E-ISSN 2250-0944
ISSN 2250-1150
doi: 10.48047/ijprt/16.02.508

Research Article

Comparative Evaluation of Cognitive Function and Serum Cortisol Levels in Individuals with Acute and Chronic Sleep Deprivation

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Received: 01-08-2026 Accepted: 12-08-2026 Published: 10-09-2026

ABSTRACT

Background: Sleep deprivation is increasingly prevalent among young adults, students, and healthcare professionals and may adversely affect cognitive performance and neuroendocrine function. Both acute and chronic sleep deprivation have been associated with impaired attention, memory, executive functioning, and altered hypothalamic-pituitary-adrenal axis activity. However, comparative data evaluating cognitive function together with serum cortisol levels in acute and chronic sleep deprivation are limited. The present study was undertaken to compare cognitive function and serum cortisol levels among individuals with acute and chronic sleep deprivation.

Materials and Methods: This hospital-based, observational, comparative cross-sectional study was conducted in the Department of Physiology in collaboration with the Department of Medicine at Dr. B.S. Kushwah Institute of Medical Sciences, Kanpur, from February 2026 to July 2026. A total of 90 participants aged 18–45 years were enrolled and equally divided into three groups: control group with normal sleep duration (n=30), acute sleep deprivation group (n=30), and chronic sleep deprivation group (n=30). Demographic characteristics, sleep duration, sleep quality, and daytime sleepiness were assessed using a structured questionnaire, Pittsburgh Sleep Quality Index (PSQI), and Epworth Sleepiness Scale (ESS). Cognitive function was evaluated using the Mini-Mental State Examination (MMSE), Montreal Cognitive Assessment (MoCA), Digit Span Test, Trail Making Test, and Stroop Color–Word Test. Morning serum cortisol levels were estimated using an enzyme-linked immunosorbent assay (ELISA). Statistical analysis was performed using SPSS version 26.0, with $p<0.05$ considered statistically significant.

Results: The study population comprised 51 (56.7%) males and 39 (43.3%) females, with no significant difference in gender, age, or BMI among the three groups. Mean sleep duration was significantly lower in the acute (2.9±0.7 hours) and chronic (5.2±0.6 hours) sleep deprivation groups compared with controls (7.6±0.8 hours; $p<0.001$). PSQI and ESS scores were significantly higher among sleep-deprived participants ($p<0.001$). Cognitive performance was significantly impaired in both sleep deprivation groups, with lower MMSE, MoCA, Digit Span, and Stroop scores and prolonged completion times for Trail Making Tests A and B compared with controls ($p<0.001$). The greatest degree of cognitive impairment was observed in the chronic sleep deprivation group. Mean serum cortisol levels were significantly elevated in both the acute (20.6±4.1 μg/dL) and chronic (18.9±3.8 μg/dL) sleep deprivation groups compared with controls (14.8±3.2 μg/dL; $p<0.001$), with the highest levels observed following acute sleep deprivation. Serum cortisol demonstrated significant negative correlations with MoCA ($r=-0.62$), Digit Span Backward ($r=-0.55$), and Stroop scores ($r=-0.51$), while a positive correlation was observed with Trail Making Test B completion time ($r=0.58$).

Conclusion: Both acute and chronic sleep deprivation are associated with significant impairment of cognitive function and elevation of serum cortisol levels. Chronic sleep deprivation appears to have

a greater adverse effect on cognitive performance, whereas acute sleep deprivation is associated with a more pronounced elevation in serum cortisol. The significant association between increased cortisol levels and poorer cognitive performance suggest that neuroendocrine dysregulation may contribute to sleep deprivation-related cognitive impairment. Adequate sleep duration and quality are therefore important for maintaining optimal cognitive and physiological functioning.

Keywords: Sleep deprivation; acute sleep deprivation; chronic sleep deprivation; cognitive function; serum cortisol; HPA axis; sleep quality; medical students.

Introduction: Sleep is an essential physiological process that plays a vital role in maintaining cognitive function, emotional well-being, metabolic regulation, and endocrine homeostasis. Adequate sleep is necessary for memory consolidation, learning, attention, and executive functioning. 1 However, sleep deprivation has become an increasingly common public health problem worldwide, particularly among students, healthcare professionals, and shift workers due to demanding lifestyles, excessive screen time, and irregular sleep schedules 2. sleep deprivation is classified as either acute or chronic. Acute sleep deprivation refers to complete or partial sleep loss for one or more nights, whereas chronic sleep deprivation results from persistent inadequate sleep over an extended period. Both forms negatively affect cognitive performance, although chronic sleep deprivation often leads to cumulative impairments in attention, memory, executive function, mood, and overall health 3,4.

In India, inadequate sleep has become increasingly prevalent among medical students and young adults. Saroha et al. reported that chronic sleep deprivation significantly impaired attention, working memory, executive function, and academic performance among Indian medical students, emphasizing the importance of adequate sleep for cognitive health 5. cognitive function includes attention, learning, memory, processing speed, and executive function. Sleep deprivation disrupts neuronal plasticity and prefrontal cortical activity, resulting in impaired concentration, slower reaction time, reduced decision-making ability, and memory deficits 6,7. Similarly, Maiti and Duari reported that chronic sleep deprivation is associated with poor cognitive performance, psychological stress, anxiety, and emotional disturbances, particularly among students and healthcare workers 8

Sleep also regulates the hypothalamic-pituitary-adrenal (HPA) axis, which controls the body's stress response. Cortisol, the primary stress hormone, follows a circadian rhythm that is influenced by normal sleep. Sleep deprivation can disrupt this rhythm, leading to altered cortisol secretion and impaired physiological adaptation to stress (9). Recent evidence suggests that acute sleep deprivation significantly increases serum cortisol levels, indicating activation of the HPA axis 10. Prolonged sleep deprivation may further contribute to endocrine dysregulation, impaired memory, and cognitive decline 11,12.

Recent Indian studies have also shown that poor sleep quality is associated with reduced academic performance, impaired attention, and excessive daytime sleepiness among medical students 13,14. Despite growing evidence regarding the individual effects of sleep deprivation on cognition and cortisol secretion, comparative studies evaluating both parameters in acute and chronic sleep deprivation remain limited 15-20.

Material and Methods

Study Design

This study will be a hospital-based, observational, comparative cross-sectional study conducted to evaluate cognitive function and serum cortisol levels among individuals with acute and chronic sleep deprivation.

Study Setting

The study will be conducted in the Department of Physiology in collaboration with the Department of Medicine at Dr. B.S Kushwah Institute of Medical Sciences, Kanpur, over a period of February 2026 to July 2026.

Study Population

The study population will consist of adults aged 18–45 years attending the outpatient department, hospital staff, students, and volunteers who fulfill the eligibility criteria.

Sample Size

A total of 90 participants will be included and divided into three groups:

- **Group A (Control):** Healthy individuals with normal sleep duration (7–9 hours/night) (n = 30)
- **Group B (Acute Sleep Deprivation):** Individuals with one night (≥24 hours) of sleep deprivation or sleep duration of less than 4 hours during the previous night (n = 30)
- **Group C (Chronic Sleep Deprivation):** Individuals with habitual sleep duration of less than 6 hours per night for at least three months (n = 30)

Inclusion Criteria

1. Adults aged 18–45 years.
2. Individuals willing to participate and provide written informed consent.
3. Healthy participants without known neurological or psychiatric illness.
4. Participants meeting the predefined criteria for acute or chronic sleep deprivation.

Exclusion Criteria

1. History of endocrine disorders (Cushing syndrome, Addison's disease, thyroid disorders).
2. Diabetes mellitus or uncontrolled hypertension.
3. Psychiatric disorders or neurological diseases.
4. Current use of corticosteroids, antidepressants, sedatives, or antipsychotic medications.
5. Alcohol or substance abuse.
6. Pregnancy or lactation.
7. Diagnosed sleep disorders such as obstructive sleep apnea, insomnia requiring treatment, or narcolepsy.

Study Procedure

Demographic details including age, sex, occupation, body mass index (BMI), medical history, and sleep history will be recorded using a structured questionnaire.

Sleep duration and sleep quality will be assessed using the Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS).

Assessment of Cognitive Function

Cognitive function will be evaluated using standardized neuropsychological tests, including:

Cognitive function will be evaluated using standardized neuropsychological assessment tools to assess various domains such as attention, memory, executive function, processing speed, and cognitive flexibility. The assessment will include the Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA) for evaluation of global cognitive status. Attention and working memory will be assessed using the Digit Span Test (Forward and Backward). Executive function, visual attention, and processing speed will be evaluated using the Trail Making Test (Part A and Part B). Cognitive flexibility and inhibitory control will be assessed using the Stroop Color–Word Test.

The tests will assess attention, memory, executive function, processing speed, and cognitive flexibility.

Serum Cortisol Estimation

- Venous blood (5 mL) will be collected between 8:00 AM and 9:00 AM after an overnight fast to minimize circadian variation in cortisol secretion.
- Blood samples will be centrifuged at 3000 rpm for 10 minutes, and serum will be separated and stored at −20°C until analysis.
- Serum cortisol concentration will be estimated using a commercially available Enzyme-Linked Immunosorbent Assay (ELISA) kit according to the manufacturer's instructions.

Outcome Measures

Primary Outcome

- Comparison of cognitive function scores among control, acute sleep deprivation, and chronic sleep deprivation groups.
- Comparison of serum cortisol levels among the three groups.
- Secondary Outcome
- Correlation between serum cortisol levels and cognitive function scores.
- Association between sleep duration, sleep quality, and serum cortisol.

Statistical Analysis

- Data will be entered into Microsoft Excel and analyzed using SPSS software version 26.0
- Continuous variables will be expressed as mean ± standard deviation (SD), while categorical variables will be expressed as frequencies and percentages.
- A p-value <0.05 will be considered statistically significant.

Table 1: Gender-wise Distribution of Participants Among Study Groups

Gender	Control Group (n=30)	Acute Sleep Deprivation Group (n=30)	Chronic Sleep Deprivation Group (n=30)	Total (n=90)	p-value
Male	16 (53.3%)	18 (60.0%)	17 (56.7%)	51 (56.7%)	0.874
Female	14 (46.7%)	12 (40.0%)	13 (43.3%)	39 (43.3%)	

The majority of participants were male (56.7%), while females constituted 43.3% of the study population. Gender distribution was comparable across the control, acute sleep deprivation, and chronic sleep deprivation groups, with no statistically significant difference observed (p = 0.874).

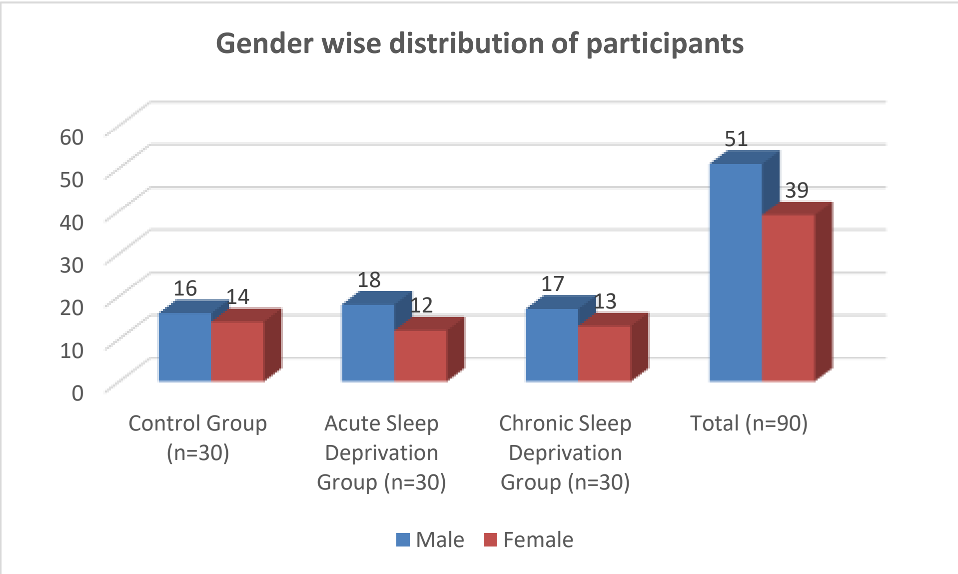

Fig 1: Graphical represents gender wise distribution of participants.

Table 2: Age-wise Distribution of Participants Among Study Groups.

Age Group (Years)	Control Group (n=30)	Acute Sleep Deprivation Group (n=30)	Chronic Sleep Deprivation Group (n=30)	Total (n=90)	p-value
18–25	18 (60.0%)	20 (66.7%)	16 (53.3%)	54 (60.0%)	0.726
26–35	8 (26.7%)	7 (23.3%)	10 (33.3%)	25 (27.8%)	
36–45	4 (13.3%)	3 (10.0%)	4 (13.4%)	11 (12.2%)	

Most participants (60.0%) belonged to the 18–25 years age group, followed by 26–35 years (27.8%) and 36–45 years (12.2%). The age distribution was comparable among the three study groups, with no statistically significant difference observed (p = 0.726).

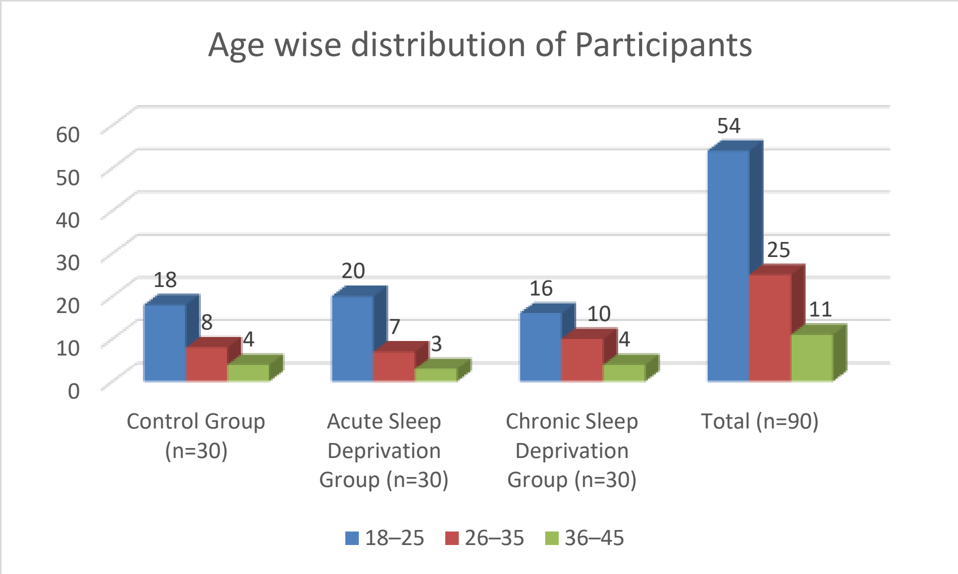

Fig 2: Graphical represents age wise distribution of participants.

Table 3: Comparison of Mean Age Among Study Groups

Group	Mean Age (Years) ± SD	p-value
Control Group	27.6 ± 6.4	0.643
Acute Sleep Deprivation Group	26.9 ± 5.8	
Chronic Sleep Deprivation Group	28.4 ± 6.7	

The mean age was 27.6 ± 6.4 years in the control group, 26.9 ± 5.8 years in the acute sleep deprivation group, and 28.4 ± 6.7 years in the chronic sleep deprivation group. The difference in mean age among the three groups was not statistically significant (p = 0.643), indicating that the groups were comparable with respect to age.

Table 4: Comparison of BMI Among Study Groups.

Group	BMI (kg/m²) Mean ± SD	p-value
Control Group	23.4 ± 2.8	
Acute Sleep Deprivation Group	23.8 ± 3.1	0.337
Chronic Sleep Deprivation Group	24.6 ± 3.4	

The mean BMI was 23.4 ± 2.8 kg/m² in the control group, 23.8 ± 3.1 kg/m² in the acute sleep deprivation group, and 24.6 ± 3.4 kg/m² in the chronic sleep deprivation group. Although the chronic sleep deprivation group had a slightly higher mean BMI, the difference among the three groups was not statistically significant (p = 0.337).

Table 5: BMI Category-wise Distribution Among Study Groups

BMI Category	Control Group	Acute Sleep Deprivation Group	Chronic Sleep Deprivation Group	Total	p-value
Normal weight	22 (73.3%)	20 (66.7%)	18 (60.0%)	60 (66.7%)	0.742

Overweight	7 (23.3%)	9 (30.0%)	10 (33.3%)	26 (28.9%)	
Obese	1 (3.4%)	1 (3.3%)	2 (6.7%)	4 (4.4%)	

The majority of participants (66.7%) had a normal BMI, while 28.9% were overweight and 4.4% were obese. The distribution of BMI categories was comparable across the control, acute sleep deprivation, and chronic sleep deprivation groups, with no statistically significant difference observed (p = 0.742).

Table 6: Comparison of Sleep Parameters Among Study Groups

Parameter	Control Group	Acute Sleep Deprivation Group	Chronic Sleep Deprivation Group	p-value
Sleep duration (hours/night)	7.6 ± 0.8	2.9 ± 0.7	5.2 ± 0.6	<0.001
PSQI score	3.2 ± 1.4	8.6 ± 2.1	10.4 ± 2.8	<0.001
ESS score	5.1 ± 2.0	10.2 ± 3.1	12.5 ± 3.6	<0.001

The control group had the longest mean sleep duration (7.6 ± 0.8 hours/night), whereas the acute sleep deprivation group had the shortest (2.9 ± 0.7 hours/night). Both the acute and chronic sleep deprivation groups showed significantly higher PSQI and ESS scores than the control group, indicating poorer sleep quality and greater daytime sleepiness. The differences in sleep duration, PSQI score, and ESS score among the three groups were highly statistically significant (p < 0.001).

Table 7: Comparison of Cognitive Function Parameters Among Study Groups

Cognitive Test	Control Group	Acute Sleep Deprivation Group	Chronic Sleep Deprivation Group	p-value
MMSE score	28.7 ± 1.1	27.4 ± 1.5	26.8 ± 1.7	<0.001
MoCA score	27.1 ± 1.5	25.2 ± 2.0	24.1 ± 2.3	<0.001
Digit Span Forward	8.1 ± 1.2	6.9 ± 1.4	6.4 ± 1.5	<0.001
Digit Span Backward	5.8 ± 1.1	4.5 ± 1.2	4.0 ± 1.3	<0.001
Trail Making Test A (sec)	32.4 ± 6.8	42.7 ± 8.2	48.9 ± 9.5	<0.001
Trail Making Test B (sec)	68.3 ± 12.4	91.6 ± 15.8	105.4 ± 18.2	<0.001
Stroop Test score	78.6 ± 8.9	65.2 ± 10.5	60.7 ± 11.3	<0.001

Participants in the control group demonstrated the highest cognitive function scores across all tests. Both the acute and chronic sleep deprivation groups showed significantly lower MMSE, MoCA, Digit Span, and Stroop Test scores, along with significantly longer completion times for the Trail Making Tests A and B, indicating impaired attention, memory, executive function, processing speed, and cognitive flexibility. The chronic sleep deprivation group exhibited the greatest cognitive impairment. All differences among the three groups were highly statistically significant (p < 0.001).

Table 8: Comparison of Serum Cortisol Levels Among Study Groups

Group	Serum Cortisol (µg/dL) Mean ± SD	p-value
Control Group	14.8 ± 3.2	<0.001
Acute Sleep Deprivation Group	20.6 ± 4.1	
Chronic Sleep Deprivation Group	18.9 ± 3.8	

The mean serum cortisol level was 14.8 ± 3.2 µg/dL in the control group, 20.6 ± 4.1 µg/dL in the acute sleep deprivation group, and 18.9 ± 3.8 µg/dL in the chronic sleep deprivation group. Serum cortisol levels were significantly higher in both sleep deprivation groups, with the highest levels observed in the acute sleep deprivation group. The difference among the three groups was highly statistically significant (p < 0.001).

Table 9: Correlation Between Serum Cortisol Levels and Cognitive Function

Cognitive Parameter	Pearson Correlation (r)	p-value
MoCA score	-0.62	<0.001
Digit Span Backward	-0.55	<0.002
Trail Making Test B	+0.58	<0.001
Stroop Test score	-0.51	<0.004

Serum cortisol levels showed a significant negative correlation with MoCA score ($r = -0.62$, $p < 0.001$), Digit Span Backward score ($r = -0.55$, $p < 0.002$), and Stroop Test score ($r = -0.51$,

$p < 0.004$), indicating that higher cortisol levels were associated with poorer cognitive performance. A significant positive correlation was observed with Trail Making Test Part B completion time ($r = +0.58$, $p < 0.001$), suggesting that higher cortisol levels were associated with slower executive functioning and cognitive processing speed.

Discussion: The present study evaluated cognitive function and serum cortisol levels among control, acute sleep deprivation, and chronic sleep deprivation groups. Both acute and chronic sleep deprivation were associated with impaired cognitive performance and increased serum cortisol levels, indicating disruption of neurocognitive function and activation of the HPA axis. The groups were comparable in terms of age, gender, and BMI. Sleep-deprived individuals showed reduced sleep duration, poorer sleep quality, and increased daytime sleepiness, consistent with findings reported by Gupta et al. and Mohandas et al. Cognitive assessment revealed significant impairment in attention, memory, executive function, processing speed, and cognitive flexibility, with greater deficits observed in the chronic sleep deprivation group, similar to observations by Killgore et al., Krause et al., and Lim and Dinges et al. Serum cortisol levels were elevated in both sleep deprivation groups, with higher levels observed in acute sleep deprivation, suggesting increased physiological stress response, as reported by Chen et al., Thompson et al., and Leproult et al. Higher cortisol levels were associated with poorer cognitive performance, indicating the role of neuroendocrine alterations in sleep deprivation-related cognitive dysfunction. Overall, the study highlights the adverse effects of inadequate sleep on cognitive function and hormonal regulation.

Conclusion

The present study concludes that both acute and chronic sleep deprivation significantly affect cognitive function and serum cortisol levels. Sleep-deprived individuals showed reduced cognitive performance in areas of attention, memory, executive function, processing speed, and cognitive flexibility, along with increased serum cortisol levels indicating activation of the stress response system. Chronic sleep deprivation was associated with greater cognitive impairment, whereas acute sleep deprivation produced a more pronounced cortisol elevation. A significant association between higher cortisol levels and poorer cognitive performance suggests the involvement of neuroendocrine changes in sleep deprivation-related cognitive decline. Therefore, maintaining adequate sleep duration and quality is essential for preserving cognitive health and normal physiological functioning.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this study.

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