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Sleep and Daytime Sleepiness in Adolescents with and without ADHD: Differences across Ratings, Daily Diary, and Actigraphy

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Abstract

Background: Children with attention-deficit/hyperactivity disorder (ADHD) experience greater sleep problems than their peers. Although adolescence is generally a developmental period characterized by insufficient sleep, few studies have used a multi-informant, multi-method design, to examine whether sleep differs in adolescents with and without ADHD.

Methods: Targeted recruitment was used to enroll an approximately equal number of eighth-grade adolescents (mean age = 13 years) with (*n*=162) and without ADHD (*n*=140). Adolescents and parents completed global ratings of sleep problems; adolescents, parents, and teachers completed ratings of daytime sleepiness. Adolescents wore actigraphs and completed a daily sleep diary for approximately two weeks.

Results: Adolescents with ADHD were more likely than adolescents without ADHD to obtain insufficient sleep on school days (per diary) and weekends (per diary and actigraphy). Adolescents with ADHD were also more likely to report falling asleep in class and to have stayed up all night at least twice in the previous two weeks (15% and 5%, respectively). In regression analyses controlling for a number of variables known to impact sleep (e.g., pubertal development, sex, medication use, having an externalizing, anxiety, or depression diagnosis), ADHD remained associated with shorter diary and actigraphy school night sleep duration, adolescent- and parent-reported daytime sleepiness, and parent-reported difficulties initiating and maintaining sleep and total sleep disturbance. Controlling for other variables, the odds of being classified with clinically elevated parent-reported sleep disturbance were 6.20 times greater for adolescents with ADHD.

Conclusions: Findings provide some of the clearest evidence yet that adolescents with ADHD experience more sleep problems and sleepiness than their peers without ADHD. It may be especially important to assess for sleep problems in adolescents with ADHD and to evaluate whether existing sleep interventions are effective, or can be optimized, for use in adolescents with ADHD who also have sleep problems.

Keywords: adolescence; attention-deficit/hyperactivity disorder; Sleep Disturbance Scale for Children; sleep duration; Sleep Habits Survey; sleep problems

Introduction

There is long-standing interest in the sleep patterns and problems of individuals with attention-deficit/hyperactivity disorder (ADHD), and it is now clear that children with ADHD experience increased reported sleep problems and daytime sleepiness than their typically developing peers (Cortese et al., 2009). There is significantly less evidence supporting group differences in objective measures of sleep, though there is indication from meta-analytic findings that children with ADHD have lower sleep efficiency and shorter sleep duration (Cortese et al., 2009) and spend more time in stage 1 sleep (Díaz-Román et al., 2016) than children without ADHD. However, very few studies have examined sleep and sleepiness in adolescents with ADHD. Adolescence is a key developmental period wherein a myriad of biopsychosocial and contextual factors impact sleep (Carskadon et al., 2004; Tarokh et al., 2016). As a result, sleep problems in adolescence have been recognized as a worldwide public health concern (American Academy of Pediatrics, 2014; Gradisar et al., 2011), with the combination of sleep and adolescence described as “the perfect storm” (Carskadon, 2011; Crowley et al., 2018). In particular, bedtimes become later, sleep duration becomes shorter, and daytime sleepiness increases. These changes in sleep and sleepiness occur across the adolescent population, and it is not clear if adolescents with ADHD experience more sleep problems and daytime sleepiness than their peers as has been found in childhood. As such, sleep in adolescents with ADHD has been identified as a research priority (Becker, 2019; Lunsford-Avery et al., 2016).

Studies that have examined sleep in adolescents with and without ADHD have yielded mixed findings. In a sample of adolescents in Taiwan, Gau et al. (Gau et al., 2010) found 40% of the 93 adolescents with a childhood diagnosis of ADHD met criteria for a sleep disorder, compared to 18% of matched comparison adolescents. A study conducted in a special educational school in Israel found adolescent males with ADHD to have later self-reported bedtimes compared to adolescent males without ADHD (Weinstein et al., 2015). A population-based study of almost 10,000 adolescents in Norway found that adolescents with high ADHD symptoms reported shorter

sleep duration, longer sleep onset latency (SOL) and wake after sleep onset (WASO), lower sleep efficiency, and greater daytime sleepiness/tiredness compared to adolescents with low ADHD symptoms (Hysing et al., 2016). In contrast, in a sample of adolescents in Taiwan, Chiang and colleagues (Chiang et al., 2010) found that ADHD symptoms were associated with earlier school night bedtimes and longer sleep duration. However, the authors acknowledged that their findings could have been due to the competitive academic demands in Taiwan such that adolescents with ADHD symptoms may be less inclined or motivated to stay up late to study.

We are aware of only two studies that have used actigraphy to compare sleep in adolescents with and without ADHD. Compared to typically developing adolescents or adolescents with bipolar disorder, Mullin et al. (Mullin et al., 2011) found adolescents with ADHD to have the shortest total sleep time (per actigraphy and daily diary) and lowest sleep efficiency (per actigraphy). However, the sample size was small (14 adolescents with ADHD) and group differences were not statistically significant. Another study found no difference in actigraphy-measured total sleep time between adolescents with and without ADHD, though ADHD was not directly assessed by the researchers but instead assessed by parent-report of a physician diagnosis (Moore et al., 2011).

In sum, there is evidence that adolescents with ADHD have more subjective sleep problems than their peers, with very little data regarding actigraphy-measured sleep. Further, as noted in a recent systematic review of sleep in adolescents with ADHD, the existing literature base is limited by studies that did not include a comparison sample, have potentially non-representative samples (e.g., clinic-referred patients), used study-specific sleep measures, or relied on small sample sizes (Lunsford-Avery et al., 2016). In addition, prior research did not consider potentially important covariates. For example, medication use and psychiatric comorbidity may be associated with poorer sleep in adolescents with ADHD (Becker, 2019; Lunsford-Avery et al., 2016). In addition, pubertal development can impact sleep, and females may be more prone to experience sleep problems, specifically insomnia, as they progress through puberty (Zhang et al., 2016).

Accordingly, in the present study we examined whether adolescents with ADHD had poorer sleep than adolescents without ADHD after controlling for a number of other variables known to impact sleep.

The present study sought to build upon previous research examining the sleep of adolescents with and without ADHD. To do so, we used (1) a large sample of adolescents with and without ADHD, determined using a structured psychiatric diagnostic interview, (2) multiple informants, including adolescents, parents, and teachers, and (3) multiple methods, including rating scales, daily sleep diaries, and actigraphy. We hypothesized that adolescents with ADHD would have more subjectively-measured sleep problems and daytime sleepiness than adolescents without ADHD. For actigraphy indices, we tentatively hypothesized that adolescents with ADHD would have shorter sleep duration and lower sleep efficiency.

Methods

Participants

Participants were 302 adolescents (ages 12-14 years) in eighth grade (M_{age}=13 years) who were recruited from local schools across two sites in the Southeastern and Midwestern United States. Targeted recruitment was used to enroll an approximately equal number of participants with and without ADHD. Thus, approximately half (*n*=162) of the sample was diagnosed with DSM-5 ADHD (120 with Predominantly Inattentive Presentation and 42 with Combined Presentation), with remaining participants (*n*=140) comprising a comparison sample without ADHD. Further description of the sample and comparisons between the ADHD and comparison groups can be found in Table 1.

Procedures

Adolescents in eighth grade and their parents were recruited across two consecutive years for a prospective longitudinal study examining sleep in adolescents with and without ADHD (see Supplemental Materials for recruitment details). Longitudinal data collection is ongoing thus only baseline data is used in the present study. The study was approved by the Virginia Commonwealth

University and the Cincinnati Children's Hospital Medical Center Institutional Review Boards, and written informed consent and assent were obtained. All potential participants went through the same assessment procedures. Families meeting screening criteria were invited to receive a comprehensive assessment, during which adolescents and their parents were administered study measures. Inclusion criteria included: (1) enrolled in eighth grade; (2) estimated Full Scale IQ ≥ 80 based on the *Wechsler Abbreviated Scale of Intelligence, Second Edition* (WASI-II; (Wechsler, 2011); and (3) enrolled in regular education classes. Exclusion criteria were: (1) meeting criteria for autism spectrum disorders, bipolar disorder, a dissociative disorder, or a psychotic disorder; (2) previous diagnosis of an organic sleep disorder (e.g., obstructive sleep apnea, narcolepsy, restless leg syndrome, periodic limb movement disorder) according to parent report during the initial phone screen, and (3) not meeting criteria for either the ADHD or comparison groups as described below. See Figure S1 for a flow diagram.

ADHD diagnosis. All potential participants underwent a comprehensive ADHD diagnostic evaluation in accordance with the Fifth Edition of the *Diagnostic and Statistical Manual for Mental Disorders* (DSM-5) criteria. Participants met criteria for ADHD on the basis of the parent version of *Children's Interview for Psychiatric Syndromes* (P-ChIPS; Weller et al., 1999). To be eligible for participation in the ADHD group, adolescents were required to meet all DSM-5 criteria for either the ADHD Combined Presentation or Predominantly Inattentive Presentation on the P-ChIPS. Specifically, participants were included in the ADHD group if parents reported ≥6 symptoms of inattention at clinically significant levels; presence of ADHD symptoms prior to age 12 years, presence of ADHD symptoms in two or more settings (e.g., home, school), evidence that symptoms contribute to home, academic, and/or social impairment; and symptoms of ADHD were not better explained by another mental disorder. Participants were included in the comparison group if the parent endorsed <4 symptoms of ADHD in both domains (i.e., inattention, hyperactivity/impulsivity) on the P-ChIPS. Additionally, both parent and adolescent report on the P-

ChIPS and ChIPS were used to determine common mental health diagnoses (i.e., mood and anxiety disorders, disruptive behavior disorders, obsessive compulsive disorder).

Measures

A brief overview of measures is provided here, with a more thorough description of the measures and internal consistency values provided in the supplemental materials.

Sleep Habits Survey (SHS). The SHS (Wolfson & Carskadon, 1998) is an adolescent-report measure of sleep. The 10-item sleep/wake problems subscale assesses the frequency of several sleep-related difficulties (1=*never*; 5=*every day/night*) with higher scores indicating more sleep problems. The 10-item daytime sleepiness subscale includes items rated on a 4-point scale (1=*no*; 4=*both struggled to stay awake and fallen asleep*) to create a total sleepiness score. One item pertaining to driving was removed since all participants were below driving age.

Seven individual items from the SHS were also used: A dichotomous item assessed whether the adolescent considers themselves to be a poor or good sleeper; another item asked whether they usually get too much sleep, enough sleep, or too little sleep; an item assessing how often adolescents thought they are getting enough sleep, with responses recoded into a three-point scale (1=*always/usually*; 2=*sometimes*; 3=*rarely/never*). Lastly, we examined four individual items from the sleep/wake problems scale that ask how often over the past two weeks participants (1) stayed up all night, (2) fell asleep in a morning class, (3) fell asleep in an afternoon class, and (4) arrived late to class because of oversleeping. These four items were dichotomized as occurring never/once and at least twice in the past two weeks given low endorsement at the more extreme anchors on these items and to categorize participants for whom the behavior occurred at what we conceptualized as a clinically significant frequency (i.e., at least once per week).

Sleep Disturbance Scale for Children (SDSC). The SDSC (Bruni et al., 1996) is a 26-item parent-rated scale. Scales include total sleep disturbances and six subscales: difficulties initiating and maintaining sleep, sleep breathing disorders, disorders of arousal (i.e., parasomnias), sleep-wake transition (e.g., sleep talking, movements while falling asleep), excessive somnolence, and

hyperhydrosis. Items are rated on a 5-point scale (1=*never*; 5=*always*). *T*-scores ≥70 are in the clinical range.

Teacher's Daytime Sleepiness Questionnaire (TDSQ). The TDSQ (Owens et al., 2000) is a teacher-reported measure of items rated on a 3-point scale (1=*never or rarely [less than once a week]*; 3=*usually [every day]*). Six items about daytime sleepiness were used.

Daily Sleep Diary. Adolescents completed sleep diaries every morning for approximately two weeks following the in-person assessment. Individual items were averaged separately across weekday and weekend diaries. Participants were asked to indicate their (1) bedtime and wake time in hours and minutes, (2) how many minutes it took to fall asleep (i.e., SOL), (3) how many hours they slept (i.e., sleep duration), (4) how many minutes they spent awake after waking up at night (i.e., WASO), and (5) and how many times they woke up during the night. Lastly, participants were asked about the overall quality of their sleep (1=*very good*; 5=*very bad*).

Actigraphy. Participants wore ActiGraph GT9X Link on their non-dominant wrist during the same period that they completed sleep diaries. The following variables were used: sleep onset and offset time (time at which the actigraph device registered the participant as asleep or awake respectively), time in bed (total time from sleep onset to offset, which has been shown to be the most accurate approximation of actigraphy-derived measure of total sleep; Short et al., 2012); sleep efficiency (the ratio of time spent asleep to total time spent in bed); and wake after sleep onset (WASO; the time spent awake after falling asleep).

Covariates. Adolescents completed the Physical Development Scale (Petersen et al., 1988) and parents were administered an adaptation of the Services Use in Children and Adolescents - Parent Interview (SCA-PI) (Hoagwood et al., 2004) to assess medication use (for ADHD, sleep [including melatonin], and/or an emotional/behavioral problem). Parents reported on family income and their child's age, sex, and race. Disruptive, anxiety, and depressive disorders were based on the diagnostic interviews conducted with the adolescent and their parent.

Analyses

Based on literature examining the reliability of daily diary and actigraphy data (Acebo et al., 1999; Short et al., 2017), participants with <5 nights of weekday data and <3 nights of weekend data were excluded from analyses using those variables. Few differences emerged between participants with and without data for these variables (see Supplemental Materials).

First, we examined the percentage of students receiving insufficient (i.e., <7 hours), possibly sufficient (i.e., ≥7 but <8 hours), and recommended (i.e., ≥8 hours) sleep duration (Hirshkowitz et al., 2015; Paruthi et al., 2016) across school and weekend days per daily diary and actigraphy[1]. Chi-square tests were conducted to compare the ADHD and comparison groups.

Second, independent samples *t*-tests were conducted comparing adolescents with and without ADHD in global sleep ratings, sleep diary, and actigraphy. Cohen's *d* was calculated as a measure of effect size, with 0.2, 0.5, and 0.8 as benchmarks for small, medium, and large effects, respectively. Chi-square tests were conducted to compare rates of adolescents with and without ADHD who described themselves as poor vs. good sleepers; as usually getting too much, enough, or too little sleep; frequency of themselves getting enough sleep (always/usually, sometimes, rarely/never); falling asleep in morning classes or afternoon classes; staying awake all night; as well as to compare the percentage of adolescents with clinical elevations across SDSC domains. Logistic regression was used to examine whether adolescents with and without ADHD differ in their likelihood of being classified with total sleep disturbance on the SDSC; odds ratio was used as a measure of effect size, with 1.5 considered a small effect, 3.5 a medium effect, and 9.0 a large effect.

Finally, analyses were conducted to examine whether significant group differences remained when controlling for site and variables known to impact sleep: sex, race (dichotomized as White or non-White), age, pubertal development, family income, any medication use (for ADHD,

[1] We sought to include excessive sleep duration (>10 hours), but too few participants fell in this category on school nights (0% using either sleep diary or actigraphy) or weekends (2% using sleep diary and 1% using actigraphy). Furthermore, the National Sleep Foundation indicates that 11 hours of sleep duration "may be appropriate" for adolescents (Hirshkowitz et al., 2015), and no participant had >11 hours sleep duration per sleep diary or actigraphy.

sleep, and/or emotional/behavioral problems), having an externalizing diagnosis (oppositional defiant disorder and/or conduct disorder), having an anxiety diagnosis, and having a depression diagnosis.

Results

Rates of Sufficient and Insufficient Sleep Duration in Adolescents with and without ADHD

Table 2 summarizes the percentage of adolescents with and without ADHD who obtain <7 hours, between 7 and 8 hours, or ≥8 hours of sleep on school nights and weekends, across both diary and actigraphy. Adolescents with ADHD were significantly more likely than adolescents without ADHD to obtain insufficient sleep on school nights based on sleep diary, with 20% of adolescents with ADHD and 10% of adolescents without ADHD reported obtaining <7 hours of sleep on school nights (p=.04). A similar pattern of insufficient sleep was found for actigraphy (13% and 8% of ADHD and comparison participants, respectively), though this difference was not statistically significant (p=.18).

Across both groups, the percentage of adolescents obtaining sufficient (≥8 hours) sleep increased on weekends (see Table 2). In comparing adolescents with and without ADHD , with either actigraphy or daily diary approximately 69% of adolescents with ADHD obtained sufficient sleep on weekends compared to approximately 80% of adolescents without ADHD (both tests statistical trends, ps=.05).

Mean Group Differences in Sleep and Sleepiness

Global sleep ratings. As summarized in Table 3, adolescents with ADHD reported significantly more sleep/wake problems and daytime sleepiness than adolescents without ADHD, with both effects of small-to-medium magnitude. In addition, adolescents with ADHD were significantly more likely than adolescents without ADHD to describe themselves as poor sleepers (28% and 15% for ADHD and comparison, respectively; X^2=5.54, p=.02). Adolescents with ADHD were significantly more likely to fall asleep in their morning classes (10% and 3%, respectively; X^2=6.05, p=.01) and afternoon classes (8% and 2%, respectively; X^2=5.18, p=.02), and to have

stayed up all night (14% and 5%, respectively; X^2=6.46, p=.01) at least twice in the previous two weeks. In contrast to the sleep duration findings reported above, adolescents with ADHD were not more likely than adolescents without ADHD to report that they usually get too little sleep (33.3% and 30.7%; X^2=0.25, p=.88) or that they rarely/never get enough sleep (15.4% and 11.4%; X^2=1.05, p=.59). Adolescents with and without ADHD did not differ in arriving late to class at least twice in the previous two weeks (4.9% and 3.6%, respectively; X^2=0.34, p=.56).

Parents of adolescents with ADHD reported significantly more sleep disturbances in their children than parents of adolescents without ADHD across all SDSC sleep domains except sleep breathing disorders (Table 3). Effect sizes were small for disorders of arousal, hyperhydrosis, and sleep-wake transition disorders, medium for excessive somnolence, and large for disorders of initiating and maintaining sleep and total sleep disturbance. As shown in Figure 1, adolescents with ADHD were more likely than adolescents without ADHD to have clinically elevated scores (≥70) across all SDSC subscales except sleep breathing disorders. Rates of elevated sleep disturbances for the ADHD and comparison groups, respectively, were: 39% and 15% (disorders of initiating and maintaining sleep), 4% and 2% (sleep breathing disorders), 9% and 1% (disorders of arousal), 14% and 4% (sleep-wake transition disorders), 26% and 9% (excessive somnolence), 4% and 0% (hyperhydrosis), and 28% and 5% (total sleep disturbance). The odds of being classified with clinically elevated sleep disturbance were 7.31 times greater for adolescents with ADHD (95% confidence interval: 3.17-16.83).

Teachers rated adolescents with ADHD as exhibiting significantly more daytime sleepiness than adolescents without ADHD, with the difference being small in magnitude (Table 3).

Daily sleep diaries. On school nights, adolescents with ADHD had, on average, a longer SOL, earlier wake time, and shorter sleep duration than adolescents without ADHD. Small-to-medium effect sizes were found for these group differences. No group differences were found for other school night diary variables, and no significant differences were found for diary-assessed sleep on weekends (Table 4).

Actigraphy. Adolescents with ADHD had an earlier sleep offset time, as well as shorter time in bed, than adolescents without ADHD on school nights as measured with actigraphy. These effects were small in magnitude. No group differences were found for other school night actigraphy variables or weekend variables (Table 4).

Group Differences Robust to Covariate Adjustment

Regression analyses were conducted to examine whether mean group differences reported above remained when controlling for other variables known to impact sleep. Full results are presented in Tables S1-S6.

In regression analyses that included these covariates along with group (ADHD vs. comparison) as predictor variables in relation to global sleep ratings, ADHD remained significantly associated with greater SHS daytime sleepiness (β=.17, p=.017), SDSC difficulties initiating and maintaining sleep (β=.25, p<.001), SDSC excessive somnolence (β=.20, p=.004), and SDSC total sleep disturbance (β=.24, p<.001). ADHD group status remained marginally associated with greater SHS sleep/wake problems (β=.16, p=.076) and SDSC disorders of arousal (β=.13, p=.079). ADHD was no longer associated with other SDSC domains or with teacher-rated daytime sleepiness (all ps>.10; Tables S1-S3). Logistic regression analyses indicated that, even when these covariates were included in the model, the odds of being classified with clinically elevated sleep disturbance were 6.20 times greater for adolescents with ADHD (95% confidence interval: 2.28-16.84) (Table S6).

In regression analyses including the same covariates and group status in relation to the significant school night diary and actigraphy variables reported above (Tables S4 and S5), ADHD group remained significantly associated with shorter diary school night sleep duration (β=-.15, p=.047), actigraphy school night time in bed (β=-.15, p=.049), and earlier diary school day wake time (β=-.18, p=.011). ADHD group status remained marginally associated with earlier actigraphy school day sleep offset time (β= -.13, p = .077) but was no longer associated with diary school night SOL (p > .05).

Across regression analyses, in the final models that also included ADHD status, a diagnosis of depression and/or anxiety were most consistently significantly associated with poorer sleep. Specifically, having a depression diagnosis was significantly associated with greater SHS sleep/wake problems and daytime sleepiness; greater SDSC difficulties initiating and maintaining sleep, disorders of arousal, and total sleep disturbance; and longer diary school night SOL. Having an anxiety diagnosis was significantly associated with greater SHS sleep/wake problems and greater SDSC difficulties initiating and maintaining sleep, sleep-wake transition disorders, excessive somnolence, and total sleep disturbance. In addition, more advanced pubertal development and having an externalizing diagnosis were both significantly associated with greater SHS sleep/wake problems and daytime sleepiness; more advanced pubertal development was also associated with shorter diary school night sleep duration. Medication use was significantly associated with greater SHS sleep/wake problems and longer diary school night SOL. Family income, sex, age, and race were unassociated with any sleep/sleepiness domains in the final regression models, with the exception of non-White race being associated with greater teacher-rated daytime sleepiness (Tables S1-S6).

Discussion

This is the first study, to our knowledge, to examine sleep in adolescents with and without ADHD using a large sample size with a careful diagnosis of ADHD in the context of a multi-informant, multi-method design. Findings build upon other studies demonstrating increased sleep problems and daytime sleepiness in adolescents with ADHD (Lunsford-Avery et al., 2016). Consistent with previous research (Cortese et al., 2009; Lunsford-Avery et al., 2016), we found greater support for increased sleep problems in adolescents with ADHD than comparison adolescents when subjective measures of sleep were used, though some group differences also emerged for actigraphy-measured sleep. Importantly, many of the group differences remained significant when controlling for variables known to impact sleep. Considered together, findings from this study indicate that adolescents with ADHD obtain less sleep than their peers, are more likely to

obtain insufficient sleep and fall asleep in class, are at greatly increased risk to experience parent-reported sleep disturbances, and have more difficulties initiating/maintaining sleep and daytime sleepiness compared to adolescents without ADHD.

A key finding from this study is that adolescents with ADHD obtain less sleep than adolescents without ADHD, with results consistent across daily diary and actigraphy methods and robust to control of a number of other variables known to impact sleep. Current recommendations are for adolescents to obtain 8-10 hours of sleep per night (with approximately 9 hours needed for optimal cognitive functioning (Crowley et al., 2018), with 7-8 hours considered possibly sufficient (Hirshkowitz et al., 2015; Paruthi et al., 2016). Per sleep diary, 20% of adolescents with ADHD and 10% of adolescents without ADHD reported obtaining less than 7 hours of sleep on school nights, and these figures rose to 54% and 44%, respectively, when examining how many adolescents obtained less than 8 hours of sleep on school nights. These figures are largely in line with previous research in typically developing samples, though our sample was comprised of eighth grade students and rates of insufficient sleep duration rise across adolescence (Eaton et al., 2010; National Sleep Foundation, 2006). In addition, the average sleep diary school night sleep duration in our sample was 7.76 and 8.06 hours for the ADHD and comparison adolescents, respectively, which is slightly lower than the average of 8.5 hours found in another study of 13-year-old adolescents (Maslowsky & Ozer, 2014). As expected, far more participants in the ADHD and comparison groups reported obtaining sufficient sleep duration on weekends. Still, a substantial percentage of our sample did not reach recommended levels of sleep duration even on weekends, especially adolescents with ADHD (with statistical trends for the weekend difference between the ADHD and comparison groups). These findings point to a troubling pattern whereby adolescents with ADHD may be prone to have insufficient sleep across both school and weekend nights, contributing to chronic shortened sleep that is likely to have a negative impact on daytime functioning.

Previous studies have also reported that adolescents with ADHD go to bed later (Weinstein et al., 2015) or earlier (Chiang et al., 2010) on school nights compared to adolescents without ADHD. We did not find any group differences in self-reported or actigraphy-measured bedtimes on either school or weekend nights. Intriguingly, adolescents with ADHD woke slightly earlier on school days (but not weekend days) than adolescents without ADHD. These findings were consistent across diary and actigraphy methods, though the finding using actigraphy was reduced to a statistical trend in the regression analysis. Parents of children with ADHD frequently note how difficult mornings can be, both in terms of waking their child and getting them ready for school (Faraone et al., 2017). Perhaps parents wake adolescents with ADHD slightly earlier as a way to manage the anticipated before-school difficulties. It should be noted that these group differences were relatively small in magnitude (the ADHD group woke approximately 12 minutes and 10 minutes earlier than the comparison group per diary and actigraphy, respectively). However, earlier morning wakings may compound over the course of a week (12 minutes earlier across five school days would be equivalent to a full hour less of sleep across the school week), perhaps contributing to the overall shorter sleep duration in adolescents with ADHD. Importantly, even seemingly small differences in sleep duration can have a negative impact on daytime functioning (Sadeh et al., 2003).

In fact, shortened sleep may be one reason why we found greater daytime sleepiness in adolescents with ADHD compared to adolescents without ADHD. Effects for greater daytime sleepiness in our ADHD sample were found across adolescent, parent, and teacher ratings, with effects for adolescent and parent ratings remaining significant in the regression analyses. Adolescents with ADHD were also more likely than adolescents without ADHD to report falling asleep in class. These findings are clinically meaningful since daytime sleepiness is common in adolescents with ADHD (Langberg et al., 2017) and associated with poorer academic performance in adolescents with ADHD (Langberg et al., 2013). We also found that adolescents with ADHD were more likely than their peers to report having stayed up all night at least twice in the previous

two weeks (15% and 5%, respectively). Although we do not know why adolescents with ADHD stayed up all night, technology use and completing homework/school projects or studying for a test are possible reasons. Adolescents with ADHD may be especially likely to have problematic technology use (Becker & Lienesch, 2018; Wang et al., 2017) as well as homework, organization, and time-management problems including procrastination (Sibley et al., 2014). In addition, although a previous diagnosis of obstructive sleep apnea was exclusionary in this study, a small percentage of participants (4% in ADHD group and 2% in comparison group) had elevated scores on the SDSC sleep breathing disorders subscale. These participants are at risk for and may have unrecognized sleep apnea that may contribute to increased daytime sleepiness. However, sleep breathing disorders was the one SDSC subscale that did not differ between adolescents with and without ADHD, alleviating concerns that sleep breathing disorders are driving ADHD in our sample. An important direction for future research will be to examine possible mechanisms underlying all-nighters in adolescents with ADHD, as well as the degree to which shortened sleep duration, earlier rise times, and/or sleep apnea symptoms contribute to elevated rates of daytime sleepiness.

Parents of adolescents with ADHD also endorsed higher rates of sleep problems for their children than parents of adolescents without ADHD. Effects were largest for difficulties initiating and maintaining sleep, excessive somnolence, and total sleep disturbance, and ADHD remained significantly associated with more problems across these domains in the regression analyses. When clinical elevations were considered, almost 40% of adolescents with ADHD had elevations in difficulties initiating and maintaining sleep (compared to 15% of adolescents without ADHD), a broad domain that includes sleep duration, SOL, sleep anxiety, and night wakings. These domains have been identified as problematic in school-aged children with ADHD (Cortese et al., 2009), and our findings document these problems also occurring in adolescence. Poorer sleep among individuals with ADHD appears to continue into adulthood, with a recent meta-analysis finding adults with ADHD to display greater SOL and shorter sleep duration, as measured by actigraphy,

and to experience greater daytime sleepiness, SOL, and frequency of night wakings, per subjective measures, than adults without ADHD (Díaz-Román et al., 2018).

Several limitations are important to acknowledge. First, this was a cross-sectional study and we were unable to evaluate whether sleep differentially changes over time for adolescents with and without ADHD. Relatedly, we were unable to examine possible reasons for increased sleep problems in adolescents with ADHD compared to their peers, and longitudinal research examining predictors of sleep problems is sorely needed (Becker & Langberg, 2017; Lunsford-Avery et al., 2016). In addition, although we incorporated global ratings, daily sleep diaries, and actigraphy, none of these methods is without limitations. Ratings and diaries may be subject to social desirability or memory distortions. Actigraphy has limitations in detecting transitions between sleep and wake states and as such, “it should not be automatically assumed that actigraphy is the stronger or more valid measure when compared to sleep diary simply because it has the status of being an objective measure” (Short et al., 2012, p. 383). Also, we were unable to include polysomnography (PSG) which has shown longer stage 1 sleep in children with ADHD compared to children without ADHD (Díaz-Román et al., 2016). An objective measure of daytime sleepiness such as the multiple sleep latency test (MLST), or an assessment of sleep disorders specifically, was not included. We also did not have participants with overly long sleep duration which would be important to examine in future studies exploring possible linear and quadratic associations of sleep in relation to functional outcomes in adolescents with ADHD. In addition, our sleep duration variables were based solely on nighttime sleep and did not include napping; future studies should consider sleep across the 24-hour period. ADHD subtype/presentation is another area for future research that we were unable to include in the current study. Relatedly, although medication use was controlled for in analyses, there are ongoing questions regarding the impact of ADHD medication use on sleep and more fine-grained analyses would be needed to more thoroughly examine the association of medication use and sleep. Finally, adolescents in this study came from

families with relatively high family incomes and parent education levels, and were primarily White, which may impact generalizability to more racially diverse or socially disadvantaged adolescents.

In conclusion, this study advances the knowledge base regarding sleep and sleepiness in adolescents with ADHD. Compared to adolescents without ADHD, adolescents with ADHD had shorter sleep, more sleep problems, and greater daytime sleepiness across ratings and sleep diaries, as well as shorter sleep duration using actigraphy. It is important for clinicians to screen for sleep problems in adolescents with ADHD (Cortese et al., 2013), particularly given recent experimental evidence showing shortened sleep duration to cause poorer daytime functioning in adolescents with ADHD (Becker et al., 2018). Findings from the present study indicate that it is important to assess sleep from the adolescents' perspective, in addition to parents' perspectives, and to assess multiple aspects of sleep (e.g., wake time, bedtime, sleep onset latency, sleep duration) across weekends and weekdays. Including actigraphy and sleep diaries would certainly be informative if feasible to collect. In addition, in the regression analyses, having a comorbid anxiety, depression, and/or externalizing diagnosis was frequently associated with poorer sleep and greater daytime sleepiness, so it remains important for clinicians to assess for conditions that commonly co-occur with ADHD. Regarding intervention, it would be informative to know if existing behavioral interventions improve sleep in adolescents with ADHD. For example, it is possible that interventions targeting homework/organization, time management, and parent-adolescent communication (Langberg et al., 2018; Sibley et al., 2018) have downstream effects for improving sleep. This possibility has not yet been tested, and it would be valuable to know how many adolescents with ADHD have improvements in sleep following behavioral intervention as well as whether certain aspects of sleep remain problematic following behavioral treatment. An additional important next step is to evaluate whether existing sleep interventions are effective, or can be optimized, for use in adolescents with ADHD and co-occurring sleep problems (Becker, 2019; Cortese et al., 2013).

Key Points

- Adolescence is characterized by poor sleep for many youth, yet few studies have examined whether adolescents with ADHD have more sleep problems than their peers without ADHD.
- This study examined sleep and sleepiness using a multi-informant, multi-method design in a large sample of adolescents with and without ADHD.
- This study found compelling support for more sleep problems, shorter sleep duration, and increased daytime sleepiness in adolescents with ADHD compared to their peers without ADHD.
- Adolescents with ADHD are also more likely than their peers to fall asleep in class and stay up all night.
- It is important to assess for sleep problems in adolescents with ADHD and to evaluate whether existing sleep interventions are effective or can be optimized for use in adolescents with ADHD and co-occurring sleep problems.

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Table 1

Sample characteristics

	Total Sample (*N*=302)	ADHD Group (*n*=162)	Comparison Group (*n*=140)	Group Differences
	M±*SD*	*M*±*SD*	*M*±*SD*	
Age	13.17±0.40	13.17±0.41	13.18±0.40	*t*=0.26, *p*=.80
Pubertal development				
Female	3.07±0.62	3.11±0.57	3.05±0.66	*t*=0.60, *p*=.55
Male	2.34±0.58	2.31±0.56	2.39±0.61	*t*=0.86, *p*=.39
Primary Household Income ($USD)	93,073±34,856	84,875±35,864	102,500±31,213	*t*=4.56, *p*<.001
ADHD Symptoms[a]				
Inattention	4.60 (3.69)	7.86 (1.18)	0.83 (1.11)	*t*=53.27, *p*<.001
Hyperactive-Impulsive	2.17 (2.40)	3.58 (2.39)	0.53 (0.90)	*t*=15.06, *p*<.001
	N (%)	*N* (%)	*N* (%)	
Female	135 (44.7)	57 (35.2)	78 (55.7)	X^2=12.80, *p*<.001
Race				X^2=9.17, *p*=.06
White	247 (81.8)	129 (79.6)	118 (84.3)	
Black	16 (5.3)	12 (7.4)	4 (2.9)	
Asian	14 (4.6)	4 (2.5)	10 (7.1)	
American Indian/Alaskan	1 (0.3)	1 (0.6)	0 (0)	
Bi/Multiracial	24 (7.9)	16 (9.9)	8 (5.7)	
Hispanic/Latinx	14 (4.6)	7 (4.3)	7 (5.0)	X^2=0.08, *p*=.78
Highest Maternal Education				
HS degree or less	14 (4.3)	10 (6.2)	4 (2.9)	X^2=7.82, *p*=.05
Partial college/vocational	56 (18.5)	33 (20.4)	23 (16.4)	
College graduate	126 (41.7)	73 (45.1)	53 (37.9)	
Graduate/professional degree	106 (35.1)	46 (28.4)	60 (42.9)	
Medication Use				
ADHD (any)	96 (31.8)	96 (59.3)	0 (0)	X^2=121.63, *p*<.001
Methylphenidate	48 (15.9)	48 (29.6)	0 (0)	X^2=49.32, *p*<.001
Amphetamine[b]	47 (15.6)	47 (29.0)	0 (0)	X^2=48.10, *p*<.001
Non-stimulant[c]	20 (6.6)	20 (12.3)	0 (0)	X^2=18.51, *p*<.001
Other Psychiatric (any)	29 (9.6)	22 (13.6)	7 (5)	X^2=6.37, *p*=.01
Antidepressant	24 (7.9)	18 (11.1)	6 (4.3)	X^2=4.78, *p*=.03
Antianxiety	2 (0.7)	1 (0.6)	1 (0.7)	X^2=0.01, *p*=1.00[e]
Antipsychotic	3 (1.0)	3 (1.9)	0 (0)	X^2=2.62, *p*=.25[b]
Sleep (any)	32 (10.6)	23 (14.2)	9 (6.4)	X^2=4.79, *p*=.03
Melatonin	31 (10.3)	22 (13.6)	9 (6.9)	X^2=4.17, *p*=.04
Other sleep medication	1 (0.3)	1 (0.6)	0 (0)	X^2=0.87, *p*=1.00[e]
Other psychiatric diagnoses[d]	107 (35.4)	74 (45.7)	33 (23.6)	X^2=16.04, *p*<.001
Any externalizing (ODD/CD)	41 (13.6)	35 (21.6)	6 (4.3)	X^2=19.20, *p*<.001
Any anxiety	73 (24.2)	46 (28.4)	27 (19.3)	X^2=3.40, *p*=.07
Any depression	24 (7.9)	16 (9.9)	8 (5.7)	X^2=1.78, *p*=.18

Note. ADHD=attention-deficit/hyperactivity disorder. ODD/CD=oppositional defiant disorder/conduct disorder. Any anxiety=presence of generalized anxiety disorder, social phobia, obsessive-compulsive disorder, and/or posttraumatic stress disorder (PTSD). Any depression=presence of major depression or dysthymia.
[a]ADHD symptoms is the number of ADHD symptoms based on parent report during the diagnostic interview.
[b]Includes amphetamine and mixed amphetamine salts.
[c]Includes guanfacine, atomoxetine, and clonidine.
[d]Presence of comorbid mental health diagnosis based on parent or adolescent report (only parents were administered ODD and PTSD modules) during the diagnostic interview.
[e]Significance based on Fisher's exact test since at least one cell had an expected count less than 5.

Table 2

Sleep diary and actigraphy-measured sleep duration in adolescents with and without ADHD

	ADHD			Comparison			Group Differences	
	<7 hours	7-7.9 hours	≥8 hours	<7 hours	7-7.9 hours	≥8 hours	X^2	*p*
Sleep diary								
School night	20.1%	34.2%	45.6%	9.6%	34.8%	55.6%	6.55	.04
Weekend	9.3%	22.1%	68.6%	5.2%	13.4%	81.3%	5.95	.05
Actigraphy								
School night	12.8%	48.6%	38.5%	7.5%	45.1%	47.4%	3.39	.18
Weekend	6.8%	24.2%	68.9%	1.7%	17.9%	80.3%	5.90	.05

Note. ADHD = attention-deficit/hyperactivity disorder.

Table 3

Differences in global sleep ratings between adolescents with and without ADHD

	ADHD	Comparison	Group Differences		
	M±*SD*	*M*±*SD*	*t*	*p*	*d*
Adolescent SHS ratings					
Sleep/wake problems	18.23±6.08	15.87±4.77	3.77	<.001	.43
Daytime sleepiness	13.02±4.09	11.72±2.89	3.23	.001	.37
Parent SDSC ratings					
Initiate/maintain sleep	66.73±14.31	56.94±11.27	6.65	<.001	.76
Sleep breathing disorders	49.76±8.00	49.66±6.50	0.12	.90	.01
Disorders of arousal	51.49±9.41	49.38±5.36	2.43	.02	.28
Sleep-wake transition	53.58±13.57	48.52±9.04	3.86	<.001	.44
Somnolence (sleepiness)	61.93±16.46	54.46±11.62	4.60	<.001	.52
Hyperhydrosis	49.25±8.80	46.37±4.09	3.73	<.001	.42
Total sleep disturbance	61.71±13.50	52.79±9.29	6.76	<.001	.77
Teacher TDSQ ratings					
Daytime sleepiness	1.19±0.34	1.11±0.20	2.24	.03	.27

Note. ADHD=attention-deficit/hyperactivity disorder. SDSC=Sleep Disturbance Scale for Children. SHS=Sleep Habits Survey. TDSQ=Teacher Daytime Sleepiness Questionnaire.

Table 4

Differences in sleep diary ratings and actigraphy-assessed sleep between adolescents with and without ADHD

	ADHD	Comparison	Group Differences		
	M±SD	*M±SD*	*t*	*p*	*d*
Diary School night[a]					
School night bedtime	10:14pm±47min	10:22pm±50min	1.32	.19	.16
School day wake time	6:41am±33min	6:53am±36min	2.91	.004	.35
School night SOL (min)	21.93±17.71	17.86±13.30	2.20	.03	.26
School night sleep duration (hr)	7.76±1.00	8.06±0.86	2.61	.01	.31
School night sleep quality	2.34±0.72	2.22±0.62	1.45	.15	.17
School night number wakings	0.56±0.64	0.48±0.65	1.10	.27	.12
School night WASO (min)	6.21±10.09	4.37±7.45	1.75	.08	.21
Diary Weekend[a]					
Weekend bedtime	11:15pm±72min	11:21pm±60min	0.80	.43	.10
Weekend wake time	8:37am±81min	8:45am±68min	0.86	.39	.10
Weekend SOL (min)	20.58±21.90	18.58±21.19	0.77	.44	.09
Weekend sleep duration (hr)	8.55±1.41	8.80±1.08	1.62	.11	.20
Weekend sleep quality	2.05±0.70	2.05±0.63	0.01	.99	.001
Weekend number wakings	0.53±0.68	0.53±0.72	0.08	.94	.01
Weekend WASO (min)	5.21±10.90	6.78±17.70	0.89	.38	.11
Actigraphy School night[b]					
Sleep onset time	10:59±51min	10:56pm±49min	0.46	.65	.06
Sleep offset time	6:38am±30min	6:48am±34min	2.60	.01	.31
TIB (hr)	7.74±0.72	7.93±0.67	2.25	.03	.27
Sleep efficiency	80.73±5.43	81.28±5.23	0.87	.39	.10
WASO (min)	86.09±26.79	87.12±28.20	0.31	.75	.04
Actigraphy Weekend[b]					
Sleep onset time	12:00am±78min	11:55pm±63min	0.57	.57	.07
Sleep offset time	8:33am±74min	8:35am±63min	0.30	.77	.04
TIB (hr)	8.65±1.08	8.75±0.82	0.85	.40	.11
Sleep efficiency	80.26±6.19	80.89±5.27	0.86	.39	.11
WASO (min)	99.01±36.59	97.12±27.10	0.47	.64	.06

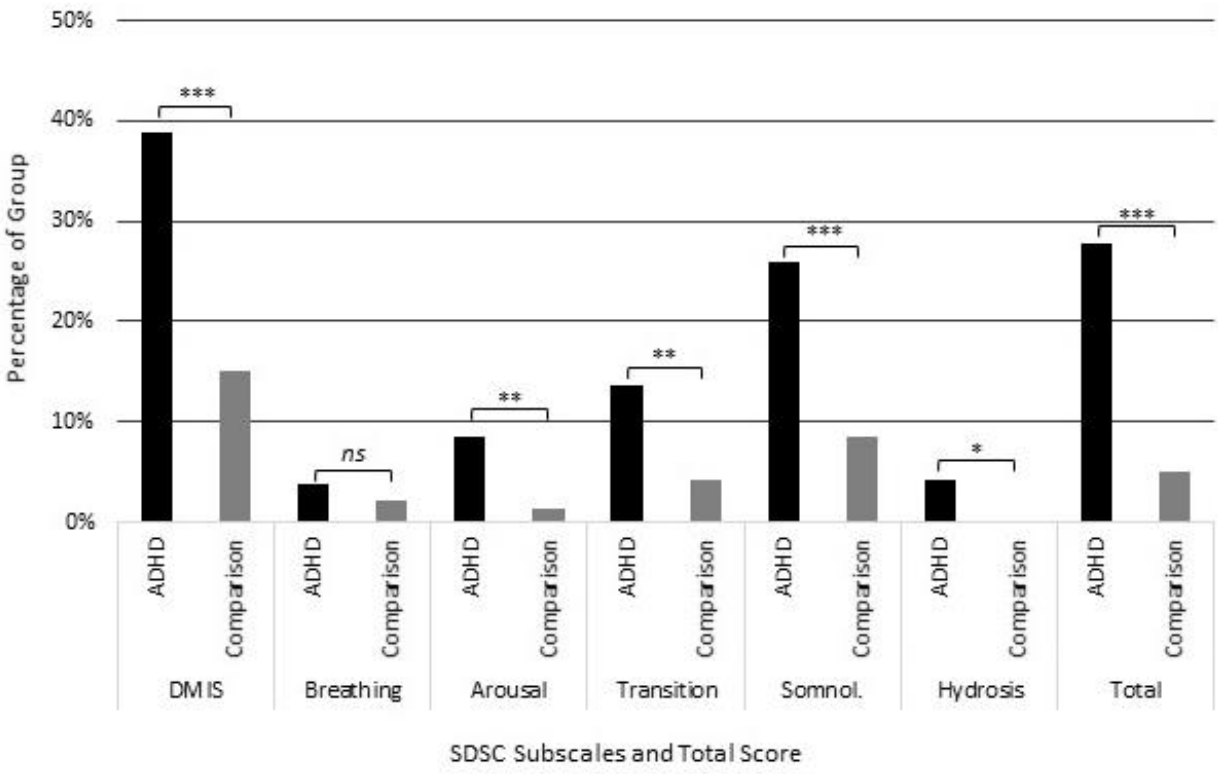
Note. ADHD=attention-deficit/hyperactivity disorder. SOL=sleep onset latency. TIB=time in bed. WASO=wake after sleep onset.

[a]N=284 for school night daily diary (≥5 nights of data); N=276 for weekend daily diary (≥3 nights of data).

[b]N=281 for school night actigraphy (≥5 nights of data); N=249 for weekend actigraphy (≥3 nights of data).

Figure 1

Percent of adolescents with and without ADHD with clinical elevations on the Sleep Disturbance Scale for Children (SDSC)



Note. Clinical elevations defined as *T*-score ≥70. ADHD=attention-deficit/hyperactivity disorder. DMIS=disorders of maintaining and initiating sleep. Somnol.=excessive somnolence.
**p*<.05. ***p*<.01. ****p*<.001.