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# Sleep Impairment Compromises Young Collegiate's Resting-State Brain Wave Activity and Prefrontal Cognition

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**Abstract**

**Introduction.** Sleep problems are common among university students and have been linked to weakened brain abilities and cognitive functioning. Electroencephalography (EEG) and event-related potentials (ERP) are important and tests routinely done to assess brain abilities and cognitive functions. Therefore, present study aims to examines the relationship between sleep functions and various domains of brain and cognitive abilities in sleep-disturbed collegiates. **Method.** Thirty-two collegiates participated in this study. Sleep functions such as sleep quality and daytime sleepiness were subjectively assessed using Pittsburgh Sleep Quality Index (PSQI) and Epworth Sleepiness Scale (ESS), respectively. EEG brainwaves (alpha-Hz, beta-Hz, delta-Hz, and theta-Hz) and ERP P300 (amplitude-μV [AMP], latency-ms [LAT]) were recorded using RMS analysis and auditory-oddball paradigm, respectively. **Results.** Pearson's correlation analysis revealed statistically significant linear correlation between PSQI and AMP ($r = -0.485$, $p = .005$), PSQI and LAT ($r = 0.354$, $p = .047$), ESS and AMP ($r = -0.478$, $p = .006$), and ESS and LAT ($r = 0.436$, $p = .013$). Considering EEG brainwaves, both PSQI ($r = -0.364$, $p = .040$) and ESS ($r = -0.409$, $p = .020$) demonstrate statistically significant linear correlation with alpha. Further, regression analysis revealed that sleep functions (PSQI and ESS) were found to significantly predict AMP, LAT, and alpha. **Conclusions.** In collegiates with sleep disturbances, measures of prefrontal cognition and EEG brainwaves are substantially correlated with sleep-related characteristics.

***Keywords***: sleep disturbance; cognitive impairment; electroencephalography; event-related potential; young collegiates

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## Introduction

In today's world, sleeplessness is a relatively common problem. Sleep problems are common among university students, with a reported prevalence ranging from 19.2 to 57.5 percent, and it can have serious long-term consequences (Manzar, Zannat, et al., 2015). Sleep disturbances have a negative impact on an individual's general physiology, including reduced cognitive performance (Sweileh et al., 2011). Babkof and colleagues (2005) discuss the relevance of the "sleep-based neuropsychological viewpoint," which argues that sleep disorders affect cognitive function by interfering with the functioning of certain cortical areas (Babkof et al., 2005). The most popular theory in this area is Horne's theory of prefrontal vulnerability (Horne, 1993). Since the hippocampus and prefrontal cortex are in charge of regulating cognition, this shows a complicated presentation of cognitive disorders. A variety of cognitive areas, including memory, executive function, concentration and attention, speed of information processing, perception, and inhibitory function are all affected by sleep disturbances (Haimov & Shatil, 2013). Importantly, cognitive and brain abilities can be assessed using a variety of techniques. The two most widely used noninvasive methods are event-related potentials (ERP) P300 and electroencephalography (EEG; Woodford & George, 2007).

According to thorough and rigorous review, ERP P300 can be utilized as a neurophysiological marker to measure cortical arousal since it is sensitive enough to detect changes in arousal level. In human participants that are sleep deprived, the majority of research analyzing ERP have reported considerably lower amplitudes and longer latencies in comparison to controls (Morris et al., 1992). It is crucial to keep in mind, though, that because all the trials were conducted in a lab and participants were compelled to skip sleep, there was potential for a number of psychological confounds. Few research studies have also attempted to address the same question by using patients with clinically documented sleep disturbances; however, their findings have been inconsistent (Turcotte et al., 2011). While some studies comparing ERP responses showed no significant effect of the previous night's sleep quality on long latency responses in sleep-disturbed participants and their healthy counterparts (Devoto et al., 2003), other researchers found significant changes in the morphology of P300 in response to the previous night's poor sleep quality (Shishkin et al., 2009). Another main noninvasive technique for gathering data from the human brain is EEG (Coburn et al., 2006). Sleep problems have been found to disrupt people's performance on resting-state EEG (Verweij et al., 2014). According to recent research, certain oscillatory patterns in spontaneous EEG are linked to neuropsychopathologies like sleep disorders, depression, and some learning disabilities. These oscillatory patterns also serve as trustworthy indicators of brain dysfunction (Coburn et al., 2006).

Therefore, corpus of research suggests that a study should look into the relationship between sleep, cognitive factors, and resting-state brain waves in order to address the impaired brain functioning in adolescents and young adults who have sleep disruptions. Therefore, in this study we primarily aim to explore the relationship of sleep function measures (such as sleep quality using the Pittsburgh Sleep Quality Index [PSQI] and daytime sleepiness using the Epworth Sleep Scale [ESS]) with cognitive abilities (such as ERP P300 latency [LAT] and ERP P300 amplitude [AMP]) and resting-state EEG measures in young collegiates with sleep impairment; and secondarily we aim to find out if the sleep impairment is a potential predictor for cognitive function deficits and brain wave disturbances. To the best of our knowledge, this is the first study to evaluate the association of sleep functions with cognitive variables and brain wave profile.

## Materials and Methods

### Sample Size

Number of subjects was determined with Software G. Power 3.1.9.2 using data from a previous study (Aseem et al., 2021), which investigated the association between sleep profile and cognitive functions using PSQI and LAT, respectively, in sleep-disturbed collegiates with mild cognitive impairment. A total of 32 subjects were shown to be necessary with the effect size of 0.52 (high), alpha level of 0.05, and power (1-beta) of 0.88.

### Procedures

With reference number 19/2/213/JMI/IEC/2019, the Institutional Ethics Committee (IEC) of Jamia Millia Islamia (Central University), New Delhi, India, approved the study. The study was carried out at Jamia Millia Islamia's Neurophysiology Lab, which is part of the Centre for Physiotherapy and Rehabilitation Sciences. The 1964 Helsinki Declaration and its updates were adhered to when doing the research for this study. After a preliminary diagnostic interview and evaluation of the entrance requirements, participants were told about the study at the first contact and their written informed consent was collected, following which screening for the impaired sleep symptoms was done using PSQI (Buysse, 1989) in young collegiates.

### Participants

A total of 50 students from Jamia Millia Islamia, 26 female and 24 male, ages 18 to 28, had their eligibility for PSQI (Buysse, 1989), with subjects experiencing sleep difficulties (poor sleepers) at the time of their recruitment with PSQI scores > 5 (Manzar, Moiz, et al., 2015) examined. Subsequently, the ESS (Johns, 1991) was employed to assess symptoms of daytime sleepiness in individuals diagnosed with insomnia. The assessment of brain waves (EEG) and cognitive function features (ERP) was then completed. Physiotherapists who performed the assessment received training on conducting the assessments as per standard operating procedure. Every test was delivered in a standardized manner, and the sequence in which they were given to each subject was followed. Out of the 50 participants, 38 met the requirements. Out of those 38, six people declined to take part in the research. The study was comprised of 32 individuals, 15 of whom were male and 17 of whom were female. Every person who was included reported having regular or modified normal vision, normal hearing, and basic English language comprehension. In order to reduce the possibility of bias in the study's results, participants were excluded if they had a history of neurological, psychological, or mental problems; alcohol consumption, substance abuse, use of centrally active drugs (that may affect ERP and EEG), or if they had taken sleeping pills for the previous 6 months. The study participants were 32 young collegiates with impaired sleep. Details of their sleep functions, cognitive functions and brain waves characteristics are shown in Table 1.

## Outcome Measures

***Sleep Functions.***

- **Sleep Quality.** The PSQI, a self-rated questionnaire consisting of 19 items, was utilized to evaluate the subjective quality of sleep throughout the preceding month. The 19 questions are aggregated into seven clinically derived component scores, each equally weighted from 0 to 3. Using the seven component scores, a total score ranging from 0 to 21 is computed; higher values correspond to lower quality sleep (Buysse, 1989).
- **Daytime Sleepiness.** Subjective daytime sleepiness is measured by ESS. The ESS uses a 4-point Likert response system (rated from 0 to 3) to assess a person's likelihood of falling asleep in different scenarios. Higher numbers indicate more extreme tiredness. The answers to each item are added up to get a total score between 0 and 24; a score of more than 10 denotes severe daytime sleepiness (Johns, 1991).

***Cognitive Functions.***

**ERP P300 latency and ERP P300 Amplitude.**

ERP P300 elements (LAT and AMP) pertaining to information processing and attention are present throughout awake. P300 is the most well-known of these elements and is thought to be the electrophysiological correlate of cognition (Hull & Harsh, 2001). The ERP P300 wave's amplitude and latency were also measured. The individual was seated in a comfortable position. The scalp was carefully cleaned with N-Prep skin preparation gel (Weaver and Company, USA) before EEG paste (Ten20 conductive) was applied to different parts of the scalp to become ready for electrode insertion. Ag-AgCl disc electrodes were employed as recording electrodes. Reference electrodes were affixed to the mastoid (A1), the active electrode on the vertex (Cz), and the ground electrode on the forehead (FPz). The techniques employed in previous studies to quantify the auditory ERP (AERP) were followed during the implantation of this electrode (S. Lee et al., 2004). While employing the typical auditory oddball paradigm, participants completed a task, and the AERP were recorded. While listening to two distinct sound types through headphones, the respondents were instructed to count the number of (rare, goal stimulus) presentations of a high-pitch tone (S1) as opposed to the number of (common, nontarget stimuli) presentations of a low-pitch tone (S2). In line with earlier research, the target: nontarget ratio for the S1 and S2 sounds was selected at random (Aseem et al., 2018; H.-J. Lee et al., 2003). Every stimulation was separated by 1 s. Every tone had a 50-ms duration. During the recording of the AERP, subjects were asked to avoid head, neck, and eye movement (Chatterjee et al., 2012).

***Resting-State EEG Brain Waves***. All participants in the current study had their resting EEG recorded on an EEG machine, which was used to examine brain activity (Fisch, 1991). Prior to recording the EEG, a square wave calibration signal with known input was captured for at least 10 s and stored with the EEG in accordance American Clinical Neurophysiology Society 2008 guideline. A check of all electrode digital EEG recording systems was stored for at least 10 s of recording (Ebersole & Pedley, 2003), and electrophysiological signals were normalized (Qureshi & Jha, 2017). To minimize circadian variations, EEG recordings were conducted at the same time of day for 20 min in a relaxed supine position with eyes closed. During each recording, environmental factors that affect EEG, such as temperature, noise, or bright light were controlled. Additionally, participants were instructed not to consume any caffeine-containing products or engage in excessive physical activity for the preceding 24 hr because these factors can also affect changes in resting EEG waves. The subjects were told to refrain from making unnecessary motions as well as from wearing any metal or electronic devices during the experiment. Before the experiment, the scalp's oil and dead skin cells were removed from the area where the electrode was attached with an alcohol swab. NūPrep skin prepping gel (Weaver and Company, USA) was then used to gently clean the scalp. Before the experiment, the participants rested in a sedentary position for 5 min. For the purpose of placing electrodes, Ten20 conductive EEG paste was applied to various areas of the scalp. Electrodes made of Ag-AgCl discs were used for recording. The EEG electrodes were placed for 16 scalp channels at frontoparietal (FP1–FP2), midfrontal (F3–F4), lateral-frontal (F7–F8), temporal (T3–T4), dorsotemporal (T5–T6), central (C3–C4), parietal (P3–P4), and occipital (O1–O2) regions following the

International 10–20 System of Electrode Placement. The left and right earlobes (A1 and A2) were used as the locations for the reference and ground electrodes. These electrodes were connected to the EEG-32 SS Traveler, a 22-channel digital EEG machine, of which 16 channels were used. Alpha waves (≥50% of the recording) were confirmed before and after the study, with electrode impedance maintained below 5 kΩ. The RMS analysis software was used to process and analyze the EEG data. By visual inspection, the sweeps and blink artifacts were eliminated. During preprocessing, recordings were re-referenced using a common average reference. In order to determine the mean power frequency (MPF), frequency band analyses were carried out using the fast Fourier transformation (FFT). The EEG frequency was set to the delta wave (0.5–4.0 Hz), theta wave (4–7 Hz), alpha wave (8–13 Hz) and beta wave (14–30 Hz), and they were analyzed and calculated with MPF. Following the exclusion of all artifacts at all channels that exceeded ±100 V, each participant's artifact-free epochs were calculated.

### Statistical Analysis

SPSS version 28.0 was utilized for conducting statistical analysis. The distribution of all outcome measures was shown to be normal using the Shapiro-Wilk test, skewness, and histogram. The outcome variables that show nonnormal distribution were analyzed using a nonparametric test or log-transformed before proceeding to inferential analysis. The Pearson correlation coefficient was used to calculate the associations between cognitive functions and sleep. *R* values of 0.10 or less are frequently seen as having a small impact, 0.10 to 0.50 as having a moderate impact, and 0.50 or more as having a considerable impact (Alghwiri et al., 2018). Multiple linear regression was performed gradually to see if sleep functions significantly predicted cognitive functions and EEG brain waves after adjusting for confounders. Regression analysis was used to investigate the predictive power of age, gender, and body mass index (BMI) in relation to sleep measurements.

## Results

A sample of 32 sleep disturbed collegiates with demographic characteristics mean (age = 20.93 ± 1.50 years, height = 161.84 ± 6.53, weight = 65.45 ± 3.98 kg, and BMI = 26.90 ± 1.09 kg/m²) was assessed for sleep functions (measured by PSQI and ESS), cognitive functions (measured by ERP P300), and brain waves characteristics (EEG; Table 1).

**Table 1**

*Mean and Standard Deviation Scores for Sleep Measures, Encephalographic Brain Waves and Cognitive Functions in College Students With Sleep Disturbance*

| Test | Mean | *SD* |
|---|---|---|
| **Sleep Measures** | | |
| PSQI (score) | 9.75 | 0.98 |
| ESS (score) | 11.50 | 0.50 |
| **EEG Brain Waves** | | |
| Alpha (Hz) | 0.02 | 0.002 |
| Beta (Hz) | 3.38 | 0.10 |
| Delta (Hz) | 0.65 | 0.09 |
| Theta (Hz) | 0.08 | 0.005 |
| **Cognitive Functions** | | |
| AMP (μV) | 3.64 | 0.59 |
| LAT (ms) | 265.14 | 45.24 |

Abbreviation: PSQI: Pittsburgh Sleep Quality Index; ESS: Epworth Sleep Scale; EEG: electroencephalography; AMP: event-related potential P300 amplitude; LAT: event-related potential P300 latency; *SD*: standard deviation. Data are presented as mean and *SD*.

To evaluate the association between several areas of sleep function (PSQI and ESS), cognitive functions (AMP and LAT), and brain waves (alpha, beta, delta, and theta), we computed Pearson's correlation (Table 2).

**Table 2**

*Correlation Analysis Between Sleep Measures (Sleep Quality and Daytime Sleepiness), EEG Brain Waves (Alpha, Beta, Delta, and Theta) and Cognitive Functions (Event-Related Potential P300 Amplitude and Event-Related Potential P300 Latency) in College Students With Sleep Disturbance (R and P Values Are Presented)*

| | **Sleep Measures** | | | |
|---|---|---|---|---|
| | **PSQI** | | **ESS** | |
| | ***r*** | ***p*** | ***r*** | ***p*** |
| **EEG Brain Waves** | | | | |
| Alpha | −0.36* | .04* | −0.40* | .02* |
| Beta | −0.11 | .53 | 0.13 | .45 |
| Delta | 0.30 | .09 | −0.03 | .83 |
| Theta | 0.31 | .07 | 0.07 | .66 |
| **Cognitive Functions** | | | | |
| AMP | −0.48** | .005** | −0.47** | .006** |
| LAT | 0.035* | .04* | 0.43* | .01* |

Abbreviation: PSQI: Pittsburgh Sleep Quality Index; ESS: Epworth Sleep Scale; EEG: electroencephalography; AMP: event-related potential P300 amplitude; LAT: event-related potential P300 latency. *$p < .05$; **$p < .01$

The relationship between PSQI and beta was computed, and it shows a nonstatistically significant weak negative correlation ($r$ = −0.11, $p$ = .53). Similar correlation analyses were performed between PSQI and delta ($r$ = 0.30, $p$ = .09) and between PSQI and theta ($r$ = 0.31, $p$ = .07), but no association was found in any of this analysis. Intriguingly, a negative linear correlation between PSQI and AMP ($r$ = −0.48, $p$ = .005**; Figure 1B), positive linear correlation between PSQI and LAT ($r$ = 0.35, $p$ = .04*; Figure 1C), and negative linear correlation between PSQI and alpha ($r$ = −0.36, $p$ = 0.04*; Figure 1A) was found, demonstrating that participants who showed increased amplitude value for P300 wave, decreased latency value for P300 wave and had less sleep problems when analyzed for PSQI score, respectively.

**Figure 1A.** *Pearson Correlation Analysis Showing the Statistically Significant Association of PSQI (Pittsburgh Sleep Quality Index) With Alpha (Resting EEG Alpha Wave).*

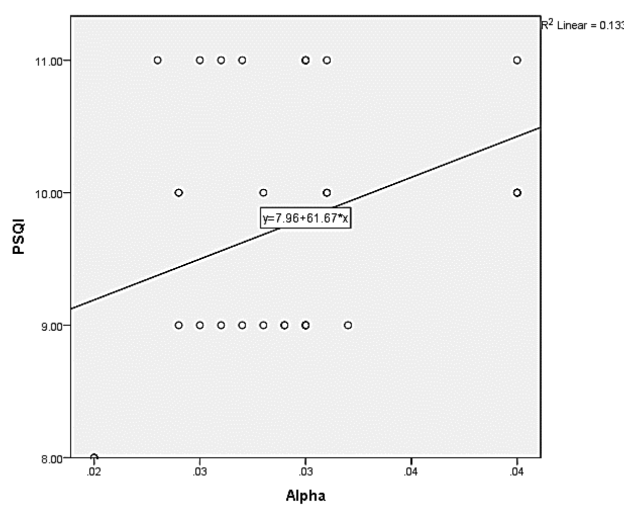


**Figure 1B.** *Pearson Correlation Analysis Showing the Statistically Significant Association of PSQI (Pittsburgh Sleep Quality Index) With AMP (Event-Related Potential P300 Amplitude).*

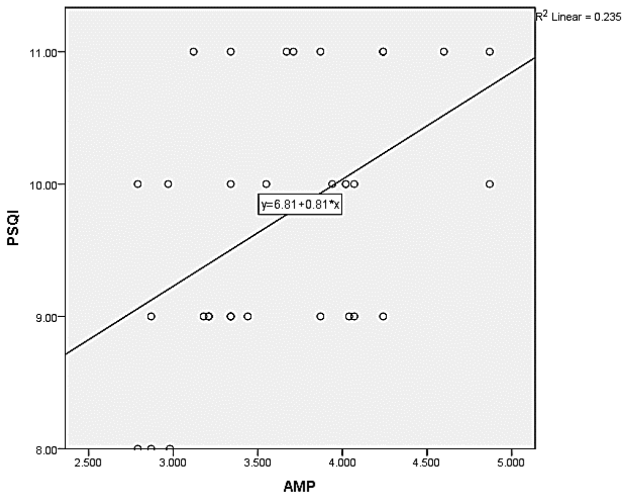
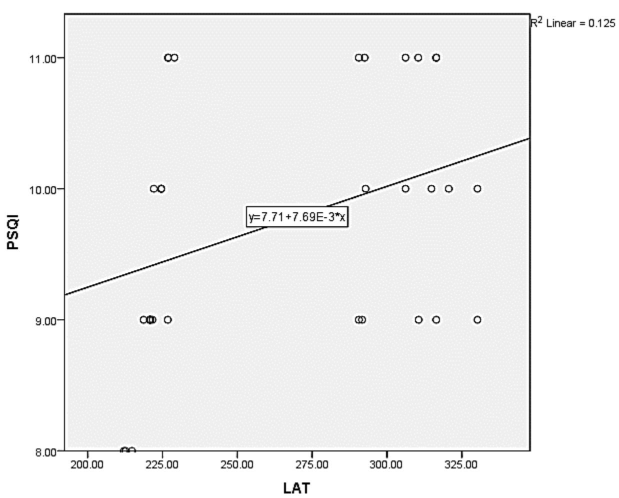



**Figure 1C.** *Pearson Correlation Analysis Showing the Statistically Significant Association of PSQI (Pittsburgh Sleep Quality Index) With LAT (Event-Related Potential P300 Latency).*




Further, participants with increased alpha power have less sleep disruption. We next conducted a Pearson's correlation for sleep function (ESS), cognitive functions (AMP and LAT), and brain waves (alpha, beta, delta, and theta; Table 2). The relationship between ESS and beta was computed, but it did not show any association ($r$ = 0.13, $p$ = .45). Similarly, a correlation analysis was also done between ESS and delta ($r$ = −0.03, $p$ = .83) and between ESS and theta ($r$ = 0.07, $p$ = .66), but no relation was found in this analysis. Importantly, a negative linear correlation between ESS and AMP ($r$ = −0.47, $p$ = .006**; Figure 2B), positive linear correlation between ESS and LAT ($r$ = 0.43, $p$ = .01*; Figure 2C), and negative linear correlation between ESS and alpha ($r$ = −0.40, $p$ = .02*; Figure 2A) were found, demonstrating that participants who showed increased P300 wave amplitude decreased P300 wave latency and are less likely to feel drowsy during daytime. Further, participants having increased alpha power have less chances of daytime sleepiness.

**Figure 2A.** *Pearson Correlation Analysis Showing the Statistically Significant Association of ESS (Epworth Sleep Scale) With Alpha (Resting EEG Alpha Wave).*

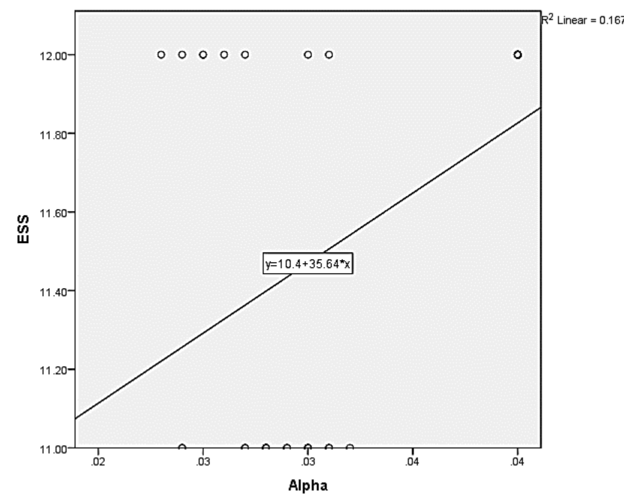



**Figure 2B.** *Pearson Correlation Analysis Showing the Statistically Significant Association of ESS (Epworth Sleep Scale) With AMP (Event-Related Potential P300 Amplitude).*

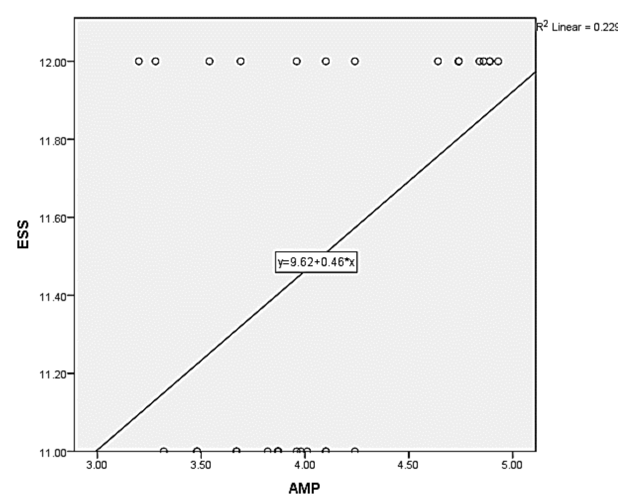
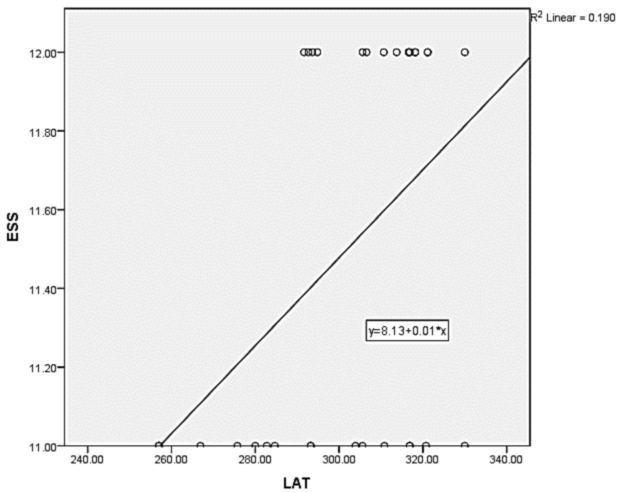


**Figure 2C.** *Pearson Correlation Analysis Showing the Statistically Significant Association of ESS (Epworth Sleep Scale) With LAT (Event-Related Potential P300 Latency).*




Multiple stepwise linear regression analyses ($R^2$) were carried out for PSQI with AMP, LAT, and alpha (Table 3). The regression analysis ($R^2$) revealed that PSQI was found to significantly predict the AMP, $F(1, 30) = 9.23$, $P = .005$*, with an $R^2$ of 0.23 and beta coefficient of −0.29; LAT, $F(1, 30) = 4.29$, $P = .04$*, with an $R^2$ of 0.12 and beta coefficient of 16.27; and alpha, $F(1, 30) = 4.58$, $P = .04$*, with an $R^2$ of 0.13 and beta coefficient of −0.002. Similarly, regression analysis ($R^2$) was carried out for ESS with AMP, LAT, and alpha (Table 3). The value of $R^2$ revealed that ESS was found to significantly predict the AMP, $F(1, 30) = 8.90$, $P = .006$**, with an $R^2$ of 0.22 and beta coefficient of −0.49; LAT, $F(1, 30) = 7.06$, $P = .01$*, with an $R^2$ of 0.19 and beta coefficient of 17.04; and alpha, $F(1, 30) = 6.01$, $P = .02$*, with an $R^2$ of 0.16 and beta coefficient of −0.005.

**Table 3**
*Findings of Multiple Stepwise Linear Regression Analysis ($R^2$ and Beta Coefficients Values are Presented)*

| Regression Weights | Beta Coefficients | $R^2$ | $F$ | $p$-value |
|---|---|---|---|---|
| PSQI → Alpha | −0.002 | 0.13 | 4.58 | .04 * |
| PSQI → AMP | −0.290 | 0.23 | 9.23 | .005** |
| PSQI → LAT | 16.270 | 0.12 | 4.29 | .04 * |
| ESS → Alpha | −0.005 | 0.16 | 6.01 | .02* |
| ESS → AMP | −0.490 | 0.22 | 8.90 | .006** |
| ESS → LAT | 17.04 | 0.19 | 7.06 | .01* |

Abbreviation: PSQI: Pittsburgh Sleep Quality Index; ESS: Epworth Sleep Scale: EEG: electroencephalography; AMP: event-related potential P300 amplitude; LAT: event-related potential P300 latency. *$p < .05$; **$p < .01$

## Discussion

It has been demonstrated that university students' sleep habits have a variety of effects on their brain and cognitive abilities. Lee and colleagues showed that sleep deprivation lengthens the LAT and shortens the AMP (H.-J. Lee et al., 2003). Furthermore, on a range of cognitive tasks, the group experiencing sleep problems did worse on a variety of cognitive tests (Haimov & Shatil, 2013). The neuropsychological batteries test (NBT; Robbins et al., 1994), electrophysiological and EEG techniques like ERP (Duncan-Johnson & Donchin 1982), and imaging techniques like functional magnetic resonance imaging (fMRI; Lee et al., 2004) are some of the methods used to test cognition. Even while fMRI is more accurate, its expensive cost prevents it from being used frequently in clinical settings. According to Hanagasi & colleagues, (2002), the ERP P300 is the most widely used and unique biomarker for assessing cognition, and it can be used often in clinics (Hanagasi et al., 2002). These assessments have reached a degree of consistency that establishes them as the gold standard for assessing higher order cognitive processes. In this work, we assessed how sleep functions (PSQI and ESS), cognitive functions (ERP P300), and brain waves (resting EEG) relate to one another in sleep-disturbed college students. Additionally, we evaluated the target sample's cognitive abilities and brain waves in relation to sleep quality parameters.

This study's main findings are as follows: (a) measures of prefrontal cognitive functions and alpha brain wave are significantly correlated with subjective sleep quality and daytime sleepiness; and (b) the PSQI global score and ESS score, which indicate overall sleep quality and daytime sleepiness respectively, were found to significantly predict cognitive alterations and EEG brain alpha rhythm in sleep-deprived college students, even after correcting for a variety of clinical covariates that may influence human brain wave profile. In the current study, sleep quality (PSQI) and daytime sleepiness in sleep-disturbed college students showed a strong link with the tests evaluating prefrontal cognitive functions like AMP and LAT evaluated on ERP P300. The current study's results are in line with those of an earlier investigation, which found a statistically significant positive association between PSQI global score and LAT and a statistically significant negative correlation between the PSQI global score and AMP (Aseem et al., 2021). These findings are in line with earlier research on smaller samples (Aseem et al., 2018), as these studies show that sleep deprivation impairs cognitive performance, mood profile, and motor function. Sleep deprivation leads to a destabilization of the waking state and overall neurocognitive function (Goel et al., 2009) by weakening the peak circadian drive for wakefulness over time (Xu et al., 2011) and affecting brain processing (Wright et al., 2012). The prefrontal cortex, the portion of the brain linked to attention and working memory, is where the detrimental effects of these neurocognitive effects are most noticeable (Alhola & Polo-Kantola, 2007) and direct correlation between sleep-related memory issues and anatomical alterations in the prefrontal cortex was found (Acosta-peña et al., 2015). Our research also showed that total sleep quality is a significant predictor of prefrontal cognitive abilities. Prefrontal cortex and anterior cingulate cortex play a major role in working memory, attention, and executive function (Kondo et al., 2004). Furthermore, neuronal activity originating from the prefrontal cortex and probably the temporoparietal junction makes up the P300 triggered in the auditory oddball (Friedman, 2003). It has been demonstrated that activating this network lessens postacute sleep deprivation (Wu et al., 1999). Very few preliminary research (Kronholm et al., 2009) demonstrate similar ability of subjective sleep measuring scales to predict cognitive deterioration, however not supported by adequate literature.

We also looked for correlations between various EEG brain waves from resting states and sleep functions (PSQI and ESS). The Pearson's correlational analysis revealed a negative statistically significant relationship between the PSQI global score and the alpha band, and it also revealed a substantial impact of the PSQI global score on the power of the alpha band. Our results support one study that discovered a statistically significant relationship between alpha band and sleep quality (PSQI; Xiong et al., 2023). This suggests that there is a correlation between the alpha EEG brain wave and the subjects' sleep quality, and that when other factors are taken into account, the subjects' sleep quality can independently influence the alpha band power. The PQSI scores, on the other hand, did not significantly affect the EEG brain waves in the beta, theta, or delta bands in this model, which may suggest that the association between the PQSI scores and other frequency bands was not significant in this dataset. Additionally, the present study's finding of a negative correlation between ESS and alpha band is consistent with earlier research (El Mekkawy et al., 2022), which shows that an increase in the patient's degree of sleepiness was accompanied by an increase in the ESS score and decrease in alpha relative power. Our results, however, showed a negative connection, in contrast to the prior study's positive correlation (Grenèche et al., 2008). This could be explained by the fact that, in contrast to what we did in our work, they employed absolute alpha power rather than relative or mean frequency alpha power in their quantitative EEG analysis.

## Conclusion

Overall, the study's findings suggest that assessing the brain function state of sleep deprived college students may be accomplished by a combination of quantitative EEG and ERP P300 analysis. In any clinical research situation, these approaches would provide sufficient recording and subsequent comparison with other neurophysiological and cognitive characteristics. Finally, our study offers early data about the relationship between sleep function measurements (PSQI and ESS) and cognitive functions associated to the prefrontal brain in a sample of college students. Moreover, there were noteworthy associations found between the alpha band EEG data and sleep functions (PSQI and ESS). Nevertheless, our study has number of possible disadvantages, one of being the small convenience sample size, which may limit the generalizability of the findings to broader college populations. Further, without a control group of students without sleep disturbances, it is challenging to establish causality or compare cognitive functioning between the groups. It should be noted that complete brain montages were not employed for resting EEG recordings in the current investigation because we measured the brain waves using

(16 + 2 = 18) electrodes. For ERP P300 recording in our work, we only used two sites (Cz and Fpz), despite the fact that high-density arrays are already available therefore, future studies might employ various numbers of channels and sensory inputs.

## Authors' Declarations

The authors declare no conflict of interest. There was no grant support for this study. There is no financial interest.

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