

THE ROLE OF MELATONIN IN THE REGULATION OF CIRCADIAN RHYTHM AND SLEEP QUALITY: NARRATIVE REVIEW

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ABSTRACT

Background: Melatonin is a pineal hormone involved in the regulation of the human circadian rhythm and sleep. Its secretion depends on the light dark cycle and decreases with age, which contributes to sleep disturbances in older adults. Circadian rhythm disorders are common in shift workers and in individuals exposed to time zone changes, which makes melatonin an important subject of clinical interest.

Aims: The aim of this narrative review was to summarize current data on the role of melatonin in circadian rhythm regulation and sleep quality in different patient groups, with particular attention to older adults and shift workers.

Methods: This review was based on the analysis of sixty five publications identified in the Polska Bibliografia Lekarska and PubMed databases for the years 2015 to 2025. Included sources described melatonin synthesis, secretion patterns, physiological functions, clinical characteristics of sleep disturbances, and the use of melatonin in endogenous and exogenous rhythm disorders. All sixty five studies were analyzed descriptively according to the standards of narrative reviews.

Results: The reviewed literature shows that melatonin improves sleep quality, reduces sleep latency by several minutes, and supports the organization of the sleep-wake cycle in individuals with rhythm disturbances. Age related secretion patterns are documented, with the highest melatonin levels in early childhood and a marked decline after the age of forty. Antioxidant and anti inflammatory properties of melatonin are described, along with findings on its role in cardiovascular and gastrointestinal regulation.

Conclusions: Melatonin is an essential regulator of the circadian rhythm and plays a clinically relevant role in sleep disturbances associated with rhythm dysregulation. It is used in older adults, shift workers, and travelers experiencing jet lag. Its dosing should be adjusted according to age and therapeutic purpose, with attention to contraindications and possible drug interactions.

Keywords: melatonin, circadian rhythm, sleep, sleep disorders, sleep quality

INTRODUCTION

The circadian rhythm is defined as “a daily cycle of behavioral changes in animals and physiological changes in plants, explained by the existence of a biological clock-internal factors regulating the periodic nature of processes such as growth and development, activity, sleep, and feeding.” [17]. The circadian rhythm also applies to humans. Each person possesses their own individual daily rhythm, which regulates the desire to transition between wakefulness and sleep and controls daily activities, determining, for example, appropriate times for eating and drinking, as well as influencing mood and emotions [9].

The center of circadian rhythm regulation, known as the suprachiasmatic nucleus (SCN), is located in the

hypothalamus. It functions by receiving light signals through the eyes [48]. The mechanism responsible for synchronizing light with physiological processes in the body was discovered only in 1998, when scientists identified a pigment in the photoreceptive cells of the retina called melanopsin. Melanopsin absorbs light reaching the retina and then, through depolarization, transmits a signal to the SCN. From the hypothalamus, this impulse is sent to specific tissues and organs, triggering appropriate physiological responses [46].

The use of light in regulating the human circadian rhythm is not coincidental. The Sun has always risen and set at specific times of day, serving as a reliable and natural marker of the sleep–wake cycle [56]. The circadian rhythm and its influence on the organization of physiological processes in living organisms were investigated, among others, by American researchers Jeffrey C. Hall, Michael Rosbash, and Michael W. Young, who were awarded the 2017 Nobel Prize in Physiology or Medicine for their discoveries [8].

The circadian rhythm, together with the homeostatic process, is the main mechanism determining the duration, quality, and timing of sleep, defined as “a spontaneously occurring and periodic physiological state characterized by the absence of movement, reduced responsiveness to stimuli, and a stereotypical posture.” [50]. In short, two main phases of sleep can be distinguished: NREM (non-rapid eye movement) and REM (rapid eye movement), which differ based on brain activity levels [37]. It is worth emphasizing that sleep—according to Maslow’s hierarchy of needs—is one of the most fundamental physiological needs of humans, essential for proper body function [33].

However, growing technological advancement, the widespread use of artificial light during evening and nighttime hours, reduced exposure to natural sunlight during the day, decreased physical activity, prolonged mental activity during the day and before bedtime, irregular meal times, and shift or irregular work schedules all contribute to circadian rhythm sleep–wake disorders (CRSWD). These disorders manifest as deteriorated sleep quality at night and decreased psychophysical performance during the day and have become a significant public health issue in developed societies [59, 60, 39, 24].

Circadian rhythm sleep–wake disorders may be classified as endogenous (including delayed sleep–wake phase disorder, advanced sleep–wake phase disorder, non-24-hour sleep–wake rhythm disorder, and irregular sleep–wake rhythm disorder) [19], or exogenous, associated with shift work or jet lag [20].

The duration, quality, and timing of sleep affect, among other factors, the levels of leptin and ghrelin (the satiety and hunger hormones). Disruption of circadian rhythm may lead to persistent feelings of hunger. Sleep also regulates glucose metabolism—sleeping fewer than six hours per night leads to deregulated blood sugar levels, increasing morning cravings for carbohydrates and sugar. Consequently, insufficient sleep is considered a risk factor for numerous diseases, including cardiovascular problems, hypertension, depression, thyroid disorders, overweight and obesity [35], weakened immunity, infertility issues, and even cancer [58]. Sleep deprivation also disrupts cortisol balance—its levels may be too high in the evening, preventing easy sleep onset, and too low in the morning, making awakening difficult [34].

One of the effective methods for managing circadian rhythm and sleep disturbances is melatonin supplementation [28, 29, 34].

The term “melatonin” derives from the Greek word *melas*, meaning “black,” referring to its role in regulating daily cycles in response to changing light conditions. Melatonin is also known as the sleep hormone, hormone of darkness, or pineal neurohormone [51].

Melatonin is a natural hormone primarily produced by the pineal gland, a small endocrine structure located in the brain [31]. Chemically, melatonin is N-acetyl-5-methoxytryptamine, an organic compound from the indoleamine group. It is synthesized from tryptophan (an amino acid obtained from food), which is converted into 5-hydroxytryptophan, then serotonin, N-acetylserotonin, and finally melatonin [18]. Figure 1 depicts the enzymatic conversion of tryptophan to melatonin in the pineal gland.

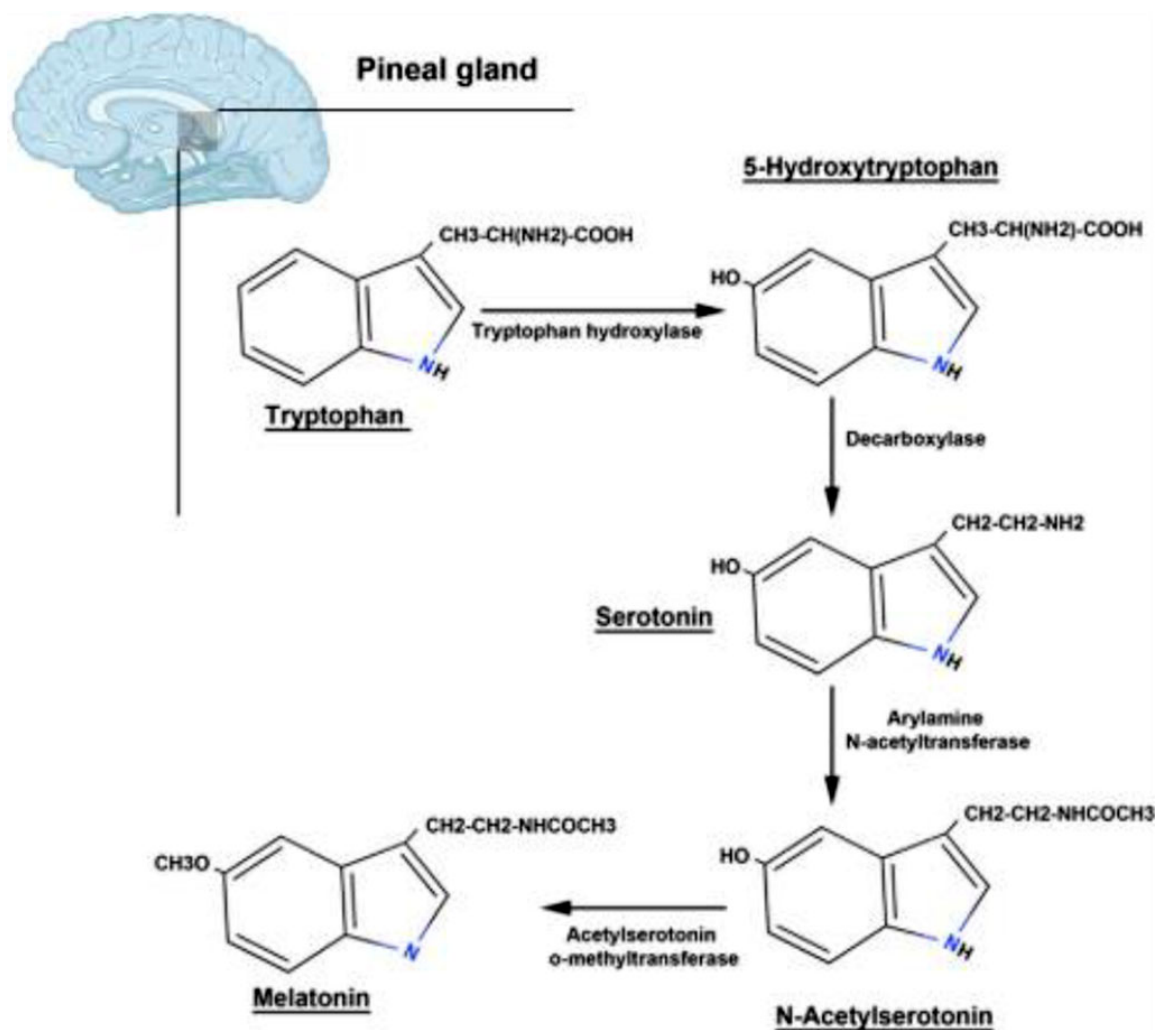


Figure 1. Synthesis of melatonin [23].

Melatonin secretion is closely related to the light–dark cycle, making it the most important regulator of the human biological clock [32]. Information about lighting conditions reaches the pineal gland through neural pathways, starting from the retinal ganglion cells containing melanopsin, through the superior cervical ganglia. As previously mentioned, in the suprachiasmatic nuclei (SCN), a signal is generated to initiate nighttime melatonin synthesis. At this time, noradrenaline is released from sympathetic nerve endings, increasing serotonin N-acetyltransferase activity and, consequently, melatonin production. Under light conditions, the SCN inhibits the paraventricular nucleus, preventing melatonin synthesis and secretion. Conversely, in darkness, this inhibition is lifted, stimulating melatonin release [65, 4].

Melatonin levels therefore rise after dusk. In darkness, melatonin synthesis increases, peaking between 2:00 and 4:00 a.m. (80–120 pg/mL). During daylight, production is suppressed, and blood levels drop rapidly (to about 5–20 pg/mL). Overall, approximately 30 micrograms of melatonin are secreted daily. The circadian rhythm of melatonin secretion appears as early as 6–9 weeks of fetal life and fully develops between 21 and 27 weeks [42].

Like all hormones, melatonin acts through receptors, which can be divided into two categories: G-protein-coupled receptors (MT1, MT2) and quinone reductase enzymes (MT3). Recent studies have shown that MT1 receptor activation is mainly involved in REM sleep regulation, while MT2 receptors influence NREM sleep; therefore, both receptor types may serve as pharmacological targets for specific sleep disorders [12, 2].

Melatonin is synthesized not only in the pineal gland but also in gastrointestinal cells, the retina, and bone marrow. Factors that stimulate melatonin production include a tryptophan-rich diet, reduced use of electronic devices, proper darkening of the sleeping environment, avoidance of caffeine and alcohol before bedtime, and increased exposure to natural daylight. Melatonin is also found in plants such as cherries, red grapes, bananas, walnuts, almonds, oats, rice, barley, and flaxseeds [14, 5], as well as in animal-derived products such as eggs, fatty fish (salmon, tuna, mackerel), and milk and dairy products [38].

RELEVANCE

Circadian rhythm and sleep disturbances are presented in the article as an important public health problem associated with exposure to artificial light, reduced natural light during daytime, irregular activity patterns, stress, and the growing number of people working in shift schedules. These factors contribute to reduced sleep quality, lower daytime performance, and increased risk of cardiovascular diseases, obesity, impaired glucose metabolism, depression, immune dysfunction, and oncological diseases.

In older adults the decline in endogenous melatonin secretion after the age of forty increases both the frequency and severity of sleep disorders, which makes the search for safe and accessible therapeutic approaches particularly important in gerontological practice.

Pronounced disruption of the daily rhythm is also documented in shift workers and in travelers exposed to desynchronization of the biological clock during time zone transitions.

Against this background melatonin is viewed as the most extensively studied regulator of the circadian cycle with documented effects on sleep latency, sleep efficiency, blood pressure, and neurovegetative regulation. The article presents a substantial body of data on its antioxidant, anti inflammatory, and neuromodulatory properties, which broadens the clinical significance of melatonin beyond sleep medicine.

NOVELTY

The author notes the absence of a comprehensive integrative review in the Polish language summarizing current literature on the role of melatonin in circadian rhythm regulation and sleep quality across different age groups, including older adults and shift workers.

The novelty lies in the systematic comparison of Polish and international publications from 2015 to 2025 with emphasis on the clinical importance of melatonin in endogenous and exogenous rhythm disturbances and in the integration of data on physiology of secretion, age related dynamics, mechanisms of action, and therapeutic effects of melatonin. The work consolidates scattered information available in Polish sources and presents a unified analytical overview oriented toward clinical application in patient groups most vulnerable to circadian dysregulation.

AIM

The aim of this narrative review is to summarize published data on the physiological mechanisms of melatonin action and its role in the regulation of circadian rhythm and sleep quality in different patient groups including older adults and individuals working in shift schedules.

Research objectives

1. To describe the mechanisms of melatonin synthesis and secretion and their relationship with circadian regulation according to published data.
2. To present information on the effects of melatonin on sleep structure and sleep quality parameters based on existing clinical and experimental studies.
3. To analyze age related changes in melatonin secretion and their association with sleep disturbances in older adults.
4. To review the use of melatonin in endogenous and exogenous rhythm disorders including shift work and jet lag in accordance with literature sources.

To summarize data on additional properties of melatonin including antioxidant and anti inflammatory effects when such information is present in the included studies.

METHODS

This narrative review was based on the analysis of 65 publications identified in the Polska Bibliografia Lekarska and PubMed databases. The search covered the years 2015 to 2025. The review included studies describing melatonin synthesis and secretion, publications on circadian rhythm regulation, and clinical papers addressing sleep disturbances in different age groups, in shift workers, and in individuals exposed to time zone changes. Articles discussing the antioxidant and anti inflammatory properties of melatonin and age related changes in endogenous melatonin levels were also included.

Inclusion criteria were as follows: publications written in Polish or English, studies directly addressing melatonin physiology or its clinical use in circadian rhythm or sleep disturbances, and papers presenting data relevant to melatonin's regulatory role. Exclusion criteria comprised publications not related to melatonin or circadian regulation and papers lacking scientific content.

All 65 sources were analyzed descriptively, without quantitative synthesis, in accordance with the methodological standards of narrative reviews, with the aim of summarizing current knowledge on the role of melatonin in circadian rhythm regulation and sleep quality.

RESULTS

Across the analyzed literature melatonin consistently appears as a key element of circadian rhythm regulation and a factor influencing sleep parameters. Multiple clinical and experimental studies confirm that melatonin improves sleep quality, reduces sleep latency, and enhances sleep efficiency. The reviewed publications indicate that melatonin supplementation shortens the time required to fall asleep by several minutes and supports the organization of the sleep-wake cycle in individuals with circadian rhythm disturbances. The antioxidant and anti-inflammatory properties of melatonin are repeatedly documented, including its ability to reduce oxidative stress and modulate inflammatory responses. The literature also shows that melatonin influences immune regulation and may enhance resistance to oxidative cellular damage. These effects are supported by studies describing the relationship between melatonin and free radical scavenging mechanisms.

DISCUSSION

The analyzed literature confirms that melatonin functions as a regulator of a disrupted circadian rhythm rather than a direct hypnotic agent. A mild reduction in blood pressure and facilitation of sleep onset are documented in studies examining the vascular effects of melatonin [11, 44].

The effect of melatonin is most pronounced in patients with sleep disturbances associated with circadian dysregulation. The included sources demonstrate improved sleep quality and a reduction in sleep latency by several minutes [15, 35]. Melatonin is recommended for individuals over the age of fifty five, for shift workers, and for persons experiencing circadian desynchronization when crossing time zones [23, 21, 49, 6, 62]. In stressful or depressive conditions the effect may be weaker. However, the literature reports improved sleep when melatonin is added to pharmacotherapy for depression [43, 3, 57].

The use of melatonin in children with sleep disorders, including autism spectrum disorder and ADHD, is confirmed in clinical observations [16]. Its antioxidant and anti-inflammatory properties are described in biochemical studies demonstrating the ability to neutralize free radicals and interact with antioxidant systems [28, 1, 53]. Experimental data on the scavenging of hydroxyl radicals indicate an important protective role in preventing oxidative cellular damage [40, 52].

The literature includes findings linking reduced melatonin levels to an increased risk of cardiovascular complications and a potential protective effect in myocardial ischemic injury [12, 45, 36]. Studies concerning the gastrointestinal tract show that melatonin participates in the regulation of intestinal motility and supports mucosal barrier integrity. These mechanisms may explain a reduction in reflux related symptoms, although without quantitative assessment of the effect [63].

Age related differences in melatonin secretion are clearly demonstrated. Levels reach approximately 250 pg per mL in children aged three to five years, decrease to 120 to 180 pg per mL in adolescents, remain at 70 to 80 pg per mL in adults, and fall to 20 to 30 pg per mL in individuals over sixty five years [7]. These values are presented in Figure 2 [31]. Older adults more frequently exhibit early sleep onset and early morning awakening [25, 22]. Younger individuals show a tendency toward delayed sleep phase [16]. Figure 2 illustrates that melatonin secretion is minimal in newborns, reaches its highest levels in early childhood, declines through puberty and middle age and becomes very low in older adults.

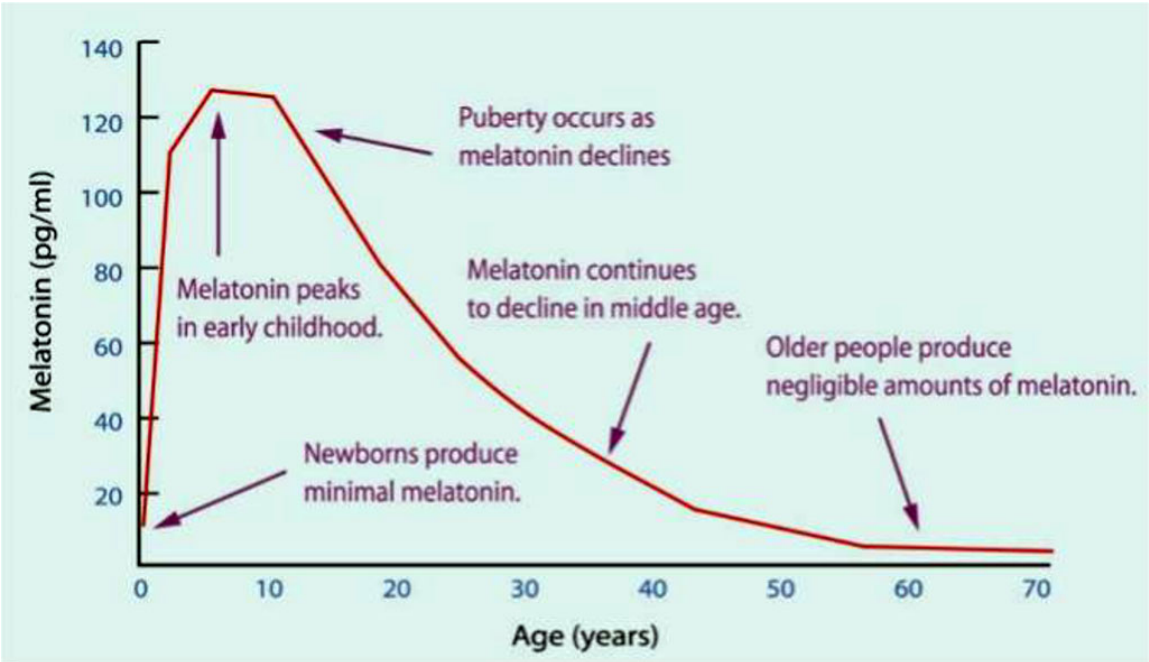


Figure 2. Circadian rhythm of melatonin secretion in individuals of different ages [57].

Insufficient melatonin secretion is associated with sleep disturbances, fatigue, and reduced concentration. Excessive intake of high supplemental doses may result in adverse effects [13, 54]. The literature provides dosing information for various clinical scenarios including circadian rhythm disorders, shift work, and jet lag. Recommended dosing ranges are presented in Table 1 [61].

Table 1. Recommended melatonin doses depending on the purpose of supplementation [61].

Purpose of supplementation	Recommended dose
Difficulty falling asleep	0.5–3 mg, 30–60 min before bedtime
Improving sleep quality	1–5 mg, 30–60 min before bedtime
Circadian rhythm disorders	2–5 mg, 1–2 h before bedtime
Shift work	2–5 mg after completing a night shift
Jet lag (time zone change)	0.5–5 mg before bedtime for several days after travel
Antioxidant support	0.5–2 mg before bedtime
Older adults (reduced melatonin synthesis)	0.5–2 mg, 30–60 min before bedtime

Taken together, the analysis of the included sources confirms the central role of melatonin as a core chronobiotic involved in circadian rhythm regulation and in maintaining physiological sleep quality.

CONCLUSIONS

Melatonin secretion, produced primarily by the pineal gland, is determined by the light–dark cycle and reaches its highest levels during nighttime hours. Numerous studies included in this review confirm the beneficial effects of melatonin on sleep quality, the reduction of sleep onset latency, and the regulation of the circadian rhythm. The presented evidence also indicates the involvement of melatonin in reducing oxidative stress, modulating immune responses, and supporting physiological functions under conditions of circadian disruption.

Melatonin is most commonly used in patients with sleep disorders related to circadian dysregulation, in individuals over the age of fifty five, in shift workers, and in travelers experiencing rhythm desynchronization caused by time

zone changes. The dosage of melatonin should be adjusted according to age and clinical purpose. The dosing schemes presented in the literature provide guidance for different clinical situations.

In Poland, melatonin is available over the counter. Issues of safety and tolerability are discussed in several included publications, although their findings are based on observational data and remain limited. Therefore, the use of melatonin, particularly long term, requires a careful approach and consideration of possible contraindications, including pregnancy, lactation, liver and kidney diseases, and the concurrent use of medications that may influence melatonin metabolism.

DISCLOSURE

CONTRIBUTION OF THE AUTHOR

The author was responsible for the conceptualization, methodology, investigation, data collection, formal analysis, writing of the original draft, review, editing and supervision.

USE OF AI

The authors declare that no artificial intelligence tools were used to generate, analyze, or interpret scientific content in this manuscript. AI assisted only in grammar checking and formatting without influencing the scientific conclusions.

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