The Role of Sleep in Global Health: From Biological Mechanisms to Social Implications

by Valentina Alfonsi*

Abstract
Sleep is a physiological process essential to the proper functioning of the body and is crucial to overall health. In recent decades, a growing body of scientific evidence has demonstrated how the quality and quantity of sleep profoundly influence our psychophysical well-being, impacting the functioning of our cognitive, metabolic, immune, and cardiovascular systems. At the same time, socioeconomic, technological, and cultural changes over the years, starting with industrialization, have contributed to a progressive reduction in sleep today, creating a real "epidemic" of sleep deprivation that characterizes our time. This article describes the main regulatory mechanisms of sleep, its essential functions for survival, and the consequences of its disruption for the individual and for society. Finally, possible strategies for promoting sleep quality at both the individual and, ultimately, global levels are presented.

Keywords
Sleep, Sleep Deprivation, Social Jet Lag, Socioeconomic Changes, Sleep Promotion Strategies, Global Health.

1. Introduction

We spend approximately a third of our lives sleeping, and, to quote one of the most prominent sleep researchers, Allan Rechtschaffen, "If sleep does not serve an absolutely vital function, then it is the biggest mistake the evolutionary process has ever made".

Sleep is one of the fundamental biological needs of human beings, as nutrition and physical activity. Although it was long considered a passive state, scientific evidence now clearly demonstrates that sleep is an active, dynamic, and finely regulated process, essential for maintaining physiological and psychological balance.

In our current society, characterized by hectic lifestyles and intensive work routines, increasing urbanization, and widespread use of digital technologies, sleep is often

* UniCamillus International Medical University of Rome.

overlooked. This phenomenon has led to the so-called "sleep deprivation epidemic", with significant consequences for individual and collective health.

Growing attention from international institutions such as the World Health Organization highlights how sleep is not just a private matter, but a crucial factor for global health, with implications ranging from chronic disease prevention to economic productivity.

The aim of this paper is to examine the physiological functions of sleep and discuss the impact of sleep deprivation and circadian misalignment on physical and mental health in contemporary society.

2. Sleep Physiology: Regulatory Mechanisms and Functions of Sleep

To fully understand the relationship between sleep and society, and how they influence each other, it is important to understand the main processes that regulate its functioning.

The regulatory mechanisms of sleep involve two fundamental systems: the homeostatic system and the circadian system [1].

The first mechanism, defined as homeostatic, refers to a "pressure" or drive to sleep that progressively increases with the time spent awake and is gradually dissipated throughout the night's sleep. This process is primarily biologically linked to the accumulation of substances such as adenosine, which increases in the brain during waking hours and induces a state of increased drowsiness. This is why substances that inhibit adenosine, such as caffeine, are effective in reducing drowsiness.

Alongside the homeostatic process, a second fundamental mechanism is the circadian process, so called because it regulates the sleep-wake rhythm over the course of a 24-hour period. This process is regulated by the sophisticated functioning of a fundamental structure located in our brain, the suprachiasmatic nucleus of the hypothalamus. This structure, which receives information about light through the retina, acts as a true "biological clock", capable of regulating the production of melatonin, an important hormone secreted by the pineal gland. Its concentration increases in the evening and peaks at night, signaling the brain when to fall asleep. This circadian process is essential not only for regulating the sleep-wake rhythm, but also for regulating circadian variations in temperature, metabolism, and cortisol levels.

Sleep, therefore, arises from the combination of these two processes and has a specific architecture that supports the performance of its essential functions [1].

First, each night's sleep consists of alternating different cycles (about 4-5) lasting approximately 90 minutes, each containing a sleep stage called NREM (Non-Rapid Eye Movement) and a stage of REM (Rapid Eye Movement) sleep, characterized by the presence of rapid eye movements.

In turn, NREM sleep is composed of a series of stages, as sleep deepens, moving from NREM Stage 1 (transition between wakefulness and sleep) to NREM Stage 2 (deepening sleep), and Stage 3 (true deep sleep, also known as slow-wave sleep).

NREM sleep accounts for 70-80% of total sleep and is essential for its restorative function and for the proper functioning of learning processes. REM sleep, in addition to the presence of rapid eye movements, is characterized by muscle atonia and brain activity similar to that of wak-

ing. In this phase, vivid dreams frequently occur, reflecting the state of activation of our brain, which effectively reprocesses the day's experiences.

As mentioned, sleep plays essential roles in our survival. Among these, the neurobiological mechanisms that occur during the night's sleep allow us to maintain the proper ability to encode information acquired during waking and consolidate it in long-term memory stores. Thanks to the dialogue between different cortical and subcortical structures in our brain (i.e., neocortex, hippocampus, thalamus), sleep is the stage where information acquired during the day is processed and stored in our declarative and procedural memory.

Sleep supports not only memory but also the regulation of the immune system through its underlying physiological processes. During the night, our body produces substances called cytokines, which help reduce the likelihood of infections or inflammation. This is why prolonged disruption of natural sleep-wake patterns can increase the risk of developing physical and psychological illnesses, lowering the immune system and making the body more vulnerable to disease [2].

Sleep also profoundly affects metabolic regulation and hormonal balance, affecting hormones such as leptin (the satiety hormone) and ghrelin (the hunger hormone), contributing to appetite levels and body weight fluctuations [3].

Recently, a growing body of research has investigated the role of sleep in the brain's "cleansing" mechanism of metabolic waste products accumulated during wakefulness, through the so-called glymphatic system. This system is essential for ensuring the removal of substances such as beta-amyloid, associated with the onset of neurodegenerative diseases such as Alzheimer's disease [4].

3. Impact of Modern Society on Sleep

Beyond the alteration of sleep-wake rhythms due to sleep disorders, life events, or individual lifestyle, in today's 24-hour society, there is an intrinsic and widespread condition of chronic sleep deprivation, which affects the population on a large scale.

The increasing modernization of our society has led to drastic changes, especially over the last two hundred years. On the one hand, the process of technological innovation has maximized the efficiency of modern life (i.e., artificial light, digital connectivity, uninterrupted commercial and healthcare services, speed of transport), on the other hand, it has had negative repercussions on various areas of life. Modern society is characterized by the demand for continuous availability, which necessarily reduces the space dedicated to rest. Night work, irregular shifts, and constant use of technology contribute to this phenomenon.

The circadian rhythms imposed by society are in fact misaligned with our endogenous rhythm, creating a discrepancy between social obligations such as school or work and our biological clock [5].

As previously described, the sleep-wake cycle is regulated by the suprachiasmatic nucleus of the hypothalamus, thanks to information from external light, which is the primary synchronizer of the circadian rhythm. Exposure to artificial light, particularly the one emitted by electronic devices, can interfere with this mechanism, delaying the onset of sleep and altering its quality. This phenomenon is particularly relevant in modern societies, where the use of smartphones

and computers is common late into the night.

The evident misalignment in today's 24-hour society between the biological clock and social rhythms leads to staying awake well beyond the necessary window, with significant consequences for physical and mental health [6].

In the short term, the effects of sleep deprivation caused by circadian dysregulation are primarily related to an increase in sleepiness and the consequent reduction in psychomotor alertness. Consequently, a decline in performance is observed, especially in tasks requiring specific cognitive functions (attention, memory, executive functions).

In the long term, prolonged sleep deprivation becomes chronic and leads to the onset of pathological processes, with the risk of developing actual organic diseases, particularly metabolic and cardiovascular diseases [7].

Given the spread of the phenomenon in recent years, a specific term has been coined to indicate this condition: "Social Jet Lag" (SJT) [8]. This term refers to the discrepancy between endogenous biological rhythms and exogenous social rhythms (school, work, commitments), which is measured by calculating the absolute difference between the midpoint (i.e., the clock time halfway between when you fall asleep and when you wake up) of sleep during free days and the midpoint of sleep on work or school days.

Approximately two-thirds of the working and student population in developing countries suffers from SJL, with a range of between one and two hours, highlighting this phenomenon as a major public health concern [9].

Daylight saving time (DST) (i.e., seasonal time change in which clocks are set forward by one hour in spring and set back by one hour in autumn) further dissociates the relationship between the sun and the social clock, moving the start of the social day forward by one hour compared to standard time. Although this method results in a reduction in energy expenditure during the period of application (from spring to autumn), the deleterious effects on individual health are widely known. The acute effects of sleep deprivation on the night of the time change have been associated with an increase in traffic accidents and heart attacks. Furthermore, many individuals require several weeks to adapt to the new rhythm imposed by DST, with a general deterioration in cognitive performance and psychophysical health [10].

Furthermore, within the context of SJL, it is interesting to note the Covid-19 pandemic impact, significantly altering social rhythms and living conditions. On the one hand, the interruption of many work activities and social confinement has reduced the extent of circadian misalignment, allowing greater adherence to rhythms and schedules consistent with one's chronotype and individual needs. On the other hand, the enormous increase in the use of digital devices has produced even more intense exposure to artificial light sources (e.g., blue light) at inappropriate times, with a consequent deterioration in sleep quality [11]. Blue light exposure in the evening reduces melatonin production and alters circadian rhythms through the activation of the suprachiasmatic nucleus, increasing alertness and delaying sleep onset.

Finally, regarding the impact of society on sleep, it is also appropriate to consider the presence of social inequalities inherent in mod-

ern society, which determine significant differences in the quality and quantity of sleep among different socioeconomic groups.

Sleep is a fundamental biological need, but its quality and duration are not equally distributed across the population. Available data confirms the existence of a social gradient in sleep. Sleep deprivation is a significant problem in the US and OECD (Organization for Economic Co-operation and Development) countries. Specifically, studies based on CDC (Centers for Disease Control and Prevention) data indicate that 33.2% of American adults sleep less than the recommended 7 hours per night, with a picture that progressively worsens in poorer countries [12].

Social inequalities profoundly influence sleep-wake rhythms. For example, people with precarious or shift jobs are at greater risk of experiencing irregular schedules and unfavorable conditions that disrupt natural sleep-wake rhythms. Furthermore, living in noisy, unsafe, overly crowded environments with poor access to healthcare has been shown to reduce sleep quality. In addition to work and environmental conditions, stress associated with potential economic challenges can also hinder sustained rest and sleep, contributing to the onset of disorders such as insomnia [13].

Finally, given the bidirectional relationship between sleep and health, poor sleep increases the risk of physical and mental illnesses, which in turn contribute to poor sleep quality. All this creates a vicious cycle that further widens the gap between populations of different social backgrounds.

Accordingly, preventive and therapeutic measures targeting better sleep patterns, both at the individual level and through specific social policies, are increasingly urgent and crucial for public health.

4. Consequences of Sleep Deprivation on Individual and Public Health

Chronic sleep deprivation, a condition affecting modern society, leads to the accumulation of a sleep debt associated with numerous diseases, including type 2 diabetes, hypertension, vascular and metabolic diseases. These conditions represent some of the leading causes of mortality globally.

Chronic sleep deprivation not only affects physical health but also has significant negative effects on mental health and well-being. Good sleep is essential for properly processing experienced events and for the ability to regulate emotions. Impaired sleep quality and quantity are therefore associated with the risk of developing psychological disorders such as depression, anxiety, and stress.

From a cognitive perspective, attention, memory, decision-making, and problem-solving skills are impacted by sleep deprivation, both in terms of reduced psychomotor alertness and alterations in the neurobiological processes underlying these functions. As a result, daytime performance is inevitably compromised, resulting in an increase in car accidents, workplace errors, and at-risk behavior.

Furthermore, disruptions in sleep-wake rhythms can lead, in predisposed individuals, to the onset of actual sleep disorders, such as insomnia, obstructive sleep apnea, narcolepsy, or restless legs syndrome. Treatment of these disorders can also be hampered by living and working conditions that conflict with proper sleep hygiene practices.

Several categories of professionals are particularly exposed

to chronic sleep deprivation, such as shift workers. Approximately 20% of the overall workforce is forced to work shifts, especially in the healthcare and transportation sectors [14]. In addition to an increased prevalence of sleep disorders in this population, disruptions in sleep-wake rhythms have negative consequences for psychophysical health and work performance. In healthcare professions, the heightened sleepiness frequently observed in shift workers, such as doctors and nurses, is associated with a greater probability of errors in clinical practice, with obvious repercussions on the service offered and, ultimately, on the health of patients.

Another at-risk group is made up of those who frequently travel across different time zones, exposing themselves to jet lag. Since the circadian system adapts rather slowly (it takes about a day to resynchronize in each time zone), jet lag occurs frequently and contributes to circadian rhythm disruption. Jet lag is associated with a wide range of consequences, from daytime sleepiness and sleep disturbances to reduced cognitive function or the onset of psychological disorders [15].

Not only specific occupational groups, but also certain age groups, are considered to be at higher risk of developing sleep problems due to the SJL. Among these, the age group most at risk is undoubtedly adolescents.

We know that sleep needs undergo wide variations throughout lifespan, progressively decreasing from birth to old age [16]. Adolescence represents a crucial period of brain maturation, in which the body and the brain require an optimal amount of sleep, equal to approximately 10 hours [17]. In this specific period, homeostatic and circadian processes undergo variations in the direction of a lower propensity to sleep during the evening hours, with a consequent tendency to fall asleep later and to demonstrate a late chronotype. This biological factor combines with a series of environmental factors, such as the increase in late afternoon or evening activities or the massive use of electronic devices close to bedtime and, above all, starting school at a time that does not align with the natural tendency to sleep longer in the morning. The combination of these factors determines the so-called "perfect storm", which leads adolescents to experience a permanent condition of sleep deprivation. Also, for this population, sleep loss leads to negative consequences not only for psychophysical well-being, but also for cognitive abilities. Several studies have demonstrated a worsening of academic performance associated with high levels of sleep deprivation in adolescents, because of increased levels of daytime sleepiness and reduced psychomotor alertness [18].

Fortunately, the deleterious effects of sleep deprivation progressively decrease with age, paralleling the reduction in social commitments due to school or work in people with many years of work experience or in retirement. Therefore, it is crucial to consider the broader context and age- and work-related factors when assessing the extent and effects of SJL.

Beyond global health, the costs of modern society-induced sleep deprivation also impact the economy. Traffic and work-related accidents, welfare policies, declining productivity, and increased health problems result in significant financial costs, especially for industrialized countries where sleep deprivation is most frequently encountered.

A recent cross-national comparative analysis of the economic costs of insufficient sleep in five countries (Canada, the United States, the United Kingdom, Germany, and Japan) estimated that the resulting financial losses amount to $680 billion annually [19].

5. Strategies to Improve Sleep and Public Health

Several studies have demonstrated the need of a dual approach to counteract the effects of sleep deprivation caused by circadian disruption: on the one hand, preventing and reducing risk conditions, and on the other, mitigating already compromised conditions to minimize the aforementioned negative effects on health and performance.

From a preventive perspective, psychoeducational interventions have proven effective thanks to the possibility of increasing knowledge of sleep processes and sleep hygiene practices (e.g., maintaining regular sleep schedules, avoiding screens before bed, creating a comfortable sleep environment, limiting caffeine and alcohol consumption). Indeed, it has been shown that at-risk workers or students are less vulnerable to potential negative consequences and better able to cope with them by learning appropriate strategies following a psychoeducational program [20].

Furthermore, to mitigate the impact of circadian disruption, it is necessary to implement effective operational interventions, both from a therapeutic and public policy perspective.

Cognitive-behavioral therapy for insomnia (CBT-I) is considered the first-line treatment for chronic insomnia. Its effectiveness has also been demonstrated in reducing the impact of circadian misalignment, across different contexts and age groups [21]. However, it is a complex and expensive intervention when applied to a large group, due to the necessary involvement of specialized professionals and the adoption of personalized cognitive and behavioral strategies. A possible solution could lie in the selection of specific categories of workers or individuals at risk, to whom targeted treatment could be addressed.

Current evidence indicates that a critically relevant factor in determining vulnerability to the deleterious effects of shift work is chronotype. Even among adolescent students, the evening circadian typology has been linked to greater negative effects on health and performance, compared to what was observed in students with a morning chronotype [22].

Not only chronotype, but also factors such as age, gender, work experience, sleep habits, and lifestyle can be elements to take into consideration when identifying populations most at risk and therefore candidates for specific sleep treatments.

What appears well-established is that, given this variability, the most effective intervention strategy is one based on an individualized approach [23]. The indiscriminate application of the same intervention protocols could not only prove ineffective, but also more expensive in terms of implementation.

Given the key role of exposure to sunlight, one of the interventions that has proven to be effective is the application of intense light therapy. Exposure to artificial light that simulates natural sunlight can help regulate sleep rhythms by directly influencing melatonin levels. This type of intervention has been widely used and proven effective both in adolescents and in shift workers [24,25].

Even in this case, the optimal solution consists in selecting those who, due to individual characteristics, particularly benefit from this intervention, for example, subjects with an evening chronotype.

It is possible to counteract the phenomenon of SJL not only through individual or group treatment and psychoeducation interventions, but also through actual changes in social policies. First of all, it could be appropriate to address the root causes by modifying work and school schedules to make them compatible with the natural physiology of sleep, thus decreasing the phenomenon of circadian misalignment.

Over the last twenty years, a growing number of studies have investigated the effects of delaying the start time of school in populations of adolescent students [18]. A consistent improvement in both alertness and academic performance, as well as an improvement in the well-being and overall health of students, has been uniformly observed. This finding is not surprising if we consider the previously described aspects of the peculiar sleep profile in this crucial phase of development.

Not only adolescents but also shift workers represent an at-risk population. Regarding this category of workers, a significant reduction in the dissociation between endogenous circadian rhythms and the circadian rhythms imposed by working hours can be achieved through specific policies to adjust work shifts, especially among healthcare professionals. Numerous studies have demonstrated that setting a maximum limit on consecutive nights (already in use in many countries) and particular types of shift rotations (forward rotation) are protective factors against the onset of sleep disorders in this population [26].

In conclusion, adequate sleep is essential for both individual well-being and the maintenance of social health. Therefore, effective countermeasures are needed to alleviate the symptoms of circadian misalignment and address its underlying cause (i.e., the discrepancy between the biological, solar, and social clocks).

Given the current state of society, it's possible that the negative impact of circadian rhythm dysregulation may even increase in the future, given the ongoing technological advances and the strengthening of policies that ensure continuity of care. For these reasons, promoting healthy sleep must be a priority on the public agenda. Furthermore, an integrated and multidisciplinary approach is needed, considering preventive and operational interventions on multiple domains (medical, psychological, and social) and targeting multiple sectors (work, school, and environment).

Possible solutions to achieve this goal include individualized therapeutic and psychoeducational programs and public health interventions, such as changing work schedules for shift workers, delaying the start of school for adolescents, or abolishing daylight-saving time.

6. Conclusions

Sleep is a fundamental aspect of global health, with implications that extend far beyond individual well-being. Its influence spans physical, mental, social, and economic domains.

In a world that is becoming ever more dynamic and interconnected, recognizing the importance of sleep and promoting healthy habits represents a crucial challenge for the future. Investing in sleep means investing in people's health, productivity, and quality of life.

Notes and References

1. Borbély A. (1982), *A two process model of sleep regulation*, «Human neurobiology», 1(3), pp. 195-204.

2. Irwin M.R., Michael R. (2015), *Why sleep is important for health: a psychoneuroimmunology perspective*, «Annual review of psychology», 66(1), pp. 143-172.

3. Spiegel K. *et al.* (2004), *Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite*, «Annals of Internal Medicine», 141(11), pp. 846-850.

4. Xie L. *et al.* (2013), *Sleep drives metabolite clearance from the adult brain*, «Science», 342(6156), pp. 373-377.

5. Roenneberg T., Merrow M. (2016), *The circadian clock and human health*, «Current Biology», 26(10): R432-143.

6. Wittmann M. *et al.* (2006), *Social jetlag: misalignment of biological and social time*, «Chronobiology International», 23(1-2), pp. 497-509.

7. Sletten T.L. (2020), *Health consequences of circadian disruption*, «Sleep», 43(1), zsz194.

8. Wittmann M. (2006), *Social jetlag: misalignment of biological and social time*, «Chronobiology International», 23(1-2), pp. 497-509.

9. Roenneberg T. *et al.* (2007), *Epidemiology of the human circadian clock*, «Sleep Medicine Reviews», 6, pp. 429-438.

10. Hadlow N.C. (2014), *The effects of season, daylight saving and time of sunrise on serum cortisol in a large population*, «Chronobiology International», 31(2), pp. 243-251.

11. Alfonsi V. *et al.* (2021), *COVID-19 lockdown and poor sleep quality: Not the whole story*, «Journal of Sleep Research», 30(5), e13368.

12. Pankowska M.M. *et al.* (2023), *Prevalence and geographic patterns of self-reported short sleep duration among US adults*, «Preventing Chronic Disease», 20, E53.

13. Morin C.M., Rodrigue S., Ivers H. (2003), *Role of stress, arousal, and coping skills in primary insomnia*, «Psychosomatic Medicine», 65(2), pp. 259-267.

14. Anttila T., Härmä M., Oinas T. (2021), *Working hours – tracking the current and future trends*, «Industrial Health», 59(5), pp. 285-292.

15. Hilditch C.J., Fischer D. (2023), *Jet lag, sleep timing, and sleep inertia*, in Rudin-Brown C., Filtness A.J. (Eds), *The handbook of fatigue management in transportation: waking up to the challenge*, CRC Press, New York, pp. 195-213.

16. Kocevska D. *et al.* (2021), *Sleep characteristics across the lifespan in 1.1 million people from the Netherlands, United Kingdom and United States: a systematic review and meta-analysis*, «Nature Human Behaviour», 1, pp. 113-122.

17. Short M.A. *et al.* (2018), *Estimating adolescent sleep need using dose-response modeling*, «Sleep», 41(4), zsy011.

18. Alfonsi V. *et al.* (2020), *Later school start time: the impact of sleep on academic performance and health in the adolescent population*, «International Journal of Environmental Research and Public Health», 17(7), 2574.

19. Hafner M. *et al.* (2017), *Why Sleep Matters-The Economic Costs of Insufficient Sleep: A Cross-Country Comparative Analysis*, «Rand Health Quarterly», 6(4), p. 11.

20. Shriane A.E. *et al.* (2023), *Healthy sleep practices for shift workers: consensus sleep hygiene guidelines using a Delphi methodology*, «Sleep», 46(12), zsad182.

21. Vallières A. *et al.* (2024), *Behavioural therapy for shift work disorder improves shift workers' sleep, sleepiness and mental health: A pilot randomised control trial*, «Journal of Sleep Research», 33(6), e14162.

22. Magnúsdóttir I. *et al.* (2025), *Efficacy of brief behavioral and sleep hygiene education with mindfulness intervention on sleep, social jetlag and mental health in adolescence: a pilot study*, «Sleep and Breathing», 29(1), 81.

23. Alfonsi V. *et al.* (2021), *Sleep-Related Problems in Night Shift Nurses: Towards an Individualized Interventional Practice*, «Frontiers in Human Neuroscience», 15, 644570.

24. Richardson C. *et al.* (2018), *A randomised controlled trial of bright light therapy and morning activity for adolescents and young adults with Delayed Sleep-Wake Phase Disorder*, «Sleep Medicine», 45, pp. 114-123.

25. Touitou Y. *et al.* (2017), *Association between light at night, melatonin secretion, sleep deprivation, and the internal clock: Health impacts and mechanisms of circadian disruption*, «Life Sciences», 173, pp. 94-106.

26. Costa G. *et al.* (2014), *Stress and sleep in nurses employed in "3 × 8" and "2 × 12" fast rotating shift schedules*, «Chronobiology International», 31(10), pp. 1169-1178.