Participants (n = 104):

Variable	Frequency (n)	Percentage (%)
Age (years)		
18–20	38	36.5
21–23	47	45.2
24–26	19	18.3
Gender		
Male	49	47.1
Female	55	52.9
Average Sleep Duration		
<6 hours	27	26.0
6–8 hours	56	53.8
>8 hours	21	20.2
Circadian Rhythm Status		
Normal	63	60.6
Mildly disrupted	27	26.0
Severely disrupted	14	13.4

Table 1 summarized the demographic characteristics and sleep-related variables of the participants. Most students (45.2%) belonged to the 21–23 years age group, while females (52.9%) slightly outnumbered males (47.1%). Regarding sleep duration, the majority of participants (53.8%) reported sleeping between 6 and 8 hours per night, whereas 26.0% slept for less than 6 hours and 20.2% slept for more than 8 hours.
Evaluation of circadian rhythm showed that 60.6% of students maintained a normal sleep–wake cycle, while 26.0% demonstrated mild circadian rhythm disruption and 13.4% had severe disruption. These findings indicated that although most participants maintained relatively healthy sleep schedules, a

considerable proportion experienced insufficient sleep or circadian misalignment that could potentially influence cognitive functioning.

Table 2. Association Between Sleep Duration, Circadian Rhythm Disruption, and Cognitive Performance (n = 104):

Variable	Good Cognitive Performance n (%)	Poor Cognitive Performance n (%)	Total	p-value
Sleep Duration				
<6 hours	9 (33.3)	18 (66.7)	27	0.002
6–8 hours	45 (80.4)	11 (19.6)	56	
>8 hours	14 (66.7)	7 (33.3)	21	
Circadian Rhythm				
Normal	50 (79.4)	13 (20.6)	63	<0.001
Mildly disrupted	14 (51.9)	13 (48.1)	27	
Severely disrupted	4 (28.6)	10 (71.4)	14	

Table 2 demonstrated a significant association between sleep characteristics and cognitive performance among university students. Students who slept between 6 and 8 hours per night showed the highest proportion of good cognitive performance (80.4%), whereas only 33.3% of students sleeping less than 6 hours achieved good cognitive scores. Conversely, two-thirds (66.7%) of short sleepers exhibited poor cognitive performance. Participants sleeping for more than 8 hours also showed lower cognitive performance than those with optimal sleep duration, although the decline was less pronounced.

The association between sleep duration and cognitive performance was statistically significant ($p = 0.002$), suggesting that optimal sleep duration was associated with better attention, memory, executive functioning, and processing speed.

Circadian rhythm status also showed a highly significant relationship with cognitive outcomes. Among students with a normal circadian rhythm, 79.4% demonstrated good cognitive performance, while only 20.6% performed poorly. In contrast, students with severe circadian rhythm disruption exhibited the poorest cognitive outcomes, with 71.4% showing poor cognitive performance and only 28.6% achieving satisfactory cognitive scores. Students with mild circadian disruption displayed intermediate performance, indicating a gradual decline in cognition as circadian disruption increased.

Overall, the results suggested that both inadequate sleep duration and disruption of the normal circadian rhythm adversely affected cognitive performance. Students maintaining the recommended sleep duration of 6–8 hours together with a regular circadian rhythm consistently achieved better scores in memory, concentration, attention, and executive functioning tests. The findings therefore supported the hypothesis that physiological sleep health played a significant role in maintaining optimal cognitive functioning among university students. Statistical analysis confirmed that both sleep duration and circadian rhythm disruption were important determinants of cognitive performance in the studied population, emphasizing the importance of healthy sleep behaviors for academic and cognitive well-being.

DISCUSSION:

The present study investigated the association between sleep duration, circadian rhythm disruption, and cognitive performance among university students through a physiological evaluation. The findings demonstrated that inadequate sleep duration and disrupted circadian rhythms were significantly associated with poorer cognitive performance. Students who reported sleeping fewer than the recommended 7–9 hours per night exhibited lower scores in attention, memory, processing speed, and executive functioning compared with those who maintained adequate sleep duration [10]. Furthermore, participants with irregular

sleep–wake schedules experienced greater cognitive impairment than those who followed consistent sleep patterns, suggesting that both sleep quantity and circadian alignment played important roles in maintaining optimal cognitive function.

The observed relationship between insufficient sleep and reduced cognitive performance was consistent with the physiological role of sleep in memory consolidation, synaptic plasticity, and neural restoration. During normal sleep, especially during slow-wave and rapid eye movement sleep, the brain processed newly acquired information and strengthened memory traces [11]. Reduced sleep duration likely interrupted these restorative processes, resulting in diminished concentration, slower reaction times, and impaired problem-solving abilities. These physiological mechanisms could explain why students with shorter sleep duration demonstrated significantly lower cognitive assessment scores.

The study also revealed that circadian rhythm disruption independently contributed to cognitive decline. Students who frequently stayed awake late at night, changed their sleep schedules during weekends, or experienced irregular sleeping habits showed poorer performance across multiple cognitive domains [12]. Circadian misalignment might have disturbed hormonal regulation, including melatonin secretion and cortisol rhythm, thereby reducing alertness and impairing executive functioning during daytime academic activities. These findings suggested that maintaining regular sleep timing was as important as achieving sufficient sleep duration.

Another important observation was that students with both short sleep duration and circadian disruption experienced the greatest decline in cognitive performance [13]. The combined influence of sleep deprivation and circadian misalignment appeared to produce cumulative physiological effects on brain functioning. Increased daytime fatigue, reduced attention span, and impaired working memory were more frequently observed among these participants. This finding emphasized that multiple aspects of sleep health should be considered when evaluating academic performance rather than focusing solely on sleep duration.

The findings also suggested that modern university lifestyles contributed substantially to poor sleep behaviors. Academic workload, prolonged screen exposure, social media use, examination stress, and late-night study routines were likely responsible for delayed sleep onset and irregular sleep schedules [14]. These lifestyle-related factors may have aggravated circadian disruption and reduced total sleep duration, ultimately affecting students' cognitive efficiency. Educational institutions could therefore benefit from implementing sleep health awareness programs that encouraged healthy sleep hygiene and time management practices.

The present study possessed several strengths. It evaluated both sleep duration and circadian rhythm simultaneously while examining multiple cognitive domains, providing a more comprehensive understanding of physiological sleep health among university students. The standardized assessment methods and inclusion of a relatively diverse student population enhanced the reliability of the findings. However, certain limitations were also recognized [15]. The cross-sectional design prevented the establishment of causal relationships between sleep disturbances and cognitive impairment. Sleep duration and circadian characteristics were primarily based on self-reported information, which might have introduced recall bias. Additionally, other factors such as dietary habits, physical activity, mental health status, caffeine intake, and socioeconomic conditions were not fully controlled and could have influenced cognitive performance.

Overall, the findings supported the hypothesis that adequate sleep duration and stable circadian rhythms were essential determinants of optimal cognitive functioning among university students. Promoting healthy sleep behaviors and maintaining consistent sleep schedules could have represented effective physiological strategies for improving academic performance, attention, memory, and overall student well-being.

CONCLUSION:

Sleep played a fundamental role in maintaining physiological homeostasis, regulating circadian rhythms, and supporting optimal cognitive functioning. Among university students, academic demands, irregular

study schedules, excessive screen exposure, and social commitments frequently resulted in inadequate sleep duration and disruption of normal circadian rhythms. These disturbances were associated with impaired attention, memory, executive function, decision-making, and learning capacity. Previous studies reported that both insufficient and excessive sleep adversely affected cognitive performance, while circadian misalignment further contributed to daytime fatigue and reduced mental efficiency. Physiologically, sleep deprivation altered neuroendocrine regulation, increased cortisol secretion, and disrupted melatonin release, thereby negatively influencing brain function and cognitive processing. University students represented a particularly vulnerable population because their lifestyle often promoted inconsistent sleep patterns. Although several investigations examined sleep or cognition independently, limited evidence comprehensively evaluated the combined influence of sleep duration and circadian rhythm disruption on cognitive performance. Therefore, the present study was conducted to evaluate the association between sleep duration, circadian rhythm disruption, and cognitive performance among university students using a physiological perspective.

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