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## ADHD and Sleep: Recent Advances and Future Directions

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### Abstract

Individuals with attention-deficit/hyperactivity disorder (ADHD) frequently have sleep disturbances, daytime sleepiness, and/or circadian rhythm abnormalities. This article reviews recent advancements and key future directions: examining group differences across the life span, advancing a developmental psychopathology perspective, moving from correlation to causation, conceptualizing ADHD as a 24-hour disorder, understanding sleep in relation to other health behaviors, and evaluating sleep in interventions for individuals with ADHD. This is an exciting time in the empirical study and clinical care of sleep disturbances and circadian rhythm alterations in individuals with ADHD. As research continues to advance, studies are increasingly using large samples and longitudinal/experimental research designs to test hypotheses that will ultimately allow for a more robust and sophisticated understanding of sleep and ADHD.

### Keywords

attention-deficit/hyperactivity disorder; chronobiology; chronotype; circadian rhythm; daytime sleepiness; developmental psychopathology; intraindividual variability; sleep

### Introduction

Despite long-standing interest in the co-occurrence of attention-deficit/hyperactivity disorder (ADHD) and sleep disturbances, empirical investigation of these two topics has only intensified in recent years. A simple literature search indicates that the research on ADHD and sleep has grown – and continues to grow – at a rapid pace. As shown in Figure 1, the literature on ADHD and sleep steadily grew from the mid-1970s through the mid-1990s (“restless sleep” was a symptom for diagnosing ADHD in the DSM-III, though removed when the DSM-III-R was published in 1987), and then started to accumulate at an increasingly fast rate. Of the 10,632 total publications from 1970–2018, a third (3,459) were

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published in just the last five years alone. The size and scope of this literature has led to a recent book devoted entirely to ADHD and sleep [1]. Needless to say, this is an exciting time for research in this area, yet it is also difficult (nay, impossible) to stay informed of the many advancements across this diverse field. In this article I prioritize research conducted in the past two years to highlight select key issues and future directions to advance the empirical understanding and clinical care of ADHD and sleep.

## Establishing Group Differences across the Life Span

As with most areas of ADHD research, early research on ADHD and sleep focused almost entirely on school-aged children. A decade ago, a seminal meta-analysis of this research documented that children with ADHD have significantly more impaired sleep compared to their healthy peers across most subjective sleep domains (e.g., bedtime resistance, sleep onset, night and morning wakings, daytime sleepiness) and some objective sleep parameters (e.g., actigraphy-measured sleep onset latency and sleep time; polysomnography-measured sleep efficiency; sleepiness based on average time to fall asleep for the Multiple Sleep Latency Test [MSLT]) [2]. However, until recently, the extent to which adolescents and adults with ADHD had more sleep disturbances than their same-age counterparts was largely unknown. Substantial progress has been made in this regard in recent years, allowing for a better understanding of sleep and ADHD across the life span.

Adolescence is a time of rapid neurobiological, developmental, and socio-contextual changes known to impact and be impacted by sleep [3]. Shortened sleep and sleep disturbances become increasingly common in adolescence, and it is important to know if adolescents with ADHD continue to have poorer sleep compared to their peers during this developmental stage. A systematic review concluded that sleep disturbances are associated with ADHD (and ADHD symptoms) in adolescence, though studies reported mixed findings and were generally limited by small or non-representative samples, non-standardized sleep and/or ADHD measures, and cross-sectional designs [4]. Recent studies have begun to advance the knowledge base regarding sleep in adolescents with ADHD. We examined sleep in a large sample of eighth-grade adolescents with ( $n=162$ ) and without ( $n=140$ ) ADHD [5•]. Adolescents with ADHD were more likely than comparison adolescents to obtain insufficient sleep on school days (per sleep diary) and on weekends (per both diary and actigraphy), and to report staying up all night in the previous two weeks (14% and 5%, respectively). Further, we found that even after controlling for a number of variables known to impact sleep (e.g., sex, pubertal development, other psychiatric disorders, medication use), ADHD was associated with shorter school night sleep duration, greater daytime sleepiness, and more sleep disturbance [5•]. These findings indicate that even during a developmental stage when sleep problems and daytime sleepiness are elevated across the population, individuals with ADHD are still more likely than their peers to have poor sleep and increased sleepiness. Recent cross-sectional studies point to the possible roles of nighttime media use [6], general technology use [7], and sleep hygiene [8] as possible factors that may contribute to sleep problems in adolescents with ADHD. Other factors that will be important to investigate include academic and organization/homework problems, comorbid psychopathologies and emotion dysregulation, caffeine and substance use, and family and peer difficulties. These factors have received surprisingly little research attention

in samples of individuals carefully diagnosed with ADHD [1], and studies are needed to test both independent and joint effects. It will likewise be important to examine sleep as a predictor of adjustment in adolescents with ADHD, including consideration of domains that typically emerge in adolescence (e.g., driving, substance use) or increase in adolescence (e.g., depression, suicidality). One longitudinal study found sleep problems to predict increases in depressive and oppositional defiant symptoms, but not anxiety symptoms, one year later in adolescents with ADHD [9]. Given the complexities and possible transactional processes, longitudinal studies with multiple timepoints are especially needed to examine predictors, consequences, and bi-directional pathways involving sleep and sleepiness in adolescents with ADHD. As just one example, organization problems may lead to sleep being displaced by other tasks, and poor or insufficient sleep may in turn lead to poorer attention in class and greater academic difficulties.

Growing attention has also been devoted to sleep in adults with ADHD, and the first meta-analysis of sleep in adults with ADHD was recently conducted [10•]. Findings were largely consistent with meta-analytic findings in children, with adults with ADHD having poorer sleep than adults without ADHD across most subjective sleep domains but few group differences in objective sleep parameters. Adults with ADHD differed from adults without ADHD on two actigraphy-derived parameters: sleep onset latency and sleep efficiency. Although the meta-analysis found no group differences on any of the polysomnography-derived parameters examined, the authors noted that few studies were available to examine certain parameters (e.g., apnea-hypopnea index; time to fall asleep during the MSLT). Studies are also needed to examine sleep microarchitecture (e.g., slow waves, sleep spindles), medication and comorbidity effects, and other factors that may underlie subjective sleep problems in adults with ADHD [10•]. In considering rates of subjective sleep disturbances, it is clear that insomnia is more prevalent in adults with ADHD than adults without ADHD [11]. For instance, a large study recently conducted in Norway found 66.8% of adults with ADHD met established cutoff criteria for insomnia, compared to 28.8% of adults without ADHD [12]. Another study of adults with clinically-elevated ADHD symptoms found 43% to report significant insomnia symptoms, 41% to report short sleep duration, and 6% to report long sleep duration [13]. These studies found current inattentive symptoms [12] or both inattentive and hyperactive-impulsive symptoms [13] to be associated with insomnia. These findings appear to be consistent with a longitudinal study that found children with ADHD to have poorer sleep quality in young adulthood, but only among those whose ADHD persisted into adulthood [14•].

## Advancing a Developmental Psychopathology Perspective

There is growing evidence that ADHD is associated with poor sleep, especially via subjective reports, across the lifespan. A crucial next step is for longitudinal research that uses a developmental psychopathology framework to understand the interplay of ADHD, sleep, and adjustment [15,16]. Understanding group differences is certainly valuable, but it will be increasingly important for researchers to move beyond group comparisons to examine *why* individuals with ADHD are at heightened risk for sleep problems, *how* sleep problems emerge and change over time for individuals with ADHD, *who* with ADHD is most at risk for developing and having persistent sleep problems, and *which* functional

outcomes are most impacted by disturbed sleep in individuals with ADHD. For example, attention, mood, and emotion regulation may be particularly impacted by inadequate or poor sleep among individuals with ADHD, whereas the impact on anxiety or social functioning may be less pronounced. In addition, there may be certain subgroups of individuals with ADHD who are more susceptible than other subgroups to the impact of insufficient/poor sleep (e.g., individuals with executive function deficits) or more likely to develop sleep problems (e.g., individuals with co-occurring internalizing psychopathology). Toward this end, both person-centered and variable-centered approaches will be important to develop a more complete understanding of sleep and ADHD across development.

A developmental psychopathology framework is especially important to understand sleep disturbances in ADHD within the context of normative sleep development. For example, seven-week-old boys at familial risk for ADHD have less stable sleep patterns (i.e., greater inconsistency from day-to-day in the amount of quiet sleep and number of awakenings) during the daytime sleep stability than comparison infants [17]. Of note, group differences were specific to daytime sleep patterns (as opposed to 24-hour periods or nighttime sleep), which the authors hypothesized may point to the role of parenting behaviors, perhaps via a disorganized environment and ways in which the sleep-wake cycle is handled [17]. More studies are needed that examine sleep and ADHD risk in early childhood, including environmental contributions, which may shed light on developmental pathways to disturbed sleep in children at risk for ADHD who do and do not go on to have the disorder. Studies using a developmental psychopathology framework are also well-suited to examine both biological and environmental contributions to sleep problems in individuals with or at risk for ADHD [14•]. Relatedly, it will be important for studies to examine not only individuals with ADHD who experience sleep disturbances, but also individuals with ADHD who do *not* experience sleep problems. A risk and resilience framework can be used to test mechanisms and moderators that are crucial to building theoretical models of the co-occurrence and differentiation of ADHD and sleep disturbances.

## Moving from Correlation to Causation

Most studies examining ADHD and sleep have been correlational, even as it has long been noted that ADHD and sleep disturbances are intricately intertwined [18–20]. Three studies have used experimental sleep protocols to examine whether shortened sleep duration is a causal contributor to functioning in youth diagnosed with ADHD. First, Gruber et al. [21] found moderate sleep restriction led to poorer performance on a Continuous Performance Test (CPT) in both children (ages 7–11 years) with ( $n = 11$ ) and without ( $n = 32$ ) ADHD, such that children with ADHD had deterioration that reached clinical levels of CPT-assessed inattention. The other two studies were both published within the last year. Cremone-Caira et al. [22] examined the impact of sleep duration on inhibitory control using a Go/No-Go task in children (ages 6–9 years) with ( $n = 11$ ) and without ( $n = 15$ ) ADHD. Findings indicated that inhibitory control improved by more than 13% from baseline when children with ADHD extended their overnight sleep duration [22].

We recently conducted an experimental sleep study examining a broader array of functioning domains, and also focused on adolescents with ADHD [23••]. Forty-eight

adolescents successfully completed the three-week sleep protocol which consisted of a phase stabilization week, followed in randomized counterbalanced order by one week of sleep restriction (6.5 hours in bed) and one week of sleep extension (9.5 hours in bed). Compared to the extended sleep week, parents reported more inattentive and oppositional behaviors and both adolescents and parents reported more sluggish cognitive tempo symptoms and greater daytime sleepiness during the restricted sleep week. In contrast to Gruber et al. [21], no effects were found for CPT performance. Nevertheless, this study provides the first evidence that shortened sleep duration is causally linked to poorer daytime functioning in adolescents with ADHD [23••]. Additional experimental studies are certainly needed, with attention to the possible impact of cumulative restricted sleep and measures that can be kept masked to sleep conditions (e.g., teacher ratings).

## Conceptualizing ADHD as a 24-Hour Disorder

Given the scope of daytime and nighttime difficulties linked to ADHD, and their interrelations, it is increasingly clear that ADHD should be conceptualized as a 24-hour disorder. ADHD is characterized by substantial variability, and despite mixed findings there is also evidence that ADHD is associated with high intraindividual variability of sleep/wake patterns [24]. For instance, in the same sample of eighth-grade adolescents described above [5•], we found adolescents with ADHD to have more variable sleep/wake patterns than their peers without ADHD using both actigraphy and daily sleep diaries [25]. An important next step is to evaluate predictors and consequences of sleep/wake variability in youth and adults with ADHD.

In addition, there is appreciable attention being devoted to investigating possible circadian rhythm alterations in individuals with ADHD. Although more studies are needed across development, individuals with ADHD may be more likely to have an evening circadian preference and later chronotype [26, 27, 28••]. Further, adults with ADHD with co-occurring sleep-onset insomnia have a delayed melatonin onset assessed using dim light melatonin onset (DLMO, a marker for the circadian pacemaker) compared to either healthy controls or adults with ADHD without insomnia [29]. Similar DLMO findings have been reported in children with ADHD [30]. Advancing our understanding of the interplay of genetic, neural, homeostatic, and circadian systems in relation to ADHD is a key research priority [19]. For instance, it has been hypothesized that a delayed circadian rhythm phase may be one cause of 'late-onset' ADHD in adolescence [31•], an intriguing possibility in need of empirical investigation.

## Understanding Sleep in Relation to Other Health Behaviors

An important direction for research is to examine sleep in the context of other health behaviors in individuals with ADHD. ADHD is associated with a range of health behaviors, including more dangerous driving, less physical activity, poorer nutrition and increased obesity, greater alcohol/substance use, and risky sexual behaviors [32–35]. Although the data are more conclusive in some of these areas compared to others, there is a pressing need to develop integrated models of health-related behaviors in ADHD. Sleep should certainly be included in such work, as many health behaviors are themselves interrelated either

directly, bidirectionally, or in a spillover and cascading fashion. An important direction for new research is to examine the interplay of sleep and other health behaviors among individuals with ADHD.

## Evaluating Sleep in Existing and Novel Interventions

A recent meta-analysis confirms that methylphenidate treatment is associated with sleep problems and several types of insomnia [36]. However, the degree to which medication impacts sleep in individuals with ADHD is a complex issue with key considerations including whether there were pre-existing sleep disturbances, dose and formulation of the medication, and length of treatment [37]. Further, recent studies conducted in children [38] and adults [12] with ADHD have called into question the notion that stimulant treatment invariably worsens sleep, underscoring the need for studies that aim to delineate which individuals with ADHD are most likely to develop sleep problems following medication initiation and/or have sleep problems persist following medication titration. There is growing evidence that melatonin reduces sleep onset delay and lengthens total sleep time in youth with ADHD [39,40]. Still, the evidence base remains small, and existing studies have a high degree of heterogeneity and/or limited sample sizes.

Behavioral interventions are recommended as the first-line treatment of insomnia, but until quite recently trials of behavioral sleep interventions in ADHD samples had not been conducted [39]. Studies have begun to address this gap, at least in school-aged children with ADHD [41–46]. Specifically a team of researchers in Australia have conducted a series of randomized controlled trials (RCTs) examining brief behavioral interventions for children with ADHD and co-occurring sleep problems [41–43, 44••]. The initial pilot RCT demonstrated feasibility and acceptability, as well as improvements in sleep and, for participants who received 2–3 sessions (as opposed to 1 session), improvements in children's quality of life and daily functioning in addition to parent anxiety [41]. The investigators then conducted a large-scale efficacy trial with three-month, six-month [42], and 12-month [43] outcome assessments. The brief sleep hygiene + behavioral strategies intervention had a modest improvement on ADHD symptoms and also improved children's sleep, behavior, and quality and life, with most effects sustained at the six-month follow-up [42]. Compared to usual clinical care, children who received the intervention were less likely to have moderate/severe sleep problems and had better daytime functioning at the 12-month follow-up [43]. However, sustained effects were small and the intervention was less effective for children who were not taking ADHD medication and for children who had parents experiencing depressive symptoms [43]. A recent cluster-randomized translational trial found that a brief, low-cost sleep intervention can be delivered by community clinicians and improve sleep in children with ADHD, though effects unfortunately did not extend to other domains of child and parent functioning [44••]. Together, these studies indicate that brief, behavioral-focused sleep interventions can be provided to families of children with ADHD with relatively low burden and cost. Nevertheless, additional work is needed to extend and optimize effects. For example, it is possible that a brief intervention will be sufficient for some families, whereas other families may need a more intensive intervention [47]. Similarly, which sleep disturbances remit following non-sleep-focused evidence-based treatments, and which are most likely to persist? Questions such as these may be optimally

addressed using a sequential, multiple assignment, randomized trial (SMART). To be sure, there has been substantial progress in beginning to evaluate behavioral sleep interventions for children with ADHD, though there is still much work to do, including evaluating cognitive-behavioral sleep interventions in adolescents and adults with ADHD.

## Conclusions

This is an exciting time in the empirical study and clinical care of sleep disturbances and circadian rhythm alterations in children, adolescents, and adults with ADHD. As research continues to advance, studies are increasingly using large samples and longitudinal/experimental designs to test hypotheses that will ultimately allow for a more robust and sophisticated understanding of sleep and ADHD. Still, far more work is needed, including in many areas not discussed herein given space limitations. This is thus an opportune time for investigators and clinicians interested in sleep and ADHD, including junior and senior investigators alike. If you haven't already, I invite you to join in studying this area of major theoretical and clinical importance. You don't have to decide now, feel free to sleep on it.

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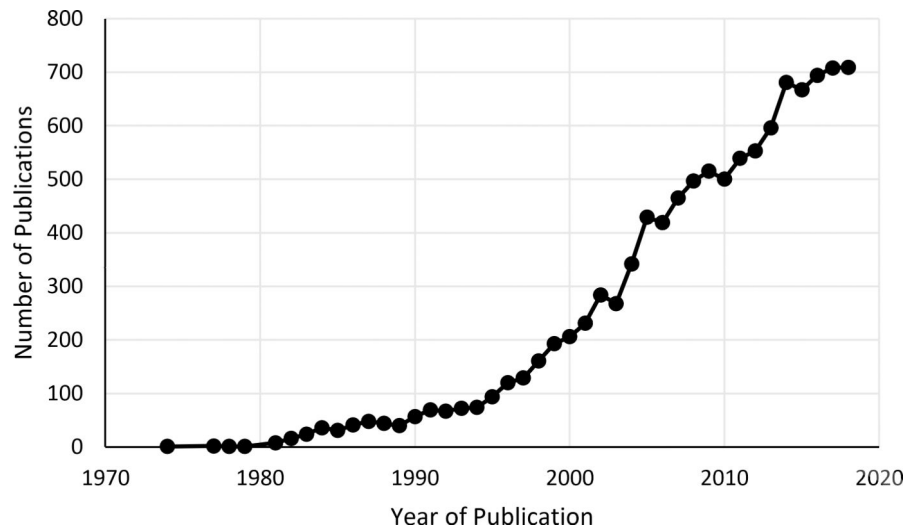


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as how circadian processes and dysfunction may contribute to etiology and/or symptomatology of ADHD. Sixty-two studies were included in this review, including 25 studies in adults and 37 studies in children/adolescents. Consistent findings were found between delayed circadian phase and later chronotype/evening preference in relation to ADHD/ADHD symptoms. The authors highlight the importance of examining chronotherapeutic approaches to “correct” underlying phase alterations and, ultimately, reducing ADHD symptoms. Also, most studies have used melatonin as a somnolent and studies are needed to test melatonin to advance circadian phase in individuals with ADHD and circadian dysfunction. Finally, there is a specific need for longitudinal studies and more studies examining polymorphisms in circadian clock genes and ADHD.

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**Figure 1. Number of publications between 1970 and 2018 that include sleep and attention-deficit/hyperactivity disorder (ADHD) in the title**

*Note.* Search conducted in PubMed on May 31, 2019. Search set to identify any publication with sleep and ADHD (or related terms such as attention-deficit/hyperactivity disorder, attention deficit disorder, hyperkinetic disorder, or hyperkinetic reaction of childhood) in the publication title (total publication N = 10,632).