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# SLEEP AS THE FOUNDATION OF HEALTH: THE ROLE OF SLEEP IN HUMAN LIFE, IMPACT ON MEMORY, MOOD, AND PHYSICAL ACTIVITY

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**ABSTRACT**

Sleep is a key component of everyone's health. It plays an important role in the body's recovery, improvement of cognitive function, and overall well-being. This thesis explores various aspects of sleep, focusing on its physiology, functions, and role in daily life. The paper includes detailed analyses of the effects of sleep on memory, the effects of deprivation, and techniques to improve sleep quality, such as sleep duration and regularity, minimising alcohol and caffeine intake, and meditation practices. The link between sleep and physical activity is also proving to be extremely important. Regular activity affects sleep quality and mental health. Finally, sleep is the foundation of health and well-being.

Despite the wealth of information we already have, the importance and role of sleep presented in the following article demonstrate that this area should invariably be the subject of further research to help us gain an even better understanding of, and therefore influence, the quality of our sleep.

**Keywords:** sleep, memory, mood, physical activity

### 1.1 Physiology of sleep

Sleep is a natural physiological state of unconsciousness. It is usually associated with stillness and is characterised by reduced reactivity to external stimuli. Sleep occurs at regular intervals, and many processes are responsible for its regulation (Cirelli C, Tononi G 2008) (Rasch B, Born J 2013). The essential elements of sleep are the homeostatic, diurnal, and ultradian processes. The homeostatic and diurnal processes are models of sleep regulation (Borbély AA, Achermann P 1999). The homeostatic process is determined by wakefulness and sleep. The increasing need for sleep is a result of progressively longer waking hours, i.e., increasing sleep deprivation. Delay or lack of sleep determines the subsequent lengthening of sleep. The diurnal process represents the diurnal control of sleep occurrence. This mechanism is linked to oscillations in temperature and melatonin secretion, and consequently to the time of day and night. It conditions the 24-hour alternation of periods of high and low sleep propensity (Achermann P, Borbély AA 2003).

The ultradian process occurs during sleep. It regulates the alternation of two dominant sleep phases: REM sleep and NREM sleep (Barbato G 2021). The REM phase is the period of sleep called the time of rapid eye movements. Almost complete muscle relaxation occurs at this time, and this is the phase in which dreams most often occur. During the REM phase, unlike the NREM phase, brain metabolism is high. The NREM phase is also known as slow-wave sleep. It is divided into three stages: shallow, intermediate, and deep sleep, which often take the designations N1, N2, and N3, where N1 denotes the shallowest sleep and N3 the deepest. The distinctiveness of these two basic sleep phases suggests that they have quite different functions (Barbato G 2021) (Borbély AA, Achermann P 1999).

### 1.2 Sleep functions

The answer to the question of what the function of sleep is continues to be debated by many researchers, as a clear answer to this question does not exist (Rasch B, Born J 2013) (Mosley M 2022). Many theories exist regarding the function of sleep. One of them states that, as sleep is associated with a decrease in body temperature, its main function is energy conservation or thermoregulation (Berger RJ, Phillips NH 1995). Other researchers attribute to sleep the role of restoring energy resources and repairing cellular tissue, arguing that the processes of protein synthesis and degradation are not equal: wakefulness shifts this balance in favour of degradation, while sleep allows for a more efficient synthesis process, which enables the restoration of balance (Oswald I 1980).

Current data also suggest an association between sleep restriction and weight gain as well as an increased risk of type 2 diabetes, which may be related to at least three factors: increased appetite, reduced energy expenditure, and changes in glucose metabolism. These data suggest a role for sleep in metabolic regulation (Knutson KL et al. 2007).

Due to the diurnal regulation of the sleep-wake rhythm, researchers are seeking analogies among diurnal variations in immune parameters in the blood. The production of some anti-inflammatory cytokines, e.g., interleukin-10, peaks during the day, whereas some pro-inflammatory cytokines, e.g., interleukin-12, reach their production peak at night, which would argue for the involvement of sleep in the regulation of adaptive immune functions (Lange T et al. 2010).

## 1.3 Sleep as an essential part of life

Sleep disorders, as well as sleep deprivation, have been an area of interest for many researchers in recent years, and, as a result, the harmful effects of sleep deprivation have been described in many studies (Cirelli C, Tononi G 2008) .

The most tragic consequence of sleep deprivation in mammals appears to be death. A study conducted on rats, kept awake by the disk-over-water method, showed that these animals developed a peripheral syndrome characterised by increased metabolism and reduced body weight, resulting in death after 2-4 weeks of continuous sleep deprivation (Rechtschaffen A, Bergmann BM 1989). Prolonged sleep deprivation also results in death in cockroaches (Stephenson R et al. 2007), flies (Shaw PJ et al. 2002), and humans suffering from fatal familial insomnia, for whom the course of sleep deprivation appears similar to the experimental model in rats. Humans with this disease develop a similar set of symptoms, resulting in death (Montagna P et al. 2002). This raises the question: Are there animals that do not sleep? There are several studies that analyse sleep in different animals. This process varies from species to species, so it is possible to find reports that mention non-sleeping animals, but to date, we do not have conclusive evidence for the existence of such species (Cirelli C, Tononi G 2008).

## 1.4 Glymphatic system

New light was shed on the role of sleep in 2012 by researchers who, for the first time, characterised the dynamics of the glymphatic system in vivo.

The central nervous system, headed by the brain, is characterised by a disproportionately high metabolic rate, yet, it completely lacks the conventional lymphatic vessels responsible for its clearance (Jessen NA et al. 2015) . The task of removing metabolic waste from the CNS and the function of liaison with the lymphatic system is attributed precisely to the glymphatic system, which maintains brain homeostasis by circulating cerebrospinal fluid (CSF) through the brain via perivascular pathways that facilitate the exchange of solutes between the CSF and interstitial fluid, thus removing neuronal metabolites from the brain parenchyma (Chong PLH et al. 2022). The essence of the glymphatic system is that its activity is greatly increased during sleep, while its function is suppressed during wakefulness (Jessen NA et al. 2015) .

Many studies suggest that a dysfunction of the glymphatic system is a common aetiology of sleep disorders and headaches (Yi T et al. 2022). Studies in rats also demonstrate that sleep specifically promotes convective fluid flow and thus the removal of metabolites from the CNS. Thus, the main function of sleep appears to be to switch on the glymphatic system and cleanse the brain of neurotoxic waste products produced during wakefulness (Jessen NA et al. 2015).

## 2.1 Effect of sleep on memory

Any living organism has a fundamental capacity of creating and storing memories that enables it to adapt its behaviour to the demands of a constantly changing environment.

Memory also allows the appropriate selection of behaviour in different situations. There are three main sub-processes involving memory functions: encoding, consolidation and retrieval. Encoding occurs when a given stimulus opens a new memory pathway. Encoding is the process most prone to atrophy, or forgetting. Consolidation is referred to when the memory pathway created during encoding is stabilised. Retrieval, on the other hand, is the process during which we are free to recall the things we remember (McGaugh JL 2000). It has been reported that the encoding process may be mutually exclusive with the consolidation process. Encoding by definition needs new stimuli, which occurs during wakefulness, which is why sleep turns out to be the optimal time window for memory consolidation (Rasch B, Born J 2013) (Walker M 2019).

The fact that sleep is intrinsic to memory consolidation is also advocated by the standard two-stage memory system. According to this system, memories are initially encoded in the short-term memory repository, i.e., the hippocampus. It is only later that they are gradually transferred to the long-term memory repository, the neocortex. The system assumes that during sleep new memories are repeatedly reactivated, enabling the neocortex to learn new memories as they are gradually reinforced and adapted to those already existing in the long-term memory. This transformation, which occurs during memory consolidation, also includes the development of new schemas and prototypes, as the core of newly learnt information is reactivated more often than divergent details (McClelland JL et al. 1995).

### 2.2 Effects of sleep deprivation

Sleep deprivation can be divided into partial and total. Partial sleep deprivation refers to nights in which sleep is shortened or interrupted. Total sleep deprivation refers to the complete absence of sleep for at least one night. Total sleep deprivation is more commonly studied due to easier monitoring of brain activity, but studies show that consistent, long-term partial sleep deprivation causes more detrimental effects (Lo JC et al. 2012).

Sleep deprivation carries several negative consequences in many areas of life. One of these is the negative impact on cognitive function. In individuals with chronic sleep deprivation, a loss of functional connectivity between the amygdala and the medial prefrontal cortex is observed. This connectivity involves the medial prefrontal cortex sending inhibitory projections towards the amygdala, while sleep deprivation disrupts this process, resulting in increased activity of the amygdala, which causes negative emotional stimuli. The whole process consequently brings inappropriate behavioural responses, such as making irrational decisions and improper social judgements (Khan MA, Al-Jahdali H 2023). A study comparing the moral judgement of people with sleep deprivation demonstrated that these individuals experienced delayed reactions and consequently greater difficulty in deciding on an appropriate course of action compared to those who received enough sleep, which illustrates how sleep deprivation impairs broader cognitive functions (Killgore WD et al. 2007).

Sleep deprivation may result in the brain's inability to process neural signals in optimal amounts in the temporal lobe region, which is responsible for memory encoding and language processing, resulting in incoherent speech (Binder JR et al. 2000).

Impaired memory storage and everyday speech may also result from decreased levels of neurotransmitters such as norepinephrine, serotonin and histamine due to sleep deprivation.

Receptors lose their ability to rest, with the consequence that neurotransmitters cannot function properly and their production is reduced. The more chronic sleep deprivation is, the more the process can worsen due to continuous brain activity (Araki T et al. 2001).

Sleep deprivation is not without its effects on attention and alertness. There are many neural networks in the human brain. Sleep deprivation seems to have the greatest impact on the following two: the brain's default network (DMN) and the frontoparietal network (FPN). The DMN is a group of brain areas that activate and deactivate depending on a person's external tasks. It influences thinking related to introspection and self-reflection. The network is active when the brain is not directed towards external tasks and the individual is focused on processing information about themselves and their life. FPNs, on the other hand, are networks and brain areas associated with attention. They take part in executive and goal-oriented functions that require cognitive tasks. This area is crucial for rule-based problem solving, actively maintaining and manipulating information in working memory and making decisions in the context of goal-directed behaviour (Wang Y et al. 2014). During sleep, the inhibitory action of the DMN and FPN is equal, ensuring a constant output of attention in the brain, whereas the process of this equal inhibition is stopped in the absence of sleep. Sleep deprivation consequently leads to dysregulation in these areas, the consequence of which is that tasks requiring attention and concentration become unpredictable (Khan MA, Al-Jahdali H 2023). Other studies show that the decrease in attentional and vigilance performance in sleep-deprived individuals may be indirectly caused by a significant decrease in relative regional glucose concentration, which was mainly observed in the thalamus and the prefrontal and posterior parietal cortex (Thomas M et al. 2000).

### 3.1 Sleep hygiene

There is no consensus on the definition of ‘sleep hygiene’. Many studies exist on this topic, but few define sleep hygiene. Researchers mainly focus on 3 areas: behavioural factors, environmental factors, and the control aspect. The most commonly considered sleep factors are caffeine consumption, alcohol consumption, exercise, sleep time, light, naps, smoking, noise exposure, temperature, calming routine, stress, and stimulus control. The lack of consistency in the definition of sleep hygiene may hinder communication between researchers, but the fact remains that sleep correlates with health and well-being, and a growing body of data shows that the number of people not getting enough sleep worldwide is increasing at a frightening rate (De Pasquale C et al. 2024).

The International Classification of Diseases (ICD-10) includes an entry termed ‘inadequate sleep hygiene’ referring to ‘bad sleep habits, irregular sleep habits, and unhealthy sleep wake schedule’, not defining what would constitute ‘bad’ or ‘irregular’ sleep habits. Sleep hygiene therefore describes modifiable behaviours and environmental changes that can be used to improve sleep quality and increase sleep duration (De Pasquale C et al. 2024) (Szczeklik A, Gajewski P 2021).

### 3.2 Sleep duration and sleep regularity

The recommended daily amount of sleep for an adult is between 7 and 9 hours per night. Sleeping less than 7 hours per night is associated with impaired immunity, increased errors, and reduced productivity (Urbanová L et al. 2023).

Sleep regularity, i.e., going to bed and getting up at a fixed time, including weekends or holidays, is also an important aspect. Irregular sleep rhythms mostly affect young adults and adolescents, who spend more time in bed on their days off: a phenomenon referred to as social jet lag associated with weight gain and insulin resistance. It is also known that irregular diurnal rhythms are associated with lower performance at work. Using weekends to sleep off any sleep deficits created on weekdays has also been shown to be less effective in optimising neurobehavioural function (Huang T et al. 2020). The importance of sleep regularity was also significantly highlighted in a recent study, which showed that people with atherosclerosis who had more frequent changes in the timing and length of sleep were more likely to have cardiovascular events (Wilckens KA et al. 2018).

### 3.3 Alcohol consumption

While alcohol is a commonly used drug that appears to help people fall asleep, it has far-reaching negative effects on the quality of sleep. The increase in adenosine levels that is associated with alcohol consumption can induce feelings of drowsiness. At the same time, alcohol affects the overall architecture of sleep, leading to sleep fragmentation and reduced quality. Studies show that even small amounts of alcohol, such as one glass an hour before bedtime, can reduce melatonin secretion by up to 20%, affecting the natural sleep cycle. In addition to this, heavy alcohol consumption leads to a disruption in cortisol secretion and can cause changes in body temperature, which is particularly evident in addicts. Chronic alcohol consumption leads to greater difficulty in falling asleep and daytime sleepiness. 'Binge drinking', i.e., consuming large amounts of alcohol in a short period of time, is associated with a higher risk of insomnia, especially in people over 50 years of age. In the context of gender differences, studies indicate that women may experience greater sleep disruption as a result of alcohol consumption compared to men, so it is recommended to avoid alcohol consumption at least three to six hours before bedtime to minimise its negative effects on sleep (Baranwal N et al. 2023) (Urbanová L et al. 2023).

### 3.4 Caffeine consumption

Caffeine is a psychoactive substance that is the most widely used in the world. Studies show that around 80% of the population regularly use coffee, although its consumption is associated with an increased duration of falling asleep or reduced total sleep time. Caffeine works by blocking adenosine receptors in the brain, which increases alertness and reduces feelings of fatigue but also negatively affects sleep rhythms. Taking caffeine at 100-150 mg (equivalent to about one cup of espresso) 3 hours before bedtime can lead to several sleep disorders, including changes in sleep architecture: an increased amount of shallow sleep and a reduction in deep sleep and REM phases. Caffeine can also delay the secretion of melatonin, further contributing to sleep difficulties. People who regularly consume caffeine may develop a degree of tolerance, which means that their response to caffeine may differ from those who consume it occasionally.

There are also genetic differences that affect caffeine metabolism, which is related to the polymorphism of cytochrome CYP1A2. Studies also show that older people may be more sensitive to the effects of caffeine. As caffeine is not only found in coffee but also in many drinks, tea, and some foods, the risk of excessive caffeine consumption increases.

Following recommendations to reduce caffeine intake, especially in the latter part of the day, can help improve sleep quality and reduce sleep problems, so avoiding caffeine 6-8 hours before bedtime is key to improving sleep quality (Baranwal N et al. 2023) (Urbanová L et al. 2023).

### 3.5 Naps

Naps can be a beneficial tool in improving overall well-being, especially in terms of reducing fatigue, improving mood, and increasing alertness. However, most recommendations emphasise that the main sleep period should last 7-9 hours per night, and naps can be considered as a supplement, especially for people who cannot sleep long enough at night for various reasons. Recommendations for naps suggest that the ideal duration is around 20-30 minutes to avoid falling into deep sleep phases. For younger people, such short naps are beneficial, but among older people, longer naps of up to 50 minutes can negatively affect the quality of nighttime sleep. It is worth noting that the effects of naps may depend on the time they are taken. Naps before noon often improve the quality of night sleep and reduce the time it takes to fall asleep, whereas naps in the afternoon can lead to sleep problems and are therefore particularly not recommended in people suffering from insomnia. Older people may tolerate evening naps better than younger people, although this may lead to getting up earlier in the morning (Baranwal N et al. 2023) (Urbanová L et al. 2023).

### 3.6 Mindfulness practice, relaxation

Relaxation plays an important role in improving the quality of sleep and in managing insomnia problems by influencing the balance of the autonomic nervous system and reducing stress. Introducing relaxation techniques before bed can help to improve one's mood and sleep quality. One of the most commonly used methods is progressive muscle relaxation (PMR), which involves systematically tensing and relaxing different muscle groups, leading to a deep state of relaxation. Thus, PMR helps to reduce muscular and mental tension. Studies show that this method can lead to a reduction in anxiety and an improvement in sleep quality, regardless of the age of the participants.

Another effective technique is mindfulness practice. Mindfulness focuses on being present in the moment, which helps to calm the mind before falling asleep. Practices such as mindfulness meditation or focusing on the breath contribute to reducing negative thoughts and falling asleep peacefully; they also have the effect of decreasing sleep disruptions and improving the overall quality of sleep.

Yoga nidra is also one of the effective relaxation practices, helping to achieve deep relaxation both mentally and physically. Studies indicate that yoga nidra has a positive effect on sleep quality, increasing the number of deep sleep phases and reducing stress levels. Practitioners of this method report a higher sense of well-being, which translates into falling asleep more easily.

Optimising the sleep environment is another important element that can affect sleep quality. It is best to create a dark, cool, and quiet sleeping environment, which promotes the achievement of deeper sleep phases. The use of white noise devices or earplugs can help to eliminate noise. It is important to use the bed exclusively for sleeping while avoiding working, studying, or watching TV in bed (Baranwal N et al. 2023) (Urbanová L et al. 2023).

### 3.7 Exposure to light

Exposure to light is crucial for regulating our diurnal rhythm, as it signals to the brain when it is time to sleep. Light, especially blue light, inhibits the secretion of melatonin, the hormone responsible for feeling sleepy. Even low levels of light, emitted by phones, can delay the process of falling asleep and impair alertness and cognitive abilities the following day. For this reason, limiting exposure to artificial light, especially from electronic devices, can promote earlier sleep and improve sleep quality. In natural environments, light intensity can reach up to 100,000 lux in direct sunlight, while at night it can decrease to around 0.1-0.3 lux, which is conducive to sleep. In artificial environments, light levels are usually much lower, at around 500 lux during the day and often no more than 100-300 lux in the evening and at night. Artificial lighting, particularly that emitted by screens, can significantly interfere with the natural sleep cycle. Factors such as the timing, intensity, and wavelength of light have a direct impact on sleep quality. Exposure to blue light just before bedtime, even at low intensities, can lead to sleep delay and suppression of the REM phase. In contrast, dimmed light in the evening has a positive effect on sleep quality and short-term memory. Studies show that exposure to orange light in the evening results in a lower sleep phase delay and increased sleepiness compared to exposure to blue light. Sleeping in modern lighting conditions, where light from a lamp or TV can reach around 40 lux, negatively affects sleep architecture compared to total darkness (Baranwal N et al. 2023) (Urbanová L et al. 2023).

## 4. The relationship between physical activity and sleep

As well as sleep, physical activity is positively associated with cognitive function, especially memory consolidation (Wilckens KA et al. 2018). For older people, sleep quality is dependent on physical activity levels: higher daily activity correlates with better sleep quality. Studies show that older people who were more active had better sleep quality and reported feeling less tired compared to the less active group. Other studies demonstrate that people who have an active lifestyle have better and longer sleep compared to those who are less active (Tsunoda K et al. 2015). Long-term exercise also promotes improved sleep quality; the effects are more pronounced with increasing activity time and number of steps taken, showing that even moderate exercise can produce positive results (Sullivan Bisson AN et al. 2019). The intensity of exercise affects the secretion of melatonin, and exercising in the evening can alter its concentration in the body. Evening exercise, regardless of its intensity, may delay melatonin secretion. In contrast, physical activity performed during the day, regardless of intensity, does not affect its levels (Buxton OM et al. 1997). The effect of physical activity on sleep quality may also be related to adenosine levels and body temperature. Some studies suggest that physical activity in the evening can improve sleep through antidepressant and anti-anxiety effects and by raising body temperature (Vitale JA et al. 2019).

The effect of exercise on body temperature is important as it decreases during sleep, and exercise may initially increase it. However, there are no clear recommendations on the timing of exercise, as there are many conflicting arguments. Nevertheless, research shows that physical activity and spending time outdoors can be non-pharmacological methods to improve sleep quality and combat insomnia. People who exercise regularly enjoy better sleep, not only in terms of its length but also in terms of its depth and quality (Murray K et al. 2017).

A study involving 305 people over 40 years of age assessed the effect of physical activity on sleep quality. Participants took part in an exercise program that included high-intensity resistance exercise and moderate-intensity aerobic exercise. Analysis of the results showed that physical activity had a positive effect on sleep quality, as reflected by participants' subjective feelings. Although no increase in sleep duration was seen, sleep quality and latency improved (Štefan L et al. 2018) .

Another study involving 377 women found that morning exercise can significantly improve sleep quality and diurnal rhythms. However, there is a need for further research into the optimal duration of physical activity and its effect on sleep to make accurate recommendations (Murray K et al. 2017). Currently, the World Health Organisation recommends that adults perform at least 150 minutes of moderate-intensity aerobic exercise or 75 minutes of high-intensity aerobic exercise per week (Sejbuk M et al. 2022).

**DISCUSSION**

The evidence presented in the paper confirms that sleep is not only a biological necessity but also an important factor affecting all aspects of human life. The chapter on sleep physiology notes that sleep is a dynamic process, regulated by internal body rhythms and external factors such as exposure to light. A review of sleep functions, especially those related to memory and information processing, shows how sleep deprivation negatively affects cognitive abilities. In the context of mental health, sleep deprivation is a significant risk factor for the development of emotional disorders.

The chapter on sleep hygiene demonstrates how even small lifestyle changes can significantly improve sleep quality. The use of methods such as limiting caffeine and alcohol intake and introducing regular sleeping hours and relaxation techniques has many benefits. Furthermore, special attention should be given to the relationship between sleep and physical activity, as regular exercise can improve sleep quality and mood.

**CONCLUSION**

Based on the research presented, it can be concluded that sleep is a foundation of health and a key element of quality of life. Neglecting it leads to serious health consequences, both physical and psychological. Implementing sleep hygiene and regular physical activity should become an integral part of lifestyle to improve sleep quality and overall well-being. This work confirms that conscious attention to sleep forms the basis for health and harmonious functioning in the most essential areas of human life, such as memory, mood, and physical activity. In light of this, further research and education on the importance of sleep should become a priority in the quest to improve public health and the quality of life of individuals.

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