REVIEW ARTICLE

Functional Importance of Sleep: An Overview

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Abstract

Sleep and dreams fascinated people from different walks of life. Though sleep has been investigated over a century, questions such as 'what physiological functions are carried out by sleep' or why do we need to sleep? still remain to be debated. We need 7–8 h of sleep to keep us active throughout the day without feeling sleepy. Such constant daily quota of sleep is maintained through a balance between sleep duration and intensity by sleep homoeostasis. Sleep is important for energy conservation, immune regulation, learning and memory etc. and, hence, important for health and survival. Sleep disturbances during development have been correlated to the poor psychological and cognitive functions. Sleep deprivation on the other hand can be fatal too. This mini review provides the reader a bird's eye view on the functions of sleep.

The phenomenon of sleep exists across the animal kingdom. Sleep is an important and critical behavioural state essential for maintaining health and survival. Sleep is defined behaviourally as a physiological state of rapidly reversible period of immobility associated with characteristic posture, reduced motor activity and increased response threshold for external sensory stimulation. During sleep, we do not interact with the external environment and often enters into dream state. Sleep is essential for the adaptation of organism to its environment and thereby important for the growth and survival. Cetaceans such as dolphins execute many functions such as locomotion, thermoregulation and so on while one hemisphere is engaged in sleep like activity. Sleep is thus necessary for proper functioning of the brain and is necessary for the survival of the organism. During the process of evolution, sleep also has undergone evolutionary changes may be to sub-serve specific functions. Birds and mammals are endowed with both non rapid eye movement (NREM) and rapid eye movement (REM) sleep states, whereas lower vertebrates exhibit only NREM sleep. Thus, REM sleep is introduced late in the phylogeny may be to meet the challenges associated with development of brain complexities and associated cognition[1].

Sleep is essential for energy conservation. Waking enhances brain plasticity events, increases protein synthesis and so on, but extended wakefulness lead to pronounced brain glycogen depletion causing energetic challenges to the brain. Sleep on the other hand protects the brain from oxidative stress and helps repair mechanisms. A constant daily quota of sleep is maintained through the mechanism of sleep homoeostasis. Recent studies provide convincing evidences on the role of adenosine and other sleep regulatory substances in establishing the homoeostatic drive for sleep[2]. In addition, other cellular energetic pathways like glycogen, electron transport, astrocyte to neuron lactate shuttle and clock transcription proteins get modulated during sleep–wake cycle. It is proposed

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that these metabolic pathways help brain to transit from an energy-attenuated catabolic wake state to sleep state where energy gets replenished[3,4,5]. Sleep deprivation on the other hand reduce glycogen store and ATP, affect cerebral protein synthesis, cell proliferation and neurogenesis[3,4]. Studies have emphasised the harmful consequences of sleep deprivation right from *Drosophila* to mammals. Sleep loss, sleep restriction or sleep deprivation brings about cognitive impairment, reduced vigilance, increased sleepiness, fatigue and disturbed mood[6,7]. The neurobehavioural effect of sleep loss has been demonstrated among shift workers, nursing professionals and frequent international travellers, medical residents on duty for long hours and among patients with chronic pain[8,9]. Sleep deprivation in humans interferes with routine normal life and impairs alertness, memory, cause disorientation and confusion even in situations that demand high levels of alertness and vigilance. Sleep deprivation affects neurogenesis, brain plasticity events and thus impede cognitive functions[6,7], alter immune system, increases the risk of cardiovascular disorders and metabolic disorders[10]. When the organism is sleep deprived, the body tries to recover the lost sleep by sleep rebound. The existence of sleep rebound after sleep deprivation reveals that sleep is essential for health and fitness. The recovery of sleep following sleep deprivation is characterised by enhanced slow wave sleep and slow wave activity. Thus, it is considered that the depleted energy during waking state gets replenished during sleep, especially, during slow wave sleep. Increased slow wave sleep after hibernation or torpor is attributed not as a part of sleep rebound but as means to neural repair and regeneration and synaptic homoeostasis. Extremely low temperatures are known to limit synaptic transmission, and thereby reducing the synaptic efficiency. Therefore, sleep is important for adaptive neuronal plasticity, which plays an important role for survival along with energy conservation[1].

The tight regulation of brain plasticity mechanisms determines the functioning and energy dynamics of the brain. It has been hypothesised that the total synaptic strength of the brain changes as function of wakefulness and sleep[11]. Synaptic strength increases during wake and reaches maximum before sleep is being induced. When sleep ensues synaptic strength decreases and reaches baseline by sleep end. Thereby, synaptic homoeostasis is maintained and is correlated with sleep. During wakeful state, learning and interaction with environment brings about increase in the strength of the synapses. This waking plasticity mechanism is associated with increased energy demands and space requirements saturating the learning capabilities. Whereas, sleep helps to prune the weak synapses and strengthen the relevant ones .It is suggested that average synaptic strength peaks at the end of wake hours, therefore, demanding enhanced slow wave activity and downscales the synaptic strength. As the synaptic strength reduces, the slow wave activity also reduces during later sleep period. This sleep dependent down scaling of synapses play an important role in learning and memory, neuronal development and growth[12].

Sleep is known to have its functional role related to memory, learning and brain plasticity. Sleep enhances the ability to recall spoken language, spatial memories, auditory patterns and motor skills. Jenkins and Dallenbach in 1924[13] for the first provided the special role of sleep in enhancement of learning. Since then many studies have provided valid information on the role of sleep in memory consolidation. What magic does sleep do for memory consolidation? It is suggested that memory traces are being reactivated in the hippocampus and are being sent to cortex during slow wave sleep for long-term consolidation[14,15]. Such reactivation process helps in the integration of memory representations in the network of pre-existing long-term memories. The memory representations are further subjected for synaptic consolidations during REM sleep[15,16]. Therefore, both NREM and REM sleep states complement each other for consolidation of memories as well as their transformation to long-term memory. Sleep thus provides an ideal state for consolidating and integrating memories.

In humans, sleep architecture undergoes prominent maturational process in sleep timing, duration and their regulatory mechanism to establish a definite adult sleep morphology[17]. Sleep plays a major role in neural maturation and proper synaptic connections during development[18,19]. Altered sleep architecture in conditions of schizophrenia, depression and anxiety disorders have been attributed to the developmental disturbances of sleep maturation process[18]. In general, sleep is important for CNS maturation, strengthens the synaptic connections, prune the unwanted connections and thus fine-tune neuronal connections to generate appropriate behaviours.

Presently, our understanding of sleep is undergoing a great paradigm shift. The classical electro encephalograph (EEG) changes that aid in defining various sleep stages represent the dynamic interaction between thalamo-cortical oscillations and the special electrophysiological properties of thalamic neurons[20]. There are now emerging evidences that SWA can be use dependent local network phenomenon of cortical columns[21]. EEG studies following learning of spatial task using left hand showed higher SWA in the right parietal region associated with coordination of spatial task. The local sleep activity induced by learning task brings about local plastic changes, which aids in enhancing the performance. Further, the down scaling events globally or locally play an important role in increasing the signal-to-noise ratio in neuronal circuits[22]. These energy-efficient events during sleep brings about great beneficial effect on brain *per se* so the cognition and performance. On the whole, sleep is an autoregulatory global mechanism, accompanied by global changes in neuronal activity and thus an integrated phenomenon of whole brain[22,23] though sleep can be evoked locally. Practices like exercise and meditation exerts beneficial effect on sleep and help to maintain proper sleep organisation even in old age[24,25]. To conclude, nature has provided the phenomenon called *sleep* as a mean to sub-serve the functions that are essential to maintain health and survival.

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