Sleep, Attention, and Executive Functioning in Children with Attention-Deficit/Hyperactivity Disorder

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Abstract

The objective of this study was to investigate potential relationships between two measures of sleep impairments (i.e., sleep duration and sleep efficiency) and cognitive functioning in children with attention-deficit/hyperactivity disorder (ADHD). Parents of 43 children (mean age = 10 years ± 1.8) with ADHD completed sleep and behavioral questionnaires. Children also wore a wrist-actigraph for seven nights and were subsequently assessed with the Conners' Continuous Performance Test-II (CPT). A significant relationship was found between lower sleep efficiency and increased variability of reaction time on the CPT. Shorter sleep duration was associated with a range of executive functioning problems as reported by the parents. The relationships between sleep duration and the executive functioning measures held even after controlling for age, gender, and use of medication, but not the relationships with sleep efficiency. These results suggest that sleep quantity is an important correlate of executive functioning in children with ADHD.

Keywords: Attention Deficit Disorder with Hyperactivity; Pediatrics; Sleep; Executive Function; Attention

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Attention-deficit/hyperactivity disorder (ADHD) is one of the most prevalent psychiatric disorders of childhood with an estimated prevalence of 5% (American Psychiatric Association [APA] 2000; Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007). Inattention (e.g., easily distracted, day-dreaming), hyperactivity (e.g., restlessness, fidgeting, inability to sit still), and impulsivity (e.g., acting without thinking of consequences) form the three clusters of ADHD symptoms. ADHD has a negative impact on numerous aspects of the affected child's life including school achievement (Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2007; Frazier, Youngstrom, Glutting, & Watkins, 2007), social relationships (Nijmeijer et al., 2008), and quality of life (Sawyer et al., 2002). Disturbed sleep is a common clinical feature among those children (Cohen-Zion & Ancoli-Israel, 2004; Corkum, Tannock, & Moldofsky, 1998) and may add to the already significant burden of the disorder by their possible impact on cognitive functioning. Sleep is indeed strongly linked to behavioral, emotional, and cognitive functioning (Dahl, 1996) and sleep disturbances may thus exacerbate the existing symptoms of children with ADHD. However, studies on the relationship between sleep and cognitive functioning in this particular population remain scarce.

Results from population-based studies suggest the presence of strong relationships between sleep disturbances and cognitive functioning. Significant associations were identified between shorter sleep duration as measured with actigraphy and lower IQ (Gruber et al., 2010). Poor sleepers, defined by lower sleep efficiency (i.e., ratio of time asleep on time in bed) on actigraphy, showed a poorer performance on a computerized measure of attention and more behavioral problems compared to good sleepers (Sadeh, Gruber, & Raviv, 2002).

Several experimental studies have also documented the impact of sleep loss in school-aged children. For instance, repeated restriction of time in bed (eight hours for first and second graders and six hours and a half for third and fourth graders) over five consecutive nights resulted in increased academic and attention problems as rated by teachers (Fallone, Acebo, Seifer, & Carskadon, 2005). A similar manipulation (restricting sleep duration by one hour) over three consecutive nights resulted in a slower reaction time on a continuous performance test (Sadeh, Gruber, & Raviv, 2003). These results lend additional support to the link between sleep duration and cognitive functioning, although such findings are yet to be documented in children with ADHD.

Studies using parental questionnaires have consistently found higher rates of sleep disturbances in children with ADHD when compared to healthy controls. For example, Owens, Maxim, Nobile, McGuinn, and Msall (2000) have shown that parents report that their child with ADHD presents significantly more bedtime resistance, longer time to fall asleep, and prolonged nocturnal awakenings compared to a control group. However, studies using objective measurements of sleep such as actigraphy and polysomnography have not always corroborated parental perceptions of sleep disturbances in their children (Cohen-Zion & Ancoli-Israel, 2004; Owens, 2005).

Notwithstanding this discrepancy between parental reports and objective sleep measures, there is evidence that a certain proportion of children with ADHD present sleep disturbances. Given the associations between sleep and cognitive functioning in normally developing children, it is plausible that sleep disturbances in children with ADHD are similarly related to their cognitive functioning. For example, in a sample of children with autism, sleep disturbances as reported by parents were associated with more severe behavioral problems

(Schreck, Mulick, & Smith, 2004), suggesting that a similar exacerbation is plausible among children with ADHD and sleep disturbances. In a clinical trial of psychostimulant treatment for ADHD, Gruber et al. (2007) found that actigraphy-defined sleep efficiency moderated the effect of psychostimulant on attention. This investigation showed a positive impact of medication treatment on a continuous performance test only in children defined as poor sleepers at baseline, suggesting that some features of ADHD may in fact be associated with sleep disturbances. Furthermore, Gruber and colleagues (2011) showed that a moderate decrease of sleep duration induced a clinically meaningful negative impact on a continuous performance test in children with ADHD. However, no association was found between actigraphic measures of sleep over five nights and results on a computerized assessment of attention in children with ADHD, whereas significant correlations were obtained in a control group without ADHD (Gruber & Sadeh, 2004).

In summary, previous studies have yielded equivocal evidence about the role of sleep duration and sleep disturbances in cognitive functioning of children with ADHD. There is a larger body of evidence, both correlational and experimental , suggesting that sleep duration may be more strongly related to daytime functioning than sleep disturbances per se. However, it remains unclear which one of these sleep indices is more relevant to cognitive functioning. To the best of our knowledge, the relationship between sleep and parental ratings of executive functioning has not been assessed in children with ADHD. The objective of this study was to investigate the relationships between sleep and cognitive functioning in children with ADHD. The main hypotheses were that shorter sleep duration and lower sleep efficiency (i.e., poorer sleep quality) would be associated with increased executive functioning problems and a lower performance on a continuous performance test.

Methods

Participants

Potential participants were all children consecutively referred to a university-based psychological clinic specializing in ADHD. These children were undergoing an assessment for suspected ADHD or for problems related to previously diagnosed ADHD (e.g., learning difficulties, anxiety) or had completed this assessment in the past year.

To be included in this study, participants had to be between 6 and 13 years old and diagnosed with ADHD. Exclusion criteria were the presence of a serious medical illness that could have had an effect on the children's sleep (e.g., epilepsy, endocrine disorders, traumatic injury, etc.), use of psychoactive medication (except for psychostimulants and atomoxetine), and IQ less than 80. Children with comorbid psychiatric disorders were included. This study is a secondary analysis of data published elsewhere (Moreau, Rouleau, & Morin, 2013).The study was approved by Université Laval institutional review board. Parents signed a written consent form and children gave their verbal consent before participation.

Measures

Actigraphy. Actiwatch-64® (Mini-Mitter Co., Inc., Bend, OR) devices were used to provide an objective method of measuring sleep. This wristwatch-like device records motor activity through an accelerometer with a sensitivity of 0.05 g-force, a bandwidth of 3 to 11 Hz, and a sampling frequency of 32 Hz. Motor activity is then digitally transformed into activity counts for each 30-second epoch. Higher activity counts suggest wakefulness and lower activity counts suggest sleep. Sleep parameters were derived using Actiware® Software version 5 which uses an algorithm that scores each epoch as either sleep or wake. This is determined by comparing activity counts of each epoch and those surrounding it with a threshold value. If the number of counts exceeds the threshold, the epoch is scored as wake; if the number is equal or below the threshold, the epoch is scored as sleep. Threshold was set at medium (40 activity counts), which has been used in previous studies experimenting with the same device and similar population (e.g., Sangal et al., 2006).

An event marker button was used to indicate bedtime and rising time. When the event marker was not activated, bedtime and wake-up time were based on the sleep diary recordings. Sleep onset time was set as the first epoch of the first section of 20 consecutive epochs (ten minutes) scored as sleep. Sleep offset time was similarly set as the last epoch of the last section of 20 consecutive epochs (ten minutes) scored as sleep. Sleep variables derived from actigraphy were total sleep time (TST; number of minutes scored as sleep between sleep onset time and sleep offset time) as a measure of sleep quantity and sleep efficiency (SE; percentage of time asleep to time spent in bed) as a measure of sleep continuity. Each variable was averaged over the recorded nights.

Participants wore the actigraph on the non-dominant wrist for seven consecutive nights. Actigraphy has been shown to be a reliable measure of sleep patterns when at least five nights are recorded (Acebo et al., 1999). One participant with less than five recorded nights was thus excluded.

Sleep diary. Sleep diary is a critical complement to actigraphy (Sadeh & Acebo, 2002) as it can provide information on any unusual event impeding actigraphic recording validity (such as sleeping in a moving car). It also provides information on bedtime and rising time that may have been missed due to failure in pressing the event marker button. A standard sleep diary typically used with adults (Morin, 1993) was adapted for use by parents to record their child's sleep patterns. Every morning, parents indicated, for the previous night, the child's bedtime, and estimated time to fall asleep, waking periods, rising time, and level of resistance to go to bed (on a 4-point Likert scale: 1 = a lot of resistance, 4 = no resistance). Parents also indicated if the child had taken any medication on the previous day and if he had school on the morning.

Children's Sleep Habits Questionnaire (CSHQ; Owens, Spirito, & McGuinn, 2000). This 33-item questionnaire provides both a total score and eight subscale scores. The subscales are Bedtime Resistance, Sleep Onset Delay, Sleep Duration, Sleep Anxiety, Night Wakings, Parasomnias, Sleep-Disordered Breathing, and Daytime Sleepiness. Parents indicate on a three-point scale the frequency of each sleep behavior: "usually" if the behavior occurs five to seven times a week, "sometimes" if the behavior occurs two to four times a week, and "rarely" if the behavior occurs zero to one time a week. They are asked to base their answers on the most recent typical week of their child. Total score ranges from 31 to 97 with higher scores reflecting more disturbed sleep. This instrument shows good validity and reliability (Owens, Spirito, et al., 2000) and has been judged as a well-established measure of children's sleep according to criteria developed by the American Psychological Association (APA) Division 54 Evidence-Based Assessment Task Force (Lewandowski, Toliver-Sokol, & Palermo, 2011). Cronbach's alpha coefficient for the scale was .77 in the present study, which is very close to that obtained in the original CSHQ study (.68 for the community sample and .78 for the clinical sample; Owens, Spirito, et al., 2000).

Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000). The BRIEF is a parent rating scale used to assess executive functioning based on observations of the child's behaviors. It contains 86 items rated by the parent on a 3-point scale reflecting the frequency of occurrence of the behavior (never, sometimes, often). Raw scores are converted to age- and gender-adjusted T-scores. It assesses various aspects of executive functioning through eight subscales (Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials, Monitor) which can be grouped in two more general indexes (Behavior Regulation, Metacognition) and in one global score (Global Executive Composite). The psychometric properties of the BRIEF are very good. Internal consistency coefficients range from .80 to .98 for the different subscales and test-retest reliability at three weeks was .91 for the global executive composite, and averaged .80 for the individual scales (Gioia et al., 2000).The BRIEF has been found to assess unique features of functioning in children with ADHD compared to other broad-band behavioral measures (Jarratt, Riccio, & Siekierski, 2005). Studies using the BRIEF in children with ADHD have found that these children are rated by their parents as showing more problems with executive functioning than control children (Jarratt et al., 2005; Sullivan & Riccio, 2007).

Conners' Continuous Performance Test-2 (CPT; Conners, 2000). In this 14-minute computerized test, the child has to press the space bar as rapidly as possible when any letter appears on the screen, except the letter "X". The respondent thus has to inhibit an automatic response to the infrequent stimulus (X). Stimuli are displayed for 250 milliseconds. The task is divided in six blocks of three sub-blocks of 20 stimuli varying in inter-stimulus interval (one, two, and four seconds). The CPT constitutes a measure of attentional processes and has been shown to be sensitive to drug treatment in children with ADHD (Epstein et al., 2006). Raw scores are converted to age- and gender-adjusted T-scores. The variables retained for analysis were mean reaction time and the variability index as measures of sustained attention, as well as omission and commission errors as measures of selective attention.

Conners' Rating Scales-Revised (Conners, 1997). The Conners' Parent Rating Scales-Revised (CPRS) and the Conners' Teacher Rating Scales-Revised (CTRS) are widely used instruments assessing symptoms of ADHD and associated emotional and behavioral features. Parents and teachers answer 80 and 59 items respectively on a scale of 0 (never) to 3 (very often) about the child's behavior during the past month. Raw scores are converted to age- and gender-adjusted T-scores on seven clinical subscales (Oppositional, Cognitive Problems, Hyperactivity, Anxious-Shy, Perfectionism, Social Problems, Psychosomatic), two global indexes (Restless-Impulsive, Emotional Lability), an ADHD index, and three DSM-IV symptoms subscales (Inattentive, Hyperactive-Impulsive, Total). Psychometric properties are well documented (Collett, Ohan, & Myers, 2003) and a validated French version is available. Internal consistency coefficients range from .73 to .94 for the different subscales.

Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS; Kaufman et al., 1997). The K-SADS is a semi-structured interview assessing past and present psychopathology using DSM-IV diagnostic criteria. When a child was using medication, the ratings indicated the most intense severity of symptoms experienced before treatment or during a medication-free period.

Procedure

Diagnosis of ADHD and of potential comorbid psychiatric disorders was based upon a best practice approach using multiple informants and sources of information. Parents and teacher of the child completed standardized behavioral questionnaires (CPRS, CTRS). The parents and the child were interviewed by a licensed child psychologist using the K-SADS. Intellectual and cognitive functioning was assessed by graduate students in clinical neuropsychology as part of the clinical assessment. The diagnosis of ADHD was confirmed based on the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text revised; DSM-IV-TR; APA, 2000) criteria after reviewing all available evidence. Six or more symptoms of inattention and/or six or more symptoms of hyperactivity/impulsivity had to be present and causing impairment in at least two settings (i.e. at home and at school). Symptoms were deemed present if they were endorsed by either parent or teacher. Some of the symptoms had to be present before the age of seven years. The diagnosis of comorbid disorders was also based on DSM-IV-TR criteria. The diagnosis of learning disabilities was based on a result lower than 1.5 SD on a standardized achievement measure or a significant IQ-achievement discrepancy. This assessment procedure was completed with all children, including those who had been previously diagnosed with ADHD in another setting and those who were already medicated. Immediately after the diagnosis of ADHD was ascertained by the clinical team, children and their parents were invited to participate in the study. All but three potential participants agreed to participate.

The CPT was administered after the last day of sleep recording in 27 participants (73%), between three days after or before the end of the recording in seven participants (18.9%), and six days after recording for one child. Two children completed the CPT task a few weeks before the sleep recordings. The CPT was administered in the morning to 26 children (50.1%) and in the afternoon to 18 children (40.9%); on weekdays to 34 children (77.3%) and during the weekend to 10 children (22.7%). BRIEF data were collected as part of the clinical evaluation of the child no more than one month before the sleep recording. Data on medication use were collected on the clinical interview and further confirmed on the sleep diary. All measures were taken during the school year.

Statistical analysis

Potential relationships between the sleep measures and behavioral and cognitive measures were first assessed using Pearson correlations. Age- and gender-adjusted T-scores were used when examining the CPT and the BRIEF measures. In order to limit the number of comparisons, only the three BRIEF general indexes were used in the analyses. Given that age was strongly correlated with TST, $r(41) = -.52$, $p < .001$, TST was examined using partial correlations controlling for age. Because age, gender, and use of medication can affect both sleep and the CPT and BRIEF measures, significant correlations were followed by multiple linear regression analyses in order to control for these potential confounders. Before conducting the analyses, data were checked for normality and collinearity assumptions and the presence of outliers. No outlier was detected. No variable deviated significantly from normality based on the Shapiro-Wilk Test and from visual inspection of the residuals. No collinearity was identified using the criteria of tolerance higher than 0.5. All analyses were conducted using PASW Statistics (version 17, Chicago, IL) and statistical significance was set at .05.

Results

Demographic information including ADHD subtype, medications, and comorbid diagnoses can be found in Table 1.

Insert Table 1 here

Results of the correlational analysis are presented in Table 2. The CSHQ was not significantly associated with any of the attention and executive functioning measures. Sleep data derived from actigraphic measurement showed that lower SE was associated with higher reaction time variability on the CPT, $r(42) = -.31$, $p = .047$. TST was associated with a much wider range of indicators. Significant relationships were found between lower TST and higher scores on all three BRIEF measures, suggesting that children sleeping less were perceived by their parents as having more problems related to executive functioning.

Insert Table 2 here

When controlling for age, gender, and use of medication, SE was no longer associated with reaction time variability, $\beta = -0.2$, $p = .17$. When controlling for age, gender, and use of medication, TST remained significantly associated with the Behavior Regulation and Metacognition indexes and with the Global Executive Composite (see Table 3), whereby a lower TST was consistently associated with poorer executive functioning. Age was found to be a significant covariate in the models predicting the Behavior Regulation and Metacognition indexes, increasing age being associated with lower scores on both measures. Gender was found to be a significant covariate in the model predicting the Metacognition index, with girls showing higher scores on this measure.

Insert Table 3 here

Discussion

The objective of the present study was to explore the potential relationships between sleep and cognitive functioning in children with ADHD. Results suggested that (a) parental reports of sleep disturbances were not associated with attention and executive functioning problems; (b) lower sleep efficiency was associated with increased variability of reaction time on a computerized test of attention; (c) lower total sleep time was associated with a wide range of executive functioning problems as reported by parents; and (d) when controlling for potential confounders, total sleep time remained significantly associated with executive functioning, but not sleep efficiency.

Results based on the CSHQ scores revealed no meaningful relationships with attention and executive functioning. This lack of relationship with some of these ADHD features is at odds with other studies in otherwise healthy children. Studies have indeed found that parental reports of sleep disturbances were linked to poorer school functioning (Meijer, Habekothe, & Van Den Wittenboer, 2000), behavioral problems (Smedje, Broman, & Hetta, 2001), and ADHD symptoms (Gau, 2006; Gaultney, Terrell, & Gingras, 2005). In the present study, however, parental reports of sleep disturbances as measured with the CSHQ were not correlated with measures of attention or executive functioning. One explanation for this result is that the CSHQ assesses a wide range of sleep problems and behaviors (sleep disordered breathing, parasomnias, daytime sleepiness, sleep onset delay, etc.). It is then possible that only some particular sleep problems are associated with daytime functioning and that lumping different sleep problems together has obscured this relationship. It might also suggest that parents are not able to detect or report reliably on sleep disturbances that are associated with attention or executive functioning problems.

Results of actigraphic measures suggest a relationship between lower sleep efficiency and poorer attentional performance as reflected by an increased variability of reaction times on the CPT. This result is consistent with the finding by Gruber and colleagues (2007) that sleep efficiency moderated the impact of psychostimulant on CPT performance in children with ADHD, more specifically on a factor reflecting reaction time variability. The hypothesis of an increase in reaction time variability of children with ADHD in continuous performance tests has received much attention in recent years, and has been suggested to be a hallmark feature of this disorder (Castellanos & Tannock, 2002). The present results, in combination with those of Gruber and colleagues, suggest that this cognitive feature in children with ADHD might be partially accounted for by lower sleep efficiency. However, it must be recognized that the size of the correlation, although statistically significant, was relatively modest, accounting for only 10% of the variance, and became nonsignificant when age, gender, and use of medication were controlled. Further investigations are needed to replicate this relationship between sleep efficiency and reaction time variability in children with ADHD.

The strongest relationships between executive functioning and actigraphic measures appeared to be with total sleep time. Reduced total sleep time was indeed associated with increased executive functioning problems as reported by the parents on the BRIEF. To the best of our knowledge, this is the first study to find a relationship between total sleep time and the BRIEF. The associations concerned most aspects of the BRIEF, from the regulation of behaviors and emotions (controlling impulses, transitioning freely from one activity/situation to another, modulation emotional responses appropriately) to the metacognitive domain (anticipating future events, setting goals, assessing one's own performance, holding information in mind for completing a task). This is consistent with studies in which children with sleep-disordered breathing have been found to have lower executive functioning as measured by the BRIEF (Beebe et al., 2004; Jackman et al., 2012). Other studies showed that an experimental manipulation of sleep duration of only one hour was associated with performance on computerized cognitive measures in both healthy children (Sadeh et al., 2003) and children with ADHD (Gruber et al., 2011). The pattern of correlations observed in the present study suggested that sleep quantity, rather than sleep continuity (as reflected by sleep efficiency) is a more important correlate of executive functioning in children with ADHD.

The present results need to be interpreted in light of some limitations. The current sample was relatively small and it is possible that limited statistical power has prevented the identification of more subtle relationships between sleep disturbances and cognitive functioning. The sample was also heterogeneous in terms of medication use and this may have contributed to the lack of relationship on some measures. It is indeed plausible that the use of medication might have prevented the expression of consequences of sleep disturbances on attention and executive functioning. The extent to which the present results may be generalized to the ADHD population is limited by the atypical composition of the studied sample. Whereas epidemiological data suggest a higher prevalence of the disorder in boys and a higher proportion of the combined subtype (APA, 2000), half of the current sample was composed of girls and of children with the inattentive only subtype. This likely reflects the particular population consulting at our clinic specializing in neuropsychological assessment. The retrospective reporting of symptom severity that was used for children already diagnosed and medicated can be problematic. This is however the recommended procedure by the authors of the K-SADS for children who are medicated at the time of the interview. The heterogeneity in the CPT administration, in terms of time of day, day of the week, and numbers of days between sleep recording and administration, might explain the relative lack of relationship with sleep measures. However, the sample was too small to examine these potential confounders, although the removal of participants who did not complete the CPT exactly after the sleep recording did not change the results. Also, the mean performances of the sample on CPT measures were mostly within normal limits, with few participants showing abnormal scores, suggesting a mild degree of ADHD and limiting our power to detect significant relationships. Because of the cross-sectional nature of the present report, causality between sleep disturbances and daytime functioning measures cannot be inferred. Although some experimental evidence support such a causal link (Fallone et al., 2005; Sadeh et al., 2003), it is not possible based on the present analyses to assume that sleep disturbances or shorter sleep lead to daytime functioning problems. For example, it remains plausible that hyperactive and disruptive behaviors around bedtime lead to shorter sleep. To disentangle this issue of causality, an interesting line of research would be to assess the impact on daytime functioning of treatments for sleep disturbances. However, preliminary results of a sleep intervention on children with ADHD and sleep disturbances suggested that the intervention was successful in addressing sleep, but did not lead to improvement of ADHD symptoms (Mullane & Corkum, 2006).

In conclusion, although ADHD is often associated with sleep disturbances, few studies have examined whether these sleep disturbances are associated with attention and executive functioning. It was found in the present study that lower total sleep time was associated with increased parental reports of executive functioning problems in a sample of children with ADHD even after controlling for potential confounders. Parental reports of sleep disturbances were not associated with attention and executive functioning. A modest correlation was found between sleep efficiency and reaction time variability, suggesting that lower sleep efficiency is associated with poorer attention, but this association was not significant after controlling for potential confounders. While a causal link cannot be established between sleep duration and executive functioning, it may be beneficial to insure that children with ADHD are obtaining an optimal amount of sleep in order to maximize their executive functioning.

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Table 1

Demographic and descriptive characteristics of the sample (n = 43)

Age in months, mean (*SD*)	120.09 (21.59)
Gender, *n* (%)	
Boys	25 (58.1)
Girls	18 (41.9)
ADHD subtype, *n* (%)	
Inattentive	23 (53.5)
Hyperactive/Impulsive	2 (4.7)
Combined	18 (41.9)
IQ, mean (*SD*)	99.22 (12.6)
Medication, *n* (%)	
None	12 (27.9)
Extented-release psychostimulant	19 (44.2)
Immediate-release psychostimulant	3 (7.0)
Atomoxetine	6 (14.0)
Atomoxetine and psychostimulant	3 (7.0)
Comorbid diagnosis, *n* (%)[a]	
None	27 (62.8)
Learning Disability	8 (18.6)
Communication Disorder	5 (11.6)
Oppositional Defiant Disorder	4 (9.3)
Generalized Anxiety Disorder	2 (4.7)

Note. ADHD = Attention-Deficit/Hyperactivity Disorder

[a] Two children present multiple comorbid diagnoses so the percentages do not add to 100%.

Table 2

Pearson correlations between sleep and cognitive measures

	M	*SD*	CSHQ Total Score	SE	TST[a]
CPT (T-score)					
Omission Errors	49.65	10.80	-.07	.03	.21
Commission Errors	50.74	9.39	.06	-.12	-.18
Mean Reaction Time	49.86	11.70	-.01	.05	.31*
Variability Index	49.32	9.14	.15	-.31*	.04
BRIEF (T-score)					
Inhibit	59.84	12.02	-.12	-.24	-.58**
Shift	60.30	13.81	.14	-.22	-.42**
Emotional Control	58.05	12.60	.12	-.22	-.44**
Initiate	59.86	10.43	.04	.09	-.19
Working Memory	69.53	8.15	-.12	.05	-.34*
Plan/Organize	65.51	10.52	-.01	-.14	-.42**
Organization of Materials	55.88	9.78	-.06	.05	-.11
Monitor	62.58	10.49	-.18	-.15	-.45**
Behavior Regulation Index	60.72	12.72	.04	-.27	-.56**
Metacognition Index	66.16	8.83	.02	-.10	-.41**
Global Executive Composite	65.00	10.47	.02	-.12	-.52**
N			43	43	43
M			42.23	79.45	465.17
SD			6.19	4.94	40.02

Note. BRIEF = Behavior Rating Inventory of Executive Function; CPT = Conners' Continuous Performance Test; CSHQ = Children's Sleep Habits Questionnaire; SE = Sleep Efficiency; TST = Total Sleep Time.

[a] The coefficients related to Total Sleep Time represent partial correlations controlling for age.

* $p < .05$. ** $p < .01$.

Table 3

Multiple linear regression models for the BRIEF Behavior Regulation and Metacognition indexes and the Global Executive Composite with total sleep time as predictor (n = 43)

Independant variables	Behavior Regulation		Metacognition		Global Executive Composite	
	β	*p*	*β*	*p*	*β*	*p*
Age	-.34	.03	-.34	.04	-.27	.10
Gender	-.15	.27	.35	.02	.14	.33
Use of medication	.19	.14	.001	.99	.10	.48
Total sleep time	-.60	<.001	-.58	.001	-.63	<.001
	R = .62		R = .54		R = .54	
	R^2 = .38		R^2 = .29		R^2 = .29	
	Adjusted R^2 = .32		Adjusted R^2 = .22		Adjusted R^2 = .22	

Note. BRIEF = Behavior Rating Inventory of Executive Function