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Cognitive effects of chronic sleep deprivation in internal medicine residents

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Abstract

Background and objective: *Assessing the effect of chronic sleep deprivation on essential neuropsychological tests, including executive functions for performance such as selective attention, inhibitory control, processing velocity, and working memory among internal medicine residents with chronic sleep deprivation in a highly demanding academic program.* **Methods:** *We conducted a prospective study measuring neuropsychological performance among internal medicine postgraduate year 1 residents in Mexico City. The study was conducted from 2012 to 2013. We used Stroop test, as well as Wechsler Adult Intelligence Scale (WAIS III) to evaluate executive functions. We performed neuropsychological assessments at the beginning of residency, and again 12 months after the baseline assessment.* **Results:** *Chronic sleep deprivation causes an alteration in selective attention, working memory, processing speed, and inhibition. This results in longer time to perform a task, as well as impaired attention during performance of a task.* **Conclusions:** *Our findings suggest that limiting the workload of residents and giving them longer off-duty hours would reflect on better and safer patient care. Nevertheless, it is still controversial that medical errors due to fatigue cause damages to patients.*

Key words: *Sleep. Deprivation. Residents. Cognitive. Effects.*

Efectos cognitivos de la privación crónica del sueño en residentes de medicina interna

Resumen

Antecedentes y objetivo: *Evaluar el efecto de la privación crónica del sueño en pruebas neuropsicológicas esenciales, que incluyen funciones ejecutivas para el desempeño como atención selectiva, control inhibitorio, velocidad de procesamiento y memoria de trabajo entre residentes de medicina interna con privación crónica del sueño en un programa académico altamente exigente.* **Métodos:** *Realizamos un estudio prospectivo que midió el desempeño neuropsicológico en residentes del primer año de posgrado en medicina interna en la Ciudad de México. El estudio se realizó de 2012 a 2013. Utilizamos la prueba de Stroop, así como WAIS III para evaluar las funciones ejecutivas. Realizamos evaluaciones neuropsicológicas al comienzo de la residencia y nuevamente 12 meses después de la evaluación inicial.* **Resultados:** *La privación crónica del sueño provoca una alteración en la atención selectiva, la memoria de trabajo, la velocidad de procesamiento y la inhibición. Esto da como resultado un mayor tiempo para realizar una tarea, así como una atención deteriorada durante la realización de una tarea.* **Conclusiones:** *Nuestros hallazgos sugieren que limitar la carga de trabajo de los residentes y darles más*

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horas fuera de servicio se reflejaría en una mejor y más segura atención al paciente. Sin embargo, todavía es controvertido que los errores médicos debidos a la fatiga causen daños a los pacientes.

Palabras clave: *Sueño. Privación. Residentes. Cognitivo. Efectos.*

Introduction

The exhausting effects of sleep deprivation on residents' performance have been a topic of interest and debate for a long time. In a landmark study from 1971, Friedman et al.[1] observed among medical residents, acute sleep deprivation impacts negatively on mood and performance. On average, a person sleeps seven to 8.5 h/day[2]. Acute sleep deprivation is defined as 24 h without sleep, while chronic partial sleep deprivation is defined as sleeping < 6 h per night for several consecutive nights[2].

Evidence exists about the impact in the quality of patient care by interfering with the number of errors and accidents made[3]. A meta-analysis of 60 studies of sleep deprivation effect found that sleeping 30 h or less per week reduced one standard deviation (SD) the overall performance and 1.5 SD of clinical performance[2].

In July 2003, the United States Accreditation Council for Graduate Medical Education (ACGME) instituted a maximum of 80 working hours per week, and 24 continuous hours per day[4]. Some leaders in surgical and medical specialties still think long working hours are necessary to acquire sufficient clinical exposure and prepare residents and interns for their future senior roles[5].

After an extensive debate about the medical, professional, ethical, and personal implications, the 2010 revision of the ACGME preserved an 80-h limit on the residents' workweek[6], with some reforms of shift length and time free of duty.

The effect of chronic sleep deprivation on performance among residents is not well known. The aim of our study was to assess the effect of chronic sleep deprivation on essential neuropsychological tests including executive functions for performance such as selective attention, inhibitory control, processing velocity, and working memory among internal medicine residents with chronic sleep deprivation in a highly demanding academic program.

Methods

Setting

We conducted a prospective study evaluating neuropsychological performance among Internal Medicine residents at Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán in Mexico City. The study was reviewed and approved by the institutional review board and ethics committee; all participants provided written informed consent. In our Institute, depending on the year of residency, Internal Medicine residents work between 60 and 130 h/week, sometimes moving between clinical duties immediately following a long call (i.e., 24 h Emergency Room shift followed by several hours at the outpatient clinic). In addition, residents have 1 or 2 h of academic lessons to prepare 5 days each week. In Mexico, the Official Norm gives total freedom to each residency-training program to decide duty hours without exceeding a maximum of nights on call to 3 times/week, at intervals not to exceed every other day[7].

Study design

First-year (postgraduate year [PGY]-1) Medical Internal Medicine residents were invited to participate. Participants were excluded if they had current depression according to Beck's depression inventory (BDI)[8], or were using psychotropic or addictive substances including recreational drugs.

Baseline neuropsychological assessment was done within 2 weeks before starting residency training and reassessed at the end of the 1st year of residency. To reduce interference of acute sleep deprivation, participants were instructed to sleep at least 8 h the night before the baseline and 12-month tests, therefore limiting the assessment to only the effects of chronic sleep deprivation.

To decrease interference of emotional state with test results, we applied BDI with scores ranging from 0 to 63, with higher scores indicative of more severe disease. Participants who had borderline clinical depression (total score of 17-20) or higher at the beginning or at the end of the study were excluded from the analysis. In addition, we applied an initial and final questionnaire of hours of sleep per day and week.

We selected a neuropsychological battery that included the Stroop test as well as subtasks from the Wechsler Adult Intelligence Scale (WAIS III) to evaluate executive functions. The Stroop test evaluates attention and concentration (words, colors, and words-colors), and selective attention by measuring interference[9]. First, subjects were asked to name a series of color words (word task);

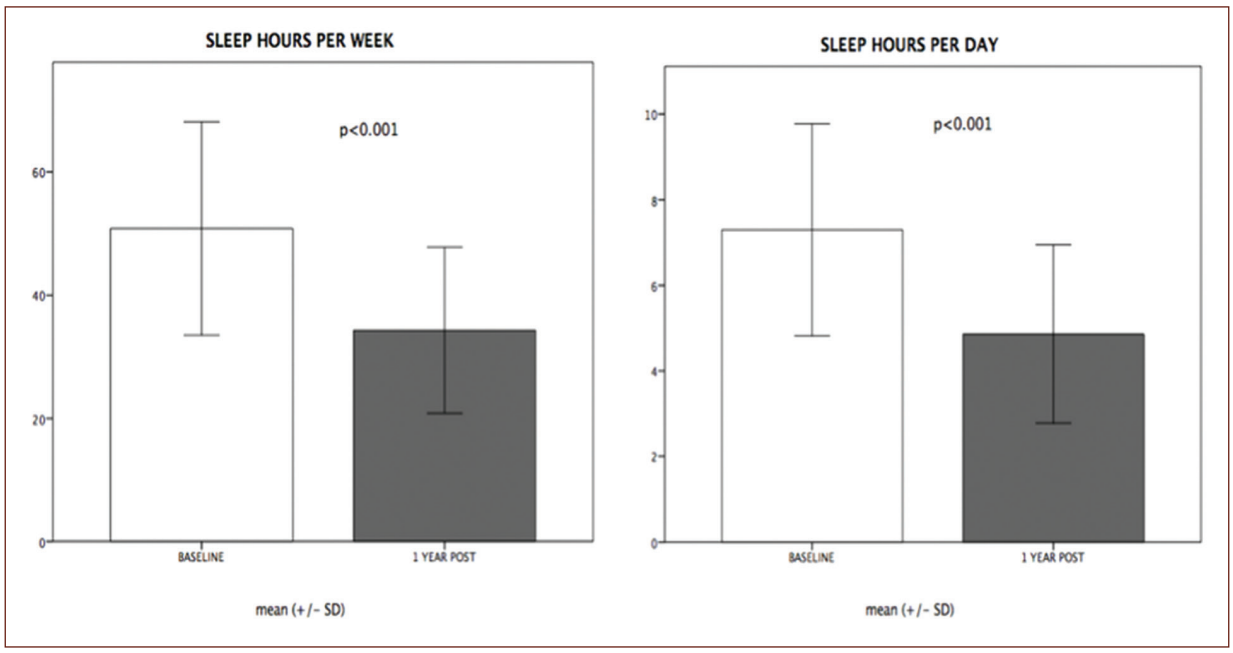

Figure 1. Sleeping time in 30 PGY1 internal medicine participants. Sleep hours per day (left panel) and per week (right panel) before starting residency training and a year thereafter. Data represented as mean ± SD. ***p < 0.001.

this component reflects basic reading rate and may be affected by speech motor problems or learning disabilities. Second, subjects were asked to name the color of a bar (colors task) of X's (e.g., XXX in blue, green, or red ink). As with the word task, performance may be affected by speech motor function; it may also be impacted by the individual's inability to name colors.

The final task was the color-word task in which subjects were shown names of colors printed in conflicting ink colors (e.g., the word "red" in blue ink) and was asked to name the color of the ink rather than the word. This component measures mental flexibility and the ability to inhibit a dominant response as well as provide a measure of the individual's ability to inhibit stimulus-bound responses and deal with interference.

WAIS III evaluates global intelligence of an individual when is fully applied. However, for the purpose of this study, we only chose tests that measured the level of activation of prefrontal cortex through selective attention, processing velocity and working memory such as digit symbol-coding, symbol search, and letter-number sequencing[10].

Statistical analysis

Parametric continuous variables are expressed as means + SD. Categorical variables are expressed as percentages. Differences in mean changes in sleep deprivation between baseline and 12-month assessments were compared in each participant by paired Student's t-test. To determine the effects of sleep deprivation on neuropsychological performance, mean changes from each neuropsychological test were compared between baseline and 12-month assessments using paired Student's t-test. All p values are two-sided and considered significant when $p < 0.05$. We used SPSS v 20.0 software for all statistical calculations.

Results

Thirty-four residents were assessed for eligibility. One subject decided not to sign the informed consent, while another one was excluded due to preexisting depression. Two participants were found to have depression at the end of the study and were also excluded from analysis. Of the 30 participants included, 16 (53.3%) were women and 14 (46.7%) were men. The mean age was 24.9 ± 1.2.

Sleep survey

As shown in figure 1, a remarkable decrease in sleeping time was observed in medical residents from the starting residency training to a year later. Residents slept

Table 1. Stroop test results in 30 PGY1 internal medicine residents at baseline (within 2 weeks before starting residency training) and after 1-year of residency

Neuropsychological test	Baseline assessment mean (± SD)	12-month follow-up assessment mean (± SD)	p
Words	49.8 (± 8.7)	47.7 (± 6.7)	0.08
Colors	48.5 (± 11.5)	42.3 (± 9.6)	0.006
Words-colors	50.6 (± 10.5)	43.8 (± 11.3)	0.002
Interference	53.2 (± 8.0)	47.8 (± 12.9)	0.02

SD: standard deviation.

Table 2. WAIS III subtasks results in 30 PGY1 internal medicine residents at baseline (within 2 weeks before starting residency training) and after 1-year of residency

Neuropsychological test	Baseline assessment mean (± SD)	12-month follow-up assessment mean (± SD)	p
Digit retention	11.8 (± 2.8)	11.3 (± 2.3)	0.10
Letter-number sequencing	12.2 (± 3.1)	10.7 (± 1.6)	0.006
Digit-symbol coding	9.1 (± 14.1)	8.6 (± 1.1)	0.03
Symbol search	13.7 (± 1.7)	11.2 (± 1.6)	< 0.001

SD: standard deviation.

around 2 h less/day ($p < 0.001$) corresponding to a decrease of around 16 sleep hours per week ($p < 0.001$).

Neuropsychological tests

Baseline scores for both Stroop and WAIS III subtask tests were normal at the beginning of medical residency training. For the Stroop test (Table 1), a significant decrease of scores was observed after 12-months of medical residency for colors, words-colors, and interference tasks ($p < 0.05$). We also observed a borderline reduction for the more elementary word task ($p = 0.08$). For the WAIS III subtask tests, the difference in the averages obtained was also significantly different between the baseline and 12-month follow-up periods for the letter-number sequencing, digit symbol-coding, and symbol-search tests ($p < 0.05$). Digit-retention task was not different between the initial and final assessments (Table 2).

Discussion

Our results indicate that chronic sleep deprivation causes an alteration in selective attention, working memory, processing speed, and inhibition. This suggests that chronically sleep-deprived medical residents not only require longer times to perform a task due to a reduced processing velocity, but also have to deal also with impaired attention during the performance of that task. Impairment of working memory may affect an individual's capacity to learn and perform simultaneous and complex procedures.

The theories about the underlying effects of sleep deprivation on the central nervous system (CNS) can be divided into two main approaches. The first one, known as the "prefrontal vulnerability hypothesis" states that lack of sleep impairs executive functions, the cognitive process mediated by the prefrontal cortex. The second, known as the "unstable state hypothesis", postulates that sleep deprivation induces a state of instability, particularly evident in tasks that require sustained attention with fluctuations of attention from time to time[11].

Executive functions include a set of self-regulation functions that enable the organization, coordination, and control of other cognitive functions, emotional responses, and behaviors[12]. The prefrontal cortex is the site of integration of such executive functions including attention, processing speed, working memory, goal-driven behavior, sequencing, inhibition, and verbal fluency.

Sleep deprivation is associated with a decline in basic cognitive functions such as sustained attention and wakefulness. These functions can be kept within certain limits despite abnormal levels of fatigue, probably because the brain is able to compensate the effects of acute sleep deprivation which may explain why a deterioration in neurocognitive function and surgical performances after acute sleep deprivation have not been proven[2,13].

Our findings add to a growing body of evidence of the underlying effects of chronic sleep deprivation on the CNS. Sleep deprivation induces a state of instability and fluctuations in tasks that require sustained attention. Given that selective attention is regulated by prefrontal cortex, our study indicates that chronic sleep deprivation interferes with executive functions such as inhibitory control, processing speed and working memory, all essential functions for complex activities, and decision-making.

Our study has limitations, including a small sample size, horizontal sampling, as well sampling from a single institution. Furthermore, performance for the digit retention subtask of the WAIS III was not apparently involved in response to chronic sleep deprivation; however, this could be because we did not make a difference among direct and inverse retention scores of this test. Instead, the score was taken as a total. The direct digit retention evaluates attention meanwhile the inverse evaluates working memory. Further studies are required to complete the data presented.

Conclusion

Our findings suggest that limiting the workload of residents and giving them longer off-duty hours will reflect on better and safer patient care. Nevertheless, it is still controversial that medical errors due to fatigue cause damages to patients. Health institutions should make every effort to reduce chronic sleep deprivation and fatigue not only among medical residents, but also medical staff at large, and assume fatigue as an unacceptable risk to both residents and patients alike.

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Conflicts of interest

None.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

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