

Impact of sleep deprivation on memory and learning

Impacto da privação do sono na memória e aprendizagem

Impacto de la privación de sueño en la memoria y el aprendizaje

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Abstract

Sleep is understood as a natural process of reduction of the body's response to external stimuli, associated with the loss of consciousness, which is useful for several functions. However, there is currently an increase in the number of individuals who do not achieve a good sleep routine, which can be attributed to an increase in exposure to factors that hinder the achievement of adequate time and quality of sleep, leading to various impacts that affect cognitive health and the processes of knowledge acquisition and consolidation. Thus, it aims to clarify the mechanisms associated with sleep deprivation and its repercussions on memory and learning. It is a literature review based on the analysis of scientific articles published from 2012 to 2022, in PubMed and Science Direct, in which the key words "sleep deprivation" AND "memory" AND "learning" were used. It was verified that sleep deprivation can impair several cognitive and affective functions, such as reduced attention, psychomotor vigilance and increased variability in behavioral responses. In relation to memory processing, the decrease of the quantity and the quality sleep time can affect the ability to retain new information and make individuals more prone to develop false memories. Therefore, realizing the fundamental role of sleep in several functions of the human body, highlighting the consolidation of memory and learning, understand the various unfavorable impacts that a reduction in the number and quality of hours of sleep can have.

Keywords: Sleep deprivation; Memory; Learning; Teaching.

Resumo

O sono é entendido como um processo natural de redução da resposta do organismo a estímulos externos, associado à perda da consciência, que é útil para diversas funções. Entretanto, atualmente, observa-se um aumento no número de indivíduos que não atingem uma boa rotina de sono, o que pode ser atribuído ao aumento da exposição a fatores que dificultam a obtenção de tempo e qualidade de sono adequados, levando a diversos impactos que afetam a saúde

cognitiva e os processos de aquisição e consolidação do conhecimento. Assim, tem como objetivo esclarecer os mecanismos associados à privação de sono e suas repercussões na memória e no aprendizado. Trata-se de uma revisão de literatura baseada na análise de artigos científicos publicados no período de 2012 a 2022, nas bases de dados do PubMed e Science Direct, nos quais foram utilizadas as palavras-chave "sleep deprivation" e "memory" e "learning". Verificou-se que a privação de sono pode prejudicar diversas funções cognitivas e afetivas, como a redução da atenção, a vigilância psicomotora e o aumento da variabilidade nas respostas comportamentais. Em relação ao processamento da memória, a diminuição da quantidade e da qualidade do tempo de sono pode afetar a capacidade de reter novas informações e tornar os indivíduos mais propensos a desenvolver falsas memórias. Portanto, percebendo o papel fundamental do sono em diversas funções do corpo humano, com destaque para a consolidação da memória e do aprendizado, entendemos os diversos impactos desfavoráveis que uma redução no número e na qualidade das horas de sono pode causar.

Palavras-chave: Privação do sono; Memória; Aprendizagem; Ensino.

Resumen

El sueño es entendido como un proceso natural de reducción de la respuesta del organismo a estímulos externos, asociado a la pérdida de la consciencia, que es útil para diversas funciones. Sin embargo, actualmente hay un aumento en el número de individuos que no logran una buena rutina de sueño, lo que puede atribuirse a un aumento en la exposición a factores que dificultan el logro de un tiempo y calidad de sueño adecuados, lo que lleva a diversos impactos que afectan la salud cognitiva y los procesos de adquisición y consolidación del conocimiento. Así, se pretende esclarecer los mecanismos asociados a la privación de sueño y sus repercusiones sobre la memoria y el aprendizaje. Se trata de una revisión bibliográfica basada en el análisis de artículos científicos publicados entre 2012 y 2022, en PubMed y Science Direct, en los que se utilizaron las palabras clave "sleep deprivation" Y "memory" Y "learning". Se verificó que la privación de sueño puede perjudicar varias funciones cognitivas y afectivas, como la reducción de la atención, la vigilancia psicomotora y el aumento de la variabilidad de las respuestas conductuales. En relación con el procesamiento de la memoria, la disminución de la cantidad y la calidad del tiempo de sueño puede afectar a la capacidad de retener nueva información y hacer que los individuos sean más propensos a desarrollar falsos recuerdos. Por lo tanto, darse cuenta de el papel fundamental del sueño en varias funciones del cuerpo humano, destacando la consolidación de la memoria y el aprendizaje, comprender los diversos impactos desfavorables que una reducción en el número y la calidad de las horas de sueño puede tener.

Palabras clave: Privación de sueño; Memoria; Aprendizaje; Enseñanza.

1. Introduction

Sleep is defined as a natural and reversible state of reduced responsiveness to external stimuli and relative inactivity, accompanied by loss of consciousness (Rasch et al., 2013). This process occurs in two main stages: rapid eye movement (REM) and non-REM (NREM) sleep, which alternate in a cyclical manner, in which, in NREM sleep, the slow wave stage (SWS) appears to play an important role in memory consolidation (Diekelmann et al., 2010). Several functions have been proposed for sleep, such as energy saving, restoration of energy resources and cellular tissue repair, thermoregulation, metabolic regulation, brain detoxification of free radicals, glycogen replenishment, synaptic plasticity and memory (Rasch et al., 2013). For this, it is recommended that adults aged 18 to 60 years sleep at least 7 hours a night and that they have habits, such as ceasing the use of electronics hours before bed and maintaining adequate temperature and light, for quality sleep (Liu et al., 2016).

However, it is known that this logic of maintaining good sleep hygiene is not a reality for a considerable portion of the population, especially the student class, which, increasingly, has been propagating a culture of sleep deprivation in favor of to dedicate more time to academic work and social activities (Patrick et al., 2017), which are often permeated by factors that also prevent students from achieving sufficient time and quality of sleep, such as the intake of alcohol, caffeine and stimulants, and the excessive use of technology (Hershner et al., 2014), proof of this is that 76% of medical students have poor sleep quality (Almojali et al., 2017). Thus, this reduction in the number of hours of sleep can have multiple negative consequences on the physical, cognitive and emotional health of these individuals (Patrick et al., 2017), in addition to impairing the processes of memory and learning (Rasch et al., 2013).

In this context, in universities in the health area, the learning process takes place through two methods: theoretical and practical. Most of students' time is spent acquiring theoretical knowledge, which is later tested on tests (Schmidmaier et al.,

2013; Augustin et al., 2014). Memory, which plays an essential role in student performance during college years, comprises three major processes - encoding, consolidation and retrieval - which, undoubtedly, can have their development interrupted by various factors, such as stress, which, is constant in the daily lives of these individuals (Rasch et al., 2013) and sleep deprivation, which has a significant impact on general neurocognitive performance, as it reduces the amount of information remembered by individuals and negatively impacts the ability to encode new memories. In addition, sleep deprivation can also be linked to false memory production that can occur at all stages of memory processing (Chatburn et al., 2001).

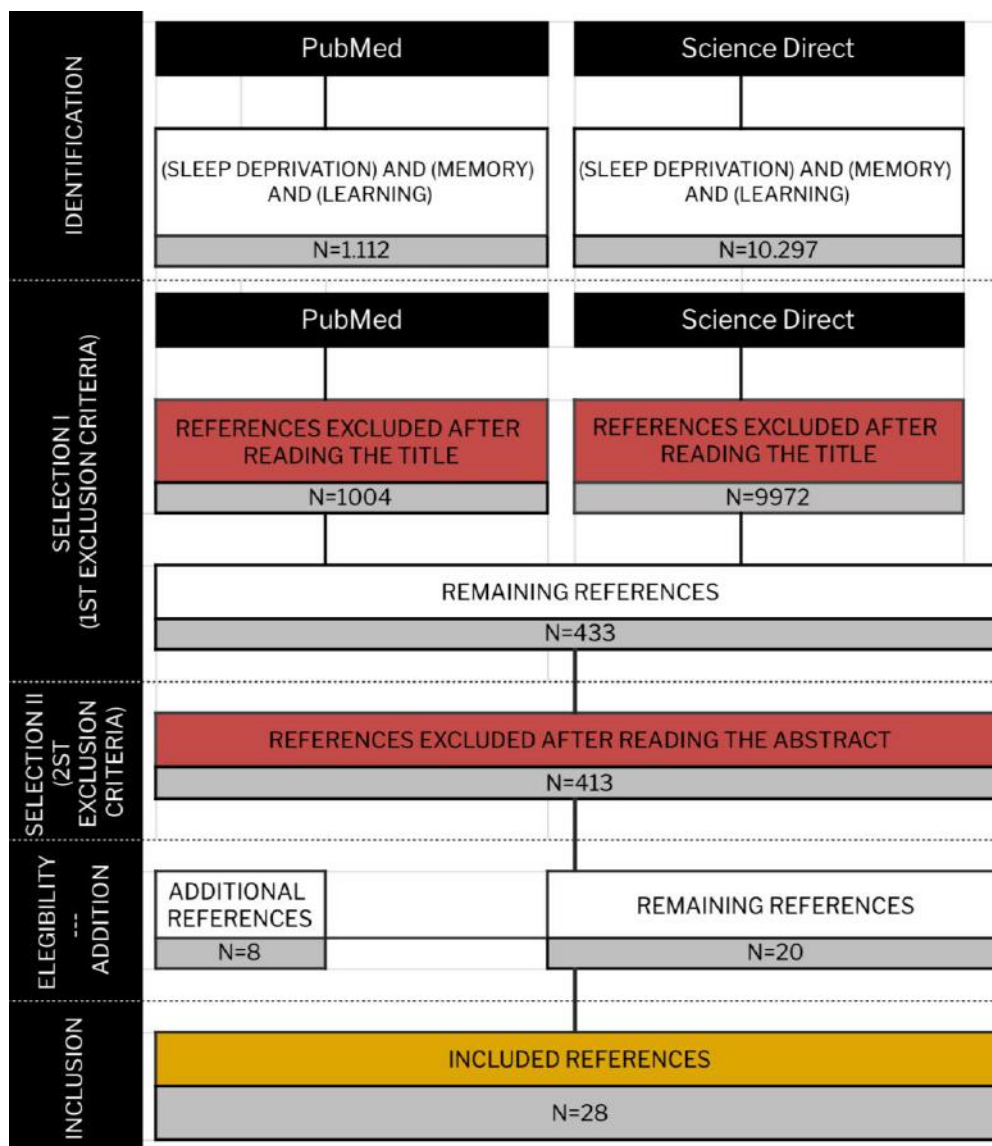
Therefore, given that associating information in long-term memory is essential for many everyday tasks, including learning and decision-making, and that sleep deprivation directly impacts these processes, the aim of the study is to carry out a literature review, in order to clarify the mechanisms associated with sleep deprivation and the impacts on memory and learning.

2. Methodology

This article presents a narrative literature review based on the analysis of scientific articles published from 2012 to 2022 in PubMed and Science Direct on sleep deprivation and the impact on memory and learning.

In applying the first set of criteria, titles that did not mention the topic "association between sleep deprivation and impact on memory and learning," articles not included in the 2012-2022 search period, and articles that were not found in English were excluded. In the PubMed database, 1.112 articles were found by the keywords "sleep deprivation" AND "memory" AND "learning" of which 108 were selected. Following the same criteria, in the Science Direct database, 10.297 articles were found using the keywords "sleep deprivation" AND "memory" AND "learning", of which 325 were selected. The second set of criteria was applied, from which abstracts that did not address the topic of sleep deprivation, memory and learning were excluded, leading to the exclusion of 413 articles. Of the total, 20 articles originally in English (including book chapters, guidelines, and case reports) remained. In order to enrich the discussion, 8 articles were manually selected and added to the search, according to their relevance (Figure 1).

Figure 1 - Flowchart of the articles selection.



Source: Authors.

3. Results and Discussion

3.1 Impacts of poor sleep on cognition

Sleep deprivation is common nowadays, however its long-term effects on cognitive performance are not yet fully understood. Recent experimental studies show that many nights of reduced sleep can impair various cognitive and affective functions (Killgore et al., 2010). These effects are cumulative from night to night and may not fully recover after a weekend's recovery sleep. In addition, sleep deprivation has global and specific effects on cognition that include reduced attention and psychomotor vigilance and increased variability in behavioral responses (Short et al., 2019).

The main point of discussion is to understand whether sleep deprivation affects all or some specific aspects of cognition more than others (Killgore et al., 2010). Complete suppression of nighttime sleep systematically disrupts the encoding of many declarative memories, this stems from the impaired function of a range of neural networks to memories and associated processes such as executive function and attention (Cousins et al., 2019). A study of 10 healthy young adults pointed out that after 24 hours of sleep deprivation, there is significant impairment in the sustained attention domain and

reaction time, however, no effect was observed with respect to short-term recognition, visual information matching, and visual memory (Csipo et al., 2021).

Sleep deprivation affects the circadian rhythm and the immune system, increases C-reactive protein (CRP) levels, and alters cortisol secretion patterns (Choshen-Hillel et al., 2020). In addition, it increases systemic inflammation, which, in conjunction with other changes, impair executive functions and compromise cognition. A study performed with residents noted that chronic sleep deprivation imposed adverse cognitive effects, impaired executive functioning, and increased impulsivity in participants (Choshen-Hillel et al., 2020).

Recent neuroimaging studies point to the association of sleep deprivation with reduced metabolic activity in a network of brain regions important for sustained attention, information processing and executive control. Among these areas, prefrontal cortex is believed to be the brain region most susceptible to the effects of sleep deprivation (Killgore et al., 2010). However, with regard to executive functions, once developed by this area, have inconsistent results when associated cause and effect relationship with deprivation. Furthermore, fast responses were associated with activation of the prefrontal cortex, motor and parietal cortical and subcortical regions, such as the basal ganglia, while slow responses were associated with activation of medial prefrontal regions.

Although sleep deprivation and disruption impair cognitive functions such as attention, executive performance, and risk behaviors, the biological basis of these effects are not fully understood (Choshen-Hillel et al., 2020). Sleep deprivation is shown to have global and specific effects on cognition by the differential susceptibility of several interdependent brain systems to such sleep scarcity. The most consistent findings are decreased attention and psychomotor vigilance. These deficits remain even with restoration of alertness and vigilance or maintenance of these with stimulants.

3.2 Poor sleep and memory and learning impacts

Among the three main processes that are affected for memory functionality - encoding, consolidation, and retrieval - it is known that the second one is the most prominent during sleep, since the sleeping brain provides ideal conditions for consolidation processes that integrate the newly encoded memory into a long-term storage (Rasch et al., 2013; Stickgold et al., 2005). It is also proposed that the same sleep rhythms responsible for consolidating new memories, in the cortex and hippocampus, simultaneously provide adaptive forgetting and filtering of unnecessary information, an essential mechanism to ensure an efficient management of neural resources (Langille et al., 2019).

In this perspective, while the consequences of decreased sleep time and quality degrade various systems throughout the body, the impacts on different forms of memory processing, especially the ability to retain memory, are the first to manifest themselves (Donlea et al., 2019). A study of sixty undergraduate students found that sleep-deprived young adults and adolescents-either one episode of total deprivation or several episodes of partial deprivation-were more likely to develop false memories and misleading information than well-rested people (Lo et al., 2016). Furthermore, working memory, which temporarily stores and retains information while a task is being performed, has also been shown to be considerably impaired when associated with poor sleep quality (Xie et al., 2019).

The processes of learning and remembering are associated with the formation and modification of specific neuronal assemblies. In this way, neurons are recruited to such assemblies as a function of their relative excitabilities and synaptic activation, followed by selective reinforcement of pre-existing synapses, formation of new connections, and elimination of overlapping synapses to ensure memory formation (Holtmaat et al., 2016). Thus, as most studies assume, the underlying learning is a pairing - synaptic strength dependent change that requires repeated experience of events presented in close temporal contiguity (Holtmaat et al., 2016; Gallistel et al., 2014).

Indeed, sleep is an active, repetitive and reversible behavior that is related to different functions that occur throughout the brain and body. Thus, its deprivation has consequences that impact psychomotor and neurocognitive performance, including learning (Benington et al., 2000; Krueger et al., 2003). From this perspective, recent studies have observed that students, from elementary school to university, who had a low quality or quantity of sleep had their ability to learn, both in theory classes and in practical activities, drastically reduced (Curcio et al 2006; Samkoff et al., 1991; Fallone et al. 2002; Wolfson et al., 2003; Stickgold et al., 2000). Furthermore, another study has shown that improvement in the perceptual learning task is linearly correlated with the amount of SWS during the first quarter of the night and with the amount of REM sleep in the last quarter (Stickgold et al., 2000).

4. Conclusion

Therefore, realizing the fundamental role of sleep in several functions of the human body, especially memory consolidation, filtering of unnecessary information and adequate neurocognitive performance, it is possible to understand the various unfavorable impacts that a reduction in the number and quality of hours of sleep can have, especially the formation of false memories, impaired working memory, and reduced ability to learn.

Finally, future studies to investigate the consequences of sleep deprivation on other systems of the human body, as well as the pathophysiological mechanisms associated with these alterations, has become important.

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