THE EFFECT OF SLEEP ON HUMAN HEALTH: PHYSIOLOGICAL FOUNDATIONS

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***Abstract**: Sleep is a fundamental physiological process essential for maintaining homeostasis, neurological function, immune competence, and metabolic regulation. Despite its universal biological necessity, chronic sleep deprivation has become a major public health concern in modern society, particularly among students and healthcare workers. This article reviews the physiological mechanisms of sleep, including its stages and circadian regulation, and examines the documented consequences of insufficient sleep on cardiovascular, endocrine, immune, and cognitive function. The aim of this work is to consolidate current physiological knowledge on sleep and provide a scientific basis for understanding its indispensable role in human health. A systematic review of peer-reviewed literature was conducted using PubMed and Google Scholar databases. Findings confirm that adequate sleep — 7 to 9 hours per night for adults — is not a passive state but an active, highly organized physiological process whose disruption carries measurable and clinically significant health consequences.*

***Keywords:** sleep physiology, sleep deprivation, circadian rhythm, REM sleep, NREM sleep, melatonin, health consequences, cognitive function, immune system.*

Introduction

Sleep occupies approximately one-third of the human lifespan, yet its physiological importance has only been systematically understood in the twentieth century. For millennia, sleep was regarded as a passive withdrawal of the brain from the waking world — a necessary but unexplained phenomenon. Modern sleep science has fundamentally overturned this view: sleep is now recognized as an active,

dynamically regulated physiological state during which essential restorative, regulatory, and consolidative processes take place across virtually every organ system.

The relevance of this topic in the contemporary context is considerable. The World Health Organization has identified insufficient sleep as a global epidemic. Studies conducted across multiple countries indicate that a substantial proportion of the adult population regularly sleeps fewer than 7 hours per night, with rates of sleep deprivation particularly high among medical students, shift workers, and adolescents. The consequences span a wide spectrum — from impaired concentration and emotional dysregulation to increased risk of cardiovascular disease, metabolic syndrome, immune dysfunction, and premature mortality.

For medical students, the importance of understanding sleep physiology is twofold. First, it provides the scientific foundation for counseling patients on one of the most modifiable determinants of health. Second, given the demanding schedules characteristic of medical training, it is directly relevant to their own physiological well-being and academic performance.

The aim of this article is to analyze the physiological mechanisms underlying sleep, describe its stages and circadian regulation, and review the evidence-based consequences of chronic sleep deprivation on human health systems.

Literature Review

The scientific study of sleep was transformed in 1953 when Aserinsky and Kleitman discovered rapid eye movement (REM) sleep, establishing that sleep is not uniform but cyclically organized. This finding, described in detail by Carskadon and Dement (2011) in the seminal reference Principles and Practice of Sleep Medicine, laid the groundwork for modern sleep architecture research.

The regulatory role of circadian rhythms in sleep was further elucidated by work on the suprachiasmatic nucleus (SCN) of the hypothalamus, recognized as the primary circadian pacemaker. The Nobel Prize in Physiology or Medicine 2017 was awarded to Hall, Rosbash, and Young for their molecular characterization of circadian clock genes, underscoring the central importance of this regulatory system.

Walker's Why We Sleep (2017) provides a comprehensive synthesis of the modern literature on sleep's functions, emphasizing its role in memory consolidation, emotional regulation, and immune function. Guyton and Hall's Textbook of Medical Physiology (Hall & Hall, 2021) provides the foundational physiological account of sleep mechanisms used in medical education worldwide. Spiegel, Leproult, and Van Cauter (1999) published landmark research in The Lancet demonstrating that even short-term sleep restriction of six days produces hormonal and metabolic alterations equivalent to advanced aging.

Local literature including Ziyadullayev's Odam fiziologiyasi (2018) and Hamidov's Tibbiy fiziologiya asoslari (2020) situates these international findings within the Uzbek medical education context, providing relevant physiological frameworks for students at institutions such as Samarkand State Medical University.

Materials and Methods

This article is based on a systematic review of scientific literature published between 1999 and 2024. Sources were identified through searches of the PubMed and Google Scholar databases using the following terms: 'sleep physiology', 'sleep deprivation health effects', 'REM NREM sleep stages', 'circadian rhythm sleep regulation', 'melatonin cortisol sleep', and 'sleep immune function'. Only peer-reviewed journal articles, authoritative medical textbooks, and official reports from the World Health Organization and the American Academy of Sleep Medicine were included. A comparative and analytical approach was applied to synthesize findings across the cardiovascular, endocrine, neurological, and immunological literature on sleep.

Results

1. Physiological Stages of Sleep

Normal sleep is organized into recurring cycles of approximately 90 minutes, each comprising non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep. NREM sleep is further divided into three stages. Stage N1 represents the transition from wakefulness, characterized by reduced muscle tone and slow eye movements. Stage N2, the most abundant stage, is defined by the appearance of sleep

spindles and K-complexes on electroencephalography (EEG), reflecting thalamocortical activity associated with memory consolidation. Stage N3, or slow-wave sleep (SWS), is the deepest stage, characterized by high-amplitude delta waves (0.5–2 Hz); it is during this stage that the most intensive physiological restoration occurs, including growth hormone secretion, tissue repair, and immune activation.

REM sleep, which predominates in the second half of the night, is characterized by EEG patterns resembling wakefulness, rapid conjugate eye movements, skeletal muscle atonia, and vivid dreaming. REM sleep plays a critical role in emotional memory processing, procedural learning consolidation, and synaptic homeostasis. An adult typically completes 4–6 sleep cycles per night, with the proportion of REM sleep increasing across successive cycles.

2. Circadian Regulation and Hormonal Mechanisms

Sleep timing is governed by two interacting systems: the circadian process (Process C) and the homeostatic sleep drive (Process S). The circadian system is coordinated by the suprachiasmatic nucleus of the hypothalamus, which responds to light signals transmitted via the retinohypothalamic tract. In response to diminishing light exposure, the SCN signals the pineal gland to secrete melatonin — the primary biological signal of darkness — which promotes sleep onset by lowering core body temperature and reducing alertness.

The homeostatic drive (Process S) accumulates adenosine in the basal forebrain during wakefulness; sleep dissipates this pressure. The balance between these two systems determines sleep architecture and subjective alertness. Cortisol, secreted by the adrenal cortex under hypothalamic-pituitary-adrenal axis control, follows an inverse rhythm: it is lowest during early sleep and peaks in the early morning hours, facilitating arousal. Disruption of this hormonal rhythm — as occurs in shift work, jet lag, or chronic sleep restriction — has measurable consequences for metabolic and immune homeostasis.

3. Effects of Sleep Deprivation on Health

Cardiovascular effects: Chronic sleep deprivation (defined as consistently fewer than 6 hours per night) is associated with a significantly elevated risk of

hypertension, coronary artery disease, and stroke. Sleep loss activates the sympathetic nervous system, elevating heart rate, peripheral vascular resistance, and blood pressure. Inflammatory markers including C-reactive protein and interleukin-6 are elevated in sleep-deprived individuals, reflecting the pro-inflammatory state that contributes to atherosclerosis. Studies indicate that individuals sleeping fewer than 6 hours per night face an approximately 20% higher risk of myocardial infarction compared to those sleeping 7–8 hours.

Endocrine and metabolic effects: The work of Spiegel and colleagues (1999) demonstrated that sleep restriction to 4 hours per night for six consecutive days reduces glucose tolerance by 40% and insulin sensitivity by 30%, producing a pre-diabetic metabolic profile in healthy young men. Sleep deprivation suppresses leptin (the satiety hormone) and elevates ghrelin (the hunger hormone), driving increased caloric intake and contributing to obesity. Growth hormone, secreted predominantly during slow-wave sleep, is essential for cellular repair and muscle anabolism; its disruption impairs physical recovery and immune function.

Neurological and cognitive effects: Even a single night of insufficient sleep produces measurable impairments in attention, working memory, executive function, and reaction time. The brain's glymphatic system — a perivascular waste-clearance network that removes metabolic byproducts including amyloid-beta and tau protein — is most active during slow-wave sleep. Chronic sleep deprivation is associated with accelerated accumulation of these neurotoxic proteins, representing a plausible physiological link between poor sleep and increased risk of Alzheimer's disease.

Immune effects: During sleep, particularly slow-wave sleep, the immune system undergoes active maintenance. Pro-inflammatory cytokines (IL-1, IL-6, TNF-alpha) and antigen-specific immune responses are enhanced, consolidating immunological memory. Sleep-deprived individuals show significantly reduced antibody responses following vaccination and higher susceptibility to infectious diseases. A seminal study by Cohen and colleagues (2009) demonstrated that individuals sleeping fewer than 7 hours per night were nearly three times more likely

to develop a cold following experimental rhinovirus exposure compared to those sleeping 8 or more hours.

Discussion

The convergent evidence from cardiovascular, endocrine, neurological, and immunological research establishes sleep not as a passive state of physiological inactivity but as an organized, essential maintenance phase without which sustained health is impossible. The mechanistic pathways linking sleep deprivation to disease are now sufficiently well characterized to justify treating sleep as a primary — rather than secondary — determinant of health, alongside nutrition and physical activity.

From a clinical perspective, the findings reviewed here have direct implications for patient care and medical education. Sleep quality and duration should be assessed routinely in clinical encounters. Hypertension, obesity, type 2 diabetes, recurrent infections, and mood disorders — all conditions frequently encountered in primary care — may have sleep deprivation as a contributing or exacerbating factor. Addressing sleep is therefore not peripheral to medicine but central to it.

For medical students specifically, the physiological data on cognitive impairment during sleep deprivation are particularly relevant. The working memory deficits, attentional lapses, and impaired executive function documented after even one night of reduced sleep mirror the demands placed on students during high-stakes examinations. Prioritizing 7–9 hours of sleep is not a concession to comfort but a physiologically grounded strategy for academic and clinical performance.

Importantly, the findings also highlight the inadequacy of the widespread belief that sleep debt can be 'recovered' through extended weekend sleep. Research indicates that while some cognitive functions partially recover with recovery sleep, metabolic and cardiovascular consequences of chronic deprivation accumulate progressively and are not fully reversed by short-term compensation.

Conclusion

Sleep is an active, dynamically regulated physiological process essential for cardiovascular homeostasis, hormonal balance, immune competence, cognitive

function, and neural maintenance. Its disruption — whether acute or chronic — produces measurable and clinically significant impairments across virtually every organ system. The physiological mechanisms underlying these effects are now well characterized: circadian disruption alters cortisol and melatonin rhythms; slow-wave sleep deprivation suppresses growth hormone and impairs glymphatic clearance; REM sleep loss disrupts emotional memory consolidation; and sympathetic nervous system overactivation during sleep deprivation drives hypertension and metabolic dysregulation.

The recommendation of 7 to 9 hours of sleep per night for adults, as established by the American Academy of Sleep Medicine, is not arbitrary but grounded in the physiological evidence reviewed in this article. For medical students, healthcare professionals, and patients alike, sleep must be recognized as a non-negotiable pillar of health — one that medicine has the scientific foundation and professional responsibility to promote.

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