Review Article

Sleep and ADHD

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ABSTRACT

This paper, intended to provide useful insights for the clinical management of sleep disturbances in attention-deficit/hyperactivity disorder (ADHD), presents a critical, updated overview of the most relevant studies on the prevalence, etiopathophysiology and treatment strategies of sleep problems associated with ADHD, including restless legs syndrome, periodic limb movements in sleep, sleep-onset delay, increased nocturnal motor activity, sleep-disordered breathing, deficit in alertness, and sleep alterations accounted for by comorbid psychiatric disorders or ADHD medications. We also discuss some possible avenues for future research in the field.

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1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common childhood behavioral disorders, with an estimated worldwide prevalence of approximately 5% in school-age children [1]. According to the diagnostic and statistical manual of mental disorders, fourth edition-text revised (DSM-IV-TR), ADHD is characterized by developmentally inappropriate symptoms of inattention, hyperactivity, and/or impulsivity, with onset before the age of 7 years, and impaired functioning in two or more settings (e.g., at school and at home [2]).

Complaints of sleep problems in children with ADHD are not uncommon in clinical practice. According to Corkum et al. [3], they are reported in up to 55% of cases. The first descriptions of sleep disturbances associated with ADHD were reported in the 1950s by Laufer and Denhoff [4], who noted, “Generally, the parents of hyperkinetic children are so desperate over the night problems that the daytime ones pale in significance.” Afterwards, in 1973, Wender [5] reported that children with “minimal brain dysfunction” (an old nosographic category including children with behavioral features similar to those found in ADHD) had “an increased frequency of sleep difficulties: difficulty in falling asleep and remaining asleep, and early awakening.” However, after these initial observations, the relationship between ADHD and sleep disturbances has been regrettably overlooked by researchers and clinicians in the field. Fortunately, in the last 10–15 years, a renewed interest has been devoted to the relationship between ADHD and sleep disorders. Using subjective (i.e., based on questionnaires) and objective (i.e., neurophysiological) measures, several groups have attempted to clarify the links between ADHD and sleep disorders.

Research in this topic is relevant from a theoretical standpoint, suggesting possible novel etiopathophysiological models of ADHD as well as new insights into the effects of sleep alterations on behavioral and cognitive functions. Advances in this field may also have a tremendous impact on day-to-day clinical practice. On one hand, the management of sleep problems in children with ADHD may significantly reduce behavioral symptom severity and improve the quality of life of these children as well as that of their families [6]. On the other hand, taking into account sleep disturbances may also be paramount in the assessment and treatment of children who are sent for consultation for symptoms of inattention, hyperactivity, and/or impulsivity but do not meet DSM-IV diagnostic criteria for ADHD. Indeed, it has been pointed out that any sleep disorder that results in inadequate sleep duration, fragmented or disrupted sleep, or excessive daytime sleepiness can lead to or contribute to problems with mood, attention, and behavior [6]. As a consequence, at least in a subsample of patients referred for inattention, hyperactivity, and/or impulsivity, these symptoms may be improved or even eliminated upon treatment of the primary sleep disorder.

In this paper we focus on the most common sleep alterations found in children with ADHD. To discern information pertinent
in day-to-day clinical practice with ADHD children, we present a critical updated overview of the most relevant studies on the prevalence, etiopathophysiology and treatment strategies of sleep problems in ADHD and discuss some possible future avenues of research in the field.

2. Sleep and ADHD: general considerations

Although clinicians, particularly child psychiatrists, might believe that sleep alterations in children with ADHD are due exclusively to the effects of ADHD drugs (particularly stimulants), available evidence suggests that ADHD drugs are only one of the possible causes of sleep disturbances associated with ADHD and that children with ADHD do present with significantly more sleep disturbances than controls, independently from medication use. As for the nature of these problems, in previous reviews of the literature on sleep and ADHD [3,7], it has been pointed out that subjective reports of sleep disturbances have not been confirmed by objective measures of sleep. In our opinion, this is not surprising since subjective studies address sleep related behaviors, while objective studies focus on sleep physiopathology, and so a perfect correlation between these two types of variables seems unlikely. It is possible that the difficulties reported as significantly higher in children with ADHD refer to inappropriate behavior in the context of problematic parent–child interaction and that parents of children with ADHD may more likely report high levels of daytime and sleep-related problematic behaviors in a sort of “negative halo effect.” However, it is interesting to note that in a recent meta-analysis [8] we concluded that children with ADHD presented with significantly more impaired sleep according to parent reports, as well as with significantly higher impairment in some objective sleep parameters. In fact, we found significantly higher bedtime resistance, more sleep-onset difficulties, night awakenings, difficulties with morning awakenings, sleep–disordered breathing, and daytime sleepiness compared with the controls (in the subjective studies). As for the objective parameters, sleep-onset latency (on actigraphy), the number of stage shifts/hour sleep, and the apnea–hypopnea index were significantly higher in the children with ADHD compared with the controls. The children with ADHD also had significantly lower sleep efficiency on polysomnography, true sleep time on actigraphy, and average times to fall asleep at the Multiple Sleep Latency Test than the controls.

These results suggest that some of the parentally reported complaints about their children’s sleep may actually be due not only to inappropriate parent–child interaction but also to objective sleep disturbances. Moreover, it is possible that the lack of correspondence pointed out in previous reviews may be due, at least in part, to methodological issues in objective studies. For example, as for difficulty/delay falling asleep, it has been suggested that children with ADHD present with a night-to-night variability in sleep patterns [9]. Therefore, it is possible that parents are more likely to recall, and thus report as “typical” those nights on which a child has significant bedtime resistance or difficulty falling asleep. Objective measures during just one or few nights may not capture the potential objective abnormalities underlying the parentally reported sleep-onset difficulties.

It has been pointed out that sleep problems in ADHD are multifactorial [6], i.e., they can be ascribed to many underlying factors. Therefore, the correct identification of such factors facilitates the appropriate management of sleep disturbances in this population.

In the following sections, we discuss the most important factors contributing to sleep alterations in ADHD.

3. Restless legs syndrome (RLS)

The first descriptions pointing to a possible association between RLS and ADHD were provided by Picchietti and Walters [10]. In a review of the literature [11] conducted in 2005, we concluded that up to 44% of subjects with ADHD have been found to have RLS or RLS symptoms, and up to 26% of subjects with RLS have been found to have ADHD or ADHD symptoms. However, these data should be considered with caution given some methodological limitations of the reviewed studies (concerning the methods used to diagnose ADHD and RLS and some possible sampling or referral biases); therefore, it is probable that the real estimates of the prevalence of RLS in ADHD and vice-versa are more conservative. Since these limitations have only in part been addressed in more recent studies published after our review [12–17], further large epidemiological and clinical methodological studies are needed to assess the real prevalence of RLS (diagnosed according to standardized criteria) in children with ADHD (diagnosed according to DSM criteria), as well as the prevalence of ADHD in children with RLS.

Several hypotheses have been proposed to explain the association between RLS and ADHD (or ADHD-like symptoms) [11]. RLS-associated sleep disturbance may cause inattentiveness, moodiness, and “paradoxical overactivity,” thus mimicking symptoms of ADHD. Another hypothesis is that diurnal manifestations of RLS (who have been reported in children) mimic ADHD symptoms. Some children who are seriously affected with RLS cannot sit in school during the day for extended periods because they get up and walk around to relieve their leg discomfort. Hyperactivity might thus lead to inattention through the mechanism of leg discomfort in a subgroup of patients. Alternatively, true ADHD and RLS can be comorbid conditions [16]: individuals with RLS and some of those with ADHD might share a common dopaminergic dysfunction. Since iron deficiency (which is a co-factor in dopamine synthesis) has been implicated into the pathophysiology of RLS [18] and has also been reported in children with ADHD [19,20], we suggested that iron deficiency is a common underlying etiopathophysiological factor to both RLS and ADHD in patients with these two conditions [21]. Further research is needed to address these speculations.

Genetic underpinnings to both RLS and ADHD are currently under investigation but, to date, no positive results have been reported [22].

From a clinical standpoint, in our and others’ experiences, RLS symptoms may exacerbate ADHD. Moreover, children with RLS can develop bedtime opposition, probably because they associate bedtime with the occurrence of the unpleasant RLS sensations. Parents may consider this refusal as the expression of a general oppositional attitude, ignoring the real cause of the child’s behavior [23]. Therefore, this sleep disorder can be overlooked in children with ADHD and oppositional behavior. In addition, it is possible that ADHD worsens RLS symptoms, as reported by Chervin et al. [24] and Wagner et al. [25]. Therefore, we believe that RLS should be systematically investigated in patients with ADHD or ADHD-like symptoms.

With regard to psychopharmacologic strategies for patients with both RLS and ADHD, some case reports have demonstrated the efficacy of low doses of dopaminergic agents (levodopa, pergolide, and ropinirole) in children diagnosed with both conditions who were previously unsuccessfully treated with psychostimulants [26,27]. However, although dopaminergic agents are considered the first-line treatment for adults with RLS, they are not approved for use in children with RLS.

As previously mentioned, iron deficiency may be a possible etiopathophysiological candidate in both RLS and ADHD. We found iron supplementation effective in the treatment of ADHD in children with RLS in a pilot randomized controlled trial [28]. Clearly, additional evidence is needed to more accurately assess the efficacy and effectiveness of iron supplementation in children with RLS and ADHD.
4. Periodic limb movements in sleep (PLMS)

In a series of studies, Piccietti et al. suggested an increased prevalence not only of RLS, but also of periodic limb movements in sleep (PLMS) among children with ADHD [29,30]. Moreover, Huang et al. found that 10.2% of children with ADHD had periodic limb movement disorder (PLMD) compared to 0% of controls [31]. This association has also been examined and confirmed by Bruni et al. [32], who pointed out that limb movements (LMs) in ADHD have low levels of periodicity, suggesting that the mechanism generating LMs during sleep in ADHD is likely to be different from that observed in RLS/PLM.

Since no randomized double-blind trials have been conducted to assess the potential effectiveness of the dopaminergic agents for ADHD and PLMS in children with both the conditions, this may represent a fruitful research avenue for the future. Moreover, since PLMS may improve after treatment with iron sulfate [33], in consideration of the possible role of iron in ADHD, it would be worthwhile to conduct randomized, placebo-controlled trials of iron supplementation for PLMS and ADHD in children.

5. Sleep-onset insomnia and dim light melatonin onset delay

It has been reported that medication-free children with ADHD and sleep-onset insomnia (SOI) exhibit a delayed evening increase in endogenous melatonin levels [34]. Therefore, it has been hypothesized that SOI in ADHD is a circadian rhythm disorder due to a dim light melatonin onset delay [34]. This may underlie and contribute to symptoms of bedtime discomfort with secondary resistance to go to bed, which may be erroneously considered as the expression of a general “oppositional-defiant disorder” [23]. Therefore, we suggest that a possible alteration in melatonin levels should be investigated in ADHD children with sleep-onset insomnia and/or bedtime resistance.

To date, one open-label study [35] and two randomized, double-blind, placebo-controlled trials [36,37] have been conducted to assess the effectiveness and tolerability of melatonin (3–6 mg/day) for the management of SOI in children with ADHD. These studies reported a significant improvement in sleep-onset delay (assessed with subjective measures), but no significant effects on daytime ADHD symptoms. In a recent follow-up study [38], no serious adverse events or treatment-related comorbidities were reported after approximately 4 years of treatment. But further evidence is needed before melatonin can be systematically recommended for SOI in children with ADHD.

Considering that a delayed evening increase in endogenous melatonin levels might contribute to SOI in children with ADHD, some investigators have also assessed the effect of light therapy (LT) in this population. In a 3-week open trial of morning bright LT, Rybak et al. [39] observed a significant phase advance in circadian (LT) in this population. In a 3-week open trial of morning bright LT, Rybak et al. [39] observed a significant phase advance in circadian preference as well as an improvement in both subjective and objective measures of ADHD. To our knowledge, no controlled study has been conducted to assess the efficacy of LT in children with ADHD, with the exception of a case report [40].

It is noteworthy to report that, to date, pharmacological agents other than melatonin have not been found effective for sleep-onset insomnia in randomized controlled trials. In particular, a recent controlled trial [41] reported that zolpidem at a dose of 0.25 mg/kg per day to a maximum of 10 mg failed to reduce the latency to persistent sleep on polysomnographic recordings after 4 weeks of treatment in children and adolescents with ADHD.

6. Increased nocturnal motor activity

Studies utilizing actigraphy have documented an excessive nocturnal motor activity (in the arms or in the legs) in children with ADHD [42,43]. Only one study [44], conducted by our group, analyzed excessive nocturnal activity in children with ADHD by means of infrared camera, confirming that children with ADHD moved significantly more often than controls and that the duration of movements was significantly longer in ADHD children. Although one might suppose that increased nocturnal motor activity fragments sleep, leading to sleep disturbance, no significant differences in PSG variables between children with ADHD and controls were observed in the infrared camera study. On the other hand, we [45] and another group [46] have reported that late-afternoon methylphenidate doses reduce nocturnal activity and improve sleep quality by consolidating sleep. But while some studies have showed that MPH three-times daily does not impact upon sleep [47] or causes only a slight decrease in sleep duration [48], others have reported that a third daily dose of MPH does worsen sleep [49]. Given these contrasting findings, late-afternoon stimulant treatment cannot yet be recommended for ADHD patients with high nocturnal motor activity, and further research to clarify this controversial issue is welcome. Nevertheless, it is possible that, at least in some cases, a third late psychostimulant dose does reduce hyperactivity in the evening leading to better sleep onset. As stated by Jerome [50], “it is a common clinical experience of clinicians treating children with ADHD that on occasion a small dose of MPH taken before bedtime can facilitate sleep. Although this is not the case for all children with ADHD it seems to be a robust clinical finding, which is not well documented in the literature.”

7. Sleep-disordered breathing and ADHD

The relationship between sleep-disordered breathing (SDB) and ADHD (as categorical diagnosis according to DSM criteria) is still controversial [51]. The results of several studies have demonstrated an association between symptoms of SDB and ADHD [52,53]. However, as some of these investigations did not use DSM-IV ADHD criteria, it is not clear whether SDB is linked with ADHD symptoms or with ADHD as a disorder diagnosed according to the standardized criteria. The above mentioned meta-analysis [8] by our group, which included studies utilizing rigorous criteria for ADHD, suggested that values of AHI in the three objective studies retained in the meta-analysis [31,54,55] were not very elevated (1.0, 5.8, and 3.57, respectively). But if one assumes, as suggested by Chervin [51], that moderate values of AHI between 1 and 5 are suggestive of pediatric obstructive sleep apnea, deserving clinical attention (which is still controversial [51,56], probably because of heterogeneous selection criteria, as the exclusion of patients with snoring plus either observed apneic episodes in sleep or EDS [56], all the previous data concur that SDB may be more frequent in children with ADHD than controls.

With regard to treatment strategies in this population, Huang et al. [57] and Dillon et al. [58] reported that children with ADHD and an apnea–hypopnea index >1 and <5 events/hour improved significantly more after adenotonsillectomy than after stimulant treatment. This suggests that appropriate recognition and surgical treatment of underlying SDB in children with ADHD might prevent the need for long-term stimulant treatment. A recent longitudinal study [59] has shown that improvements are maintained 2.5 years after surgery.

8. Deficit in alertness

Children with ADHD may have a deficit in alertness. It has been hypothesized that excessive motor activity could be a strategy used by ADHD children to stay awake and alert [60]. Subjective questionnaires completed by parents of ADHD children may not be suitable to assess sleepiness, which could be masked by
hyperactivity. On the other hand, the Multiple Sleep Latency Test (MSLT) is considered the “gold standard” method for assessing alertness. The results of two studies [55,61] using the MSLT have confirmed excessive daytime sleepiness in children and adolescents with ADHD. Interestingly, data on cyclic alternating pattern in subjects with ADHD confirmed that they may present with a hypoaroused state [62]. Of note, adults with ADHD have been reported to present with excessive daytime sleepiness. In a recent study, up to one-third of adults with ADHD had subjective sleepiness (a score of >12 on the Epworth Sleepiness Scale) [78]. In this investigation, inattention scores were significantly correlated with excessive daytime sleepiness severity scores. The nature of excessive daytime sleepiness has yet to be determined: excessive daytime sleepiness might be a primary disorder or the consequence of some other sleep alteration. If excessive daytime sleepiness is actually a primary disorder in ADHD, these findings suggest new potential therapeutic strategies for a subgroup of children who present with ADHD associated with an alteration in sleep or wakefulness, and who may not respond adequately to first-line stimulant treatments, such as MPH and amphetamine salts. Wake-promoting agents could be an important alternative to stimulants in these children. The use of the wake-promoting, non-stimulant agent modafinil has been proposed for this specific indication [61], although the drug is not approved for this use. If tolerance of modafinil in children can be proven, double-blind studies could be conducted to evaluate the potential usefulness of this agent specifically in children with ADHD and excessive daytime sleepiness.

9. Sleep disturbances and psychiatric comorbidities

Psychiatric comorbid disorders, including oppositional disorder, conduct disorder, mood disorders, anxiety disorders, learning disorders, developmental coordination disorder, and tic/Tourette Syndrome, are frequent in ADHD [63]. Most of these psychiatric disorders might be associated with significant sleep disturbances, from a subjective and, less consistently, objective standpoint [64]. In consideration of the impact of psychiatric comorbidities on sleep, we suggest to systematically evaluate associated psychopathologies in patients with ADHD, especially when sleep problems are reported. The appropriate treatment of comorbid disorders may improve sleep, but the clinician should keep in mind that some medications used to treat these conditions may negatively impact sleep (e.g., selective serotonin reuptake inhibitors).

10. Effects of medications on sleep

Psychostimulants (MPH, amphetamine, and lisdexamfetamine dimesylate) are the first-line, US Food and Drug Administration approved treatments for ADHD, followed by the non-stimulant atomoxetine (ATX). However, non-approved drugs, such as bupropion, tricyclic antidepressants, alpha-agonists, and modafinil, are also used [63].

It has been suggested that stimulants used in the treatment of ADHD lead to sleep disturbances. In particular, it has been reported in some studies that stimulants have effects on sleep-onset delay [65], night awakenings [66], shorter sleep duration and dysomnias [67]. However, subjective and objective studies investigating the effects of stimulants on sleep in ADHD have produced mixed results. While some investigators have reported, among other outcomes, lengthened total sleep time, increased sleep-stage shifts, increased number of rapid eye movement (REM) sleep periods, elevated indices of REM activity, and REM-period fragmentation, others did not confirm these findings (for a review, see the introduction of the paper by Sangal et al. [68]). It is difficult to combine the results of these studies because of the different stimulant formulations, doses, and dose-scheduling protocols used. As stimulant use may be associated with the so-called “rebound effect” (i.e., increase over base-line values in ADHD symptoms when the medication wears off) it is also possible that reported sleep problems may be linked with such restlessness rather than occurring as a direct action of the agents themselves. However, some studies employing a third daily dose of stimulant (to avoid the rebound effect) did indeed find a more significant sleep-onset delay [48,69]. Considering this evidence, and also on the basis of clinical experience, it is possible to conclude that stimulants may negatively impact sleep due to a direct or a secondary “rebound” effect. Vulnerability to these negative effects is likely to be related to individual factors. As highlighted by Brown and McMullen, while some patients with ADHD are able to get to sleep easily within just a few hours of taking a dose of stimulant, others need an interval of 6–8 h [70].

Regarding the effect of atomoxetine (ATX) on sleep in children with ADHD, in a recent randomized, double-blind, crossover study comparing the effect of MPH given three times daily and ATX given twice daily, Sangal et al. [68] found that MPH increased sleep-onset latency significantly more than did ATX, considering both actigraphic and PSG data. Moreover, both child diaries and parental reports indicated a better quality of sleep with ATX compared with MPH. Both medications decreased night-time awakenings, but the decrease was greater with MPH. Clearly, these results need to be replicated in additional studies. On the basis of the abovementioned effects of ADHD medications on sleep, a panel of ADHD experts [71] proposed a number of strategies to manage sleep alterations caused by stimulant use (Table 1). If the impact of these treatments upon sleep is caused by a “rebound effect,” in the current author’s clinical experience, giving a low dose of MPH in the late afternoon or evening could be helpful. Doses in late evening could also be considered if the rebound effect persists. As noted more than 30 years ago by Kinsbourne, “if a hyperactive child wakes during the night, giving him a stimulant should help him go back to sleep” [72]. This has never been systematically explored.

11. Conclusion: evaluation of sleep issues associated with ADHD/ADHD symptoms in clinical practice

Although a lot of work has yet to be done, current evidence and clinical practice suggest that, even if ADHD is not purely a result of sleep disturbance, it is conceivable that, at least in some children, the condition is a “24-hour” disorder, and that sleep disruption caused by increased nocturnal activity contributes to daytime symptomatology. Bearing this possibility in mind, the relationship between sleep disorders and ADHD should be considered by healthcare practitioners as part of the global approach to the management of ADHD. We recommend that the practitioner screens for clinical sleep problems in patients referred for ADHD by specifically asking questions regarding the symptoms of sleep disorders (e.g., deficits in alertness, sleep-onset delay, increased nocturnal activity). As for sleep-onset delay, in particular, the following questions to gain insight into the etiology of sleep-onset delay could be useful: “Do you feel worried when you are in your bed at night?”; “Do you feel sad when you are in your bed at night?”; “Would you like to fall asleep but you cannot?”; “Do you have unpleasant sensations in your legs when you are in your bed?”; “Do you feel restless at bedtime and do you think this prevents you from falling asleep”?

In the authors’ opinions, these screening questions should be asked regardless of the nature of the chief complaint from parents (e.g., bedtime opposition) or from children (e.g., inadequate time asleep). This screening should systematically be conducted at each visit.
As for biochemical assessment, measurement of serum ferritin levels may be indicated if there are clinical elements suggesting a diagnosis of RLS-PLMS, since children with RLS-PLMS have been reported with low serum ferritin levels [33]. Interestingly, it has also been reported that iron sulfate treatment decreases PLMI [33], although large randomized, double-blind, controlled studies are needed to evaluate the efficacy, tolerability and appropriate form of iron supplementation for children with RLS (and, in particular, ADHD plus RLS).

If appropriate, further sleep studies (by means of PSG, actigraphy and/or MSLT) should be undertaken and sleep disorders treated accordingly to the current practice.

Particular attention should be paid to the differential diagnosis of sleep issues associated with ADHD, i.e., the clinical situations where ADHD symptoms are mimicked by a primary sleep disorder. In particular, the clinician should consider RLS and SDB.

The treatment of specific sleep disturbances should be conducted according to the evidence reported in the specific sections of this paper.

In conclusion, an appropriate management of sleep issues in children with ADHD may contribute to a better quality of life for ADHD children and their families.

12. Future perspectives

There is increasing evidence of alterations of sleep in children with ADHD, albeit at present there is still a lack of evidence on the most effective and safe treatment strategies (both pharmacological and non-pharmacological). Looking ahead, one of the most important issues in the research on the relationship between ADHD and sleep disturbances is to conduct methodological sound studies controlling for the possible confounding effects of psychiatric comorbidities and ADHD on sleep variables. Once we gain further insight in the relationship between ADHD and sleep, appropriate treatment strategies of sleep disturbances in subjects with ADHD should be systematically addressed. One research area which needs to be developed is represented by the effectiveness of behavioral strategies for sleep problems in children with ADHD. To our knowledge, there are only two reports specifically assessing behavioral strategies for sleep problems in children with ADHD. In the first study, Mullane and Corkum [73] reported the effectiveness of a 5-week manual intervention for dyssomnia in 3 children with ADHD (gains were generally maintained at the 3-month follow-up). In the second study by Weiss et al. [37], sleep hygiene reduced initial insomnia to <60 min in 5 out of 27 children with ADHD. Therefore, given the limited evidence, further larger controlled studies on non-pharmacological treatment strategies for sleep problems in children with ADHD is welcome. Moreover, since evidence on the effectiveness of some medications (such as dopaminergic agents for RLS) comes from single cases or case series, further large randomized controlled studies on the effectiveness and tolerability of medication for sleep disorders associated with ADHD are needed. Besides randomized controlled trials on the effectiveness of pharmacological and non-pharmacological treatments for sleep disturbances in ADHD, there are some under-explored areas of research. The interesting issue of the relationship between ADHD and narcolepsy or primary disorders of vigilance has yet to be fully explored. In our meta-analysis [8], we concluded that subjects with ADHD present with higher daytime sleepiness than controls, but no methodological sound evidence has been published on the relationship between narcolepsy and ADHD. Another area of research which is still under-developed is the relationship between ADHD and parasomnias, which could provide important insights into the pathophysiology of ADHD and could suggest useful treatment strategies to improve sleep quality in ADHD. Finally, possible genetic underpinnings and neuroimaging correlates of the association between sleep disturbances and ADHD lay the ground work for fruitful and innovative avenues of research.

Disclosures

The authors have no relevant financial relationships to disclose.

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References


