PalArch's Journal of Archaeology of Egypt / Egyptology

SLEEP DEPRIVATION REDUCES COGNITIVE PERFORMANCE – A REVIEW

Dr Sridevi.G[1]
[1]Associate Professor,Department of Physiology,Saveetha Dental College and Hospital,Chennai -77
[1]sridevig.sdc@saveetha.com

Dr Sridevi. G. SLEEP DEPRIVATION REDUCES COGNITIVE PERFORMANCE – A REVIEW--Palarch's Journal Of Archaeology Of Egypt/Egyptology 17(7), 1559-1567. ISSN 1567-214x

Keywords: sleep deprivation, cognitive dysfunction, alertness, concentration, memory

ABSTRACT

Sleep is vital for each living organism to regain the optimal health and well being**.** The optimal duration of sleep is high in infants around 12-16 hrs a day, teens around 8-10 hours and adults and older people require 7-8 hrs/ day. Sleep deprivation suppresses the immune system, increases the risk of hypertension and Diabetes mellitus, influences the secretion of growth hormone, testosterone and cortisol. The influence of sleep deprivation on brain structures modulates the activity of the central nervous system, decreased alertness and concentration, decreased reaction time and impaired ability to focus on timed tasks. Sleep deprivation is disruptive to working memory and executive processing in the prefrontal cortex of the brain. The communication between prefrontal cortex and hippocampus are areas involved in consolidation of long-term memory consolidation and this connection is abolished in sleep deprivation. Sleep deprivation has profound effects on higher cognitive skills of a person. So, sufficient sleep is strongly recommended for normal well-eing of all living organisms irrespective of age, sex and species.

INTRODUCTION

Sleep is one of the important physiological mechanisms that is required to maintain optimal health and wellbeing. Sleep is vital to the body just like exercise and a good balanced diet. Optimal Sleep enhances concentration and productivity, more energy gain, strengthens the immune system, lowers the inflammation, prevents depression and improves social and emotional intelligence and also lowers the risk of cardiovascular disease. (*Website*, no date a)

Sleep is a basic human need just like food, clothing and shelter. Sleep deficiency or sleep deprivation is a condition when a person is deprived of his

natural cycle of sleep. The optimal duration of sleep is high in infants around 12-16 hrs a day, teens around 8-10 hours and adults and older people require 7-8 hrs/ day. (*Website*, no date a, *Website*, no date b) . Thus , the average sleep length is about 7 and 8.5 hrs per day. (Kripke*et al.*, 2002)

IMPACTOF SLEEP DEPRIVATION ON BODY AS A WHOLE

Sleep deprivation suppresses the immune system and makes a person prone to respiratory infections. Prolonged loss of sleep raises the blood pressure and blood glucose level , changes the body weight and raises the fat storage and thus increases the risk of hypertension and Diabetes mellitus. Insufficient sleep influences the secretion of growth hormone, testosterone and cortisol and leads to stunted growth, fertility problems, etc. Disturbances in sleep can be a mental problem or a nuisance that can affect the quality of sleep which affects the performance of a person at work or school the next day.(*Website*, no date c). So, Sleep is one of the most important factors for energy conservation, body restitution, recovery and thermoregulation. In addition, sleep is also considered important for cognitive performance and even memory consolidation (Maquet, 2001)

PEOPLE AT HIGH RISK OF SLEEP DEPRIVATION

Sleep deficiency affected all individuals irrespective of age, sex, race and ethnicities. Occupation induced sleep deprivation in caregivers, shift workers like nurses, doctors, security guards etc are more vulnerable. Another influences on people are lifestyle choices that make people avoid sleep , abusing drugs and alcohol and untreated medical problems and sleep disorders. Certain clinical conditions that affect sleep are obesity, depression, heart disease, cardiac failure, stroke , transient ischemic attack, attention - deficit hyperactivity disorder (ADHD). (*Website*, no date d; Maquet, 2001)

Sleep is a vital process that is regulated by two mechanisms namely, a homeostatic mechanism and a circadian mechanism. (Achermann, 2004). The homeostatic mechanism governs the sleep wakeful cycle which is a neurophysiological phenomenon that consists of alternating intervals of activity and restfulness in an organism for a 24-hour day and night cycle (Murillo-Rodríguez *et al.*, 2019). The circadian mechanism involves an endogenous rhythmic oscillator that influences the threshold of onset and offset of sleep. These two mechanisms work integrated to maintain the rhythm of sleep wake cycle in the body.

Researchers have proposed many mechanisms that underlie the cognitive performance on sleep deprivation. Cognitive impairment would be a result from impaired attention and alertness, slowered responses to tasks and awake instability, attention lapses and inattentiveness caused by sleep deficiency. (Dorrian, Rogers and Dinges, 2004; Dorrian and Dinges, 2005). The attention lapses are microsleeps that have been recorded as shorter periods of sleep seen in electro-encephalography (EEG) activity (Priest *et al.*, 2001)

Sleep deprivation is found to impair cognitive performance by modulating the activity of certain brain areas like prefrontal cortex. This area of the brain is involved in language , analytic and divergent thinking, executive functions, creative ordering and thinking. Specific areas of the brain are more vulnerable

for sleep loss and these areas have been explored using positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) (Harrison and Horne, 1998; Priest *et al.*, 2001)
In relation to sleep deprivation many cognitive processes have been investigated, but the major cognitive domains judged were attention and working memory. Attentional memory focusses on sustained attention and vigilance functions whereas working memory concentrates on verbal and acoustic information, sketch pad to enclose visuospatial information, episodic buffer that integrates information from different sources. (Baddeley, 2007). These two cognitive functions are centralized to frontal lobes and these two functions are impaired with prolonged sleep deprivation. (Harrison and Horne, 1998, 2000; Priest *et al.*, 2001)
Studies have investigated on various tasks like visuo-spatial and auditory attention, serial addition and subtraction tasks, reaction time tasks and vigilance test like psychomotor vigilance test, choice- reaction time tasks. In working memory, choice- reaction time tasks were performed. (Dinges, 1985)

Sleep deficiency impairs visuomotor functioning which can be measured using tasks that involve letter cancellation, digit symbol substitution, maze tracing, iconic memory and saccadic eye movements, decreased oculomotor functioning and impaired vision etc. (Raidy and Scharff, 2005) (De Gennaro, 2001)

Researchers investigated that working memory was not affected even with 51 hrs of sleep deprivation , but cognitive tasks were impaired much and also affects the executive process of cognition compared to nonexecutive cognitive processing. (*Website*, no date b, *Website*, no date e)

Findings from a research showed that adverse changes in sleep over time with a decrease of 6, 7, 8 hours of sleep. Sleep deprivation is associated with lower scores on a variety of cognitive functions. (Michelle, 2014) .

A study evaluated the cognitive performance of students of Bradley University in 2010 by subjecting them to 8 hours sleep and 24 hours of awakening. They students were evaluated on various cognitive tests. And they self reported that they were poor on all the tasks they performed. Students who slept well were good at performing all the tasks compared to non-sleepers. (*Website*, no date f)
The influence of sleep deprivation on brain structures modulates the activity of the central nervous system , decreased alertness and concentration, decreased reaction time and impaired ability to focus on timed tasks. All these functions pertaining to frontal lobe are profoundly affected by sleep deficiency. (*Website*, no date g)

Another study investigated among 57 student participants at University of Wisconsin-Madison. We performed the interpersonal and intrapersonal analysis of the participants to investigate the effects of sleep deprivation on physiological parameters Biopac reaction test, pulse oximeter task and carbon dioxide detector, task related to reaction times and cognitive ability using a math test with multiplication problems with gradual increase in task , stroop test consisting of 60 items. There was no significant difference in the heart rate

and its variation and mean reaction times in sleep deprived and normal subjects. The sleep deprived subjects obtained an overall lower mean score in Stroop Test and math exam compared to normal subjects. The possible explanation for more scores in participants with good sleep , because rested participants would answer fast without any mistakes and they were able to concentrate on longer time reaction tests.

Another study investigated the subjective sleepiness, mood changes and cognitive performance focusing on working memory, sustained attention and executive functions after sleep deprivation for 5 hours in bed for 7 nights and recovery sleep for 3 nights among 56 healthy adults in a boarding school. The students were evaluated using a battery of cognitive tests and the results revealed that even partial sleep deficiency impairs cognitive function and causes mood changes and decreased alertness and it did not recover even after 2 nights of recovered sleep. (*Website*, no date g, *Website*, no date h)

Sleep and memory

Sleep is the vital process that helps to consolidate the memory. For consolidation of memory, there are three processes involved, acquisition of information through learning, stabilization of memorized contents and recall of consolidated information. Without sufficient sleep, the brain loses the power of consolidation and recall of the memorized information. Researchers have identified that hippocampus and neocortex are involved in processing and storage of long term memory. During sleep , the hippocampus reviews , processes and replays the events that happened on that day and gets stored as long term memory. Certain kinds of memory become active and stable during rapid eye movement sleep and some memories get secured during slow wave sleep. (*Website*, no date i)

Another study evaluated the impact of sleep deficiency on the human brain in terms of positive aspects of reward, working attention, working memory, hippocampal memory by neuroimaging studies. Certain regions of the brain processes the signaling of sleep pressures. Such sleep pressures are caused by molecules like adenosine and signals from the hypothalamus and governs the sleep wakefulness cycle. (*Website*, no date i; Porkka-Heiskanen, 1997)). Neuroimaging analysis explained that frontoparietal association cortices are very sensitive to sleep pressures and basal ganglia structures and subcortical thalamus are also influenced by circadian rhythm . So changes in sleep rhythm might have the possibility to affect cognitive processing functions. (Muto, 2016)

Sleep deprivation and attention

Another cognitive function that is more prone to be affected by sleep loss are attention and concentration. Studies have also reported that increasing sleep pressures in a dose dependent manner seriously affects attention and concentration related tasks. (Van Dongen*et al.*, 2003). Studies confirmed that regions of the brain like dorsolateral prefrontal cortex and intra parietal sulcus pertaining to attention related tasks are more profoundly affected by sleep deprivation. (Chee *et al.*, 2011)). Fronto-parietal network, thalamus, posterior cingulate gyrus, medial prefrontal cortex are significantly reported to be affected by sleep deprivation. The thalamus is an important area of the brain

that affects cortical attention related areas through the ascending awakening signals. Sleep deprivation alters activity of amygdala and prefrontal cortex which respond to negative emotional stimulus. The reward centres of the brain namely medial prefrontal cortex, subcortical areas in striatum and orbitofrontal cortex are more susceptible affected by sleep deprivation. (Website) . Suppression of these areas is responsible for attention task related and goal targeted behaviours.(Greicius et al. 2003)

Another study evaluated the effect of sleep deficiency and sleep debt in relation to emotions and anger. This study by Bauducco et al. was a cross sectional study conducted among 2767 students in teenagers aged 12 – 16 years and subjecting them to sleep deprivation. They observed that less than the recommended duration of sleep showed a peculiar behavior named by the author as "norm-breaking behavior" and increased emotional changes like anger, anxiety and even depression. Thus, good sleeping practices are possibly recommended to reduce the emotional barriers towards sleep. (Bauducco et al. 2016)

Effects of excessive sleepiness

Another side of the discussion is increased sleepiness or chronic sleepiness also has adverse effect on brain functions, it slows down the thought processes, inability to concentrate and focus after too much sleep impairs the memory. In children and teens sleep deprivation affected the learning process and affects memory and on the other hand excessive sleepiness can produce hyperactivity disorders in children that can even hamper their learning. Teenagers are also more prone to lose the memorizing capacity, diligence and focusing and attention related activities. Excessive sleepiness slows the reaction time in driving a task and doing work that requires a quick response. Chronic sleepiness also poses a greater risk for depression in adults. (Website)

Studies in sleep deprivation with sleep apnea, restless leg syndrome in adults manifest with poor cognitive functions. (Haensel et al. 2009; Pearson et al. 2006).. The cognitive functions commonly tested were simple reaction time (simple attention), stroop test (complex attention), Sternberg memory task (working memory), Digital symbol coding (speed processing), Mill Hill Vocabulary scale (reasoning and intelligence) ,Wechslet Memory scale (short term memory and reasoning). All these tasks were significantly impaired in sleep deprivation. (Lim and Dinges 2010). Sleep deprivation is disruptive to working memory and executive processing in the prefrontal cortex of the brain. The communication between prefrontal cortex and hippocampus are areas involved in consolidation of long-term memory consolidation and this connection is abolished in sleep deprivation. (Walker and Stickgold 2006)

Though the connection between sleep deprivation and learning, memory and attention was very explored in adults, studies on children are still scanty. Few studies have documented the effects of low duration and quality of sleep and sleepiness during daytime on various cognitive tasks in several categories of children.

A research led by Buckhalt reported that inadequate sleep are the important causes of impaired attention, low concentration and memory among children. Children also fail to reach their learning objective in the activities of the school and engage in behavioural and emotional disturbances.(Buckhalt 2011) Another study by Sadeh et al considered sleep as an important factor to analyse the interpersonal and intrapersonal differences in their academic performances, learning, memory, attention, focusing and even reasoning tasks among children.(Sadeh 2007)

Obstructive sleep apnea in children have been associated with poor performance in tasks related to cognition.(Kheirandish and Gozal 2006). And children with sleep disorders are tend to score poorly in cognitive tasks.(Beebe 2006) . Treatment of sleep disorders have greatly improved cognitive functions in children.(Chervin et al. 2006)

A review study explained the relationship between sleep and cognitive functions among children. With enough observational and clinical findings, the review explored that inadequate sleep resulted in impaired focused attention, tiredness, fatigue, decreased threshold in negative expressions like frustration, anxiety and irritation. This review also confirmed that sleep loss is more prone to affect cognitive executive, emotional and attentional functions of the prefrontal cortex. (Dahl 1996)
A study investigated that sleep is a basic functional factor for physical as well as cognitive development and explored that there existed strong association between sleep disorders and impaired cognitive functions in 1180 children in the age group 7-10 years. The researcher used a sleep deprivation questionnaire and a screening test named Bender Visual Motor Gestalt Test among two groups of children, normal group 633 subjects and 547 sleep deprived subjects. The results revealed that sleep deficiency caused cognitive dysfunction in 39% sleep deprived in 8 yrs old and the frequency of cognitive dysfunction in sleep deprived and control groups were equal among 7-10 year old children. (Website)
The cognitive functions and skills not only depend on sleep , but other factors like children workload, family disharmony, low income, psychological problems at home and at school, expectations from mother, anger imposed by mother on children ‘s demands also produce anxiety and anger in children which can manifest as sleep disorders. (Morrell 1999)

Studies from literature revealed that 7-10 year old children present with physical and psychological characteristics and 8 year old children presented with different behaviours that can even follow a pattern not related to this age group. 7-8 yrs children behaved differently compared to other ages and 9-10 yrs old children showed the same pattern of cognition and sleep. (Brobergет al. 1997; Pellizzer and Hauert 1996; Guérin et al. 1993)
Many researchers have confirmed the association that existed between sleep deprivation and growing brain. A study ventured to determine the molecular mechanisms and cellular pathways bound to this association in early adolescence in Drosophila. The study determined that excessive sleep produces effective durations of brain plasticity among Wild Canton-S Drosophila melanogaster. The flies were derived from sleep for the first full

day of adult life and made to recover for 3 days for recovery sleep. Day 1 of adult life is a very crucial period in the development of flies, so sleep deprivation is very critical. Recovery sleep on day 2,3 ,4 can help in recovery from learning impairments.

Lower Short term memory, decreased response inhibition was observed in aversive phototaxic suppression. sleep deprivation did not affect the dopaminergic neurons but the dopaminergic pathways were significantly affected observed by increased transcription levels in D2R and dDA1 (dopaminergic) receptors These impairments were reversed by dopamine agonist and pharmacological interventions as confirmed by immunohistochemistry, mRNA profiling methods.(Seugnet et al. 2011)

Sleep is very significantly important during postnatal periods of brain development in children. This period is vital for neonatal plasticity. Sleep deprivation around the postnatal period has significant impairments in developmental tasks. This effect is not only prevalent in early part of life, but also in adolescence with long lasting deficiency in hippocampal functioning circuits in rats. (Shaffery et al. 2006)

CONCLUSION

Sleep is the vital process that helps rejuvenate the body and mind to its optimum functional state. Sleep deprivation has profound effects on brain structures that modulates the activity of prefrontal cortex and hippocampus that produces decreased alertness and concentration, impaired learning and memory, decreased reaction time and impaired ability to focus on timed tasks in individuals. Even in children sleep deficiency resulted in poor performance in cognitive tasks and academic activities. Thus sufficient sleep is strongly recommended for normal well being of all living organisms irrespective of age, sex and species.

REFERENCES

Baddeley, A. (2007) Working Memory, Thought, and Action. OUP Oxford.

Chee, M. W. L. et al. (2011) 'Effects of sleep deprivation on cortical activation during directed attention in the absence and presence of visual stimuli', NeuroImage, pp. 595–604. doi: 10.1016/j.neuroimage.2011.06.058.

De Gennaro L, Ferrara M, Curcio G, et al. Visual search performance across 40 h of continuous wakefulness: Measures of speed and accuracy and relation with oculomotor performance. PhysiolBehav. 2001;74:197–204

Dinges DF, Powell JW. Microcomputer analyses of performance on a portable, simple visual RT task during sustained operations. BehavRes Meth Instr Comp. 1985;17:652–5.

Dorrian, J. and Dinges, D. F. (2005) 'Sleep Deprivation and Its Effects on Cognitive Performance', Sleep: A Comprehensive Handbook, pp. 137–144. doi: 10.1002/0471751723.ch19.

Dorrian, J., Rogers, N. L. and Dinges, D. F. (2004) 'Psychomotor Vigilance Performance: Neurocognitive Assay Sensitive to Sleep Loss', Sleep Deprivation, pp. 39–70. doi: 10.3109/9780203998007-4.

Harrison, Y. and Horne, J. (1998) 'Sleep loss impairs short and novel language tasks having a prefrontal focus', Journal of Sleep Research, pp. 95–100. doi: 10.1046/j.1365-2869.1998.00104.x.

Harrison, Y. and Horne, J. A. (2000) 'Sleep Loss and Temporal Memory', The Quarterly Journal of Experimental Psychology A, pp. 271–279. doi: 10.1080/027249800390772.

Kripke, D. F. et al. (2002) 'Mortality associated with sleep duration and insomnia', Archives of general psychiatry, 59(2), pp. 131–136.

Maquet, P. (2001) 'The Role of Sleep in Learning and Memory', Science, pp. 1048–1052. doi: 10.1126/science.1062856.

Michelle A , Miller, Havley Wright, Josie Hough and Franscesco.P.Cappuccio. Sleep and cognition. 2014.

Murillo-Rodríguez, E. et al. (2019) 'Sleep Disorders and Genes', The Behavioral, Molecular, Pharmacological, and Clinical Basis of the Sleep-Wake Cycle, pp. 143–158. doi: 10.1016/b978-0-12-816430-3.00008-7.

Muto V, Jaspar M, Meyer C, Kussé C, Chellappa SL, Degueldre C, Balteau E, Shaffii-Le Bourdiec A, Luxen A, Middleton B, Archer SN, Phillips C, Collette F, Vandewalle G, Dijk DJ, Maquet P. Local modulation of human brain responses by circadian rhythmicity and sleep debt. Science. 2016 Aug 12; 353(6300):687-90.

Porkka-Heiskanen, T. (1997) 'Adenosine: A Mediator of the Sleep-Inducing Effects of Prolonged Wakefulness', Science, pp. 1265–1268. doi: 10.1126/science.276.5316.1265.

Priest, B. et al. (2001) 'Microsleep during a Simplified Maintenance of Wakefulness Test', American Journal of Respiratory and Critical Care Medicine, pp. 1619–1625. doi: 10.1164/ajrccm.163.7.2007028.

Raidy, D. J. and Scharff, L. F. V. (2005) 'Effects of sleep deprivation on auditory and visual memory tasks', Perceptual and motor skills, 101(2), pp. 451–467.

Van Dongen, H. P. A. et al. (2003) 'The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation', Sleep, 26(2), pp. 117–126.

Website (no date a). Available at: 1. https://www.medicalnewstoday.com/articles/325353#more-social-and-emotional-intelligence. (Accessed: 8 August 2020).

Website (no date b). Available at: 2. https://www.nhlbi.nih.gov/health-topics/sleep-deprivation-and-deficiency (Accessed: 8 August 2020).

Website (no date c). Available at: 6. https://www.nhlbi.nih.gov/health-topics/sleep-deprivation-and-deficiency (Accessed: 8 August 2020).

Website (no date d). Available at: 5. https://www.medicalnewstoday.com/articles/307334#effects-on-the-body (Accessed: 8 August 2020).

Website (no date e). Available at: 17. https://www.mdedge.com/neurology/article/72610/alzheimers-cognition/sleep-deprivation-affects-distinct-cognitive-processes (Accessed: 8 August 2020).

Website (no date f). Available at: 19. Pilcher JJ & Walters AS (2010). How Sleep Deprivation Affects Psychological Variables Related to College Students' Cognitive Performance. Journal of American College Health 46, 121-126. http://www.tandfonline.com/doi/pdf/10.1080/07448489709595597?needAccess=true. (Accessed: 8 August 2020).

Website (no date g). Available at: 20. Alhola P & Polo-Kantola P (2007). Sleep deprivation: Impact on cognitive performance. Neuropsychiatric Disease and Treatment 3, 553-567. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2656292/ (Accessed: 8 August 2020).

Website (no date h). Available at: 22. June C. Lo, PhD, Ju Lynn Ong, PhD, Ruth L.F. Leong, BSSc, Joshua J. Gooley, PhD, Michael W.L. Chee, MBBS, Cognitive Performance, Sleepiness, and Mood in Partially Sleep Deprived Adolescents: The Need for Sleep Study, Sleep, Volume 39, Issue 3, March 2016, Pages 687–698, https://doi.org/10.5665/sleep.5552. (Accessed: 8 August 2020).

Website (no date i). Available at: 23. https://www.webmd.com/sleep-disorders/sleep-deprivation-effects-on-memory (Accessed: 8 August 2020).