

Sleep problems predict comorbid externalizing behaviors and depression in young adolescents with attention-deficit/hyperactivity disorder

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Abstract Children and adolescents with attention-deficit/hyperactivity disorder (ADHD) experience high rates of sleep problems and are also at increased risk for experiencing comorbid mental health problems. This study provides an initial examination of the 1-year prospective association between sleep problems and comorbid symptoms in youth diagnosed with ADHD. Participants were 81 young adolescents (75 % male) carefully diagnosed with ADHD and their parents. Parents completed measures of their child's sleep problems and ADHD symptoms, oppositional defiant disorder (ODD) symptoms, and general externalizing behavior problems at baseline ($M_{\text{age}} = 12.2$) and externalizing behaviors were assessed again 1 year later. Adolescents completed measures of anxiety and depression at both time-points. Medication use was not associated with sleep problems or comorbid psychopathology symptoms. Regression analyses indicated that, above and beyond demographic characteristics, ADHD symptom severity, and initial levels of comorbidity, sleep problems significantly predicted greater ODD symptoms, general externalizing behavior problems, and depressive symptoms 1 year later. Sleep problems were not concurrently or prospectively associated with anxiety. Although this study precludes making causal inferences, it does nonetheless provide initial evidence of

sleep problems predicting later comorbid externalizing behaviors and depression symptoms in youth with ADHD. Additional research is needed with larger samples and multiple time-points to further examine the interrelations of sleep problems and comorbidity.

Keywords ADHD · Anxiety · Comorbidity · Conduct problems · Depression · Longitudinal · Sleep

Introduction

It is clear that children and adolescents with attention-deficit/hyperactivity disorder (ADHD) experience much higher rates of sleep problems than their peers without ADHD [1, 2]. In a large sample of youth with ADHD, approximately 30 % had mild sleep problems and an additional 45 % had moderate to severe sleep problems [3]. In particular, youth with ADHD have greater bedtime resistance, longer sleep onset latency, poorer sleep quality, and greater daytime sleepiness compared to youth without ADHD [4–7].

In addition to sleep problems, youth with ADHD are also at increased risk for experiencing comorbid mental health problems, including both externalizing (e.g., oppositionality and aggression) and internalizing (e.g., anxiety and depression) symptoms [8, 9]. Across studies, approximately 45–84 % of youth with ADHD meet criteria for comorbid ODD, 25–35 % for an anxiety disorder, and 25–30 % for a depressive disorder [10]. Moreover, up to 67 % of youth with ADHD have at least two comorbid disorders [11]. This is noteworthy because youth with ADHD who have a comorbid condition often experience greater social impairment [8, 12, 13], poorer academic functioning [14, 15], and increased risk for delinquency and substance use [16, 17] in comparison to those without comorbid

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conditions. In addition, psychiatric comorbidity has been identified as an important predictor of the persistence of ADHD as children and adolescents with ADHD transition to adulthood [18–20]. Despite these findings, remarkably little research attention has been devoted to identifying predictors of comorbidity among youth with ADHD, which is critical to inform prevention and intervention efforts.

Despite the fact that sleep is clearly linked with neurobehavioral functioning [21], perhaps through such mechanisms as executive functions (EF) [22] and affect regulation [23], no study to date has examined whether sleep problems prospectively predict comorbidity among youth diagnosed with ADHD [67]. However, a number of studies have cross-sectionally examined whether psychiatric comorbidity affects or not the sleep patterns of youth with ADHD. For example, Moreau et al. [24] recently found that youth with ADHD and comorbid internalizing or externalizing problems had greater bedtime resistance, shorter sleep duration, more frequent night waking, and greater daytime sleepiness than youth with ADHD alone. In terms of specific comorbidities, several studies have shown that youth with ADHD who have comorbid anxiety or depression have more sleep problems than youth with ADHD alone [25–28]. Evidence to date is more mixed in terms of whether comorbid oppositional defiant disorder (ODD) symptoms or conduct problems are associated with increased sleep problems in youth with ADHD. Specifically, whereas two studies did not report an association between comorbid ODD and increased sleep problems among children with ADHD [28, 29], other studies have found both internalizing and externalizing problems to be associated with overall sleep problems among children with ADHD [30, 31]. Similarly, Ivanenko et al. [27] found sleep duration and sleep latency to be strongly correlated with both externalizing and internalizing problems among 174 children evaluated at a pediatric mental health clinic, 45 % of whom were diagnosed with ADHD. Finally, Lyckett and colleagues [32, 33] recently found that among children with ADHD, those who have both internalizing and externalizing comorbidities experience the highest rates of sleep problems.

Taken together, there appears to be a convergence of evidence suggesting that sleep problems are associated with comorbid internalizing problems among youth with ADHD and possibly associated with comorbid externalizing problems as well. However, the extant research is limited in two primary ways. First, with the exception of one study that examined comorbidity as a predictor of sleep problem persistence among youth with ADHD [32], all other studies conducted to date in this area have used a cross-sectional design, leaving it unclear if sleep problems predict increases in comorbid symptoms over time among youth with ADHD. However, research

conducted in representative population sample of youth provides evidence of sleep problems longitudinally predicting increases in both internalizing and externalizing problems [34]. A second limitation of research examining sleep and comorbidity among youth with ADHD is the tendency in most studies to combine anxiety and depression [24, 27, 28, 32, 33], thus reducing specificity and possibly clouding differential associations of sleep problems in relation to these two internalizing domains. Indeed, the one study that did distinguish between comorbid anxiety and depression among children with ADHD found that comorbid anxiety was concurrently associated with greater sleep problems whereas comorbid depression was not [25].

In sum, there is a clear need for research that (1) examines whether sleep problems longitudinally predict comorbidity among youth with ADHD, and (2) differentiates between comorbid anxiety, depression, and externalizing symptoms. The present study is an initial step in addressing these two gaps in the literature. Specifically, we examined whether sleep problems would predict later anxiety, depression, or externalizing behaviors over a 1-year period in a sample of 81 young adolescents comprehensively diagnosed with ADHD. In order to determine whether sleep problems actually predicted increases in comorbid symptoms and to bolster confidence in the findings, we controlled for baseline comorbidity as well as demographic characteristics and ADHD symptom severity in our models. Although mixed findings have been reported in the literature, we hypothesized that sleep problems would significantly predict later anxiety, depression, and externalizing behaviors among youth with ADHD.

Methods

Participants

Participants were 81 young adolescents (61 males, 20 females) with ADHD between the ages of 10 and 14 at baseline ($M = 12.20$, $SD = 0.95$). Per criteria described below, 42 participants were diagnosed with ADHD predominantly inattentive type (ADHD-I) and 39 participants were diagnosed with ADHD combined type (ADHD-C). Approximately 80 % of the participants were Caucasian ($n = 64$), with the remaining participants being Black ($n = 11$), multiracial ($n = 5$), or Hispanic/Latino ($n = 1$). Participants' annual family income ranged from less than \$10,000 to over \$225,000 ($M = \$54,248$; $Median = \$37,500$). Thirty-three participants (41 %) were taking medication for ADHD at T1, and 38 participants (47 %) were taking medication for ADHD at T2.

Procedures

Data were collected as part of a two-site randomized clinical trial (RCT) examining school-based psychosocial interventions for young adolescents with ADHD. The two time-points examined in the present study, referred to hereafter as T1 and T2, were collected 1 year apart. Participants included in the current set of analyses were included in the community care (i.e., control) condition and, therefore, did not receive any intervention services from study personnel while participating in this study (it is possible that these youth received intervention elsewhere over the course of the study). The study was reviewed and approved by the Institutional Review Board (IRB) and was conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments.

Recruitment was conducted through three primary methods: (1) study announcement letters were mailed to the parents of all students attending identified middle schools at both of the study sites, (2) staff at these schools directly informed parents of some students about the opportunity to participate in this study, and (3) fliers were posted in each participating school. Primary caregivers (hereafter “parents”) who contacted the research staff in response to these recruitment activities were given additional information and were administered a phone screen to assess initial eligibility. On the phone screen, parents had to indicate that their child had a diagnosis of ADHD or had to endorse their child as currently exhibiting at least 4 of 9 Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) [35] symptoms of inattention on a rating scale to be scheduled for an inclusion/exclusion evaluation. The ADHD inattentive symptoms were administered during the phone screen since the study required participating youth to meet criteria for either the ADHD-I or ADHD-C subtypes (and, thus, all eligible youth had to display inattentive symptoms). At the inclusion/exclusion evaluation, all parents signed informed consent and youth provided assent. The inclusionary criteria were (a) meeting full diagnostic criteria for ADHD-I or ADHD-C; (b) an $IQ \geq 80$ as estimated using the Wechsler intelligence scale for children, fourth edition (WISC-IV) [36]; and (c) not meeting criteria for a primary diagnosis of a pervasive developmental disorder or meeting diagnostic criteria for any of the following: bipolar disorder, psychosis, substance dependence other than tobacco, or obsessive–compulsive disorder. Of the 326 youth enrolled in the RCT, 104 were randomized to the community care condition and 81 of these had complete data for the current study variables and were used in analyses.

ADHD diagnoses were determined using procedures similar to those used in the Multimodal Treatment Study of ADHD (MTA) [37]. Primarily, the presence of ADHD

symptoms was established using the Children’s Interview for Psychiatric Syndromes—Parent Version (P-ChIPS) [38, 39], a well-validated structured diagnostic interview that was administered to parents by advanced doctoral students and doctoral-level psychologists. The parent report of ADHD symptoms on the P-ChIPS could be supplemented with the teacher report of ADHD symptoms as reported on the Disruptive Behavior Disorder rating scale (DBD) [40]. The DBD [40] is a well-validated teacher-report measure of DSM-IV ADHD, ODD, and CD symptoms, with items rated on a four-point scale (0 = not at all present, 3 = very much present). If a parent reported at least four symptoms in either ADHD symptom domain on the P-ChIPS, these symptoms could be supplemented with nonoverlapping symptoms (items rated as occurring “pretty much” or “very much”) on the teacher-reported DBD. However, supplementation could only occur if the teacher endorsed at least four symptoms in a domain as occurring “pretty much” or “very much” on the DBD. The same supplementation rules were used to make ADHD subtype determinations. Finally, other criteria for DSM-IV ADHD (i.e., age of onset, pervasiveness, impairment, and ruling out the possibility of other causal disorders) had to be met. The P-ChIPS was also used to assess for the presence of comorbid psychiatric disorders. Using DSM-IV criteria, 54 % of the participants ($n = 44$) met criteria for comorbid ODD or CD and 33 % of the participants ($n = 27$) met criteria for a comorbid internalizing disorder (anxiety or depression).

Measures

Sleep problems

Items from the child behavior checklist for ages 6–18 (CBCL/6–18) [41] were used to measure adolescents’ sleep problems. Although the CBCL does not contain a distinct sleep scale, sleep-specific items are often used by researchers as a measure of sleep problems (e.g., [42–45]). In examining how the CBCL sleep items correlated with daily sleep diaries and objective measures of sleep (i.e., actigraphy, polysomnography), Gregory et al. [46] found the CBCL sleep items to be significantly correlated with several of the other sleep variables. In addition, Becker, Ramsey, and Byars [47] found a composite of the CBCL sleep items to be significantly and strongly correlated with the total score of the well-validated Children’s Sleep Habits Questionnaire (CSHQ) [48] in a large sample of children referred to a sleep disorders center. Moreover, Becker et al. found the CBCL sleep composite to evince similar correlations as the CSHQ total score with youths’ social problems and psychopathology symptoms [47]. As further evidence for the predictive validity of the CBCL sleep measure for the current analyses specifically, the CBCL sleep items

have been shown to longitudinally predict anxiety/depression and aggression in adolescence [49]. The six CBCL sleep items used in the present study were “nightmares”, “overtired without good reason”, “sleeps less than most kids”, “sleeps more than most kids”, “trouble sleeping”, and “talks or walks in sleep”. A mean score of these items was calculated (Cronbach’s $\alpha = 0.61$), with higher scores indicating poorer sleep functioning. Each item is rated on a three-point scale (0 = not true, 1 = somewhat or sometimes true, 2 = very true or often true).

ADHD and ODD symptoms

Parents also completed the DBD [40], and sum scale scores were used in the present study as a continuous measure of ADHD inattentive, ADHD hyperactive-impulsive, and ODD symptoms. Baseline ADHD symptom severity was used as a covariate in all analyses, and follow-up ODD symptom severity was used as a primary outcome of interest in the present study.

Externalizing behaviors

The 12-item Externalizing Problems subscale of the parent-completed Social Skills Improvement System (SSIS) [50] was used to measure youths’ general externalizing behavior problems. The externalizing problems subscale was chosen since it includes a range of disruptive behaviors, including items similar to ADHD hyperactive-impulsive symptoms (e.g., “has difficulty waiting for turn”) as well as items assessing oppositional behaviors (e.g., “talks back to adults”) and more severe conduct problem/aggressive behaviors (e.g., “bullies others”, “fights with others”, “forces others to act against their will”). Parents completed this measure at both baseline and follow-up. Items are rated on a four-point scale (0 = never/not true, 3 = almost always/very true). Internal and test–retest reliability of the SSIS are good, and adequate criterion, convergent, and discriminant validity have been established [50].

Depression symptoms

Youth completed the Reynolds Adolescent Depression Scale, Second Edition (RADS-2) [51] at baseline and follow-up as a measure of their own depressive symptoms. The RADS-2 includes 30 items that measure youths’ depressive symptoms (including dysphoric mood, anhedonia/negative affect, negative self-evaluation, and somatic complaints). Each item is rated on a four-point scale (1 = almost never, 4 = most of the time), with some items reverse-coded before summing the items to create subscale and total scores with higher scores indicating greater levels of depressive symptoms. Internal consistency and test–retest reliability

across both school-based and clinical samples demonstrated alphas ranging from 0.80 to 0.93 for the subscale and total scores [51]. Content, convergent, and discriminant validity of the RADS-2 has also been established [51]. The participant’s total *T*-score was used in analyses.

Anxiety symptoms

Youth also completed the Multidimensional Anxiety Scale for Children (MASC) [52, 53] at baseline and follow-up as a measure of their anxiety. The MASC is a 39-item self-report measure of anxiety symptoms in youth (including physical symptoms, harm avoidance, social anxiety, and separation/panic). Item responses range from 0 (never true about me) to 3 (often true about me). Internal consistency for the subscales is adequate (>0.70), and concurrent, convergent, and divergent validity has been established [52–54]. The participant’s total *T*-score was used in analyses.

Analytic approach

First, preliminary analyses were completed to examine the distribution of the data and the bivariate correlations among the study variables. Next, correlation analyses were conducted to examine whether adolescent demographic characteristics, comorbid psychiatric diagnoses, ADHD symptoms, sleep problems, and externalizing behaviors and internalizing symptoms at the baseline (T1) were bivariate associated with externalizing behaviors and internalizing symptoms 1 year later at follow-up (T2). Finally, hierarchical multiple regression analyses were conducted to examine whether T1 sleep problems predicted T2 externalizing behaviors and internalizing symptoms above and beyond T1 externalizing behaviors/internalizing symptoms, adolescent demographics (i.e., age, sex, race), comorbid psychiatric diagnoses (i.e., having a comorbid ODD/CD or anxiety/depression disorder), and ADHD symptoms. Specifically, demographics, psychiatric comorbidities, ADHD symptoms, and baseline scores on the corresponding outcome of interest were entered on step 1, followed by sleep problems on step 2. For all analyses, statistical significance was set at $p < 0.05$.

Results

Correlation analyses

Absolute values of skew and kurtosis for all study variables were below 1.5. Bivariate associations of adolescent demographics, presence of a comorbid psychiatric diagnosis, T1 ADHD symptoms, T1 externalizing behaviors/internalizing symptoms, and T1 sleep problems with T2

Table 1 Correlations between youth characteristics, ADHD symptoms, comorbid symptoms, and sleep problems at T1 with externalizing behaviors and internalizing symptoms at T2

T1 variables	<i>M</i> ± <i>SD</i>	T2 variables			
		ODD symptoms (8.65 ± 5.26)	Externalizing problems (10.90 ± 6.14)	Anxiety symptoms (49.51 ± 11.75)	Depression symptoms (45.73 ± 10.66)
Youth characteristics					
Age	12.20 ± 0.95	−0.03	−0.10	−0.07	−0.07
Sex	–	−0.04	−0.03	−0.002	−0.02
Race/ethnicity	–	0.21 [†]	0.31**	−0.08	−0.03
Medication use ^a	–	0.17	0.11	0.04	−0.07
ADHD subtype	–	0.10	0.28*	−0.05	−0.09
ODD/CD diagnostic status	–	0.43***	0.40***	0.10	0.18
ANX/DEP diagnostic status	–	0.23*	0.03	−0.001	0.04
ADHD symptoms					
Inattention	18.60 ± 5.88	0.36**	0.42***	−0.15	0.02
Hyperactivity-impulsivity	11.60 ± 6.88	0.41***	0.57***	−0.10	−0.08
Comorbid symptoms					
ODD	9.26 ± 5.72	0.68***	0.54***	−0.03	0.11
Externalizing problems	12.36 ± 6.22	0.63***	0.64***	−0.10	0.03
Anxiety	47.01 ± 10.49	0.11	0.06	0.47***	0.38***
Depression	44.14 ± 8.51	0.16	0.01	0.37**	0.53***
Sleep functioning					
Sleep problems	0.35 ± 0.35	0.46***	0.45***	0.11	0.21 [†]

N = 81. For race/ethnicity, non-Caucasian = 0, Caucasian = 1. For sex, female = 0, male = 1. For ADHD subtype, ADHD-I = 0, ADHD-C = 1. For ODD/CD diagnostic status, no ODD or CD diagnosis = 0, ODD or CD diagnosis = 1. For ANX/DEP diagnostic status, no anxiety or depression diagnosis = 0, anxiety or depression diagnosis = 1

ADHD attention-deficit/hyperactivity disorder, CD conduct disorder, ODD oppositional defiant disorder

[†] $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

^a As with T1 medication use, T2 medication use was not associated with T2 ODD symptoms ($r = 0.17$), T2 externalizing problems ($r = 0.07$), T2 anxiety ($r = -0.07$), or T2 depression ($r = -0.04$), all $ps > 0.10$

externalizing behaviors/internalizing symptoms are summarized in Table 1. As shown, having a comorbid ODD/CD diagnosis and ODD symptoms, externalizing problems, inattention, and hyperactivity-impulsivity at T1 were each significantly correlated with T2 ODD symptoms and externalizing problems. Sleep problems were not associated with being on a medication for ADHD at either T1 ($r = 0.14$, $p = 0.23$) or T2 ($r = 0.02$, $p = 0.86$), nor was T1 or T2 ADHD medication use associated with any of the T2 psychopathology domains. T1 sleep problems were also significantly correlated with both T2 externalizing behavior domains ($ps < 0.001$). T1 anxiety and depression symptoms were each significantly associated with T2 anxiety and depression symptoms, and although youth characteristics and other T1 psychopathology symptoms were not bivariate associated with T2 anxiety/depression symptoms, these variables were nonetheless controlled for in the subsequent regression models since these variables may still contribute variance in predicting these outcomes. In terms

of T1 sleep problems and T2 anxiety/depression symptoms, there was no association between sleep problems and anxiety symptoms at the 1-year follow-up ($r = 0.11$, $p = 0.34$), whereas parent-reported sleep problems at T1 were marginally significantly associated with youth-reported depression symptoms 1 year later ($r = 0.21$, $p = 0.06$).

Regression analyses predicting externalizing behaviors

Hierarchical regression analyses were conducted to examine whether sleep problems (entered at step 2) predicted adolescents' externalizing behaviors 1 year later above and beyond demographics, comorbid psychiatric diagnoses, and ADHD symptom severity (entered at step 1). Results are summarized in Table 2. Baseline (T1) externalizing behaviors were also controlled for in each model, and, as expected, T1 externalizing behaviors were a very strong predictor of T2 externalizing behaviors across both the ODD symptom severity and SSIS externalizing problems

Table 2 Hierarchical regression models predicting T2 externalizing behaviors

	Step 1 model summary			Step 2 model summary		
	<i>B</i>	SE	β	<i>B</i>	SE	β
DV: T2 ODD symptoms	$\Delta F(8,72) = 8.90^{***}$, Adj. $R^2 = 0.44$			$\Delta F(1,71) = 7.58^{**}$, Adj. $R^2 = 0.49$, $\Delta R^2 = 0.05$		
Age	−0.15	0.51	−0.03	−0.21	0.49	−0.04
Race	0.71	1.20	0.06	−0.16	1.19	−0.01
Sex	−1.35	1.04	−0.11	−0.92	1.01	−0.08
ODD/CD diagnostic status	0.54	1.09	0.05	0.18	1.05	0.02
ANX/DEP diagnostic status	1.14	0.99	0.10	0.27	1.00	0.02
T1 ADHD-I Symptoms	0.02	0.10	0.02	0.02	0.10	0.02
T1 ADHD-HI symptoms	−0.04	0.09	−0.06	−0.07	0.09	−0.10
T1 ODD symptoms	0.61	0.12	0.66 ^{***}	0.59	0.11	0.65 ^{***}
T1 sleep problems	–	–	–	3.99	1.45	0.26 ^{**}
DV: T2 externalizing problems	$\Delta F(8,72) = 7.54^{***}$, Adj. $R^2 = 0.40$			$\Delta F(1,71) = 6.79^*$, Adj. $R^2 = 0.44$, $\Delta R^2 = 0.05$		
Age	−0.10	0.62	−0.02	−0.15	0.60	−0.02
Race	1.14	1.55	0.08	0.21	1.53	0.01
Sex	−0.93	1.27	−0.07	−0.48	1.24	−0.03
ODD/CD diagnostic status	1.50	1.29	0.12	1.12	1.25	0.09
ANX/DEP diagnostic status	−0.46	1.20	−0.04	−1.49	1.22	−0.12
T1 ADHD-I symptoms	0.08	0.12	0.07	0.08	0.11	0.08
T1 ADHD-HI symptoms	0.18	0.13	0.20	0.15	0.12	0.17
T1 externalizing problems	0.37	0.15	0.37 [*]	0.34	0.14	0.35 [*]
T1 sleep problems	–	–	–	4.61	1.77	0.26 [*]

N = 81. For race/ethnicity, non-Caucasian = 0, Caucasian = 1. For sex, female = 0, male = 1. For ADHD subtype, ADHD-I = 0, ADHD-C = 1. For ODD/CD diagnostic status, no ODD or CD diagnosis = 0, ODD or CD diagnosis = 1. For ANX/DEP diagnostic status, no anxiety or depression diagnosis = 0, anxiety or depression diagnosis = 1

ADHD attention-deficit/hyperactivity disorder, CD conduct disorder, ODD oppositional defiant disorder

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

domains. Thus, these analyses evaluated whether T1 sleep problems would predict T2 externalizing problems after controlling for the expected temporal stability in adolescents' externalizing behaviors. In the model predicting T2 ODD symptoms (Table 2, top panel), T1 sleep problems were positively associated with greater ODD symptoms ($\beta = 0.26$, $p = 0.008$; $\Delta R^2 = 0.05$) after controlling for T1 ODD symptoms and the other variables included in the model. Similarly, in the model predicting general externalizing problems (Table 2, bottom panel), T1 sleep problems were positively associated with greater externalizing problems ($\beta = 0.26$, $p = 0.01$; $\Delta R^2 = 0.05$) after controlling for T1 externalizing problems and the other variables included in the model.

Regression analyses predicting internalizing symptoms

Similar hierarchical regression analyses were conducted to examine whether sleep problems (entered at step 2) predicted adolescents' internalizing symptoms 1 year later above and beyond demographics, comorbid psychiatric diagnoses, ADHD symptom severity, and T1 internalizing symptoms (entered at step 1). Results are summarized in Table 3. As expected, T1 internalizing symptoms strongly predicted T2 internalizing symptoms. As shown in Table 3, T1 sleep problems did not significantly predict anxiety

($\beta = 0.13$, $p = 0.30$; $\Delta R^2 = 0.01$) after controlling for T1 anxiety symptoms and the other variables included in the model (Table 3, top panel). However, T1 sleep problems were positively associated with greater depression symptoms ($\beta = 0.23$, $p = 0.045$; $\Delta R^2 = 0.04$) after controlling for T1 depression symptoms and the other variables included in the model.

Discussion

This study examined sleep problems as a predictor of comorbid externalizing behaviors and internalizing symptoms in young adolescents diagnosed with ADHD. Parent-rated sleep problems at baseline predicted parent-rated symptoms of ODD and externalizing problems and youth-rated depressive symptoms 1 year later. Importantly, sleep problems predicted these outcomes after controlling for baseline levels of ODD, externalizing, and depressive symptoms, and also after controlling for demographic characteristics and comorbid diagnostic status (see Tables 2, 3). Specifically, after accounting for youth characteristics and the stability of psychopathology over a 1-year period, sleep problems accounted for an additional 5 % of the variance in predicting youths' ODD/externalizing behaviors and an additional 4 % of the variance in predicting youths'

Table 3 Hierarchical regression models predicting T2 internalizing symptoms

	Step 1 model summary			Step 2 model summary		
	<i>B</i>	SE	β	<i>B</i>	SE	β
DV: T2 anxiety symptoms	$\Delta F(8,72) = 3.14^{**}$, Adj. $R^2 = 0.18$			$\Delta F(1,71) = 1.11$, Adj. $R^2 = 0.18$, $\Delta R^2 = 0.01$		
Age	-1.50	1.37	-0.12	-1.56	1.37	-0.13
Race	-2.54	3.23	-0.09	-3.50	3.36	-0.12
Sex	0.37	2.82	0.01	0.82	2.85	0.03
ODD/CD diagnostic status	2.25	2.66	0.10	1.84	2.68	0.08
ANX/DEP diagnostic status	-0.41	2.68	-0.02	-1.38	2.83	-0.06
T1 ADHD-I symptoms	-0.13	0.26	-0.07	-0.13	0.26	-0.07
T1 ADHD-HI symptoms	-0.17	0.23	-0.10	-0.21	0.23	-0.12
T1 anxiety symptoms	0.52	0.12	0.46***	0.50	0.12	0.45***
T1 sleep problems	-	-	-	4.35	4.13	0.13
DV: T2 depression symptoms	$\Delta F(8,72) = 4.15^{***}$, Adj. $R^2 = 0.24$.			$\Delta F(1,71) = 4.18^*$, Adj. $R^2 = 0.27$, $\Delta R^2 = 0.04$.		
Age	-1.23	1.19	-0.11	-1.33	1.17	-0.12
Race	0.33	2.84	0.01	-1.30	2.89	-0.05
Sex	1.02	2.49	0.04	1.71	2.46	0.07
ODD/CD diagnostic status	1.69	2.38	0.08	1.04	2.36	0.05
ANX/DEP diagnostic status	1.07	2.34	0.05	-0.54	2.43	-0.02
T1 ADHD-I symptoms	0.27	0.23	0.15	0.27	0.22	0.15
T1 ADHD-HI symptoms	-0.23	0.20	-0.15	-0.30	0.20	-0.19
T1 depression symptoms	0.66	0.13	0.53***	0.64	0.13	0.51***
T1 sleep problems	-	-	-	7.16	3.50	0.23*

N = 81. For race/ethnicity, non-Caucasian = 0, Caucasian = 1. For sex, female = 0, male = 1. For ADHD subtype, ADHD-I = 0, ADHD-C = 1. For ODD/CD diagnostic status, no ODD or CD diagnosis = 0, ODD or CD diagnosis = 1. For ANX/DEP diagnostic status, no anxiety or depression diagnosis = 0, anxiety or depression diagnosis = 1. ADHD attention-deficit/hyperactivity disorder, CD conduct disorder, ODD oppositional defiant disorder
 * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

depressive symptoms 1 year later. Given the complex processes that likely contribute to the presence of comorbidity among youth with ADHD, these findings are theoretically and clinically important. Together, these findings suggest that sleep problems are not only associated with externalizing and depressive symptoms, but also that sleep problems contribute to the developmental trajectory of externalizing behaviors and depressive symptoms across time. This is especially noteworthy because prior sleep research in ADHD samples has primarily been cross-sectional. Further, these data were collected in a young adolescent sample ($M_{age} = 12$ at baseline and 13 at follow-up), and adolescence is a high-risk period for the development of antisocial behaviors and depressive disorders [9].

To date, most of the research on the association between sleep and externalizing behaviors in youth with ADHD has been cross-sectional and findings have been mixed, possibly due to the small samples included in these studies (*Ns* across studies = 27–45) [5, 30, 55]. To the best of our knowledge, the present study is the first to longitudinally evaluate the relation between sleep and externalizing behaviors problems for youth with ADHD. There was a significant association between sleep and externalizing behavior problems broadly and DSM-based ODD symptoms specifically, as rated 1 year post-baseline, even after controlling for comorbid ODD/CD diagnostic status and

baseline levels of externalizing and ODD symptom severity. As such, this study provides the strongest evidence to date that sleep problems may contribute to the developmental trajectory of externalizing behaviors in youth with ADHD, exacerbating externalizing behavior problems over time.

The results of the present study also indicated that parent-rated sleep problems significantly predicted youth-rated depressive symptoms even after accounting for baseline levels of depressive symptoms. Our findings suggest that this is an important area for future research since rates of depression increase as children enter adolescence [9] and adolescents with ADHD experience much higher rates of depression and suicidal ideation in comparison to their typically developing peers [56, 57]. In contrast, no association was found between sleep problems and symptoms of anxiety. Although previous cross-sectional studies indicate that youth with comorbid ADHD and anxiety may experience poorer sleep functioning [25, 26], our study suggests that sleep problems do not increase risk for anxiety symptoms over time for young adolescents with ADHD. It is possible that parents are less attuned to certain sleep problems that may be linked to anxiety such as long sleep onset latency or night waking. However, the CBCL measure of sleep functioning used in this study is also limited in its ability to assess for these specific sleep disturbances and the use

of longer sleep measures that include items specific to sleep onset, night waking, and sleep-related anxiety (e.g., CSHQ) [48] may yield different findings from those reported in this study. Another intriguing possibility is that the interrelations of sleep and internalizing symptoms are different for anxiety and depression: sleep problems may contribute to increased depression in youth with ADHD whereas anxiety may contribute to increased sleep problems among youth with ADHD. This possibility remains to be empirically tested, and it is likewise clear that the lack of an association between sleep and anxiety in our study will need to be replicated in future studies with larger samples and over a longer developmental period before drawing firm conclusions.

Although sleep problems seem to impact subsequent psychopathology more so than the reverse [58], it is important to point out that the relation between sleep and psychopathology in youth may be bi-directional [58, 59]. For example, Shanahan et al. [34] recently found sleep problems to predict and also be predicted by internalizing and oppositional behaviors in a representative sample of 1,420 youth. Evidence is mixed in terms of whether comorbid oppositional-defiant behaviors exacerbate the sleep problems of youth with ADHD specifically [5, 28, 29], although several studies have found oppositional-defiant behaviors to negatively impact the sleep functioning of youth with ADHD [27, 31]. In terms of sleep problems and depressive symptoms, although the associations between sleep problems and depression may be reciprocal in nature [60], available longitudinal and experimental studies from non-clinical samples indicate that sleep problems more clearly predict depression rather than the reverse [61, 62]. This is especially important to consider since sleep disturbances are part of the diagnostic criteria for depression (as well as for anxiety); it is possible that sleep problems are a useful marker for identifying youth who are at risk for developing depression. Nonetheless, future longitudinal research with additional time points collected over longer periods is needed to evaluate the potential for reciprocal associations between sleep and psychopathology in youth with ADHD specifically [67] (see [58] for an example of this in a community sample). Likewise, it will be important for future research to not only consider sleep problems as identified at a single time point but to also consider the stability of sleep problems over time when examining the long-term effects of sleep problems among youth with ADHD [32, 33].

In addition to examining reciprocal associations, future research should examine mediators that shed light on the processes by which sleep problems contribute to increased ODD/externalizing behaviors and depressive symptoms among youth with ADHD [67]. Sleep problems are associated with a decrement in typically developing youths' executive functioning as well as increased behavior problems [23, 63, 64]. Since youth with ADHD often experience EF

deficits, the added presence of sleep problems may make youth with ADHD especially vulnerable to the negative effects of sleep problems on EF. Deficits in certain aspects of EF such as response inhibition may in turn lead to an increase in behavior problems in youth with ADHD [65]. Another process by which sleep problems may be related to externalizing problems and depressive symptoms is emotion dysregulation. Insufficient or inadequate sleep negatively impacts self-regulation and emotion regulation capabilities [23, 59], which may in turn lead to both externalizing problems and depression [66]. It will be important for future research to extend the findings of the current study by examining mechanisms underlying the link between sleep functioning and comorbid psychopathology in youth with ADHD [67].

Limitations

As noted above, sleep and externalizing behavior problems were both rated by parents and there is potential for within rater bias. Indeed, rater bias likely explains why having a comorbid ODD/CD diagnosis (based on a diagnostic interview conducted with the parent) was associated with T2 ODD symptoms and externalizing problems (based on parent ratings), whereas having a comorbid internalizing diagnosis was not associated with T2 anxiety or depression symptoms (based on youth ratings). It is important to note, however, that youth with ADHD are not considered valid reporters of their own externalizing behaviors and best-practice recommendations are to gather this information from parents and teachers (see [68] for a review). This is in contrast to best-practice assessment recommendations for internalizing symptoms which clearly state that youth self-report is optimal, especially in adolescence [69, 70], which is consistent with the procedures used in this study. In addition, our reliance on the CBCL for measuring youths' sleep functioning is a limitation and it will be important for future research to include well-validated measures of parent- and youth-reported sleep functioning in tandem with objective measures of youths' sleep (e.g., polysomnography, actigraphy). Another limitation is the modest sample size ($N = 81$) and the potential that this limited power to detect effects. However, as noted earlier, the present study's sample of young adolescents with carefully diagnosed ADHD is actually fairly large in comparison to most of the prior work in the area.

Conclusion

Research on the relation between sleep problems and functioning in youth with ADHD is in the very early stages. Currently, there is not enough longitudinal work completed

to draw any firm conclusions about whether sleep problems impact the developmental trajectory of externalizing or internalizing behaviors in youth with ADHD. Research is sorely needed in this area because evidence-based treatments for youth with ADHD do not address sleep in any way. Although best-practice recommendations state that sleep should be assessed as part of an ADHD evaluation to rule-out the possibility that sleep problems are causing inattention [71], only recently have recommendations for treating sleep problems that are comorbid among youth with ADHD begun to be developed [72]. Additional research is needed to guide recommendations on how sleep and ADHD treatments should be optimally sequenced and on the role of ADHD medication [72, 73]. Additional longitudinal work is needed so that evidence-based ADHD interventions can be developed that effectively incorporate sleep as a direct target of treatment.

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