

Adolescents' Hormone Level and Circadian Rhythm: A Literature Review

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Abstract:

Adolescence is characterized by complicated hormonal and neural interactions, particularly within circadian rhythms. The roles of melatonin, growth hormone, and cortisol in shaping adolescent circadian rhythms are clarified, as well as their implications for physical and mental health. Circadian rhythm disorders (CRDs), including delayed sleep phase disorder (DSPD), are prevalent in adolescents. Hormonal imbalances exacerbate sleep disturbances. Building upon previous studies, this literature review explores the specific contributions of these hormones to sleep patterns, circadian regulation, and the development of CRDs, with a focus on DSPD. The objectives include examining melatonin's distinct role beyond sleep-wake cycles, illuminating the correlation between growth hormone and cortisol secretion patterns and sleep behaviours, and exploring interventions for DSPD in adolescents. Through an examination of the correlation between hormonal systems and circadian rhythm, the author offers novel perspectives on the physiological and behavioural factors underlying adolescent sleep disturbances. This understanding is crucial for tackling the challenges associated with circadian rhythm and fostering optimal health and well-being during such a pivotal developmental stage.

Keywords: Circadian rhythm; adolescents; hormones; circadian rhythm disorders; delayed sleep phase disorder.

1. Introduction

Adolescence is a critical period marked by numerous developmental changes, both physiological and psychological, that significantly impact an individual's well-being. The 10 – 18 years in adolescents, also called the disability-adjusted life years, are important in public health as they measure the burden of disease and disability in this age group. The interaction of several neuronal and hormonal systems in teenage circadian cycles is essential at this stage. Melatonin, known for its role in regulating the sleep-wake cycle, plays a pivotal part in shaping the overall circadian system during adolescence. Alongside melatonin, the secretion of growth hormone and cortisol undergoes significant changes, profoundly influencing metabolic and physiological processes. Understanding these interconnected hormonal dynamics and their influence on adolescent circadian rhythms is essential for comprehending the broader landscape of adolescent development.

This literature review is structured around comprehending the dynamic interplay of key hormonal systems, melatonin, growth hormone, and cortisol, within the framework of adolescent circadian rhythms. It explores their

specific roles in shaping sleep patterns, overall circadian regulation, and implications for adolescent health. In addition, this research strives to provide an understanding of how these hormone systems are connected and how they affect teenage sleep patterns. This contributes to a deep understanding of circadian rhythm disorders (CRDs), especially delayed sleep phase disorder (DSPD), and potential intervention strategies to support adolescent health and well-being.

2. Mainbody

2.1 Melatonin and Circadian Rhythm in Adolescents

Melatonin, also N-acetyl-5-methoxytryptamine is an important physiological sleep regulator in diurnal species including humans. The endogenous rhythm for melatonin secretion is generated by the suprachiasmatic nuclei (SCN) of the hypothalamus and entrained to the light-dark cycle [1]. Dim light activates the SCN to trigger melatonin secretion from the pineal gland, whereas blue light or daylight suppresses melatonin production. It secretes less during the day, starts to secrete as night falls and peaks between 2 and 4 am after midnight. When dim light trig-

gers the production of norepinephrine from retinal photoreceptors, the SCN relays retinal information to the pineal gland via a multisynaptic pathway with connections being made sequentially to the paraventricular nuclei of the hypothalamus, the preganglionic sympathetic neurons in the upper thoracic cord, the superior cervical ganglia, and finally to the pineal gland where norepinephrine release stimulates the rate-limiting steps in melatonin synthesis [2].

To begin with, melatonin is a hormone which is regulated by the duration of darkness. The fundamental role of melatonin is to transmit information about the daily cycle of light and darkness to various body systems. This information serves to coordinate functions that respond to changes in day length, such as seasonal patterns. The seasonal variations in human physiological functions, potentially influenced by changes in the melatonin signal, persist [3]. Moreover, the nightly secretion of melatonin, a robust biochemical indicator of nighttime, helps to regulate daily biological rhythms [4]. While our understanding of this hormone's functions in humans largely stems from connections between clinical observations and melatonin release, melatonin plays a crucial role in stabilizing and reinforcing the synchronization of circadian rhythms, particularly those related to core body temperature and sleep-wake patterns. Furthermore, the coordination of other bodily functions on a circadian basis also relies on the melatonin signal, including aspects like the immune system, antioxidant defences, blood clotting, and glucose regulation. Particularly in adolescents, melatonin exerts a profound influence on various physiological and behavioural processes, including the timing of puberty, mood regulation, and cognitive function. During adolescence, the secretion of melatonin follows a distinct pattern, with the onset of melatonin release occurring at a later time compared to pre-adolescent children and adults. This delayed onset contributes to the well-documented phenomenon of the delayed sleep phase, wherein adolescents often experience difficulty falling asleep at an early hour, leading to inadequate sleep duration [5]. Fluctuations in melatonin levels during this pivotal developmental period can result in significant and enduring ramifications. These disruptions have the potential to influence the vulnerability to mood disorders such as depression, bipolar spectrum disorder, and schizophrenia. In short, they may impact cognitive function and metabolic homeostasis over an extended period [6]. This underscores the critical role of melatonin in neurodevelopmental processes and its potential significance in the onset and progression of various neurological and psychiatric conditions.

Furthermore, melatonin's influence on adolescent circadian rhythms encompasses neurobiological mechanisms

that extend to the regulation of pubertal timing. Given melatonin's pivotal role in the timing of puberty, it serves as a key link between the circadian system and the broader process of adolescent development. Melatonin's impact on cognitive function during adolescence is a topic of substantial interest. Studies have demonstrated that melatonin influences memory, learning, and attention, all of which are critical components of cognitive function essential for academic performance and overall development during adolescence. Understanding the intricacies of melatonin's role in shaping cognitive abilities during this developmental stage presents opportunities to explore interventions aimed at optimizing cognitive function and academic achievement in adolescents.

Administering melatonin from outside sources can be done through various methods, each with different levels of effectiveness and dosages. For instance, using the intranasal route allows for rapid absorption and high bioavailability, but we still need more human studies to make clear conclusions about its effectiveness [7]. Transdermal patches offer slower and varying absorption rates, while oral transmucosal administration leads to high plasma concentration by bypassing initial metabolism. Subcutaneous injection results in quick absorption but doesn't offer specific advantages. The two most common methods, intravenous and oral administration, are known for their inconsistent effectiveness due to variable bioavailability. The liver enzyme cytochrome P450 is mainly responsible for breaking down melatonin, after which the byproducts are combined with sulfuric acid and then expelled through urine [8]. Thereupon, melatonin helps treat sleep issues in adults and children. The impact of melatonin from external sources is most apparent when the body's natural melatonin levels are low, like during the day or in individuals who don't produce enough melatonin, and is less noticeable when endogenous melatonin is sufficient. In comparison to a placebo, using melatonin for an extended period may lead to some mild side effects such as fatigue, faintness, and queasiness, though there haven't been reports of any major side effects.

In conclusion, the role of melatonin in shaping adolescent circadian rhythms is multifaceted, encompassing not only sleep patterns but also pubertal timing, mood regulation, cognitive function, and overall well-being. This hormone's influence extends far beyond its traditional association with sleep, reaching into the realms of adolescent development and health. Gaining insight into the complex relationship between melatonin and adolescent circadian rhythm holds promise. It not only addresses immediate health challenges, but also fosters positive long-term outcomes as individuals progress from adolescence into adulthood.

2.2 Growth Hormone and Cortisol's Correlation with Adolescent Sleep Patterns

Growth hormone and cortisol play significant roles in modulating sleep patterns, particularly in adolescents, exerting influence through intricate biological mechanisms. Growth hormone, primarily released during deep sleep stages, contributes to various aspects of sleep regulation, while cortisol, known for its diurnal rhythms, impacts the initiation and maintenance of sleep. These hormonal factors collectively influence the sleep-wake cycle, affecting both the structure and quality of sleep in adolescents.

Growth hormone, a pivotal hormone involved in growth and development, exhibits distinct pulsatile secretion, with the highest levels typically occurring shortly after the onset of sleep, specifically during slow-wave sleep (SWS) stages [9]. This pulsatile release is integral to the restorative functions of sleep, contributing to tissue repair, muscle growth, and overall physical development. In adolescents, growth hormone secretion may be particularly pronounced during the initial part of the night, coinciding with the early occurrence of SWS. Stawerska's team suggested that disruptions in the release of growth hormone, whether due to sleep disturbances or other factors, can impact growth trajectories and potentially affect overall physical development during adolescence [10]. Furthermore, growth hormone secretion has been associated with the regulation of sleep architecture. Adolescents experiencing alterations in growth hormone release may encounter disruptions in the amount and distribution of SWS, potentially impacting the overall quality of sleep. Consequently, irregularities in growth hormone secretion could lead to compromised sleep-related physiological processes, influencing not only physical growth but also cognitive functions and overall well-being during this critical developmental stage [11].

Conversely, cortisol, a key stress hormone, exhibits a distinctive diurnal pattern, with peak levels typically occurring in the early morning and declining throughout the day. However, in adolescents, this diurnal rhythm may undergo alterations, resulting in delayed peak times of cortisol secretion. Such shifts in cortisol dynamics can influence the sleep-wake cycle, impacting both sleep initiation and maintenance [12]. Elevated evening cortisol levels have been associated with difficulties falling asleep, potentially leading to delayed sleep onset in adolescents, thereby contributing to disruptions in the sleep schedule. Moreover, the disruption of cortisol rhythms can perpetuate sleep disturbances by affecting sleep continuity [13]. Adolescents experiencing disrupted cortisol dynamics may demonstrate increased awakenings during the night, leading to fragmented sleep patterns. These disruptions

could further exacerbate the challenges associated with maintaining consistent and restorative sleep, ultimately impacting overall sleep quality.

The interplay between growth hormone and cortisol extends beyond their individual effects on sleep, as these hormones exhibit complex interactions within the context of sleep regulation. Studies have suggested potential bidirectional relationships between growth hormone and cortisol, wherein alterations in one hormone may impact the secretion or activity of the other. Additionally, the balance between these hormones is essential for normal metabolic regulation, suggesting that disturbances in their respective rhythms could contribute to broader metabolic implications, potentially impacting sleep-related metabolic processes in adolescents.

Generally speaking, growth hormone and cortisol play integral roles in shaping the sleep patterns of adolescents. GH, with its pulsatile release during SWS, contributes to physical development and sleep architecture. Disruptions in growth hormone secretion may impact growth trajectories and sleep-related physiological processes, impacting both physical and cognitive functions. Conversely, cortisol, with its diurnal rhythmicity, influences sleep initiation and maintenance. Dysregulation of cortisol rhythms may lead to delayed sleep onset and fragmented sleep patterns, affecting overall sleep quality [13]. The interactions and balance between these hormones are crucial for normal sleep regulation and metabolic homeostasis, underscoring the need for further research to clarify their roles in adolescent sleep patterns.

2.3 Circadian Rhythm Disorders and Delayed Sleep Phase Disorder in Adolescents

Adolescence represents a critical phase characterized by substantial physiological and psychological transformations, including notable shifts in sleep patterns. During this developmental period, CRDs hold significant sway over adolescent health and well-being [14]. These disorders are closely intertwined with hormonal fluctuations, particularly melatonin, cortisol, and growth hormone, which play important roles in regulating the sleep-wake cycle.

CRDs denote a dissonance between an individual's internal body clock and the external environment, resulting in disruptions in the timing of sleep. Among adolescents, CRDs typically materialise as irregular sleep-wake patterns, often marked by challenges in falling asleep at socially acceptable bedtimes. Such disturbances align with alterations in melatonin secretion, which experiences a delayed onset during adolescence, contributing to the inclination for adolescents to stay up later at night, thereby exacerbating the difficulties associated with maintaining

consistent sleep schedules [15]. Moreover, an imbalance of cortisol levels can further complicate the situation, potentially leading to delayed peak times of cortisol secretion, affecting the ability to initiate sleep and impacting the overall quality and duration of sleep, thereby aggravating existing circadian misalignments and perpetuating the challenges associated with CRDs [16].

DSPD is typified by a persistent inability to fall asleep at conventional or socially acceptable bedtimes, resulting in delayed sleep onset and subsequent difficulties waking up in the morning. This disorder commonly emerges during adolescence, coinciding with the natural shift in circadian rhythms during this developmental phase [17]. Melatonin, a key regulator of sleep-wake cycles, assumes a central role in DSPD. In adolescents with DSPD, melatonin secretion peaks at later times, contributing to delayed sleep onset and perpetuating the cycle of nighttime alertness. Furthermore, disruptions in growth hormone secretion, which typically occurs predominantly during deep sleep stages, may further complicate the implications of DSPD in adolescents, potentially impacting the restorative functions of sleep and influencing physical development during this crucial stage of growth and maturation.

The implications of CRDs and DSPD extend beyond mere sleep disturbances, also manifesting adverse outcomes encompassing academic performance, mental health, and overall well-being. Academic challenges frequently arise due to difficulties waking up early in the morning, leading to absenteeism and decreased attentiveness during school hours. Additionally, chronic sleep deprivation stemming from these disorders can contribute to heightened levels of stress, anxiety, and depression among adolescents [18]. Moreover, disrupted hormonal rhythms linked with CRDs and DSPD may have lasting effects on physical development and metabolic regulation.

Overall, CRDs and DSPD in adolescents have profound implications, intertwining with hormonal imbalances to impact various facets of their lives. Understanding the complex interactions between melatonin, cortisol, growth hormone and sleep disorders is crucial for devising effective interventions aimed at ameliorating the detrimental effects of these disorders on adolescent health and well-being. A multidisciplinary approach is required to address these issues, integrating insights from endocrinology, sleep medicine, and psychology to develop comprehensive strategies tailored to the unique needs of adolescents grappling with CRDs and DSPD.

3. Limitations and Future Outlooks

There are various obstacles facing the study of adolescent circadian rhythms, hormone levels, and sleep patterns at

the moment. Even though research has advanced significantly, a thorough understanding of how these components interact still has to be achieved. One limitation of current scientific research is the lack of large sample studies worldwide, which leads to the heterogeneity of teenagers included. For example, the difference in socioeconomic level, cultural backgrounds, or geographic regions, all of which may have a substantial effect on hormone regulation and sleep habits. Furthermore, longitudinal studies that could shed light on the long-term consequences of disturbed sleep and hormonal changes during adolescence are frequently absent from the literature currently in publication.

Future research directions could focus on utilizing advanced technology to collect real-time data, allowing for a more detailed analysis of sleep patterns and hormone fluctuations. Moreover, interdisciplinary approaches integrating fields like genetics, neuroscience, and behavioural psychology could offer a more holistic understanding of the complex relationships among sleep, hormones, and circadian rhythms in adolescents. Exploring targeted interventions, including personalized sleep hygiene strategies and hormone regulation techniques, holds promise for improving adolescent well-being and long-term health outcomes.

4. Conclusion

In conclusion, the multifaceted roles of melatonin, growth hormone, and cortisol in shaping adolescent sleep patterns are pivotal for comprehending and tackling the challenges associated with CRDs and DSPD. Melatonin, growth hormone and cortisol don't just regulate sleep; they affect pubertal timing, mood regulation, cognitive function, academic performance and overall wellness. Perturbations in these hormone levels intricately intertwine with CRDs and DSPD, exacerbating sleep disturbances and yielding adverse outcomes for adolescents. Hence, the interaction between hormones and sleep disorders demands critical attention from adolescents, parents, educators, and healthcare professionals. This literature review adeptly combines insights from neurobiology, endocrinology and psychology to offer guidance in crafting tailored interventions, aiming to mitigate the impact of these disorders on adolescent health and well-being.

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