ORIGINAL ARTICLE

Effect of Partial Sleep Deprivation on Auditory Event Related Potential and Reaction Time in Medical Students

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Abstract

The aim of the present study was to evaluate the effects of partial sleep deprivation on the cognitive status and alertness of medical students using auditory event related potential (ERP) and auditory reaction time (RT) using sleep questionnaire, Stanford Sleepiness Scale (SSS), auditory ERP (P300) and RT. Sleep time was significantly shorter in the test condition as compared to the baseline values ($p<0.001$). Significantly higher values on the SSS ($p<0.05$) were found after sleep restriction. The P300 latency and amplitude significantly decreased ($p<0.01$ and $p<0.001$ respectively) when the test values were compared to the baseline. RT also showed a significant decrease ($p<0.001$) in the test condition as compared to the baseline values. However, no significant correlation could be ascertained between SSS and P300 amplitude and latency as well as RT. This study demonstrates that partial sleep deprivation produces variable effects on the cognitive status of medical students as reflected by the decrease in P300 amplitude and latency. Alertness of medical students seemed to show an improvement as reflected by the decrease in RT.

Key Words

Alertness, Cognition, Partial Sleep deprivation, Neurobehavioral Function

Introduction

The effect of altered sleep quality and quantity has a significant bearing on the psychological and physiological profile of an individual including medical students. Sleep deprivation has been found to degrade aspects of neurocognitive performance and alertness (1). Specific behavioral and cognitive domains like mood, executive attention, reaction time (RT), working memory and divergent higher cognitive function have been consistently found to be vulnerable to 2-5 days of total sleep deprivation (2).However, studies of partial sleep deprivation (i.e. sleep restriction to <6hours per night), have produced inconsistent results on cognitive performance and neurobehavioral functions (3, 4). Partial sleep deprivation is a common condition afflicting one third or more of normal adults in modern society due to a wide range of factors including professional demands, social and domestic responsibilities and sleep disorders (5). Therefore, there is increasing concern about the potential deleterious effects of insufficient sleep in some groups of society including medical students who are under perpetual physical and mental stress and who also tend to lead a sleep-deprived life. This aspect has been studied in interns, residents and emergency physicians (6, 7). These studies suggest that sleep loss contributes to adverse events and medical errors occurring in hospitals. Much less is known about how partial sleep deprivation affects the cognitive status and behavioral functions in the medical students.Sleep deprivation has also been seen to induce alterations in the morphology of auditory event related potential (ERP) (8). The use of auditory ERP provides a neurophysiological means of investigating higher cerebral function that is related to attention, cognition, information processing and working memory as well as level of arousal (9). Most of the studies have been done to evaluate the effects of total sleep deprivation on ERP (10, 11). However, there is paucity of available literature on the changes produced in the morphology of P300 component of ERP following partial sleep deprivation.Hence, the present study was conducted with the aim to evaluate the effects of partial sleep deprivation on the cognitive status and alertness of medical students using auditory ERP and RT.

Material and Methods

The study was conducted in the department of Physiology, MAMC, New Delhi. Approval from the IEC & written informed consent was obtained.The study

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group comprised of 34 (26 male, 8 female), apparently healthy, normal, young medical student volunteers randomly slected in the age group of 17-20 years.They had no history of medical, neurological, hearing or sleep related disorder. Those who were chronically sleep deprived were excluded from the study.

Experimental Design: The subjects served as their own controls. They were tested twice, once during a light academic schedule with no written theory examinations for a week (baseline) and once on the day of written theory examination of first MBBS professional subjects (test). On experimental days, four tests were administered in the same order in the afternoon between 1-4 P.M. The subjects first completed a questionnaire for self-assessment of their sleep habits followed by subjective rating, which included Stanford Sleepiness Scale (SSS). They then carried out auditory ERP (P300) and auditory reaction time (RT) tests. The test recordings were done after the written theory examination to avoid undue stress and discomfort to the students. As it is not possible to measure P300 for all students on the same day, evaluation was carried out across different written theory examinations. Therefore, correlation of the results with the performance of the students during the examination was not part of the study design. In case of female subjects, the recordings were taken during the preovulatory phase to rule out changes related to the menstrual cycle.

*Questionnaire:*In both the experimental sessions, the subjects were first given a questionnaire about. (i) Sleep habits (normal length and normal bedtime) (ii) Self estimated sensitivity to sleep deprivation (iii) Length of sleep the night before

Subjective Sleepiness: Subject's self-ratings of sleepiness were assessed using SSS3. The SSS is a one-item choice scale consisting of seven numbered statements that describe alertness states ranging from 1-7.

Recording of ERP (P300): P300 was measured in a standard audiometric, soundproof room using an E.B.Neuro machine (Evoked potential measuring system-Galileo NT Firenze, Italy) as per the guidelines of the International Federation of Clinical Neurophysiologists. The latency and amplitude of the waveform were recorded and saved in the computer as reported by Nuwer *et al* (12).

Recording of Reaction Time: Auditory RT was measured using a simple electrical setup in quiet surroundings in the laboratory. A signal marker with two tapping keys, a short-circuiting key, a recording drum and 6 volts of mains supply was connected in series. Recorded of the auditory RT in milliseconds was done as reported by Borker AS *et al* (13).

Statistical Analysis

The data obtained as mean and standard deviation. Wilcoxon's non-parametric test and Spearman rank order correlation test was done for the behavioral results and subjective rating data. The critical value for the 2-tailed correlation was set at a 5% level of significance. P300 amplitude and latency and auditory RT data in both sessions of the study were compared by applying student's paired't' test. The p value of statistical significance was set at 0.05. 5X5 correlation coefficient grid was created and Pearson correlation coefficient was calculated for the percentage change in each of the variables. The correlation was considered significant if the p value was <0.05.

Results

The results were calculated from 34 students who participated in all evaluations. Two subjects who reported having slept for < 6 hours in the baseline condition were excluded from the study. 2 male and 3 female subjects dropped out of the study.As can be seen in *table I*, sleep time was significantly shorter in the test condition as compared to the baseline values ($p<0.001$). Significantly higher SSS values, ($p<0.05$) were found after sleep restriction.*Table II* shows the mean and standard deviation of the baseline and test P300 latency and amplitude and auditory RT. The P300 latency and amplitude significantly decreased ($p<0.01$ and $p<0.001$ respectively) when the test values were compared to the baseline. Auditory RT also showed a significant decrease ($p<0.001$) in the test condition as compared to the baseline values. *Figure 1(a-d)* represents the results of the questionnaire during the light academic schedule and in the test session. Approximately 53% of the subjects had slept for < 4hours on the night prior to the examination.64% of the partially sleep deprived subjects rated themselves as "not especially" sensitive to sleep deprivation.There was no significant correlation of SSS with P300 amplitude and latency and RT ($r = -0.22$, $p = 0.21$; $r = -0.02$, $p = 0.92$; $r = 0.20$, $p = 0.25$; respectively).

Discussion

The experimental design of the present study is different from that of earlier studies, where either cumulative effects of partial sleep deprivation were studied or they were performed under strict, continuous surveillance (3-5, 10-11). Sleep restriction in this study was carried out in conditions simulating a real life situation, wherein all the subjects adhered to their usual schedule. This ensured better compliance and willingness of the participants to take part in sleep deprivation experiment. Lesser number of females participated, as their protocol was difficult to establish. In most cases the gap between

a baseline and test recording was 1-2 months. It did not extend across different time of day and seasons, hence, there was no cause related to diurnal or seasonal variations in the recordings.The participants reported sleeping for 7.03 + 0.76 hours per night during light academic schedule. Although, the reason for this duration of sleep at baseline was not clear, we considered the length of sleep in this study to be acceptable as a baseline, since a habitual 6-8 hours of sleep per night was also set as a baseline in many other partial sleep restriction studies (4, 14-15). On examination day, they slept an average of 4.15 + 1.14 hours, with a difference of 2.88 + 1.24 hours. This sleep duration was less than the 4.5-5.5 hours of uninterrupted sleep generally required per night to maintain maximal performance (16). The increase in SSS on the examination day was less significant ($p<0.05$) as compared to the significant decrease ($p<0.001$) in sleep duration. This is in close agreement to a previous controlled-dose-response study performed on chronic sleep restriction (17). In this study, much smaller increases in subjective sleepiness and fatigue ratings were reported following 4 and 6 hours time in bed for two weeks.The results of the present study revealed that there was a significant decrease ($p<0.001$) in P300 amplitude along with a significant decline ($p<0.01$ and $p<0.001$ respectively) in both P300 latency and RT following partial sleep deprivation. This is in contradiction to other studies, but in a different context (10). In these studies, decrease in P300 amplitude was accompanied with increased P300 latency and RT following total sleep deprivation. However, in another study conducted during 18 hours of sleep restriction, the researchers have shown that the changes in P300 amplitude and latency were not associated with significant changes in RT (11). Such variability during cognitive and motor performance in sleep-deprived subjects has been hypothesized to reflect wake state instability. This refers to the unpredictable cognitive performance of a sleep deprived individual influenced by interactive, reciprocally inhibiting neurobiological systems mediating sleep initiation and wake maintenance (18). Multiple brain areas including inferior parietal lobule, frontal lobe, hippocampus, medial temporal lobe and locus ceruleus have been postulated as generators of P300 (19). Motivation and partial sleep deprivation are two factors that can be considered to explain the results. An enhanced motivation and alertness is present during the examination time. The ability of the sleep- deprived subjects to engage in motivated behavior to compensate for or mask the cognitive effects of sleep loss is also well-recognized (20). Another factor to be considered is the increased activation of frontal and prefrontal cortices that occurs during performance of a familiar working memory task under periods of increased homeostatic drive for sleep (15). Considering that the oddball task as well as auditory RT was relatively simple, it is plausible that the decrease in P300 latency and RT may be due in part to the subjects' prior experience at carrying out these experimental tasks. Moreover, examination as a stress could have led to noradrenergic brain activation (21).Moreover this can be explained on the basis of recent reports sugesting sleep deprivation to affect neuroendocrine function, hormone release and metabolism(22,23). This, in turn, could have induced facilitation of neural processes promoting alertness, attention, motivation and working memory response in medical students. It is also believed that a short duration of sleep deprivation may not impair tasks that are designated to test higher cortical function and the ability to maintain sustained attention is the only consistent finding (20).Furthermore, intersubject & intrasubject differences in the basal sleep need & in

Table I. Behavioral and Subjective Rating Data (n=34)

S. No.	Variable	Baseline	Test	Wilcoxon z	P value
1.	Sleep time (hours)	7.03 ± 0.76	4.15 ± 1.14	-5.12	<0.001
2.	SSS	2.00 ± 0.74	2.12 ± 0.73	-2.00	<0.05
3.	Hours of sleep loss	-	2.88 ± 1.24	-	-

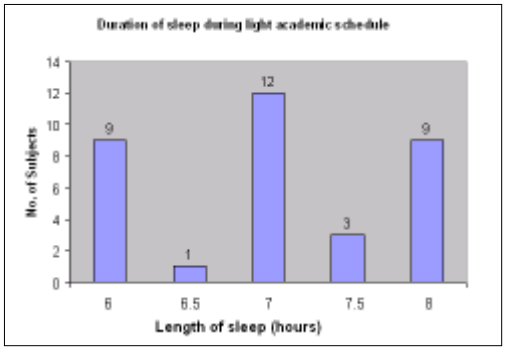
Values are Mean + SD

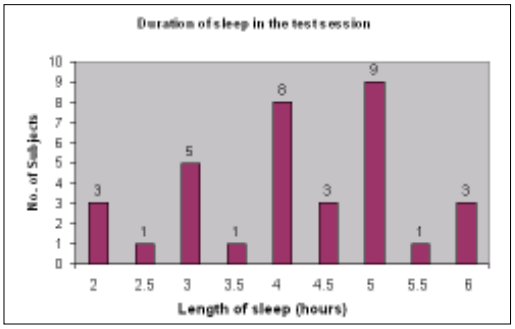
Table II. P300 Amplitude, Latency and Auditory RT in Baseline and Test Conditions

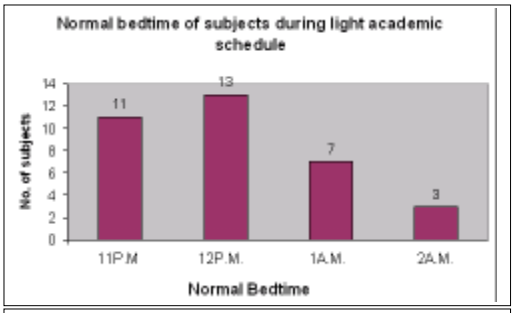
S. No.	Variable	Baseline	Test	P value
1.	P300 amp.(μV)	17.33 ± 6.42	14.27 ± 5.15	<0.001
2.	P300 lat.(msec)	311.71 ± 23.41	297.91 ± 27.88	<0.01
3.	RT (msec)	200.59 ± 34.59	155.59 ± 36.24	<0.001

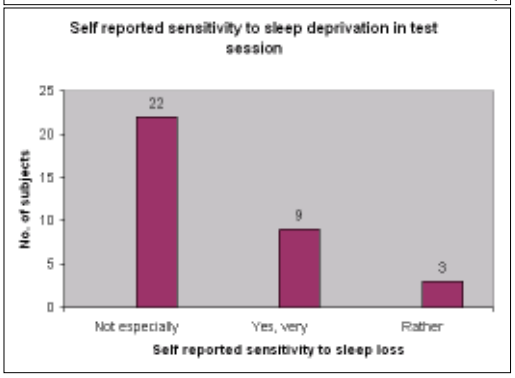
Values are Mean + SD; P300 amp. = P300 amplitude; P300 lat. = P300 latency; RT = Reaction time; μV= Microvolt; msec = Milliseconds

Fig Ia-d. Results of the Questionnaire on Normal Sleep Habits, Self Reported Sensitivity to Sleep Deprivation & Length of Sleep the Night Before Written Examination









resistance to and vulnerability to the cognitive effects of sleep loss have also been observed (1).Interaction between various neurotransmitter systems regulating alertness & cognition may influence the neural generators of these potentials (P300 & RT) in the brain.

Conclusion

The above electro-neurophysiological evidence of decrease in reaction time and amplitude and latency of the P300 wave, represent variable effect on psychomotor vigilance and cognitive status in medical students on the examination day. This may be attributed to the resultant effect of partial sleep deprivation and motivation.

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