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ORIGINAL ARTICLE

Assessing the impact of sleep restriction on the attention and executive functions of medical students: a prospective cohort study

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Abstract

Objective To compare the performance of medical students regarding attention and executive functions during a period of sleep restriction (insufficient sleep; period of classes) and a period of free sleep (sufficient sleep; vacation period).

Background Sleep deprivation is associated with poor academic outcomes. Few studies have assessed the cognitive changes associated with sleep deprivation due to insufficient sleep syndrome in students and how they occur in real-life situations.

Methods This was a prospective cohort study. Medical students were assessed at two moments (class and vacation). The interval between assessments was 30 days. The Pittsburgh Sleep Quality Index, the Consensus Sleep Diary, the Montreal Cognitive Assessment, the Psychomotor Vigilance Test (PVT) and the Wisconsin Sorting Cards Test were used.

Results Forty-one students were assessed, 49% were female, with a median age of 21 (20; 23) years. There was a lower number of hours slept (5.75 (5.4; 7.0) vs 7.33 (6.0; 8.0) hours; $p=0.037$), and a significantly poorer performance in the PVT (mean reaction time, $p=0.005$; Minor lapses, $p=0.009$) during the period of classes when compared to the vacation period. There was a correlation between the variation in hours of sleep of the two assessments and a variation in minor lapses in the two assessments (Ro: -0.395; $p=0.011$; Spearman's correlation).

Conclusions Students had fewer hours of sleep and more reduced attention during the period of classes than during the vacation period. This decrease in sleeping hours was correlated with more impaired attention.

Keywords Sleep deprivation · Attention · Executive function · Neuropsychological tests · Cognitive dysfunction · Students

Introduction

The need for sleep varies significantly among individuals and throughout life. According to the recommendation of the American Academy of Sleep Medicine, it is estimated that adults should regularly sleep 7 or more hours a night in order to promote optimal health [1, 2]. Despite this, around thirty percent of adults sleep less than 6 h [3].

Sleep deprivation exists when sleep is insufficient to maintain adequate alertness, performance, and health, either because of reduced total sleep time (decreased amount) or sleep fragmentation due to frequent awakenings, impairing the architecture of the sleep stages (decreased quality) [4].

Chronic sleep deprivation develops when an individual routinely sleeps less than the amount needed for optimal functioning [4]. Symptoms of excessive daytime sleepiness associated with chronic and voluntary sleep restriction characterize insufficient sleep syndrome (ISS) [5]. This may impair physical health and cognition, affecting memory, attention, and executive functions [6–9], thereby negatively impacting work and academic life and the quality of life .[10, 11].

The electrophysiological environment produced during sleep is important for consolidating new memories that were learned during the day [12]. In addition, sufficient healthy

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sleep at night restores the neurochemical homeostasis of the ascending reticular activating system (ARAS), thereby helping it to function well during the following day, enabling the necessary levels of alertness and attention to be maintained for waking daytime activities [13]. Sleep deprivation also impairs the activities of the prefrontal cortex, leading to reduced levels of attention and executive functions [14].

Some studies have demonstrated an association between shorter sleep duration and impaired cognitive functions, but most of these have been performed with artificial manipulation of sleep duration in sleep laboratories [13, 15–17]. These studies observed a decline in sustained attention, long-term memory and executive functions [13, 14, 16].

University students are especially affected by insufficient sleep syndrome. They present a high prevalence of insomnia and stress that may interfere with sleep quality [18–20]. Students also often have a voluntary restriction of sleep time so as to meet their academic and/or social demands, which thereby interferes with the amount of sleep [20]. Insufficient sleep is associated with poor academic outcomes for these students [21–23]. However, few studies have assessed the cognitive changes resulting from insufficient sleep. Changes in sustained attention, working memory, and executive function have mainly been reported [7, 21]. There are no studies, however, that assess the effect of sleep restriction in real-life situations in this group [16].

This study aims to compare the performance of medical students with regard to attention and executive functions during a period of insufficient sleep (period of classes) and a period of sufficient sleep (vacation period).

Method

This was a prospective cohort study, and included medical students who were regularly enrolled in the first 4 years of medical school at the Universidade Federal de Pernambuco, in the city of Recife, North-eastern Brazil.

Each class has its own WhatsApp group where information on academic activities is communicated. Study participants were recruited through advertisements made in these groups (convenience sample).

It was estimated to include 40 students. This number was not estimated from the sample size calculation, but rather from the number of participants who had been included in previous studies. Those which had conducted an objective comparison of cognition in a before–after model had included between 9 and 72 participants, with a median of 16 participants per study [16].

The students were assessed at two moments: during a period with no classes (vacation), in which they had the opportunity to follow a normal course of sleep and later during a period when they were attending classes, when there is a voluntary restriction of sleep time in order to meet academic demands, characterized as insufficient sleep. The second assessment was undertaken 30 days after the first. At the moment of the assessment during the period of classes, students were not sitting exams. Subjects were included between January and June 2021.

All volunteers signed an informed consent form. This research was approved by the Research Ethics Committee of the Health Sciences Center, Universidade Federal de Pernambuco, Recife (CAAE: 40486620.2.0000.5208; number of the approval document is: 4.488.618).

Instruments used

1. SLEEP-50. This is a screening test to assess whether there are potential risks of sleep disorders that could influence the quality of sleep. The test consists of 50 questions with answers based on the previous month, and which may be assessed on a scale of 1 to 4 (1—never or rarely; 4—high frequency). The questions track insomnia, obstructive sleep apnea, circadian rhythm disorders, narcolepsy, nightmares, restless legs syndrome, sleepwalking, as well as assessing factors that influence sleep and the impact of sleep on daily activities [24].
2. The Brazilian version of The Hospital Anxiety and Depression Scale (HADS) was also used, which is subdivided into two subscales of seven items, one for depression and one for anxiety. Individuals with 8 or more points in the respective subscales were classified as having possible anxiety or possible depression [25].
3. Consensus Sleep Diary (CSD) used to assess sleep time and the number of awakenings the night before the two assessments [26, 27].
4. Pittsburgh Sleep Quality Index (PSQI) used to assess sleep of the previous month and answered at the beginning of the two study periods. It is a validated method based on polysomnographic studies and consists of 19 self-assessment questions, which assess various parameters such as an estimate of sleep latency, sleep duration, and the frequency of sleep problems. This questionnaire provides an index from 0 to 21 points. Higher index scores denote poorer sleep quality. Scores higher than 5 are suggestive of significant sleep problems [28].
5. Montreal Cognitive Assessment (MoCA). This is a cognitive screening test that is widely used in clinical assessments and has demonstrated sensitivity in detecting cognitive changes resulting from sleep restriction and sleep disorders [29]. This test was applied in the two assessments. As the MoCA was reapplied within a period of less than 3 months, in accordance with the developer's instructions, different versions of the test were used in order to try to reduce the learning effect [30]. The test was administered by an interviewer

with certification for applying it (certification number BRMOTPE7054526-01).

6. Psychomotor Vigilance Test (PVT). This test assesses attention through an individual's reaction time after a stimulus [14]. This test is available through the PC-PVT software and lasts approximately 10 min per participant [31]. It is a highly reliable and sensitive method to assess the effect of sleep deprivation on attention [14]. For this test, the Steelseries Rival300s mouse was used. The mean reaction time to stimuli is measured in milliseconds and minor lapses are assessed. The definition of minor lapses are responses that exceed 500 ms after the stimulus has appeared [31].
7. Wisconsin Sorting Cards Test (WCSC). This test was used to assess executive functions and was performed on a computer through the Psytoolkit platform with 60 sessions. In each session, the individual receives four cards, with individual characteristics of color, shape and number, and has to join each one of them with a new card received, according to an unknown criterion. Each session had a criterion to be extracted. In this way, through trial and error, the individual is able to extract the criterion that was followed. This test is widely used in sleep research. The data provided by this test are the number of perseverative errors that demonstrate difficulty in cognitive flexibility, one of the components of executive functions. A higher number of errors is associated with a difficulty in controlling impulses and low cognitive flexibility, both components of the executive function domain [32].

Statistical analysis

The statistical analyses were performed using SPSS 21.0 (IBM Corporation, Armonk, NY, USA).

Quantitative data were presented as medians and interquartile range (percentiles 25–75) since all distribution was non-normal according to the Kolmogorov–Smirnov test. Absolute and relative frequency distributions were constructed for the qualitative variables.

Numerical variables were compared using Wilcoxon Signed Rank Test.

The difference between the second and first assessment (T2–T1) was calculated for Sleep Duration (CSD), PSQI, MoCA, Mean Reaction time (PVT), Minor lapses (Psychomotor Vigilance Test), Perseverative errors (WCSC). To analyze the possible correlation between cognitive parameters variation and sleep duration variation or PSQI variation, Spearman's correlation coefficients were calculated.

All tests were leveled by a 0.05 significance.

Results

Fifty-eight students were contacted, who demonstrated an initial interest in participating in the research. Of these, 6 did not take part in the first assessment and 11 did not attend the second, because they had contracted COVID-19. Thus, 41 individuals were included in the analysis, 49% were female, the median age was 21 (20; 23) years, 42% presented possible anxiety; 29%, possible depression; 24% presented possible insomnia; 17% reported nightmares and 15% presented signs of sleep apnea. Figure 1 shows the study flowchart. Seven students were in the first year, 7 students were in the second year, 20 were in the third year and 7 were in the fourth year of medical school. Thirty-five students reported not taking medication to sleep, one took medication less than once a week, 2 took it once or twice a week, and 3 took medication three or more times a week.

Students had the same number of awakenings the night before the first (median: 1 (0; 2)) and second (median: 1 (0; 2)) evaluations.

Table 1 presents a comparison of the cognitive assessment during the last week of vacation (first assessment) and after 1 month of classes (second assessment). There was a statistically significant decrease in the number of hours slept and a significantly poorer performance on the psychomotor

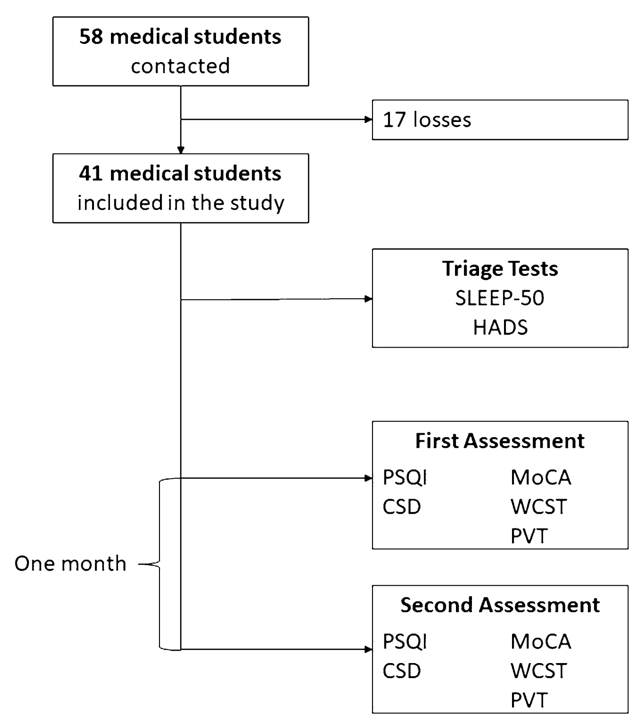

Fig. 1 Flowchart of the study. *HADS* Hospital Anxiety and Depression Scale, *PSQI* Pittsburgh Sleep Quality Index, *CSD* Consensus Sleep Diary, *WCST* Wisconsin Sorting Cards Test, *PVT* Psychomotor Vigilance Test

Table 1 Cognitive and sleep assessment of volunteers

Characteristics	Median (first evaluation)	Median (second evaluation)	*P*-value
Pittsburgh sleep quality index	5.0 (3.5; 8.5)	6 (4.0; 7.5)	0.119
Hours slept the day before	7.33 (6.0; 8.0) hours	5.75 (5.4; 7.0) hours*	0.037
Montreal cognitive assessment	28.0 (27.5; 29.0)	29.0 (28.0; 29.5)*	0.015
Mean reaction time (psychomotor vigilance test)	275 (265; 295) ms	283 (272; 306) ms*	0.005
Minor lapses (psychomotor vigilance test)	1 (0.5; 1.0)	1 (0.5; 2.5)*	0.009
Perseverative errors (Wisconsin sorting cards test)	6.0 (6.0; 7.5)	6.0 (5.0; 7.0)	0.229

Data are presented as Median (P25; P75); Wilcoxon Signed Rank Test

vigilance test in the second assessment. An increase was also observed in the MoCA test score between the two test periods.

Table 2 presents the correlations between the differences of the two assessments of sleep duration and quality with regard to cognitive performance. There was a significant negative correlation between the variation of hours slept and the variation of minor lapses, demonstrating that those who presented the greatest decrease in hours slept also presented a poorer performance in the attention test.

Discussion

To the best of our knowledge, this was the first study to compare student cognition during two different time periods with different amounts of sleep and using validated instruments. Most studies that assess the consequences of sleep restriction in students have been based on university exam scores. These studies have shown that sleep deprivation is associated with poor test results, thereby suggesting that sleep deprivation has repercussions on academic life [33, 34]. However, the use of academic test results limits the generalization of these studies, since the formulation of questions and difficulties inherent to the disciplines may vary from institution to institution and even in courses at the same institution [7, 35].

A lower amount of sleep was observed during the period of classes than during the vacation period, thereby proving that the amount of sleep is different in the two periods. No difference was observed in sleep quality (PSQI) between the two periods.

Students performed significantly worse in tests that assessed attention (average reaction time and number of minor lapses) in the period with less sleep (period of classes) compared to the vacation period. The difference in hours of sleep between the two assessments correlated with the difference in the results in the attention test (Minor lapses; PVT), demonstrating that a decrease in the hours of sleep correlates with reduced attention. No change was observed in the assessment of controlling impulses and cognitive flexibility (WSCT).

Our results are supported by other studies. A Dutch study assessed the attention span of university students with a questionnaire on the ability to concentrate while studying and observed a positive correlation between chronic sleep loss and the ability to concentrate [36]. Mishra et al. analyzed the attention span with the same tool as the present study and observed a reduced reaction time after a single night of sleep restriction [37]. Pérez-Olmos and Ibáñez-Pinilla compared students on the day immediately following night shifts with students who did not work. Students who had been on shifts the night before presented a reduced performance in tests of attention [38].

Table 2 Spearman's correlation between the Sleep Duration and the Pittsburgh Sleep Quality Index (PSQI) variances and the cognitive evaluations variances

Variables		MoCa (T2–T1)	Mean reaction time (PVT) (T2–T1)	Minor lapses (PVT) (T2–T1)	Perseverative errors (WCST) (T2–T1)
Sleep duration (CSD) (T2–T1)	Correlation (Rô) (*p*-value)	0.095 (0.555)	− 0.295 (0.061)	− 0.395 (0.011)	0.055 (0.733)
PSQI (T2-T1)	Correlation (Rô) (*p*-value)	− 0.106 (0.508)	0.067 (0.678)	0.099 (0.537)	0.204 (0.202)

MoCa Montreal Cognitive Assessment, *CSD* Consensus Sleep Diary, *WCST* Wisconsin Sorting Cards Test, *PVT* Psychomotor Vigilance Test. T2–T1: evaluation 2–evaluation 1

The first domain to be affected by sleep deprivation is attention [13, 14]. Attention has four components: tonic alertness, phasic alertness, selective attention, and sustained attention. Attention is the most affected cognitive component in acute sleep deprivation, especially the tonic alertness component [39]. The PVT primarily assesses tonic alertness [14, 39]. As the students showed a difference in the number of hours slept the night before the tests but did not show a difference in the PSQI, which assesses the quality of sleep in the month before the application of the questionnaire, our findings probably reflect the effects of acute insomnia.

Impaired attention has a dose-dependent effect, reducing proportionately with increasing sleep restriction time [40]. With excessive prolongation of wakefulness, there is an increase in homeostatic pressure for sleep. Thus, there is a reduction in cortical activating stimuli by the ascending reticular activating system (ARAS). The action of ARAS becomes erratic, decreasing the neuronal response in activities that demand constant attention, as in the frontoparietal neuronal network [14, 41]. These changes result in an instability of attention, causing attention lapses (called “microsleeps”), which were observed in this study (the minor lapses) [40].

Executive functions are more affected by a greater intensity and/or chronicity of sleep deprivation [14]. It is possible that the negative impact of sleep reduction in our study was not of sufficient magnitude to affect other more complex cognitive functions, such as executive function. Cognitive flexibility is a component that varies little with sleep deprivation [39].

There was an improvement in the MoCA score in the second assessment of the students. The developer of the MoCA has indicated that repeating this instrument may be harmed by the learning effect, and to alleviate this situation, recommends the use of different versions of the questionnaire [42]. This recommendation was followed in the present study, but it is possible that there was a residual learning effect that could explain this performance improvement. Our study population was university students. The MoCA score was high in both assessments. Thus, it is also possible that this instrument was not adequate to measure small differences in this young, healthy, and highly educated population.

Our study has some limitations. Our sample was a convenience sample, so it may not be representative of the student population. However, the frequency of depression, anxiety [18, 43] and insomnia [18] are close to those observed in cross-sectional studies conducted at different universities in the same city. We did not calculate the sample size, so we cannot rule out the possibility that the study did not have the power to detect small differences between the two assessment periods. There was a 21% loss to follow-up between the first and second assessments. However, losses of up to 30% in cohort studies do not compromise the internal validity of the study. We chose to have a 30-day interval between the two assessments in order to reduce possible losses. This range may not have been sufficient to detect the more chronic effects of sleep deprivation on cognition. Even so, we observed a reduction in the attention span. We suggest that future studies also include an assessment three months after the start of classes.

Our work has some strengths. We used a sleep diary to measure the amount of sleep. The hours of sleep were not manipulated by the researchers, as the intention was to have a situation closer to real life. The use of validated instruments increases the generalization capacity of our study and also facilitates its reproducibility and favors its internal validity.

Conclusion

During the period of classes, students sleep less. This acute sleep deprivation is associated with a functional impairment, identified as a reduction in the level of attention, with a potentially negative impact on academic performance.

Authors' contributions PMA, CMRF, PSRF conceived the original idea. PMA, CMRF, PSRF developed the theoretical framework. All authors contributed to the interpretation of the results. All authors discussed the results and contributed to the final version of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors report that there were no conflicts of interest.

Ethical approval All volunteers signed an informed consent form. This research was approved by the Research Ethics Committee of the Health Sciences Center, Universidade Federal de Pernambuco, Recife (CAAE: 40486620.2.0000.5208; number of the approval document is: 4.488.618).

Consent for publication Not applicable.

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