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Impact of sleep on executive functioning in children with Down syndrome

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Abstract

Background—Sleep problems have an impact on executive functioning in the general population. While children with Down syndrome are at high risk for sleep problems, the impact of these sleep problems on executive functioning in school-age children with Down syndrome is less well documented. Our study examined the relationship between parent-reported and actigraphy-measured sleep duration and sleep quality with parent- and teacher-reports and neuropsychology assessments of executive functioning among school-age children with Down syndrome.

Method—Thirty school-age children with Down syndrome wore an actigraph watch for a week at home at night. Their parent completed ratings of the child's sleep during that same week. Children completed a neuropsychology assessment of their inhibitory control, ability to shift, and working memory. Their parents and teachers completed rating scales to assess these same constructs of executive functioning.

Results—Parent reports of restless sleep behaviours on the Children's Sleep Habits Questionnaire (CSHQ), but not actigraph-measured sleep period or efficiency, was predictive of parent-reports of concerns with inhibitory control, shifting and working memory, and of teacher-reports of inhibitory control. No measure of sleep was predictive of executive functioning as measured by the neuropsychology assessment.

Conclusion—The study findings corroborate the preliminary literature that sleep problems are related to executive functioning in children with Down syndrome, particularly in the area of inhibitory control across home and school. These findings have implications for understanding contributing factors to academic performance and school behaviour in children with Down syndrome.

Keywords

Down syndrome; trisomy 21; sleep; executive functioning; children

Children with Down syndrome experience a high rate of organic (31–66%) and behavioural (52–69%) sleep problems (Carter, McCaughey, Annaz, & Hill, 2009; de Miguel-Diez, Villa-Asensi, & Alvarez-Sala, 2003; Esbensen & Hoffman, 2017a; Stebbens, Dennis, Samuels, Croft, & Southall, 1991). Specifically, children with Down syndrome experience higher rates

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of obstructive sleep apnoea (OSA), sleep onset difficulties, frequent night awakenings, and premature awakening (Breslin, Edgin, Bootzin, Goodwin, & Nadel, 2011; Carter et al., 2009; Churchill, Kieckhefer, Bjornson, & Herting, 2014; de Miguel-Diez et al., 2003; Epstein, Pillar, Tzichinsky, Here, & Lavie, 1992; Esbensen, 2016; Marcus, Keens, Bautista, von Pechman, & Ward, 1991; Maris, Verhulst, Wojciechowski, Van de Heyning, & Boudewyns, 2016; Stebbens et al., 1991). These sleep problems contribute to shorter sleep duration and fragmented sleep or poorer sleep quality.

In the general paediatric population, sleep problems directly contribute to poor behavioural regulation and executive functioning. Children with behavioural sleep problems are reported to have difficulties with attention, impulse and behavioural control, and challenges with learning and memory (Beebe, 2011; Dewald, 2010; Fallone, 2002; Paavonen, Porkka-Heiskanen, & Lahikainen, 2009; Paavonen, Raikkonen, et al., 2009; Steenari, 2003). Regarding behavioural regulation, comparable preliminary findings of a relationship between sleep problems and behavioural concerns are reported among children with intellectual and developmental disabilities. Parent reports of sleep problems are related to parent-reports of maladaptive behaviours in adolescents with developmental disabilities and in children with autism spectrum disorders (Didden, Korzilius, Aperlo, Overloop, & Vries, 2002; Malow et al., 2006; Quine, 1991; Richdale, Francis, Gavidia-Payne, & Cotton, 2000; Stores & Wiggs, 2001). Recent reports support the relationship between sleep problems and behaviour problems specifically in children with Down syndrome (Esbensen & Hoffman, 2017b). In this population, parent-reports of sleep problems are related to both parent- and teacher-reports of conduct problems, anxious symptoms, and hyperactivity. Further, sleep problems measured using actigraphy are related to both parent- and teacher-reports of hyperactivity.

Less extensively documented is the relationship between sleep problems and executive functioning in children with developmental disabilities, or more specifically, with Down syndrome. Initial speculation is that there is a relationship between sleep problems and inattention among individuals with intellectual disabilities (Harvey & Kennedy, 2002). However, preliminary findings are mixed in Down syndrome. Using parent-reports of sleep problems and inhibitory control in pre-schoolers with Down syndrome, a bidirectional relationship is identified between these two variables (Lukowski & Milojevich, 2017). In two different studies of school-age children with Down syndrome measuring sleep with actigraphy, contradictory findings are presented regarding the relationship between sleep and inattention (Ashworth, Hill, Karmiloff-Smith, & Dimitriou, 2015; Esbensen & Hoffman, 2017b). Using ambulatory polysomnography to measure OSA in young school-age children with Down syndrome, those with OSA demonstrate poorer performance than children without OSA on cognitive flexibility (Breslin et al., 2014). While initial efforts have focused on the relationship between different sleep problems and inattention, the relationship between sleep problems and executive functioning in children with Down syndrome needs to be better understood.

Down syndrome predisposes individuals to a distinct phenotype, with a characteristic pattern of cognitive strengths and weaknesses (Dykens, Hodapp, & Finucane, 2000). Compared to mental-age matched typically developing children, children with Down syndrome are

reported to exhibit challenges with executive functioning, with specific challenges in inhibitory control, the ability to cognitively set-shift, and with working memory (Daunhauer, Fidler, Hahn, et al., 2014; Lee et al., 2011).

Inhibitory control is defined as the ability to curb or regulate attentional or behavioural responses. Relative deficits in inhibitory control are reported on parent-report measures, but not on teacher-reports, for children with Down syndrome compared to mental-age matched typically developing peers (Daunhauer, Fidler, Hahn, et al., 2014). Further, children with Down syndrome exhibit symptoms consistent with diagnoses of Attention Deficit Hyperactivity Disorder at rates 3–5 times higher than their peers in the general population, and at rates 2–3 times higher than their peers with intellectual and developmental disabilities (Dekker & Koot, 2003; Ekstein, Glick, Weill, Kay, & Berger, 2011; Froehlich et al., 2007). However, these findings of relative weaknesses in inhibitory control in children with Down syndrome receive inconsistent replication in the literature when using neuropsychological assessments; some confirming the finding of a relative weakness (Borella, Carretti, & Lanfranchi, 2013; Costanzo et al., 2013; Lanfranchi, Jerman, Dal Pont, Alberti, & Vianello, 2010) and others finding no specific area of relative weakness (Carney, Brown, & Henry, 2013; Costanzo et al., 2013; Pennington, Moon, Edgin, Stedron, & Nadel, 2003).

Shifting is defined as the ability to transition from one task or activity to another. This concept includes having cognitive flexibility to switch between tasks. Different to the pattern of findings related to inhibitory control, children with Down syndrome demonstrate difficulties with shifting on neuropsychology tasks, but not on parent- or teacher-reports of preschool or young school-age children (Campbell et al., 2013; Carney, Brown, et al., 2013; Costanzo et al., 2013; Daunhauer, Fidler, Hahn, et al., 2014; Landry, Russo, Dawkins, Zelazo, & Burack, 2012; Lanfranchi et al., 2010).

Working memory is defined as the ability to hold content in mind to complete tasks. Specific areas of challenge are identified in working memory among children with Down syndrome, with relative weaknesses in verbal working memory compared to visual working memory (Baddeley & Jarrold, 2007; Carney, Henry, et al., 2013; Costanzo et al., 2013; Landry et al., 2012; Lanfranchi et al., 2010; Rowe, Lavender, & Turk, 2006). These areas of weakness in working memory are identified both on neuropsychology tasks and on omnibus teacher-reports of working memory (Daunhauer, Fidler, Hahn, et al., 2014; Lanfranchi et al., 2010). However, others have not replicated these findings, demonstrating comparable performance on working memory task to typically developing children and more difficulty with long-term memory tasks (Pennington et al., 2003).

This pattern of findings regarding areas of weakness in executive functioning has several implications for assessing the relationship between sleep problems and executive functioning among children with Down syndrome. First, the findings suggest that the relative weakness in executive functioning may be impacted by context (home or school) and how executive functioning is assessed (direct assessment or informant-report). Thus, context and measurement format need to be considered when evaluating the relationship between sleep problems and executive functioning. Second, the different pattern of findings at different ages for various forms of executive functioning suggests that areas of weakness

may emerge at different ages and therefore one needs to consider age in analyses. Further highlighting the need to consider age in analyses linking sleep problems and executive functioning is the finding that age is reported to be related to the frequency of sleep problems, with younger children with Down syndrome experiencing more night wakings than adolescents with Down syndrome (Carter et al., 2009). And third, when assessing working memory in children with Down syndrome, one should assess for both verbal and nonverbal/visual working memory.

Even so, there is also great variability across individuals with Down syndrome in many domains of development, including executive functioning (Silverman, 2007). Given the high rate of sleep problems and problems with executive functioning among children with Down syndrome, there is a need to understand the relationship between these two constructs. Understanding what factors contribute to variability in executive functioning in individuals with Down syndrome has down-stream implications. Among young school-age children, executive functioning skills have an impact on school performance, including school behaviours and academic performance (Daunhauer, Fidler, & Will, 2014; Will, Fidler, Daunhauer, & Gerlach-McDonald, 2016). Thus, gaining a better understanding of the potential impact of sleep problems on the executive functioning of children with Down syndrome will inform intervention packages to maximize academic performance.

In this study, we focus on the relationship between sleep problems and executive functioning in school-age children with Down syndrome. We assess sleep problems of duration and quality using both objective (actigraphy watches) and subjective (parent-report) measures. We assess executive functioning addressing both context (home and school) and measurement form (informant-report and neuropsychology assessments). We hypothesize that both parental-report and actigraphy measures of poorer sleep will be related to elevated rates of executive dysfunction, as measured by inhibitory control, shifting, and working memory. First, we will assess how parent and actigraphy measures of sleep duration and quality relate to parent-reports of executive functioning. Second, we will assess how these measures of sleep relate to teacher-reports of executive functioning. And third, we will assess how these measures of sleep relate to the child's performance on a neuropsychology battery.

Method

Participants

Study participants included 30 children with Down syndrome and their parent, as part of a larger community-based study on sleep and associated daytime behaviour and cognition. Children with Down syndrome ranged in age from 6 to 17 years of age (M = 11.68 years, SD = 2.73), were primarily male (60%) and Caucasian (93%). Standard full scale IQ scores on the Kaufman Brief Intelligence Test-2 ranged from 40–65 (M = 44.57, SD = 6.46) (Kaufman, 2004). Standard scores on the Broad Index score of the Scales of Independent Behavior-Revised ranged from 15–93 (M = 51.26, SD = 21.62) (Bruininks, Woodcock, Weatherman, & Hill, 1996). Respondents were primarily mothers (96.6%).

Procedure

Families were recruited based on the age of the child and a diagnosis of Down syndrome. Parents provided information on the child's demographics and completed behavioural rating forms. To measure sleep, parents completed the Children's Sleep Habits Questionnaire (CSHQ), a measure of behavioural sleep disturbances. For seven consecutive nights at home, children wore an actigraph watch. To measure executive functioning, parents and teachers completed the Behavior Rating Inventory of Executive Function (BRIEF). Teacher reports were collected from 25 teachers (four children participated during school break, and teacher forms were not returned for one child). Children also completed a neuropsychology battery to assess executive functioning. All study activities were approved and overseen by the Institutional Review Board at the medical centre.

Measures

Sleep—Two sleep measures - an actigraph and parent-reported questionnaire - provided complementary information on sleep duration and quality. The actigraph provides an objective measure of sleep that closely resembles a watch and measures movement. The Micro-mini Motionlogger Actigraph (Ambulatory Monitoring, Inc.) was placed on the wrist of the participant 30 minutes before bedtime and removed from the wrist 30 minutes after rising in the morning. The movement data was processed using a validated sleep scoring algorithm, which differentiates between sleep and wake states (Micro-Mini Motionlogger Instruction Manual, 2000; Sadeh, Sharkey, & Carskadon, 1994). Action W software provided by the manufacturer was used to analyse sleep parameters. Two actigraph measures were selected for use in the current analyses: (1) sleep duration, the time from when the child fell asleep to when the child woke up, also known as the sleep period; and (2) sleep efficiency which, as the percent of the sleep duration period that the child spent in actigraph-scored sleep, offers an objective index of sleep quality. Sleep period and sleep efficiency were determined for each night a child wore the actigraph, then averaged across the week to obtain more stable indexes for current analyses.

To complement the objective actigraphy measures of sleep duration and quality, we also used subjective measures of these sleep variables, using parent-report. Parent questionnaires provide input from a longer-term observer (Beebe, 2012). The Children's Sleep Habits Questionnaire (CSHQ) is a 33-item sleep screening instrument for children and assesses major childhood medical and behavioural sleep disorders over a typical week (Owens, Spirito, & McGuinn, 2000). Although designed for use in paediatric populations under 10 years of age without intellectual disabilities, the CSHQ demonstrates strong psychometric properties and validity in identifying behavioural sleep problems in school-age children with Down syndrome ages 6–17 years (Esbensen & Hoffman, 2017a) and has demonstrated validity in other paediatric populations characterized by intellectual and developmental disabilities (Veatch et al., 2016). Two subscales assessing sleep duration and quality on the CSHQ were selected for use in the current analyses. The CSHQ includes a three-item Sleep Duration subscale that assesses parent perception of child's sleep efficiency and consistency. The CSHQ has several other scales that could relate to sleep quality. After inspection of the most common sleep problems reported in the sample, we elected to use the Parasomnias subscale as the parent-reported measure of sleep quality. Although this seven-item subscale

incorporates actual parasomnias (e.g., sleep-talking), it also includes an item related to restlessness/movements during sleep that was most often endorsed by parents.

Executive Functioning—The BRIEF (5–18) Parent and Teacher Forms are rating scales of everyday skills measuring executive functioning (Gioia, 2000). It measures skills of inhibition, shifting attention, emotional control, initiating tasks, problem-solving, working memory, and monitoring activities. Items are rated on a 3-point Likert-type scale from (1) Never to (3) Often. The BRIEF demonstrates strong psychometric properties when used with children with Down syndrome (Edgin et al., 2010). The subscales of Inhibit, Shift and Working Memory were selected as predictors for the current analyses as they target common areas of concern in children with Down syndrome.

A battery of neuropsychological assessments assessing inhibition, cognitive set-shifting, and working memory was administered to the children with Down syndrome. Inhibitory control was assessed using a cat/dog and day/night Stroop task (Lanfranchi et al., 2010). Children were timed on how quickly they were able to label cats as dogs and dogs as cats, or suns as moons and moons as suns. The number of incorrect responses was tallied. Children ranged from being able to use the labels of “cat” and “dog” to using word approximations, to creating animal sounds “meow” and “woof”. The ratio of the time to complete the task over the number of items correct was calculated. As there was significant kurtosis in cat/dog scores (10.1), the scores for the day/night task were used for analysis. Cognitive set-shifting ability was assessed using a rule-shift task (Lanfranchi et al., 2010). Children learn to label coloured cards, and then shift to a new task of identifying if a coloured card matches a preceding card. Working memory was assessed using the nonverbal and verbal working memory subtests of the Stanford-Binet 5th edition (Roid, 2003). As there was significant kurtosis in standard scores (4.1 for nonverbal standard score, 12.2 for verbal standard score), raw scores were used for analyses.

Data Analysis

Preliminary analyses generated descriptive information and correlations among measures of sleep duration and quality, and measures of executive functioning. Multiple linear regression then tested whether the sleep measures predicted parent- and teacher-reports of executive functioning and performance on neuropsychological assessment. Sleep duration, as measured by the CSHQ, was moderately correlated with CSHQ Parasomnias and contributed to concerns with multicollinearity in this small sample and thus was removed from the final regression model. Separate final regression models were run to predict parent and teacher ratings on the BRIEF subscales of Inhibit, Shift and Working Memory from CSHQ Parasomnias, and actigraph measures of sleep period and sleep efficiency. No covariates were added to the model as age and gender are accounted for in calculating BRIEF t-scores.

Hierarchical linear regression analyses were run to predict performance on the Day/Night inhibitory control task, the cognitive set-shifting task and the Stanford-Binet nonverbal and verbal working memory raw scores. Age of the child and gender were entered as covariates in the first step as sleep concerns vary with age in individuals with Down syndrome and as

behaviour concerns vary with gender and age in individuals with intellectual disability (Ashworth, Hill, Karmiloff-Smith, & Dimitriou, 2013; Schroeder, Tessel, Loupe, & Stodgell, 1997). In the second step, CSHQ-parasomnias, actigraphy-based sleep period and actigraphy-based sleep efficiency were entered as predictors.

Results

The means and standard deviations for sleep measures, for parent and teacher measures of executive functioning and the child's neuropsychological assessments are presented in Table 1. Descriptive data for the CSHQ are presented as item means, reflecting the total score divided by the number of items on the subscale to support comparison across subscales containing a different number of items. Inter-correlations between measures of sleep and executive functioning are presented in Table 2.

Sleep predicting parent reports of executive functioning

Our first research question addressed how parent-reports of sleep quality and actigraphy measures of sleep period and sleep efficiency relate to parent reports of executive functioning on the BRIEF Inhibit, Shift, and Working Memory subscales (see Table 3). Between 1/5 to 1/3 of the variance on each parent-report measure of executive functioning was statistically predicted by the collective sleep variables (R^2 change = .22 – .33). The CSHQ parasomnia subscale was related to parent-reported subscales of Inhibit ($\beta = .49$, $p < .05$), Shift ($\beta = .40$, $p < .05$), and Working Memory ($\beta = .56$, $p < .05$). Children with more restless sleep concerns were reported by parents to have more concerning symptoms of curbing impulses, shifting from one task to another and keeping items in mind.

Sleep predicting teacher reports of executive functioning

Our second research question addressed how parent-reports of sleep quality and actigraphy measures of sleep period and sleep efficiency relate to teacher reports of executive functioning on the BRIEF Inhibit, Shift, and Working Memory subscales (see Table 3). Over a quarter of the variance on the BRIEF Inhibit subscale was statistically predicted by the collective sleep variables (R^2 change = .26). The CSHQ parasomnia subscale was only related to the teacher-reported Inhibit subscale ($\beta = .48$, $p < .05$). Children with more restless sleep concerns were reported by teachers to have more concerning symptoms of curbing impulses.

Sleep predicting performance on neuropsychology assessments of executive functioning

Our third research question addressed how parent-reports of sleep quality and actigraphy measures of sleep period and sleep efficiency relate to the child's performance on neuropsychology assessments of inhibitory control, shifting and nonverbal and verbal working memory (see Table 4). Gender, but not age, was a significant predictor of child performance on the verbal working memory task. Females recalled more verbal items than males. Neither age nor gender were significant predictors of child performance on the other neuropsychology tasks. No sleep index significantly predicted child performance on neuropsychological tasks assessing inhibitory control, shifting or nonverbal and verbal working memory.

Discussion

The current study examined the relationship between parent- and actigraphy-reports of sleep problems (duration and quality) with parent-, teacher- and neuropsychology assessments of executive functioning (inhibition, shifting, working memory) in school-age children with Down syndrome. Parent-report of restless sleep behaviour (as measured by the CSHQ Parasomnia subscale), but not actigraphy reports of shorter sleep duration or poorer sleep efficiency, was predictive of executive dysfunction across all three parent-report measures of inhibitory control, shifting and working memory, and of teacher-reports of challenges with inhibitory control. No measures of sleep problems were predictive of the child's performance on neuropsychology assessments. The present findings support the general preliminary literature that sleep problems are related to informant-reports of daytime inattention and executive functioning (Breslin et al., 2014; Esbensen & Hoffman, 2017b; Lukowski & Milojevich, 2017).

Our findings specifically demonstrate an association with parent-reports of restless sleep and parent- and teacher-reports of inhibitory control, corroborating prior literature that identified a relationship between parent-reports of sleep problems and of inhibitory control (Lukowski & Milojevich, 2017). Our findings add to the literature by replicating this finding in an older population of children with Down syndrome, and extending the finding to the school environment. That restless sleep accounts for over 25% of the variance in inhibitory control at home and at school is not a trivial amount. This finding highlights the need to support sleep at home to improve executive functioning across settings, and for schools to be made aware of sleeping patterns to best understand a child's performance at school. These interventions become especially salient given the impact of executive functioning on school behaviour and academic performance (Daunhauer, Fidler, & Will, 2014; Will et al., 2016).

Further, parent-reports of restless sleep were associated with poorer shifting and working memory. These findings are novel and extend our understanding of the relationship between sleep problems and executive functioning. However, we did not corroborate the prior literature has linked sleep problems, specifically OSA, to neuropsychology assessment of shifting (Breslin et al., 2014). Thus, the nature of the sleep problem may have differential impacts on aspects of executive dysfunction. Oxygen deprivation during OSA may be a more clinically significant sleep problem than restless sleep, and thus have a greater impact on the neuropsychological assessment of the ability to shift. Whereas parents may pick up on a more global impact of restless sleep than what is identified on a specific neuropsychological battery.

We did not identify an association between sleep problems and any neuropsychology assessment of inhibitory control, shifting, verbal or nonverbal working memory. Thus, while these areas of executive functioning are relative weaknesses identified in neuropsychology assessments in Down syndrome, they may not be the areas of executive functioning impacted by the sleep problems evaluated in this study. Among older adolescents and young adults with Down syndrome, reports of sleep problems were associated with a verbal fluency task and a nonverbal assessment of inhibitory control (Chen, Spanò, & Edgin, 2013). These patterns of findings suggest targeting areas of executive functioning more broadly, rather

than specific areas of deficits, as we continue to examine the impact of sleep problems in children with Down syndrome.

The sample size in this pilot study was small and underpowered for conducting further statistical analyses with other sleep indices. That parent-reports of sleep were related to all parent-reports of executive functioning raises questions of shared method variance. Despite these limitations, our findings replicate and extend findings previously reported in the literature of a relationship between sleep problems and executive dysfunction in school-age children with Down syndrome. Additionally, using a multi-method assessment of sleep and executive functioning allowed for a broader examination of the relationship between these two constructs and extended findings to the impact of restless sleep on inhibitory control at school. Further work is needed to explore the bidirectional relationship between executive functioning and how they may impact sleep in this older age group (Lukowski & Milojevich, 2017). Further work is also needed to understand the impact of sleep on other aspects of executive functioning.

Children with Down syndrome frequently experience poor, shorter, and disrupted sleep (Esbensen & Schwichtenberg, 2016). This study contributes to our understanding of the practical impact of sleep on the executive functioning of children with Down syndrome, particularly inhibitory control. With the downstream impact on academic performance, our findings provide a rationale to educate parents of children with Down syndrome on the importance of sleep, and to educate medical providers to screen for both behavioural problems associated with sleep and for OSA (Bull & Genetics, 2011).

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Table 1

Mean scores for measures of sleep and child neuropsychology assessments.

	Mean (SD)	Range
Parent report (subscale mean 1–3)		
CSHQ Duration *	1.42 (0.60)	1.0 – 3.0
CSHQ Parasomnias	1.35 (0.29)	1.0 – 2.0
Actigraphy		
Sleep period (minutes)	551.34 (38.35)	466.43 – 618.64
Sleep efficiency (percent)	87.08 (5.89)	72.49 – 95.51
BRIEF Parent (t-score)		
Inhibit	63.60 (13.16)	41–88
Shift	61.43 (11.33)	40–83
Working Memory	62.27 (10.16)	36–82
BRIEF Teacher (t-score)		
Inhibit	69.84 (17.12)	44–112
Shift	64.96 (18.75)	42–114
Working Memory	74.92 (13.40)	50–99
Neuropsychology Battery		
Inhibitory Control		
Ratio speed/correct Cat-Dog *	3.58 (3.53)	0.19–18.00
Ratio speed/correct Day-Night	2.26 (1.28)	0.88–5.75
Shifting		
Number incorrect	8.12 (6.11)	0–20
Working Memory		
SB5 Standard Score *	52.83 (8.01)	43–80
SB5 Nonverbal Standard Score *	2.63 (2.66)	1–12
SB5 Verbal Standard Score *	1.07 (0.25)	1–2
SB5 Nonverbal Raw Score	11.13 (4.46)	2–21
SB5 Verbal Raw Score	6.17 (3.05)	0–12

Note: CSHQ scores reflect the total score divided by the number of items to achieve an item mean. Actigraphy measures are averaged over the week the actigraph is worn.

* not used in final analyses

Table 2

Correlations between measures of sleep and executive functioning.

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	CSHQ Duration	–												
2	CSHQ Parasomnias	.51**	–											
3	Sleep period	−.20	.07	–										
4	Sleep efficiency	.03	−.23	.26	–									
5	BRIEF-parent Inhibit	.31	.43*	−.16	−.15	–								
6	BRIEF-teacher Inhibit	−.23	.41*	.05	−.08	.56**	–							
7	Neuropsych Inhibit	.22	.04	.03	.04	.10	−.07	–						
8	BRIEF-parent Shift	.22	.41*	.21	−.10	.38*	.27	−.21	–					
9	BRIEF-teacher Shift	−.27	.08	.05	−.08	.26	.63**	−.10	.32	–				
10	Neuropsych Shift	.21	.02	.02	.04	.08	−.07	.61**	−.10	.02	–			
11	BRIEF-parent WM	.40**	.49**	−.19	.02	.46*	.35	.19	.46*	.21	.12	–		
12	BRIEF-teacher WM	.07	.18	.05	.19	.27	.68**	.15	.24	.54**	.01	.53**	–	
13	Neuropsych nonverbal raw WM	−.11	−.012	.19	.10	−.09	.03	−.11	−.19	.11	−.15	−.25	−.02	–
14	Neuropsych verbal raw WM	−.35	−.09	.20	.40**	−.08	.16	.28	.03	.17	−.54**	−.16	.21	.41*

* p < .05,

** p < .01

Table 3

Predicting parent and teacher reports of executive function from sleep.

	BRIEF Parent			BRIEF Teacher		
	Inhibit	**Shift**	**Working Memory**	**Inhibit**	**Shift**	**Working Memory**
	β	**β**	**β**	**β**	**β**	**β**
CSHQ Parasomnia	.49 *	.40 *	.56 **	.48 *	.20	.22
Sleep period	−.26	.17	−.27	−.09	−.12	−.07
Sleep efficiency	−.01	−.05	.24	−.11	−.30	.15
R^2total	.28 t	.22	.33 *	.26	.17	.06

* p < .05,

** p < .01

Table 4

Predicting neuropsychology assessment of executive functioning from sleep.

	Inhibitory Control: Ratio speed/correct Day/Night		Shifting: Number incorrect		Working Memory: SB5 Nonverbal Raw Score		Working Memory: SB5 Verbal Raw Score	
	R^2change	**β**	**R^2change**	**β**	**R^2change**	**β**	**R^2change**	**β**
Step 1	.09		.06		.10		.19[t]	
Age		−.14		−.19		.19		.07
Gender		−.27		−.16		.24		.43*
Step 2	.00		.01		.05		.06	
Age		−.13		−.14		.25		.20
Gender		.28		−.19		.19		.35
CSHQ Parasomnia		−.01		−.02		.00		.13
Sleep period		.07		.04		.21		.07
Sleep efficiency		.00		.09		.07		.26
R^2 total	.09		.07		.14		.25	

* $p < .05$