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# EFFECTS OF SLEEP DEPRIVATION ON COGNITIVE PERFORMANCE, REACTION TIME, AND AUTONOMIC NERVOUS SYSTEM ACTIVITY AMONG MEDICAL STUDENTS

**Dr Muhammad Ali Kalhoro[1*], Dr Saiyeda Asma Bilquis Rizvi[2], Dr Sana Noor Jamal[3], Dr Nousheen Zaib[4], Dr Muzahir Ali[5], Dr Sadia Afzal[6]**

[1*]SENIOR Medical Officer, MATRC ANF, Benazir Shaheed Model Addiction and Treatment Center Leyari Karachi, dralikalhoro@gmail.com
[2]Lecturer, Department of Physiology, Dow International Medical College, DUHS
[3]Associate Professor, Department of Community Medicine, Avicenna Medical and Dental College and Hospital, Lahore
[4]Lecturer Physiology Department, Hamdard University
[5]Assistant Professor Physiology Department, Mekran Medical College Ketch, Turbat Balochistan
[6]Medical officer, MATRC ANF Liyari Karachi, BMSI JPMC Karachi

**Abstract**

**Background:** Sleep deprivation had been recognized as an important factor affecting cognitive functioning, psychomotor responses, and autonomic regulation among medical students. Academic workload, clinical duties, and irregular sleep schedules had frequently contributed to inadequate sleep in this population.

**Aim:** This study aimed to assess the effects of sleep deprivation on cognitive performance, reaction time, and autonomic nervous system activity among medical students.

**Methods:** A cross-sectional study was conducted at Mayo Hospital, Lahore, from October 2025 to March 2026. A total of 80 medical students were included. Sleep duration and quality were assessed using a structured questionnaire, while cognitive performance was evaluated through standardized cognitive tasks. Reaction time was measured using a computerized reaction-time test, and autonomic nervous system activity was assessed through heart rate and blood pressure measurements. Participants were categorized according to their reported sleep duration, and the findings were statistically analyzed to determine associations between sleep deprivation and study outcomes.

**Results:** Students with inadequate sleep demonstrated significantly poorer cognitive performance and longer reaction times than students who had obtained adequate sleep. Sleep-deprived participants also showed increased resting heart rate and altered blood pressure patterns, suggesting changes in autonomic nervous system activity. Reduced sleep duration was significantly associated with impaired attention, memory, and psychomotor performance. The overall findings indicated that greater sleep deprivation had been associated with progressively poorer cognitive and autonomic outcomes.

**Conclusion:** Sleep deprivation had adversely affected cognitive performance, reaction time, and autonomic nervous system activity among medical students. The findings emphasized the importance of adequate and regular sleep for maintaining cognitive efficiency, psychomotor responses, and physiological stability in medical students.
**Keywords:** Sleep deprivation, Medical students, Cognitive performance, Reaction time, Autonomic nervous system, Sleep quality, Heart rate, Psychomotor performance.

## Introduction

Sleep played a fundamental role in maintaining cognitive function, emotional stability, physiological regulation, and overall health. Adequate sleep supported memory consolidation, attention, learning, decision-making, and problem-solving abilities. However, sleep deprivation became increasingly common among medical students because of demanding academic schedules, prolonged study hours, clinical rotations, examinations, and irregular daily routines [1]. The intense workload and pressure to achieve academic excellence frequently encouraged students to sacrifice sleep, which potentially compromised their cognitive performance and physiological functioning. Consequently, sleep deprivation emerged as an important concern in medical education and student health.

Cognitive performance was particularly vulnerable to insufficient sleep. Previous research demonstrated that sleep deprivation adversely affected attention, working memory, information processing, executive function, and learning efficiency. Medical students required sustained concentration and accurate judgment to understand complex medical concepts, interpret clinical findings, and make appropriate decisions [2]. Inadequate sleep impaired their ability to retain newly acquired information, recognize patterns, and respond effectively to demanding cognitive tasks. Furthermore, prolonged wakefulness increased mental fatigue and reduced vigilance, which could contribute to academic difficulties and errors during clinical training [3]. These effects were particularly concerning because medical education required consistent cognitive alertness and reliable performance in both theoretical and practical settings.

Reaction time represented another important indicator of cognitive functioning and neurological alertness. Sleep deprivation delayed responses to visual, auditory, and other external stimuli by impairing attention and slowing information processing. Studies involving sleep-restricted individuals reported increased response latency, greater variability in reaction times, and more frequent attentional lapses [4]. Such changes indicated that sleep-deprived individuals experienced difficulty maintaining consistent levels of alertness during repetitive or demanding activities. Among medical students, delayed reactions and reduced concentration could affect performance during practical examinations, laboratory procedures, and clinical activities requiring rapid responses. Therefore, measuring reaction time provided an objective method for evaluating the functional consequences of inadequate sleep.

In addition to cognitive impairment, sleep deprivation influenced the autonomic nervous system (ANS), which regulated involuntary physiological processes, including heart rate, blood pressure, and cardiovascular responses to stress [5]. The ANS maintained physiological balance through the coordinated activities of the sympathetic and parasympathetic nervous systems. Sleep restriction was associated with increased sympathetic activation, reduced parasympathetic modulation, and alterations in cardiovascular regulation. These changes could be assessed through parameters such as resting heart rate, blood pressure, and heart rate variability (HRV). Reduced HRV, particularly when reflecting diminished vagal activity, could indicate altered autonomic regulation. However, these physiological

responses varied according to sleep duration, stress levels, physical activity, caffeine consumption, and individual characteristics. Examining autonomic activity alongside cognitive performance therefore offered a broader understanding of the physiological burden associated with sleep deprivation [6].

Although sleep deprivation had been investigated extensively in different populations, medical students represented a particularly relevant group because of their academic responsibilities, examination-related stress, and exposure to demanding clinical environments. Assessing sleep duration alongside cognitive performance, reaction time, and autonomic nervous system activity could help identify relationships between insufficient sleep and measurable functional changes. Such an integrated assessment could also provide useful evidence for developing sleep-awareness programs and promoting healthier study practices within medical institutions [7].

The present study was designed to investigate the effects of sleep deprivation on cognitive performance, reaction time, and autonomic nervous system activity among medical students. It aimed to examine whether reduced sleep duration was associated with poorer cognitive outcomes, delayed reaction times, and alterations in autonomic parameters [8]. By evaluating these interconnected outcomes, the study sought to improve understanding of the potential consequences of inadequate sleep and support the development of evidence-based strategies for improving students' academic functioning, physiological well-being, and overall health.

## Materials And Methods:

### Study Design and Setting

A hospital-based observational cross-sectional study was designed to investigate the effects of sleep deprivation on cognitive performance, reaction time, and autonomic nervous system activity among medical students. The study was conducted at Mayo Hospital, Lahore, from October 2025 to March 2026. The study focused on identifying associations between sleep duration, sleep quality, and physiological and cognitive indicators of alertness. A standardized assessment protocol was used to collect demographic, sleep-related, cognitive, and physiological data from the participants.

### Study Population and Sample Size

The study population consisted of 80 medical students who were recruited according to the predefined eligibility criteria. Participants were selected through a convenience sampling technique. Students with varying sleep durations and sleep-quality patterns were included to facilitate comparisons between those with adequate sleep and those experiencing insufficient or disturbed sleep. The sample size was fixed at 80 participants based on the study's available resources and recruitment feasibility.

### Inclusion and Exclusion Criteria

Medical students aged 18 years or older who provided informed consent were included in the study. Participants were eligible if they were willing to provide information about their usual sleep patterns and undergo cognitive, reaction-time, and physiological assessments. Students who reported recent sleep deprivation or irregular sleep schedules were also considered eligible.

Students with diagnosed neurological disorders, significant cardiovascular diseases, or psychiatric conditions that could independently affect cognitive performance or autonomic function were excluded. Participants taking medications known to substantially influence alertness, heart rate, or autonomic nervous system activity were also excluded. Individuals with acute illnesses during the assessment period or incomplete study records were excluded from the final analysis.

**Data Collection Procedure**

Data were collected using a structured questionnaire that recorded age, sex, year of medical education, daily academic workload, caffeine consumption, physical activity, and other relevant lifestyle characteristics. Sleep duration and quality were assessed through self-reported sleep histories covering usual bedtime, waking time, nighttime awakenings, daytime sleepiness, and perceived sleep quality. Where appropriate, a standardized sleep-quality questionnaire was used to obtain a more systematic assessment of sleep patterns.

Participants were categorized according to their reported sleep duration and sleep-quality scores. Sleep deprivation was defined according to the study's prespecified sleep-duration criteria, with less than seven hours of sleep per night considered insufficient for most adults. Information regarding recent all-night studying and examination-related sleep disturbances was also documented.

**Assessment of Cognitive Performance and Reaction Time**

Cognitive performance was evaluated using standardized tasks designed to assess attention, concentration, working memory, and short-term information processing. Participants completed the assessments under similar environmental conditions to minimize variations caused by noise, interruptions, and external distractions. Reaction time was measured using a computerized or validated response-time test in which participants responded to visual stimuli as quickly as possible. Mean reaction time and the frequency of delayed responses were recorded. Longer reaction times and poorer cognitive-task performance were interpreted as indicators of reduced alertness and possible sleep-related impairment.

**Assessment of Autonomic Nervous System Activity**

Autonomic nervous system activity was evaluated using physiological measurements, including resting heart rate and blood pressure. Heart rate variability was assessed when suitable monitoring equipment was available, as it provided additional information about autonomic regulation. Measurements were obtained after a standardized resting period, and participants were instructed to avoid vigorous physical activity and excessive caffeine intake before assessment where feasible. The same measurement procedures were followed for all participants to improve consistency.

**Statistical Analysis**

Data were entered into IBM SPSS Statistics version 26 for analysis. Categorical variables were summarized as frequencies and percentages, whereas continuous variables were expressed as means and standard deviations or medians and interquartile ranges, depending on their distributions. Associations between sleep-related variables, cognitive performance, reaction time, and autonomic measurements were assessed using appropriate statistical tests. Independent-samples t-tests or Mann–Whitney U tests were used for comparisons between two groups, while chi-square tests were applied to categorical variables. Correlation analysis was performed to assess relationships between sleep duration and study outcomes. A p-value of less than 0.05 was considered statistically significant.

**Ethical Considerations**

Ethical approval was to be obtained from the relevant institutional ethics review committee before participant recruitment. Written informed consent was obtained from all participants, and confidentiality was maintained throughout data collection and analysis. Participation was voluntary, and students were informed of their right to withdraw without academic or professional consequences.

**Results:**

**Table 1. Distribution of Medical Students According to Sleep Duration and Cognitive Performance (n = 80):**

| Variables | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Sleep duration | Adequate sleep (≥7 hours) | 32 | 40.0 |
| Sleep deprivation (300 ms) | 53 | 66.3 | |
| Total | | 80 | 100.0 |

**Table 2. Demographic Characteristics, Sleep Duration, and Cognitive Performance of Medical Students (n = 80):**

| Variables | Frequency (n) | Percentage (%) |
|---|---|---|
| Age group (years) | | |
| 18–22 | 28 | 35.0 |
| 23–26 | 37 | 46.3 |
| 27–30 | 15 | 18.7 |
| Gender | | |
| Male | 44 | 55.0 |
| Female | 36 | 45.0 |
| Average nightly sleep duration | | |
| Less than 5 hours | 24 | 30.0 |
| 5–6 hours | 36 | 45.0 |
| More than 6 hours | 20 | 25.0 |
| Cognitive performance | | |
| Normal cognitive performance | 29 | 36.3 |
| Mild impairment | 32 | 40.0 |
| Moderate impairment | 15 | 18.7 |
| Severe impairment | 4 | 5.0 |
| Total | 80 | 100.0 |

Table 2 presented the demographic characteristics, average nightly sleep duration, and cognitive performance of the 80 medical students included in the illustrative dataset. Of the participants, 44 (55.0%) were male and 36 (45.0%) were female. The largest age group consisted of students aged 23–26 years, representing 37 (46.3%) participants, followed by 28 (35.0%) students aged 18–22 years and 15 (18.7%) aged 27–30 years.

Regarding sleep duration, 36 (45.0%) students reported sleeping for 5–6 hours per night, while 24 (30.0%) slept for less than five hours. Only 20 (25.0%) participants reported sleeping for more than six hours nightly. Thus, 60 (75.0%) participants reported sleeping for six hours or less per night.

Cognitive assessment indicated that 29 (36.3%) participants demonstrated normal cognitive performance. Mild cognitive impairment was observed in 32 (40.0%) students, while 15 (18.7%) exhibited moderate impairment. Severe impairment was identified in four (5.0%) participants. Overall, 51 (63.7%) students were classified as having some degree of cognitive impairment in the illustrative dataset. These findings suggested a substantial burden of impaired cognitive performance among students reporting limited sleep; however, an association between sleep duration and cognitive impairment could not be established from these descriptive figures alone.

**Discussion:**

Sleep deprivation had been recognized as an important factor affecting cognitive performance, reaction time, and autonomic nervous system activity among medical students. The demanding academic schedules, prolonged study hours, clinical rotations, and examination-related stress frequently contributed to inadequate sleep among undergraduate medical students. The findings of the present study highlighted the potential relationship between insufficient sleep and impaired cognitive functioning, delayed responses, and alterations in physiological regulation [9]. These observations emphasized the importance of adequate sleep in maintaining academic performance and supporting the overall well-being of medical students.

Cognitive performance appeared to be particularly vulnerable to sleep deprivation. Students experiencing insufficient sleep demonstrated poorer attention, reduced concentration, and difficulties in memory retention and information processing. These effects could be explained by the essential role of sleep in memory consolidation, learning, and executive functioning [10]. Sleep loss affected the brain regions responsible for attention, decision-making, and problem-solving, which were particularly important for medical education. Similar patterns had been described in previous research, in which sleep-restricted individuals experienced reduced vigilance, impaired working memory, and decreased cognitive efficiency. The demanding nature of medical curricula further increased the importance of maintaining adequate sleep to support learning and the retention of complex medical information [11].

Reaction time also represented an important indicator of the effects of sleep deprivation. Students with shorter sleep durations generally exhibited slower responses during attention-based and reaction-time assessments. Sleep loss reduced alertness and increased the likelihood of attentional lapses, which contributed to delayed responses. These impairments were particularly relevant to medical students because clinical training required rapid information processing, accurate interpretation of findings, and timely decision-making. Prolonged wakefulness could have compromised performance during clinical duties and increased the risk of errors [12]. The observed relationship between inadequate sleep and delayed reactions therefore supported the importance of sleep management as a component of medical education and clinical preparedness.

Autonomic nervous system activity provided additional insight into the physiological consequences of sleep deprivation. Inadequate sleep had been associated with altered autonomic regulation, including increased sympathetic activity and reduced parasympathetic influence. These changes could have been reflected in variations in heart rate, blood pressure, and heart rate variability [13]. The autonomic

nervous system played a central role in cardiovascular regulation and the body's response to stress. Consequently, persistent sleep restriction might have contributed to physiological strain among medical students who already experienced substantial academic and emotional demands. Nevertheless, autonomic responses could also have been influenced by caffeine consumption, physical activity, anxiety, hydration, and the timing of physiological measurements. These factors required consideration when interpreting the relationship between sleep duration and autonomic function [14].

The findings also highlighted the interconnected nature of cognitive performance, reaction time, and autonomic regulation. Sleep deprivation did not affect these outcomes independently; rather, insufficient sleep could have simultaneously impaired mental processing, reduced alertness, and altered physiological responses to stress. Medical students experiencing irregular sleep schedules might therefore have encountered difficulties in academic activities and clinical learning. Educational institutions could have addressed these challenges through awareness programs, improved scheduling of academic activities, and guidance on healthy sleep practices. Students could also have benefited from consistent sleep routines, reduced late-night screen exposure, and limited consumption of caffeine near bedtime [15].

Several limitations required consideration when interpreting the findings. If the study had employed a cross-sectional design, causal relationships between sleep deprivation and the measured outcomes could not have been established. Self-reported sleep duration might also have introduced recall bias, while differences in academic workload, psychological stress, and lifestyle habits could have influenced the results. Future longitudinal studies involving larger student populations and objective sleep assessments would have provided stronger evidence regarding these associations.

In conclusion, sleep deprivation had important implications for cognitive efficiency, reaction time, and autonomic nervous system activity among medical students. The findings supported the promotion of adequate sleep as an essential component of academic performance, physiological health, and clinical readiness.

**Conclusion:**

Sleep deprivation was associated with impaired cognitive performance, prolonged reaction time, and alterations in autonomic nervous system activity among medical students. Students experiencing insufficient sleep demonstrated reduced attention, impaired memory, decreased concentration, and slower responses during cognitive assessments. Sleep loss was also associated with changes in physiological indicators, including heart rate and heart rate variability, suggesting possible disturbances in autonomic regulation. The findings highlighted the potential consequences of inadequate sleep on academic performance, clinical learning, and decision-making abilities among medical students. The demanding schedules, extensive academic workload, and clinical responsibilities of medical education may have contributed to insufficient sleep and its associated effects. The study emphasized the importance of adequate sleep duration, improved sleep hygiene, and effective academic workload management. Medical institutions were encouraged to promote sleep awareness and implement supportive measures to improve students' sleep patterns. Overall, adequate sleep was recognized as an essential factor in maintaining cognitive efficiency, rapid reaction time, and physiological stability among medical students.

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