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Impact of sleep restriction on affective functioning in adolescents with attention-deficit/hyperactivity disorder

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Abstract

Background—Shortened sleep and affective disturbances are both prevalent in adolescents with attention-deficit/hyperactivity disorder (ADHD), yet the causal link between these domains has not been examined. This study investigated whether shortened sleep duration is causally linked to affective functioning in adolescents with ADHD.

Methods—Participants were 48 adolescents (75% male) ages 14–17 years with ADHD who successfully completed a three-week sleep protocol using an experimental crossover design. The protocol included a phase stabilization week, followed, in randomized counterbalanced order, by one week of sleep restriction (6.5 hours in bed) and one week of sleep extension (9.5 hours in bed). Sleep was monitored with objective actigraphy, and all participants included in this study obtained ≥1 hour actigraphy-measured sleep duration during extension compared to restriction. Parents and adolescents provided daily ratings of positive and negative affect during the extension and restriction conditions. Ratings of affect, internalizing symptoms, and emotion regulation were collected at laboratory visits conducted at the end of each week.

Results—Both parents and adolescents reported greater depressive symptoms and lower positive affect during restriction compared to extension. Parents also reported greater negative affect and emotion dysregulation among adolescents during sleep restriction than extension. No effects were found for parent- or adolescent-reported anxiety symptoms or for adolescent-reported emotion regulation or negative affect.

Conclusions—Findings from this study provide the first evidence that shortened sleep duration is a causal contributor to the affect and mood disturbances frequently experienced by adolescents with ADHD, particularly as observed by parents. Targeting sleep may be important to reduce affective disturbances in adolescents with ADHD.

Keywords

ADHD; adolescence; affect; anxiety; attention-deficit/hyperactivity disorder; comorbidity; depression; emotion regulation; functional impairment; sleep deprivation

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Introduction

Adolescents with attention-deficit/hyperactivity disorder (ADHD) experience more sleep problems, including insufficient sleep duration, delayed sleep onset latency, more variable sleep/wake patterns, and increased daytime sleepiness, compared to adolescents without ADHD (for reviews, see Becker, 2019; Lunsford-Avery, Krystal, & Kollins, 2016; Mulraney, Sciberras, & Becker, 2020). For example, adolescents with ADHD are 6.2 times more likely than their peers without ADHD to have a parent-reported sleep disturbance (Becker, Langberg, Eadeh, Isaacson, & Bourchtein, 2019). Further, correlational studies have found sleep problems to be associated with poorer daytime functioning in adolescents with ADHD (Becker, Langberg, & Evans, 2015; Hysing, Lundervold, Posserud, & Sivertsen, 2016; Stein et al., 2002). To examine whether shortened sleep duration is *causally* linked to daytime functioning in adolescents with ADHD, we recently conducted a crossover sleep restriction/extension study and found shortened sleep to cause greater inattention, oppositionality, and sleepiness (Becker, Epstein, et al., 2019). The current paper extends these findings by examining the causal impact of shortened sleep on affective functioning in adolescents with ADHD.

Observational studies find poor or insufficient sleep to be associated with poorer affective functioning in adolescents (Becker, Langberg, & Byars, 2015; Brand et al., 2016; Shochat, Cohen-Zion, & Tzischinsky, 2014). Studies with typically developing adolescents also have found sleep deprivation (Short & Louca, 2015) or varying degrees of sleep restriction (Baum et al., 2014; McMakin et al., 2016; Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010) to causally impact affective functioning. Using a similar protocol as the present study, Baum and colleagues (2014) found that adolescents had worsened mood (e.g., increased anxiety and anger, lower vigor) following five days of sleep restriction (6.5 hours in bed) compared to five days of sleep extension (10 hours in bed), though no effect was found for depressive symptoms specifically. Both adolescents and parents also reported poorer emotion regulation and greater irritability following sleep restriction (Baum et al., 2014). Other studies have also found sleep restriction (ranging from 2 to 5 hours in bed) to cause increases in negative affect and/or decreases in positive affect (Lo, Ong, Leong, Gooley, & Chee, 2016; McMakin et al., 2016; Talbot et al., 2010). McMakin et al. (McMakin et al., 2016) extended these findings to the social context and found evidence for observed negative affective behavior during a peer conflict task after sleep restriction.

In building from previous work conducted in typically developing adolescents, it is especially important to examine the impact of sleep restriction on the affective functioning of adolescents with ADHD. Adolescents with ADHD are at increased risk for experiencing co-occurring internalizing psychopathology, including anxiety and depression (Becker & Fogleman, 2020; Smalley et al., 2007). In addition, deficits in emotion regulation are increasingly recognized as a core feature of ADHD (Faraone et al., 2019). Furthermore, emotion regulation deficits in children with ADHD are associated with a more severe ADHD phenotype (Sobanski et al., 2010) and prospectively predict greater functional impairment in adulthood (Barkley & Fischer, 2010). Given these findings, there has been recent interest in developing and testing interventions targeting emotion and mood for children and adolescents with ADHD (Meinzer, Hartley, Hoogesteyn, & Pettit, 2018; Rosen

et al., 2018). Sleep is not currently included in these interventions. If shortened sleep contributes to poorer affective functioning in adolescents with ADHD, then sleep may be an important, yet currently unaddressed, treatment target for this population.

The present study used an experimental sleep restriction/extension protocol to examine shortened sleep duration as a causal contributor to poorer affective functioning in adolescents with ADHD. Based on previous research with typically developing adolescents (Baum et al., 2014; Lo et al., 2016; McMakin et al., 2016; Talbot et al., 2010), we hypothesized that adolescents with ADHD would experience lower positive affect, higher negative affect, increased internalizing symptoms, and greater emotion dysregulation during a sleep restriction condition compared to a sleep extension condition.

Methods

Participants

Participants were 48 adolescents (75% male) ages 14–17 years (M = 15.21, SD = 1.15) diagnosed with ADHD who successfully completed the three-week sleep protocol described below. All participants had an IQ ≥ 70 (*Range* = 79–132) based on the Kaufman Brief Intelligence Test, Second Edition (Kaufman & Kaufman, 2004). Sample characteristics, including comorbid diagnoses based on the Kiddie Schedule for Affective Disorders and Schizophrenia for School-Age Children (K-SADS) (Kaufman et al., 1997) interview conducted separately with the adolescent and parent, are provided in Table 1.

As in our previous study (Becker, Epstein, et al., 2019), although 72 adolescents entered the sleep protocol, only the 48 who were adherent to the sleep protocol (defined a priori as ≥1 hour longer nightly sleep during sleep extension compared to sleep restriction) were included in current analyses given the aim to test the impact of sleep restriction and extension. There were no significant differences between adherent and non-adherent participants in demographic characteristics, ADHD symptom severity, ADHD presentation, sleep/sleepiness, or psychiatric comorbidity (see Becker et al., 2019 for details). In addition, there were no significant differences between adherent and non-adherent participants in parent- or adolescent-reported internalizing symptoms or emotion regulation assessed at the inclusion visit (all ps > .20).

Procedures

All study procedures were approved by the Cincinnati Children's Hospital Medical Center Institutional Review Board (IRB). Signed informed consent and assent were obtained. Recruitment materials were distributed via local schools, in the community, and at Cincinnati Children's Hospital Medical Center where the study was conducted during the summers of 2016 and 2017. Materials described a study examining sleep in adolescents with ADHD but did not specifically mention (nor target) adolescents with sleep problems.

Full Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) (American Psychiatric Association, 2013) criteria for ADHD Predominantly Inattentive or Combined Presentation on the K-SADS parent interview was required for eligibility. Exclusion criteria included autism, bipolar disorder, obsessive-compulsive disorder, or

psychosis; meeting screening criteria for the possible presence of sleep-disordered breathing or restless leg syndrome using the Pediatric Sleep Questionnaire (Chervin & Hedger, 2001; Chervin et al., 2007); history of epilepsy or head trauma resulting in loss of consciousness; IQ < 70; regular high caffeine use (>1 coffee/energy drink/day or 3 caffeinated soft drinks/day); highly atypical sleep duration (routinely obtaining <6 hours of >9.5 hours on school nights); or obligations that required a bedtime later than 10:00PM or waking prior to 6:00AM. Participants taking stimulant medication were allowed if the family was willing to discontinue the medication for the three-week sleep protocol during the summer. In the first year, all participants taking melatonin or a non-stimulant psychiatric medication were excluded; in the second year, these were not exclusionary but only allowable if discontinued during the summer.

Sleep protocol—As in previous studies of typically developing adolescents (Baum et al., 2014; Beebe et al., 2008), participants were involved in a three-week sleep manipulation protocol administered during the summer break from school to avoid impacting scholastic performance. All sleep occurred in the home environment and was monitored via sleep diaries and actigraphy. After a stabilization week whereby participants were asked to wake at a time that would allow them to arrive at the research location by 8:00AM, participants were asked to systematically change their bedtimes to accommodate sleep extension and sleep restriction conditions. A within-subjects, crossover design was used, such that all adolescents participated in both the sleep restriction and sleep extension conditions, with the order of conditions randomly counterbalanced across participants. During the sleep extension condition, adolescents adjusted their bedtime to allow 9.5 hours in bed. This 9.5-hour “in bed” window was selected because, allowing for 30 minutes to fall asleep, (a) 9 hours is how long adolescents sleep during controlled trials of sleep satiation (Carskadon et al., 1980) and naturally on non-school nights (National Sleep Foundation, 2006), (b) this results in a well-rested state in adolescents (Beebe et al., 2008), and (c) this conforms to clinical recommendations for adolescents (Hirshkowitz et al., 2015; Paruthi et al., 2016). During the sleep restriction condition, adolescents adjusted their bedtime to allow 6.5 hours in bed, which in previous studies using this protocol resulted in an average of 6.1–6.3 hours of nightly sleep (Beebe et al., 2008). This sleep restriction condition reflects a realistic dose of sleep restriction (similar to school-night sleep of 15–20% of healthy adolescents; Wolfson & Carskadon, 1998) that is feasible and induces daytime sleepiness, inattention, and oppositionality in typically developing adolescents (Baum et al., 2014; Beebe et al., 2008).

Primary data collection occurred throughout the week (via actigraphy and daily diaries) and at a laboratory visit each Friday at the end of each condition. To monitor sleep and adherence to the protocol, participants wore a wrist-mounted actigraph (Micro Motionlogger©, Ambulatory Monitoring, Inc.) throughout the sleep protocol to gather an objective measure of sleep. At each Friday assessment, actigraph data were downloaded and both the actigraphy data and sleep diaries were reviewed with the adolescent and their parent. In tandem with visually inspecting the sleep diaries, a validated algorithm (Sadeh, Sharkey, & Carskadon, 1994) was used to obtain objective estimates of sleep duration. The 48 adolescents included in current analyses averaged 1.6 hours longer actigraphy-measured

sleep per night during the sleep extension condition than during sleep restriction ($p < .001$; additional details available in Becker, Epstein, et al., 2019).

Measures

Daily affect—Adolescents and parents completed the 10-item Positive and Negative Affect Scale, Short Version (PANAS) (Ebesutani, Okamura, Higa-McMillan, & Chorpita, 2011) at the laboratory visits at the conclusion of the sleep extension and sleep restriction weeks. The 10-item PANAS includes a positive affect scale (*joyful, cheerful, happy, lively, proud*) and a negative affect scale (*miserable, mad, afraid, scared, sad*), with each item rated on a five-point scale (1 = *very slightly or not at all*, 5 = *extremely*). Total mean scale scores were calculated (adolescent positive affect αs = .90 and .91, for sleep extension and sleep restriction, respectively; adolescent negative affect αs = .90 and .75; parent positive affect αs = .93 and .90; parent negative affect αs = .70 and .78). In addition, both adolescents and parents completed a daily diary which included the 10-item PANAS.

Emotion regulation—The Emotion Regulation Checklist (ERC) (Shields & Cicchetti, 1997) and Difficulties in Emotion Regulation Scale (DERS) (Gratz & Roemer, 2004) were used at each laboratory visit to assess parent- and adolescent-reported emotion regulation, respectively. The ERC consists of 24 items rated on a four-point scale (1 = *never;* 4 = *always*). The DERS consists of 36 items rated on a five-point scale (1 = *almost never*; 5 = *almost always*), with higher scores indicating more difficulties with emotion regulation. Total mean scale scores were calculated (ERC αs = .77 and .76 for sleep extension and sleep restriction, respectively; DERS αs = .88 and .90).

Internalizing symptoms—At each laboratory visit, adolescents and parents completed the Revised Child Anxiety and Depression Scales (RCADS) (Chorpita, Moffitt, & Gray, 2005; Chorpita, Yim, Moffitt, Umemoto, & Francis, 2000; Ebesutani et al., 2010; Ebesutani, Chorpita, et al., 2011), a 47-item measure that assesses *DSM*-based anxiety and depression disorder symptoms on a four-point scale (1 = *never*, 4 = *always*). To ensure that any differences across sleep conditions were not attributable to the protocol's expected impact on sleep, two separation anxiety items ("feel scared to sleep on my own", "I worry when I go to bed at night") and one depression item ("I have trouble sleeping") related to sleep were removed before computing scale scores. Total mean scale scores were calculated for the remaining 35 anxiety symptoms (adolescent αs = .95 and .95 for sleep extension and sleep restriction, respectively; parent αs = .93 and .89) and the remaining nine depressive symptoms (adolescent αs = .83 and .80 for sleep extension and sleep restriction, respectively; parent αs = .79 and .71).

In addition, at each laboratory visit adolescents completed the depressed mood subscale of the Sleep Habits Survey (SHS) (Wolfson & Carskadon, 1998). The depressed mood scale includes six items (e.g., "Feeling unhappy, sad or depressed") rated on a three-point scale (1 = *not at all;* 2 = *somewhat;* 3 = *much*). For the present study, two items of sleepiness ("feeling too tired to do things") and sleep problems ("having trouble going to sleep or staying asleep") were removed before calculating total sum scale scores (αs = .82 and .75 for sleep extension and sleep restriction, respectively).

Analyses

Our primary analyses examined the extent to which sleep restriction was associated with internalizing symptoms, affect, and emotion regulation. A paired samples *t*-test for each outcome variable was conducted comparing the sleep restriction and sleep extension conditions, with an alpha threshold of 0.05[1]. Cohen's *d*, corrected for dependence in within-subjects data, was computed as a measure of effect size, with 0.2, 0.5, and 0.8 as benchmarks for small, medium, and large effects, respectively (Cohen, 1988). Secondary analyses were conducted examining daily-level positive and negative affect across the sleep restriction and sleep extension weeks. Specifically, repeated-measures general linear models were conducted with both sleep condition (sleep restriction and sleep extension) and day (days 1 through 5) as within-subjects factors, with separate models conducted for adolescent and parent ratings and for positive and negative affect. Our effect of interest was whether there was a main effect of sleep condition, though we also examined whether there was a main effect of day of the week as well as the sleep condition × day interaction. Partial eta-squared (η_p^2) was computed as a measure of effect size, with 0.01, 0.06, and 0.14 as benchmarks for small, medium, and large effects, respectively (Cohen, 1988).

Results

Impact on Weekly Ratings of Affect, Emotion Regulation, and Internalizing Symptoms

Table 2 summarizes findings for the outcome variables assessed at the laboratory visits following sleep restriction and sleep extension. Parents reported significantly lower positive affect, higher negative affect, and poorer emotion regulation during sleep restriction compared to sleep extension, with medium to large effects for positive affect and emotion regulation (*d*s = 0.82 and 0.56, respectively) and a small to medium effect for negative affect (*d* = 0.44). In contrast to parent ratings, significant differences were not found for adolescent-reported negative affect or emotion regulation. Although statistically significant effects were not found for adolescent-reported positive and negative affect, small effects were found in the expected direction for these domains (both *d*s = 0.20).

In considering internalizing symptoms, parents reported significantly greater depressive symptoms during sleep restriction compared to sleep extension, with a large effect (*d* = 0.84). Adolescents reported significantly greater depression on the SHS, but not on the RCADS, during sleep restriction compared to sleep extension, with small effects for both measures (*d*s = 0.31 and 0.26, respectively). Significant differences were not found for either parent- or adolescent-reported anxiety[2].

Impact on Daily Ratings of Positive and Negative Affect

Repeated-measures general linear models indicated a significant effect of sleep condition on both parent-reported positive affect, $F(1,41) = 10.02$, $p = .003$, $\eta_p^2 = .196$, and adolescent-

[1]The pattern of findings was unchanged when nonparametric Wilcoxon signed-rank tests were used.
[2]Sleep manipulation order did not interact with any of the affective functioning variables to moderate effects of the sleep manipulation (all *p*s > .10), with one exception: there was a significant interaction between manipulation order and adolescent self-reported anxiety symptoms (*p* = .03). However, follow-up tests indicated that the sleep protocol did not significantly impact anxiety regardless of manipulation order (*p*s > .05).

reported positive affect, $F(1,44) = 4.20$, $p = .046$, $\eta_p^2 = .087$. As shown in Figure 1, parent- and adolescent-reported mean scores for positive affect were lower across all five days of sleep restriction than sleep extension. In addition, there was a significant effect of day for both parent- and adolescent-reported positive affect (ps = .026 and .008, respectively), with positive affect trending lower later in the week. As shown in Figure 2, daily negative affect ratings were generally higher during sleep restriction than extension, but this reached statistical significance only on parent-report, $F(1,41) = 6.07$, $p = .018$, $\eta_p^2 = .129$, not adolescent-report, $F(1,44) = 2.45$, $p = .125$, $\eta_p^2 = .053$. Although visual inspection of both figures suggests that sleep restriction resulted in progressively lower parent-reported positive affect and higher parent-reported negative affect over time, there was not a significant effect of day or a significant week × day interaction for either parent- or adolescent-reported negative affect (ps > .05).

Discussion

The present study provides evidence that shortened sleep duration causally contributes to poorer affective functioning in adolescents diagnosed with ADHD. Insufficient sleep duration worsens mood and emotion regulation in adolescents with ADHD, particularly as observed by parents.

Across both daily diary and laboratory visit measures, parents reported less positive affect and more negative affect during sleep restriction compared to extension, with medium to large effect sizes. Although effects of the sleep manipulation on affect ratings were in the same direction on adolescent self-reports, effect sizes were much smaller effects, generally falling just short of statistical significance. Previous research with typically developing adolescents has found sleep restriction to impact a) both positive and negative affect (Study 1 in McMakin et al., 2016), b) negative but not positive affect (Study 2 in McMakin et al., 2016), or c) positive but not negative affect (Dagys et al., 2012; Lo et al., 2016; Talbot et al., 2010). Of note, each of these previous studies used variations of the self-report PANAS and did not collect parent ratings of adolescents' affect. We are unaware of any study that has used the parent-report PANAS to assess affect across sleep restriction and extension in adolescents. However, in considering parent-report of adolescents' affect, our findings are consistent with Baum et al. (2014) who found sleep restriction to impact both positive mood (e.g., vigor/activity) and negative mood (e.g., anger/hostility).

Sleep restriction increased emotion regulation difficulties according to parent-report but not adolescent-report. This contrasts with a previous study that used a similar sleep protocol and found sleep restriction to negatively impact emotion regulation across both parent and adolescent informants (Baum et al., 2014). However, our findings are consistent with an experimental sleep study conducted with school-aged children (ages 8–12 years) which found restricted sleep to worsen parent-reported, but not child-reported, emotion regulation (Vriend et al., 2013). In addition, emotion dysregulation is closely linked to irritability in youth with ADHD (Faraone et al., 2019), and previous work with typically developing adolescents has found restricted sleep to increase parent-reported irritability but not adolescent-reported irritability (Beebe et al., 2008). It may be that youth themselves are less able to reflect on their emotional reactivity, or to observe changes over the relatively short

periods used in the sleep protocol. Also, as parents and adolescents completed different measures of emotion regulation in the present study, it is unclear if the discrepant pattern of findings across raters is due to informant differences or measurement differences. It would be beneficial for future research to further examine how restricted sleep impacts emotion in adolescents with ADHD, including attending to informant differences and distinguishing between emotion generation and emotion regulation (Palmer & Alfano, 2017).

A previous observational study found sleep problems to longitudinally predict increases in depressive symptoms one year later in adolescents with ADHD, whereas sleep problems were not concurrently or prospectively associated with anxiety symptoms (Becker, Langberg, & Evans, 2015). Our findings provide experimental support for differentiating the impact of sleep on depression and anxiety in adolescents with ADHD. Specifically, sleep restriction resulted in significantly increased depressive symptoms, but not anxiety symptoms, with findings largely consistent across parent and adolescent informants. This pattern fits with our findings that sleep restriction impacted positive affect more so than negative affect, as low positive affect is a defining feature that distinguishes depression from anxiety (Clark & Watson, 1991). Our findings suggest that insufficient sleep should be incorporated into models that aim to identify mechanisms linking ADHD and depression (Meinzer & Chronis-Tuscano, 2017). This is especially important given the increased impairment and suicide behaviors among individuals with ADHD who have co-occurring depression (Balazs & Kereszteny, 2017; Daviss, 2008).

Given the prevalence and impact of affective disturbances in ADHD, interventions have recently been developed to target emotion and mood problems specific to this population (Meinzer et al., 2018; Rosen et al., 2018). Our findings suggest that targeting sleep may be an important factor to include for optimizing treatment effects. Taking a different approach, directly treating sleep may lead to improvements in mood and emotion regulation. There is some evidence that improving sleep also improves emotional functioning in school-aged children with ADHD (Hiscock et al., 2015; Keshavarzi et al., 2014; Sciberras et al., 2019), though improvements in emotional functioning were not found when a brief sleep intervention was delivered by community-based clinicians (Hiscock et al., 2019). Studies have yet to evaluate evidence-based cognitive-behavioral sleep interventions in adolescents with ADHD, which will be important given the developmental changes and contexts that occur in adolescence that have implications for intervention delivery. Our findings showing shortened sleep to cause poorer daytime functioning point to this as an important area for clinical attention (Becker, 2019).

Several limitations are important to acknowledge. First, our measures were limited to parent and adolescent rating scales, which may lack objectivity and could not be masked to sleep condition. It is reassuring that we did not find universal effects across all domains examined in this study, bolstering confidence that findings were not attributable to response bias. Nevertheless, it would be beneficial for future research to incorporate other performance-based measures (e.g., emotional Stroop task), and administering the sleep protocol during the school year would allow for collecting ratings from teachers and peers who could be masked to the sleep conditions. Second, our study was limited to adolescents with ADHD and did not include a comparison sample of adolescents without ADHD. We were thus

unable to examine whether the magnitude of effects differs for adolescents with and without ADHD or whether certain effects (e.g., depressive symptoms) are especially relevant to youth with ADHD. Third, the sample was of a modest size, which limited statistical power to detect small effects (e.g., on adolescent self-report). Finally, the sample had relatively low rates of psychiatric comorbidity. The extent to which findings generalize to more clinically severe samples of adolescents with ADHD is unknown.

In conclusion, the current study provides the first evidence that shortened sleep is causally contributes to poorer affective functioning in adolescents with ADHD. These findings are especially important given the prevalence and impact of emotion dysregulation and mood disturbances in this population. Findings suggest that targeting sleep may be important to reduce these problems in adolescents with ADHD.

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Key Points

- Shortened sleep and affective disturbances are both prevalent in adolescents with attention-deficit/hyperactivity disorder (ADHD).
- This experimental sleep restriction/extension study provides evidence that shortened sleep duration causally contributes to poorer affective functioning in adolescents diagnosed with ADHD, particularly as observed by parents.
- Findings align with correlational research in demonstrating sleep restriction to result in increased depressive symptoms, but not anxiety symptoms, in adolescents with ADHD.
- There has been recent interest in developing and testing interventions targeting emotion and mood disturbances in children and adolescents with ADHD. Findings from this study suggest that targeting sleep may be an important factor to include for optimizing treatment effects.

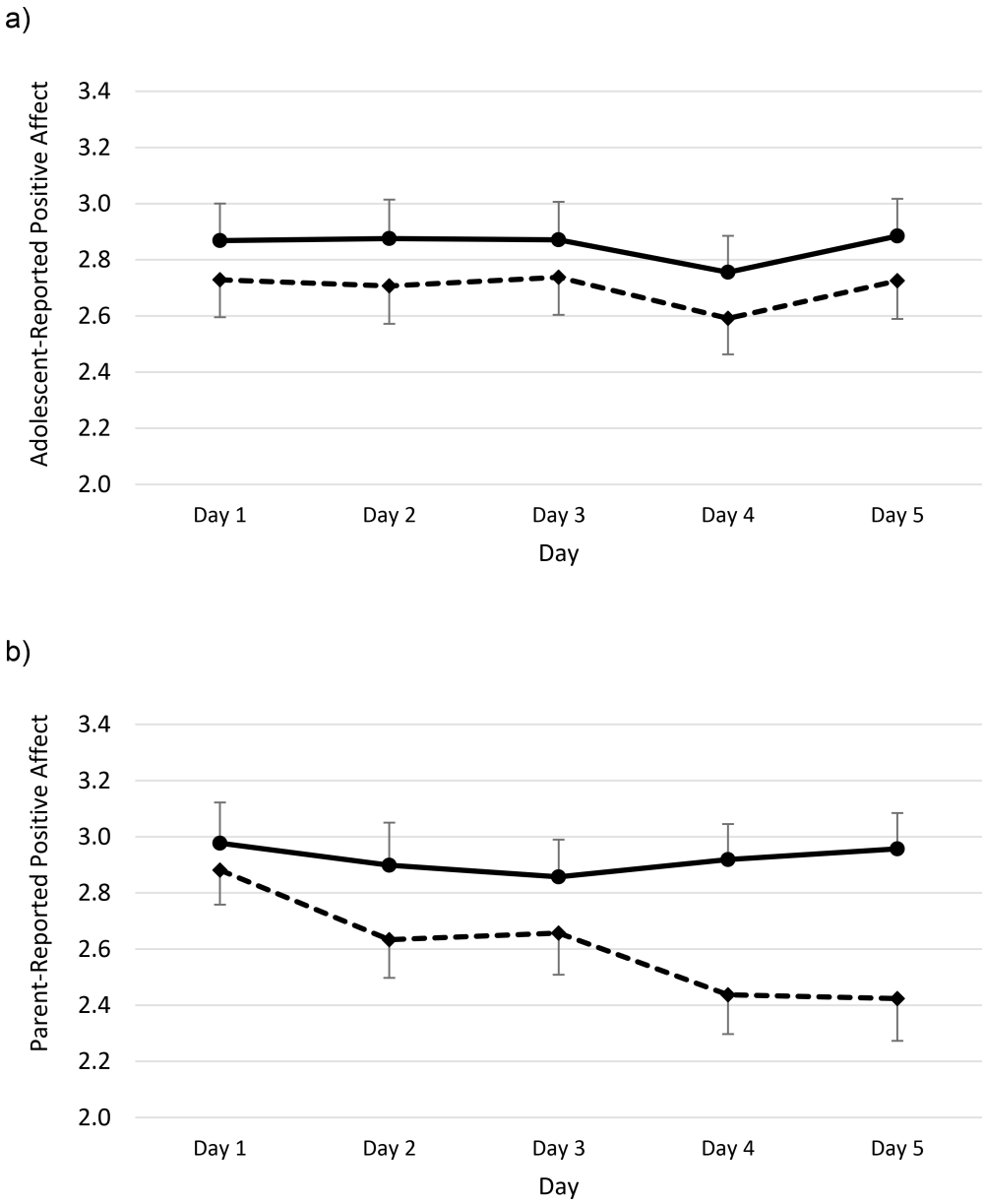

Figure 1.

Daily positive affect during sleep extension (solid lines) and sleep restriction (dashed lines). Higher scores indicate greater positive affect. Adolescent-reported positive affect is dispalyed in panel a, parent-report of adolescent positive affect is displayed in panel b. Bars indicate standard errors.

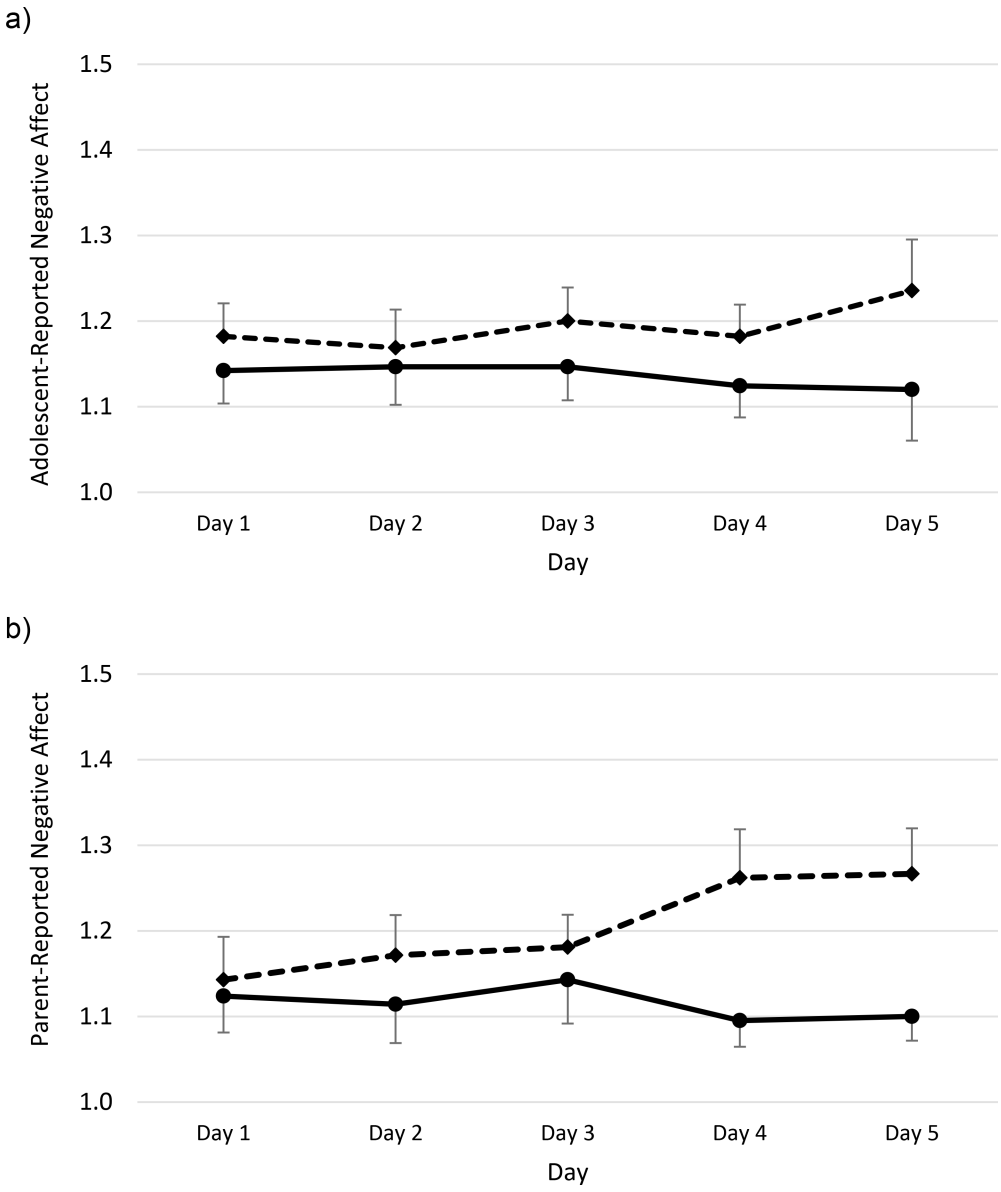

Figure 2.

Daily negative affect during sleep extension (solid lines) and sleep restriction (dashed lines). Higher scores indicate greater negative affect. Adolescent-reported positive affect is displayed in panel a, parent-report of adolescent positive affect is displayed in panel b. Bars indicate standard errors.

Table 1

Sample Characteristics (N = 48)

	M ± *SD*
Age	15.21 ± 1.15
IQ	102.90 ± 11.64
	N(%)
Sex	
Male	36 (75.0%)
Female	12 (25.0%)
Race/Ethnicity	
White	37 (77.1%)
Black	5 (10.4%)
Hispanic	1 (2.1%)
Multiracial	5 (10.4%)
Baseline Medication Status[a]	
Stimulant	35 (72.9%)
Nonstimulant	4 (8.3%)
Melatonin	1 (2.1%)
Any medication	37 (77.1%)
Family Income[b]	
Up to $40,000	4 (8.3%)
$40,001 - $60,000	8 (17.0%)
$60,001 - $80,000	4 (8.5%)
Over $80,000	31 (66.0%)
ADHD Presentation[c]	
Combined	11 (22.9%)
Inattentive	37 (77.1%)
Comorbid Diagnoses[c]	
Depression/Dysthymia	1 (2.1%)
GAD	4 (8.3%)
PTSD	0 (0%)
Mania	0 (0%)
ODD	2 (4.2%)
CD	0 (0%)
Any Comorbidity	6 (12.5%)

Note: ADHD = attention-deficit/hyperactivity disorder. CD = conduct disorder. GAD = generalized anxiety disorder. ODD = oppositional defiant disorder. PTSD = posttraumatic stress disorder.

[a] All participants were taken off any medication prior to starting the three-week sleep protocol.

[b] One parent declined to answer the family income question.

[c] ADHD and comorbid diagnoses established using the *Kiddie Schedule for Affective Disorders and Schizophrenia for School-Age Children* (K-SADS) conducted separately with the parent and adolescent (using an "or" rule), with ADHD diagnosis and presentation based on interview with the adolescent's parent.

Table 2

Differences in Affective Functioning During Sleep Restriction and Sleep Extension in Adolescents with ADHD

	Sleep Restriction	Sleep Extension	Paired samples *t*-tests comparing sleep restriction and extension		
	M* ± *SD	***M* ± *SD***	***t***	***p***	***d***
Positive affect					
PANAS (parent)	2.66 ± 0.80	3.13 ± 0.83	4.96	<.001	0.72
PANAS (adolescent)	2.88 ± 0.93	3.09 ± 0.95	2.01	0.051	0.20
Negative affect					
PANAS (parent)	1.33 ± 0.47	1.15 ± 0.31	−3.05	0.004	0.44
PANAS (adolescent)	1.25 ± 0.42	1.18 ± 0.29	−1.34	0.182	0.20
Emotion regulation					
ERC (parent)	1.88 ± 0.28	1.76 ± 0.28	−3.83	<.001	0.56
DERS (adolescent)	2.04 ± 0.45	2.02 ± 0.42	−0.69	0.496	0.10
Anxiety					
RCADS (parent)	0.24 ± 0.21	0.21 ± 0.23	−1.72	0.093	0.25
RCADS (adolescent)	0.36 ± 0.35	0.34 ± 0.37	−0.68	0.501	0.10
Depression					
RCADS (parent)	0.45 ± 0.32	0.26 ± 0.30	−5.80	<.001	0.84
RCADS (adolescent)	0.41 ± 0.38	0.32 ± 0.38	−1.81	0.077	0.26
SHS (adolescent)	4.83 ± 1.42	4.56 ± 1.30	−2.16	0.036	0.31

Note: All measures were completed at a laboratory visit following sleep restriction and sleep extension. ADHD = attention-deficit/hyperactivity disorder. DERS = Difficulties in Emotion Regulation Scale. ERC = Emotion Regulation Checklist. PANAS = 10-item Positive and Negative Affect Scale. RCADS = Revised Child Anxiety and Depression Scales. SD = standard deviation. SHS = Sleep Habits Survey.