The Effects of Obstructive Sleep Apnea on Hippocampal Structure and Function in Adults Over Time

Obstructive Sleep Apnea (OSA) is a common disorder, according to sleep epidemiologist Chamara Senaratna and their colleagues (2017). Francis L'Heureux, a researcher in neuroimaging (2021), and their colleagues define OSA as a condition characterised by repeated blockage in the upper airway during sleep. This causes a decreased or complete restriction of the respiratory flow. On the other hand, Lifeng Li, a radiologist, and their colleagues (2025) illustrate the diagnosis for OSA, which includes a 90% reduction in airflow, continuous for more than 10 seconds. Hypopnea, a lesser form of OSA, is defined as at least 10 seconds of a drop in airflow of ≥30% (Huang L. et al., 2023) . These episodes that include a lack of respiratory flow cause sleep fragmentation and possible chronic hypoxia, ultimately impairing neurological function. With OSA impacting 49% of elderly people annually, and a significant number of undiagnosed and untreated cases, it is important to understand the effects of OSA on the quality of life.

Due to this prevalence, effective therapy strategies are crucial to prevent hypoxia, sleep fragmentation, and a decrease in oxygen saturation. Current treatment for OSA is the use of a machine that creates continuous positive airway pressure, referred to as a CPAP. For those without treatment, OSA episodes consist of a lack of respiratory flow, causing sleep fragmentation and possible chronic hypoxia, ultimately impairing neurological function. Neuroscientist John Lizman and their colleagues (2018) underscored the importance of this finding through their research, describing that the hippocampus plays a major role in memory, navigation, and cognition. This means that the hippocampus is vital to the quality of life, as well as basic cognitive functions. The hippocampus and parahippocampus are particularly sensitive to the lack of respiratory flow (L'Heureux, et al. 2021). However, with the CPAP treatment, the regions of the hippocampus and parahippocampus showed a positive increase in cerebral blood flow, as well as stabilizing levels of oxygen saturation. (L'Heureux, et al. 2021). The increase in rCBF and stable oxygen saturation plays an important role in the vital function of the hippocampus and, therefore, the rest of the brain.

This paper will explore how obstructive sleep apnea significantly impairs hippocampal structure and function through processes such as altering cerebral blood flow, inducing intermittent hypoxia, and disrupting functional connectivity, contributing to cognitive decline. Continuous positive airway pressure (CPAP) intervention is vital to prevent and promote recovery from the progressive damage of the hippocampus.

EVIDENCE OF HIPPOCAMPAL CHANGE DURING OSA

Through an fMRI study, cognitive impairment found in patients with OSA was, in fact, linked to structural and functional changes in their hippocampal and parahippocampal regions (Huang L. et al., 2023b). This link could be because fragmented sleep contributes to a range of change in the function of the hippocampal region, that the exact causes and significance of these factors are challenging to research quantitatively and tangibly. Kianoush Khalili, a physician specializing in Sleep Medicine, and their colleagues found that elderly adults with obstructive sleep apnea had worse spatial navigational memory performance than their healthy peers. This demonstrates a relationship between cognitive impairment through hippocampal changes. They concluded this to be linked to the functional change in the hippocampus, theorizing oxygen desaturation during OSA as a significant factor. This research suggests that interventions may not only prevent cognitive decline but actively restore cognitive abilities by increasing respiratory flow during sleep.

Several studies report an increase in cognitive function after 6 months of CPAP treatment, indicating a 6 month period as a vital time for regenerative and preventative healing (Huang L. et al., 2023). The patients' increased score on the Montreal Cognitive Assessment (MoCA), demonstrated an increase in the functional connectivity throughout the hippocampus. The Montreal Cognitive Assessment (MoCA) is a test taken by patients to determine their cognitive performance through the method of puzzle solving. The MoCA is scored out of 30, and any score less than 26 is considered cognitively impaired. People with OSA are more likely to demonstrate a score of less than 26, indicating mild cognitive impairment (L'Heureux F. et al., 2021). These results show that OSA causes significant impairment to a patient's cognitive function. This emphasizes the degenerative effects of the disorder on individuals'daily lives.

A cognitive decline in patients recorded through fMRI can be linked to a change of blood flow in the hippocampal regions (L'Heureux F. et al., 2021). An abnormal increase or decrease in blood flow can be a cause for hypertension and hypoxia, inhibiting the function and reliability of the hippocampus. The study explored further, describing that the regional cerebral blood flow (rCBF) stabilizes, as predicted by researchers during intervention occurring through treatment such as the CPAP (L'Heureux F. et al., 2021). These findings highlight the causational relationship of OSA's frequent episodes of reduced respiratory flow having a severe impact on vital areas of the brain . More specifically, the left hippocampus was found to exhibit a statistically significant change in rCBF with treated patients with OSA (L'Heureux F. et al., 2021). However, alterations in rCBF have been observed to vary in significance across different severities of OSA. This reduced rCBF could be caused by lack of sleep, so their system has trouble regulating and compensating the blood flow and integrity of the hippocampus. This is called the vasoreactivity, or the body's ability to regulate rCBF levels (L'Heureux F. et al., 2021). With a decrease in vasoreactivity, an abnormal drop in rCBF levels would lead to a lack of resources and nutrients, vital in hippocampal functioning. The parahippocampal region and hippocampus were the most susceptible to reduced blood flow in patients with untreated OSA (Mak et al., 2017; Wierenga, Hays, & Zlatar, 2014). This means that the hippocampus is one of the earliest regions to exhibit structural change that impairs cognition. This sensitivity highlights degenerative damage during OSA, and makes it a critical region for understanding the cognitive effects in patients.

SEVERITY OF HIPPOCAMAL DAMAGE

The change in blood flow exhibited by patients with OSA is concerning because it can lead to intermittent hypoxia (Huang L. et al., 2023). Hypoxia is a complication resulting from a lack of blood flow in body tissues (Liu X. et al. 2025). During OSA,the increased risk of the lack of blood flow toward tissues such as the hippocampus increases the likelihood of hypoxia. This may ultimately lead to permanent brain damage or death if not promptly treated, as stated by the Rosalind Franklin University of Medicine and Science (Madbouly E. M. et al., 2014). While hypoxia can be an extreme effect of OSA, the reduced blood flow to the hippocampus can over time severely impair its function and contribute to progressive cognitive decline (L'Heureux F. et al., 2021).

To further explore the process of hippocampal dysfunction, a study conducted by Xiangming Liu and their colleagues (2025) at Central South University analyzed animal models to determine neuroinflammatory markers in the hippocampus. Associated with chronic intermittent hypoxia, OSA patients also exhibit an elevated level of pro-inflammatory cytokines in the hippocampal tissue. An elevated amount of these have degenerative effects on cell reproduction in the tissue (L'Heureux F. et al., 2021). In the hippocampus, the function is altered, causing patients to have cognitive deficits, such as impaired memory and learning. This progressive damage is dangerous because individuals with milder OSA are often undertreated, and therefore will continue to experience intermittent hypoxia, causing a progressive hippocampal damage over time (Madbouly E. M. et al., 2014).

Impaired hippocampal flood flow may also disrupt neural networks critical for memory related functions. To investigate the biological perspective, the study by Xiangming Liu and their colleagues (2025) also examined additional potential neuroimaging markers for OSA, as demonstrated by the aberrant functional connectivity (FC) in patients. This is the measure of how communicative regions of the brain interact. Aberrant FC patterns shown in patients with OSA reflect disruptive cognitive network interaction, meaning the brain has to work harder to perform the same tasks (Li L. et al., 2025). Building on this, recent studies such as one conducted by Ling Huang and their colleagues (2023) have focused on how FC supports key functions through neural activity. A strong FC is needed between the hippocampus, cuneate lobe, and prefrontal cortex (Huang L. et al., 2023). This unique pattern is involved in semantic processes and social emotional cues.

Ling Huang also states that treatment is important due to the hippocampus' sensitivity to damage caused by OSA. It can be speculated from these findings from the study that any change in the FC of the hippocampus may have a direct correlation to sleep quality and cognitive performance. Huang highlights the vulnerability of the hippocampus, emphasizing the crucial value of treatment. This study dived further, describing that the CPAP can reverse or prevent damage (Huang L. et al., 2023). In older adults, these changes in the hippocampus may show up as noticeable difficulties in memory or alertness during waking. Clinical predictions described 30.11% of patients exhibiting cognitive impairment and 55.96% experiencing excessive sleepiness (Li L. et al., 2025). However in another study, only 15% experience excessive sleepiness (Sforza E. et al., 2015). This demonstrates an inconsistency in results. It is important to note that this study conducted by Lifeng Li primarily included an older aged sample, indicating that it might not be generalizable to the OSA demographic. This dichotomy in findings demonstrates the progressiveness of excessive sleepiness in OSA with age. This is likely due to the severity of hypoxic damage to neuronal networks that promote wakefulness in patients with OSA (Zhu Y. et al., 2007). This damage to the hippocampus primarily occurs during sleep that results in a lack of respiratory flow, this fragmented sleep may be the main contributor to excessive sleepiness. During sleep, actions such as memory consolidation during non-rapid eye movement slow wave sleep relies on the function of the hippocampus (Khalili K. et al., 2023). Interruption during this vital process impairs memory, and continued damage from a change in rCBF further harms cognitive activity. During treatment, the hippocampus and parahippocampus are the most sensitive due to these vital functions during sleep (Huang L. et al., 2023). These regions responded positively to treatments, and in patients with severe sleep apnea, damage improved quickly. Cognitive impairment is reversed and returns to normal. Treatment such as the CPAP leads to reductions in disease severity, normal blood pressure in the hippocampus and other regions, and improves the quality of life according to the director of a sleep medicine program for university hospitals, Susheel Patil and their colleagues (2019).

TREATMENT

The CPAP, the most common treatment, operates by keeping the airway open during sleep, thereby considerably reducing the number of episodes during sleep, improving sleep efficiency and preventing further damage (Giles T.L. et al., 2006). In CPAP treatment, Nasal mask interfaces (masks that cover just the nose), are preferred over full-face masks due to more efficient treatment and better adherence during sleep (Patil S.P. et al., 2019). As stated above, several studies support the claim that the hippocampus is very receptive to treatment. Following 6 months of treatment, there was a significant improvement in the structure and function in hippocampal and parahippocampal regions. This was additionally followed by an improvement in previously impaired cognitive function and improvements in the MoCA test, where it matched the control group (Huang L. et al., 2023). This indicates significant recovery through the hippocampus.

Additionally, the FC improved in the hippocampal areas. This study only looked at 6 months of treatment, a vital period during intervention. During recovery, it is important to note that in order to improve blood flow on a substantial level, long treatment is necessary in patients with severe OSA (L'Heureux, et al. 2021). This is to allow vascularization recovery in areas that have progressive damage and are sensitive to OSA , such as the hippocampus, to stabilize rCBF. By initially reducing intermittent hypoxia, then the CPAP can continue improving rCBF levels. This means the CPAP improves rCBF by first reversing the stress caused by hypoxia and sleep fragmentation. Restoring sleep quality is crucial, and the CPAP therapy significantly improves hippocampal dysfunction from alleviating intermittent hypoxia. The improved rCBF additionally allows for the hippocampus to have an improved FC, and function like normal, such as consolidating memories, and memory retrieval. Consistent CPAP use is critical to attenuate the degenerative effects of OSA. Consistent use has been demonstrated to preserve the integrity of the function in hippocampal regions, and fight against cumulative damage from recurrent hypoxia (Patil S.P. et al., 2019).

Earlier intervention is important because it prevents the progressive hippocampal decline resulting from changes in rCBF and FC. This means it is easier to prevent progressive damage from hypoxia and other factors than reverse damage already done. In a study on CPAP intervention, patients with a more severe OSA were found to be more compliant and likely to engage in treatment (Patil S.P. et al., 2019). On the other hand, patients with milder OSA were less likely to adhere to the CPAP therapy. This can create bias results in OSA treatment studies. Due to this link, individuals with severe sleep apnea might acquire more neuroprotective benefits and prevent further damage to the hippocampus by reducing hypoxia and neuroinflammation. This goes the other way, as in patients with mild OSA are more susceptible to experience a progressive cognitive decline as their hippocampus is gradually experiencing hypoxia.

CONCLUSION

Overall, it can be suggested that obstructive sleep apnea significantly impairs hippocampal structure and function through processes such as altering cerebral blood flow, inducing intermittent hypoxia, and disrupting functional connectivity, contributing to cognitive decline. Continuous positive airway pressure (CPAP) intervention is vital to prevent and promote recovery from the progressive damage of the hippocampus. Prompt treatment is important to treat OSA due to hippocampal sensitivity (Huang L. et al., 2023). Neglecting treatment can further the progression of hippocampal damage and therefore leading to decreased rCBF in sensitive areas (L'Heureux, et al. 2021). Further research of damage should be explored through neuroimaging studies. In this same study, there have been few neuroimaging studies that evaluate the impact of CPAP on brain function other than reported wakefulness. There have also been a few studies looking at the change in FC patterns in the hippocampal region, providing a basis for further neuroimaging studies (Huang L. et al., 2023). Due to the lack of information about the long-term effects of CPAP treatment, it is important to further explore its potential advantage to positive recovery. Also, there are many studies that focus on moderate to severe OSA, so further exploration of the effects of mild OSA should be explored. And finally, because older people experience additional effects of OSA such as excessive sleepiness, there should be more exploration on older patients with OSA. There should also be studies looking to prevent OSA rather than just treating it and trying to reverse the damage (Li L. et al., 2025). This may further reduce damage to the hippocampus through identifying early risk factors, as well as proving more cost effective. Word count: 2528

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