

Age-Related Changes in Circadian Rhythms and Their Effects on Cognition and Psychological Well-Being: A Literature Review

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URNCST Journal
"Research in Earnest"

Abstract

Introduction: Circadian rhythms, the internal “clocks” that control a variety of physiological processes, have been found to change considerably throughout one’s lifetime. Young adults tend to be more “evening” people, while older adults tend to be more “morning” people due to age-related changes in their sleep-wake cycles. This review aims to discuss the corresponding physiological and psychological changes that occur due to the changing circadian rhythms that come with age.

Methods: A literature search was conducted using the databases PubMed, PsycINFO, and AgeLine. Keywords included variations of “circadian rhythms”, “aging”, “chronotype”, “cognition”, “depression”, “mood”, “bipolar disorder”, and “anxiety”. Studies were selected and findings regarding the physiological and psychological changes due to circadian rhythms and aging were reviewed.

Results: Research shows that age-related disruptions in circadian rhythms are associated with cognitive and psychological decline. Diminished sleep quality is associated with older age, due to the aforementioned underlying dysregulated circadian rhythms. Sleep deprivation is associated with increased levels of fatigue, stress, and overall mood disturbances. Moreover, circadian rhythm abnormalities associated with old age are related to greater mood disturbances, depression, and anxiety.

Discussion: Poor sleep and older age are important factors that can negatively affect one’s mood and emotional well-being. It is imperative that healthcare providers consider these factors when consulting and treating patients. Populations such as shift workers have been found to have impaired levels of alertness, mood, memory, and cognitive performance due to their dysregulated circadian rhythms. Furthermore, time of day plays a crucial role in the educational success of children and adolescents. Young individuals with an evening chronotype are put at a disadvantage for early school start times due to their opposing optimal times of performance.

Conclusion: Circadian rhythm dysfunction that is commonly associated with aging has the potential to contribute to adverse outcomes in human health, including cognitive deficits and pathological conditions. Future research efforts should concentrate on further clarifying the relationship between changing circadian rhythms and its impact on psychological well-being.

Keywords: circadian rhythms; aging; chronotype; cognition; depression; mood; bipolar disorder; anxiety

Introduction

As the saying goes, “the early bird catches the worm”. This can be said for older adults who prefer to wake up early in the morning. Prior research has suggested that older adults tend to be more “morning” people, and younger adults tend to be more “evening” people [1]. This may be due to age-related changes in circadian rhythms, or internal “clocks” that control a variety of physiological processes over a 24-hour oscillatory cycle [2,3]. Circadian rhythms change considerably throughout one’s lifetime, which are largely influenced by aging and morbidity [2]. Prolonged disruptions of circadian rhythms influence negative health consequences, which may be exacerbated in older adults [2,4,5]. Sleep and circadian rhythms play a large role in

various domains of cognition [6]. For example, a decline in cognitive performance would be expected with sleep deprivation [3]. The mechanisms of how circadian rhythms change as one ages, as well as their effects, still remain unclear.

Chronotype is the variation of an individual’s pattern of early or late time preference in activity [1,7]. Morning individuals have been shown to report increased energy and alertness, a stable personality, and more frequent positive emotions [1]. In contrast, evening people are usually active late and go to bed later in the night [7]. Age has been known to be a strong predictor of one’s chronotype [1,7]. Dijk et al. [8] found that older adults who went to bed earlier (i.e., morning chronotype) had higher melatonin levels and lower

body temperatures at earlier times in the day. Furthermore, some research suggests an individual's circadian clock gradually shifts as one ages. Morning chronotypes begin in childhood, but slowly transition to evening chronotypes during young adulthood [1]. However, when one approaches their early 60s, circadian rhythms begin to revert back to a morning chronotype [1]. Both total sleep time and sleep quality are estimated to decrease beginning from mid-life (ages 36–50) to the eighth decade [9]. Regardless of chronotype, individuals demonstrate superior cognitive performance at their optimal time of day, and deficits in cognitive performance at their suboptimal time of day, a phenomenon known as the synchrony effect [10]. Indeed, morning chronotypes tend to have greater productivity in the morning and poorer productivity in the late evening, while evening chronotypes tend to demonstrate the opposite effect [10]. The synchrony effect can also have a substantial impact on many cognitive abilities in addition to psychological well-being. However, literature surrounding this synchrony effect remains unclear.

Therefore, this review paper aims to investigate how age-related changes in circadian rhythms influence cognition and psychological well-being, including mood changes and psychiatric disorders. Circadian rhythm disturbances may pose a risk for cognitive impairment and psychological disorders, particularly in older adults [11]. In terms of cognition, literature was reviewed with respect to the effects of age-related circadian rhythm changes on attention, memory, and executive functioning. These three processes are compromised in healthy aging, and may be further impacted with age-related dysregulations in circadian rhythms.

Literature regarding typical mood changes that are influenced by age-related changes in circadian rhythms are also reviewed, where it is expected that older and younger adults experience better mood during their optimal times of day. Dysregulation of circadian rhythms and sleep-wake disorder increases the susceptibility to numerous mood-related pathological conditions, such as major depressive disorder (MDD), generalized anxiety disorder (GAD), and bipolar disorder (BP) [12,13]. In fact, recurrent episodes of insomnia or hypersomnia are on the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) diagnostic criteria for GAD [14]. MDD and GAD are psychiatric disorders that share a considerable degree of comorbidity, genetic correlation, and similar pathophysiology [14]. BP is a psychiatric disorder associated with impaired cognition and extreme shifts in mood, behaviour, and energy [13]. Psychological well-being and mood disorders may be further compromised with age-related dysregulation in circadian rhythms.

Methods

A literature search was conducted using the databases PubMed, PsycINFO, and AgeLine. Studies between the years of 2000 to 2021 were included. Keywords included

variations of “circadian rhythms”, “aging”, “chronotype”, “cognition”, “depression”, “mood”, “bipolar disorder”, and “anxiety”. Studies included data from peer-reviewed journals describing changes in circadian rhythm and age, as well as their direct effects on cognition or psychological well-being. In addition, these studies must include older adults or have a comparison between younger and older adults. Systematic and literature reviews, conference abstracts, and irrelevant articles were excluded.

Results

A total of 102 relevant articles were initially identified. These studies were screened for eligibility based on their title and abstract. Sixty-four articles remained and were subsequently examined for inclusion criteria, after which 14 studies remained and were ultimately included in the review.

Cognition: Sleep Quality and Synchrony Effect

Cognitive function is reduced as one's sleep quality diminishes in the aging population [15-18]. Older adults who had poor sleep quality demonstrated a slower speed of processing, poorer executive function, memory, and decreased concentration [15-17]. Some research has shown an association between weaker circadian rhythms in older women and cognitive decline [16].

Much research surrounding cognition has examined the synchrony effect and circadian rhythms [18-22]. Regarding age, younger adults outperformed older adults in all cognitive domains examined, regardless of the time of day [18-20]. Within the domain of memory, time of testing did not significantly differ for younger adult performance; however, this factor was significant for older adults [18,19]. In these studies, older adults had difficulty retrieving memory in the afternoon and evening, but had no difficulty in the morning [18,19]. In a study by May et al., [18] 26% and 19% of older adults performed poorly in memory retrieval in the morning and midday, respectively. However, 39% of older adults performed poorly in memory retrieval at night, which significantly differed between time of day [18]. A separate study by May et al. [21] found similar results, where older adults performed memory tests at their optimal and non-optimal times of day. Younger adults were found to perform better at their optimal time of day in the evening than in the morning, contrasting the previous May et al. [21] study. Two other studies demonstrated similar findings whereby older and younger adults are attentive and alert at their optimal time of day, thereby exemplifying the synchrony effect [20,22]. This finding was supported by magnetic resonance imaging, where older adults who tested in the morning demonstrated similar patterns of brain activity in cognitive control regions as young adults did in the evening [20]. In a study by West et al., [22] alertness, which was measured by a subjective alertness rating scale, was greater for younger adults in the evening compared to older adults who were more alert in the morning. Furthermore, older adults who tested in the afternoon

demonstrated decreased resistance to distraction in comparison to the older adults who tested in the morning [20]. Overall, cognitive function diminishes as one ages; however, older adults' cognition is highest during the morning and midday, in comparison to the evening.

Mood Changes

The literature shows that changes in mood are influenced by time of day. As determined by Schwarz et al., [23] sleep deprivation has profound effects on mood and emotional regulation of both younger (ages 18–30) and older adults (ages 60–72). Regardless of age, there was an expected correlation between sleep deprivation and mood changes, such that sleep-deprived participants felt more fatigued, stressed, and reported lower vigour and positive affect. Both age groups displayed significant increases in total mood disturbances subsequent to sleep deprivation. Although older adults experienced higher levels of mood disturbances following sleep deprivation than younger adults, older adults were more successful at mitigating the associated increased fatigue, mood disturbances, and cognitive attenuation than young adults.

A study conducted by Hill & Chtourou [24] determined that morning individuals exhibited a significant increase in depression, anger, and fatigue, as well as a decrease in vigour as the day elapsed. Compared to morning individuals, evening individuals demonstrated a significant increase in vigour as the day progressed. Four hundred and thirty five young adults (ages 17–38) and 297 older adults (ages 59–79) were studied to determine whether age differences in chronotype impacted emotional well-being [1]. Regardless of age, morning chronotypes were found to be associated with better overall health compared to those of evening chronotypes. Older morning adults reported significant improvement in mood and higher levels of positive affect as the day progressed, compared to younger evening adults. These studies demonstrate the differences in emotional well-being between age groups, namely how older morning adults experience more mood fluctuations throughout the day than their younger counterparts.

Major Depressive Disorder, General Anxiety Disorder, and Bipolar Disorder

Alterations in circadian rhythms have been observed in individuals with MDD across the lifespan, with an estimated 80% of this population suffering symptoms of insomnia [25]. Almeida & Pfaff [26] studied the sleep quality of 1029 participants over the age of 60, where 36% reported trouble falling asleep, 54% reported restlessness, and 35% reported early morning awakening. Nineteen percent of participants reported sleep difficulties that fell into all three categories. In regards to aging, this study also found that over 60% of older adults in contact with their general practitioner complained of poor sleep, and these individuals were nearly four times more likely to be depressed than those who did

not complain of poor sleep. Within the group of older adults that reported compromised sleep quality, approximately one-third presented with symptoms of depression.

Similarly, sleep disturbances and insomnia have also been observed in individuals with GAD, particularly older adults [12]. In a study by Brenes et al., [27] 110 older adults (ages 60–94) completed the Insomnia Severity Index (ISI), a DSM-4 questionnaire that assesses several categories of sleep, including sleep onset, sleep duration, early morning awakening, and sleep dissatisfaction. A higher score on the ISI indicated greater insomnia symptoms. The ISI scores were found to be highest among individuals diagnosed with GAD, and lowest among individuals without GAD. Sleep disruptions were more common among older adults with GAD, with 52–68% of participants reporting insomnia, and 90% of participants reporting poor sleep quality overall. After sleep maintenance, early morning awakening was the second most common complaint associated with sleep difficulties in older adults.

Individuals with BP also experience alterations in sleep, attributed to changes in their circadian rhythms. In a study comparing sleep efficiency of individuals with BP to individuals with insomnia and to healthy controls, Harvey et al. [28] found that the BP group consistently reported longer sleep durations and lower daytime activity than either group. Both the BP and insomnia groups reported lower sleep efficiency scores in comparison to controls. Seventy percent of individuals in the BP group had a clinically significant sleeping problem, with 55% of the group meeting the criteria to be diagnosed with insomnia. A study conducted by Mansour et al. [29] studied the relationship between chronotype, age of disease onset, and frequency of rapid mood swings (RMS) in a sample of 70 individuals with BP, 80 individuals with schizophrenia, and 349 healthy controls. The study found that the BP group demonstrated age-dependent scores, with the highest frequency of evening chronotypes being younger adults with BP. Individuals with BP who experienced RMS expressed evening chronotypes more than those who did not experience RMS. Unlike the control or schizophrenia groups, an earlier BP onset contributed to a greater proportion of evening chronotypes in BP. These studies demonstrate the relationship between altered circadian rhythms and individuals with MDD, GAD and BP, attributing to the notable changes seen in their sleep-wake cycles such as reduced sleep quality [26,27,29].

Discussion

This review demonstrates how age-related changes in circadian rhythms influence cognition and psychological well-being, including mood changes and psychiatric disorders. Various similarities were observed throughout the literature that support the aforementioned age-related disruptions in circadian rhythms.

Theories Behind Circadian Rhythm Dysfunction

There are a variety of theories surrounding why circadian rhythms change with age, including dysregulation of the suprachiasmatic nucleus (SCN), decreased sensitivity to light, and reduced circulating melatonin levels [30-35].

The SCN is the principal component within mammals that hosts the internal clock and has the role of being the circadian rhythm oscillator [31]. The SCN regulates endocrine, physiological, and behavioural effects of circadian rhythms, which may all become susceptible to impairments with aging [31]. Both the natural age-related degradation of the SCN and a decrease in vasoactive-intestinal peptide (VIP) neurons within the SCN are theorized causes of a deteriorated circadian oscillator [31,36]. Important for circadian function, VIP neurons demonstrate a recurring diurnal 24-hour pattern, whereby young adults (under age 50) exhibit low amounts of VIP at night and peak values in the morning [31,37]. Contrastingly, the SCN of older adults (above age 50) have reduced total amounts of VIP neurons and follow a reversed diurnal cycle, suggesting a disrupted circadian cycle [31,37]. The circadian rhythm disruptions that can arise due to a deteriorated SCN are thereby particularly found within the elderly population [36,37].

Melatonin is a hormone secreted by the pineal gland, and has been viewed as a marker of circadian rhythms [33]. In humans, melatonin acts on the SCN to promote sleep by weakening the wake-promoting signals of the circadian clock [38]. Melatonin also acts on the default mode network to induce fatigue and sleep-like changes [38]. It has been widely documented that there is an age-dependent decrease in the nighttime secretion of melatonin as one ages [32-35]. Nighttime melatonin levels in older adults were approximately 50% lower compared to younger adults in a study by Van Coevorden et al. [34]. Decreased circulation of nighttime melatonin levels are associated with impaired sleep, attributed by the close association between the circadian melatonin system and the circadian sleep system [38]. One explanation for this is the “melatonin replacement” hypothesis, which suggests that increasing melatonin levels will improve sleep overall [38]. This hypothesis supports the relationship between old age, reduced melatonin production, and impaired sleep [38].

Light plays a critical role in one’s circadian rhythm; this includes the timing, intensity, and duration of light exposure [33,39]. Light is connected to the circadian system through the retina and photoreceptors that connect to the hypothalamus through the retinohypothalamic tract, terminating at the SCN [33]. The strength of the neural and chemical signal to, from, and within the SCN can be affected as one ages, through reductions in retinal light sensitivity and the duration of bright light exposure [33,39]. Reports suggest that older adults receive lower levels of light exposure and a reduced time of light exposure [33]. Older adults can receive approximately 33% less bright light than younger individuals, according to one study [33]. These reduced

levels of bright light have been found to be associated with sleep fragmentation and disordered circadian rhythms [30].

Theoretical Implications

The literature reviewed supports the idea that as an individual ages, their chronotype gradually shifts from evening to morning. This aligns with research by Biss & Hasher [1], which examined the gradual shift from evening to morning chronotypes due to changing circadian rhythms related to aging. Furthermore, early morning awakening was one of the most reported complaints associated with sleep difficulties in the study by Brenes et al. [27]. Therefore, the presence of pathological conditions such as MDD and GAD may exacerbate the effects of reduced sleep quality and quantity that older adults experience [26].

Along with the reduced sleep quality in older individuals due to dysregulation of circadian rhythms, poorer sleep quality is correlated with diminished cognitive performance, regardless of chronotype [40]. Importantly, chronotype has an influential role in the pathological conditions examined in this review [40]. Research has suggested behavioural treatments for insomnia are less effective in individuals who exhibit evening than morning chronotypes [41]. Furthermore, there is research to support the association between BP and evening chronotype [13]. By comparing individuals with BP to controls, Mansour et al. [29] demonstrated that individuals with BP were more likely to exhibit evening chronotypes, which is further supported by additional studies [42-44].

Clinical Implications

As evident in the results, sleep and age are considerable factors in one’s mood and behaviour. Therefore, these are important elements for clinicians to take into account when consulting and diagnosing patients, particularly older adults. The findings from this review are clinically relevant, namely due to the prevalence of psychiatric disorders in older adults. Current literature has noted that 1–5% of the older population suffer from MDD, approximately 2% have been diagnosed with GAD, and 0.5–1% of the population are reported to have BP [45-48]. Reduced sleep quality has also been reported within older adults diagnosed with these psychiatric disorders [48]. Thus, it is essential for physicians to acknowledge that sleep quality and disruptions may affect the mood of their patients during clinical evaluations and exacerbate their presenting symptoms.

Occupational and Educational Implications

Shift work entails working irregular and beyond conventional hours, and is associated with sleep deprivation and extreme fatigue [49-51]. The effects of shift work manifest in various bodily disruptions, such as in circadian rhythms, mood, and cognitive performance [49-51]. As fatigue impacts critical cognitive functioning, shift work can lead to reduced work efficiency, and ultimately increase

fatigue-related errors and injuries in the workplace [49-51]. This research may inform readers on the various cognitive implications surrounding shift work, such as error-prone behaviours that can decrease workplace productivity. Research suggests that as an individual's shift work experience increases, their performance in immediate recall significantly decreases [50]. However, there is currently no evidence of a correlation of late-life cognitive impairments between individuals who were once long-term shift workers and individuals who were not [52].

Children and adolescents start school early in the morning, which puts students with evening chronotypes at an educational disadvantage [53,54]. The demand to be awake and mentally focused in the morning is particularly difficult for adolescents who perform better at night due to the synchrony effect. Those with evening chronotypes obtain lower grades on average compared to morning chronotypes, and are also more likely to sleep less on school nights, which can further impair cognition, mood, and emotion [3,23,53]. Studies have demonstrated that academic performance can be improved when school times align with adolescent chronotypes and their optimal time of day [54]. For example, Preckel et al. [55] studied how the chronotypes of high school students impacted their academic performance, and found that greater cognition and overall academic achievement were associated with morning chronotypes. In comparison, students with evening chronotypes had a significantly negative association with academic achievements, such as a lower grade point average [55]. From the literature, it is evident that disruptions in circadian rhythms occur throughout the lifespan in an age-dependent manner. Adolescents with morning chronotypes display higher cognitive performance in academia [55]. However, older adults with the same morning chronotype exhibit overall reduced cognitive performance [15-17]. This pattern of findings demonstrates how the interaction between age and chronotype is a crucial factor in cognition, considering older morning adults (and not younger morning adults) exhibit diminished cognitive performance.

Limitations

A limitation within this review is the low number of studies that were yielded from the literature searches (14 in total). This may be due to the strict inclusion criteria which reduced the number of studies for analysis. More independent studies are needed in order to better understand the cognitive and psychological effects of aging associated with changing circadian rhythms. Additionally, older adults were prioritized in the field of psychiatric disorders, as sleep disturbances are highly prevalent in this population [56]. There is also a lack of longitudinal studies in the literature, which poses a limitation since these studies are useful in observing the same participants over time. It is essential for future literature to measure these changes across the lifespan to have a holistic perspective on this subject matter.

Conclusions

Therefore, the phrase "the early bird catches the worm" does often apply to older adults, but these circadian changes may also put them at a greater disadvantage to cognitive and psychological decline. There is evidence to support the association between age-related changes in circadian rhythms and their influence on cognition and psychological well-being. Within the domain of cognition, sleep quality diminishes as one ages, which in turn has been associated with poor cognitive performance. Additionally, the synchrony effect is strongly associated with one's age and chronotype, demonstrating positive cognitive performance during an individual's optimal time of testing. Both time of day and circadian rhythm dysfunction vastly influence alterations in mood, whereby sleep deprivation manifests mood disturbances and lowers positive affect. Studies have shown a positive correlation between disrupted circadian rhythms and depression [25,26]. Frequent episodes of insomnia have been observed in MDD and GAD, which is associated with the increased prevalence of sleep disruptions in older adults [27]. Additionally, circadian rhythm dysfunction alters sleep in BP, which is associated with longer sleep duration, yet reduced sleep quality [28]. Future research efforts should focus on the intersections of aging, circadian rhythms, and psychological effects. This can guide both researchers and clinicians in the right direction towards understanding the broad implications circadian rhythm dysfunctions have on overall aging and well-being.

List of Abbreviations Used

MDD: major depressive disorder
GAD: generalized anxiety disorder
BP: bipolar disorder
DSM: diagnostic and statistical manual of mental disorders
ISI: insomnia severity index
RMS: rapid mood swings
SCN: suprachiasmatic nucleus
VP: vasoactive-intestinal peptide

Conflicts of Interest

The authors Aoife McMahon, Raymond Tolentino, and Phoebe Thum declare that they have no conflict of interests.

Ethics Approval and/or Participant Consent

This literature review did not require ethics approval and/or participation consent. As this paper is a review article, the purpose of this study was to summarize and analyze previous articles, as opposed to conducting a primary study. All literature included in this review had previous ethics approval in their respective studies.

Authors' Contributions

AM: made contributions to the design of the study, collected and analyzed data, drafted the manuscript, and gave final approval of the version to be published.

RT: made contributions to the design of the study, collected and analyzed data, drafted the manuscript, and gave final approval of the version to be published.

PT: made contributions to the design of the study, collected and analyzed data, drafted the manuscript, and gave final approval of the version to be published.

Acknowledgements

The authors gratefully acknowledge their mentor, Ricky Chow, for his continuous support and guidance. His generous efforts have not gone unacknowledged and the authors send their utmost appreciation for his contribution to this paper.

Funding

This study was not funded.

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Article Information

Managing Editor: Jeremy Y. Ng

Peer Reviewers: Ricky Chow, Sumeya Mukhtar

Article Dates: Received Apr 02 21; Accepted Jun 06 21; Published Jun 24 21

Citation

Please cite this article as follows:

McMahon A, Tolentino R, Thum P. Age-related changes in circadian rhythms and their effects on cognition and psychological well-being: A literature review. *URNCST Journal*. 2021 Jun 24: 5(6).

<https://urncst.com/index.php/urncst/article/view/258>

DOI Link: <https://doi.org/10.26685/urncst.258>

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