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Mediatory role of executive functioning in children and youth with Down syndrome

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Abstract:	Individuals with Down syndrome (DS) commonly experience challenges with sleep, executive functioning, everyday memory, and symptoms of attention deficit hyperactivity disorder (ADHD). A path analysis was conducted to determine if executive function mediated the relationship between sleep problems and both everyday memory and ADHD symptoms. Parents of 96 children and youth with DS completed questionnaires related to sleep, executive functioning, everyday memory, and ADHD symptoms. Results showed that executive functioning fully mediated the relation between sleep and both everyday memory and ADHD symptoms. Implications for education and intervention for children and youth with DS are discussed.

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Abstract

Individuals with Down syndrome (DS) commonly experience challenges with sleep, executive functioning, everyday memory, and symptoms of attention deficit hyperactivity disorder (ADHD). A path analysis was conducted to determine if executive function mediated the relationship between sleep problems and both everyday memory and ADHD symptoms. Parents of 96 children and youth with DS completed questionnaires related to sleep, executive functioning, everyday memory, and ADHD symptoms. Results showed that executive functioning fully mediated the relation between sleep and both everyday memory and ADHD symptoms. Implications for education and intervention for children and youth with DS are discussed.

Keywords: Down syndrome, trisomy 21, sleep, memory, attention, executive functioning

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Sleep problems are an area of concern in individuals with Down syndrome (DS) that can have a physiological cause or be behavioral in nature. A common physiological sleep problem in DS is obstructive sleep apnea (OSA) which occurs when the individual's upper airway becomes intermittently obstructed, often due to macroglossia, hypotonia, and glossoptosis (Donnelly et al., 2004). Approximately 31-63% of children with DS have an OSA diagnosis (Breslin et al., 2011; Carter et al., 2009; de Miguel-Diez et al., 2003). Behavioral sleep disorders are also pervasive in DS, with difficulties with sleep onset, frequent night awakenings, sleep maintenance, sleep anxiety, and early waking reported in 52–69% of children and adults with DS (Breslin et al., 2011; Carter et al., 2009; Esbensen et al., 2016).

The association between high rates of sleep problems and greater difficulties with cognitive and daily functioning experienced by individuals with DS has been widely discussed (Chawla et al., 2020; Esbensen, Schworer, et al., 2021). Previous studies have shown that various sleep problems in individuals with DS are associated with executive functioning (EF) challenges (Chen et al., 2013; Esbensen & Hoffman, 2018; Joyce et al., 2020; Lukowski & Milojevich, 2017). First, parent reports of sleep problems in school-aged children with DS were predictive of parent- or teacher-reports of three main domains of EF including inhibitory control, shifting, and working memory (Esbensen & Hoffman, 2018). More frequent sleep problems were also positively related to lower memory function in children with DS relative to typically developing children (Lukowski et al., 2020). Finally, sleep problems have been connected to higher rates of Attention Deficit Hyperactivity Disorder (ADHD) symptoms in children with DS (Esbensen et al., 2018). Specifically, actigraph measured sleep period was predictive of daytime parent-reported inattention and hyperactivity/impulsivity, and parent-reported sleep duration was predictive of parent-reported inattention (Esbensen et al., 2018).

The link between difficulties with EF and both memory and ADHD symptoms has also been demonstrated. EF broadly refers to a set of higher-level cognitive processes responsible for managing, coordinating, organizing, assembling, ordering, and monitoring lower-level cognitive, emotional, and behavioral functions (Diamond, 2013). Challenges with EF are associated with inattentive symptoms in both individuals with and without ADHD in the general population (Berlin et al., 2004; Brocki et al., 2010; Thorell & Wåhlstedt, 2006). Further, greater EF difficulties predicted higher rates of ADHD symptoms in children with DS (Esbensen, Hoffman, et al., 2021). EF domains are also associated with everyday memory in both individuals with and without intellectual disabilities (Van der Molen et al., 2010).

Given the evidence for the connection among sleep problems, EF, memory, and inattention, *and* the association between EF and both memory and ADHD symptoms reported specifically among individuals with DS, it can be posited that EF may play a mediatory role in the impact sleep problems have on memory dysfunction and ADHD symptoms. Disruption of higher control EF processes may negatively affect lower-level functions even if the lower-level functions present as unimpaired (Salthouse et al., 2003). Several cross-sectional studies have reported on the mediating role of EF on the link between different physiological, environmental, and psychological effects and a variety of cognitive and daily functioning, such as attention and memory function (O'Bryant et al., 2011; Parks et al., 2011), academic performance (Schmidt et al., 2017; Visier-Alfonso et al., 2020), behavioral problems (Fatima & Sheikh, 2014; Fernandez-Prieto et al., 2021), and daily performance (Engel-Yeger & Rosenblum, 2021; Whittingham et al., 2014). EF has also been found to mediate the association between sleep problems and child aggressive and social behaviors among preschool children (Shin et al., 2017). Longitudinal studies also provide evidence for the mediatory role of EF in the relation between psychological and parenting effects on behavioral and academic functions (Roman et al., 2016; Sulik et al.,2015; Bindman et al., 2015), supporting the need for investigation into additional child outcomes that may be mediated by EF.

Beebe and Gozal (2002) initially proposed a multidimensional model that may justify the mediatory role of EF in the relation between sleep and everyday memory. In the model, sleep-related restorative processes are disrupted by sleep disturbance, which leads to chemical and structural cellular injury in the nervous system. It is posited that the impact on the nervous system also affects prefrontal brain regions expressed as EF challenges that, consequently, result in behavioral and cognitive challenges (Beebe & Gozal, 2002). Consistent with this proposed model, several studies have shown that at the neurological level different indicators of sleep are more associated with prefrontal regions of the brain largely involved in EF compared to posterior and central regions implicated in lower-level cognitive and behavioral functioning (Bernier et al., 2010; Killgore et al., 2013; Muzur et al., 2002; Verweij et al., 2014). Specifically, it has been noted that everyday memory seems to be associated with a central structure of the brain known as hippocampal formation which is frequently regulated by efferent projections of the prefrontal cortex (Burwell & Agster, 2008; Del Arco & Mora, 2009). Thus, sleep problems experienced by individuals with DS may indirectly affect daily memory functions through neurological effects on the prefrontal cortex involved in EF which, in turn, may deregulate hippocampal formation involved in everyday memory. This model has not been directly tested or replicated among individuals with DS.

The substantial decrease in relative metabolism of the prefrontal cortex resulting from sleep disturbances can also justify the mediatory role of EF in the relation between sleep disturbance and ADHD symptoms. The prefrontal cortex is a predominant brain region involved in ADHD (Curatolo et al., 2010). Neuroimaging studies reported some functional and structural abnormalities in the prefrontal cortex of individuals with ADHD in comparison with control subjects (Curatolo et al., 2010; Hadas et al., 2021; Qiu et al., 2011; Salavert et al., 2018). Furthermore, the link between functional/structural prefrontal abnormalities, impairment in EF, and inattention symptoms has been reported in both individuals with and without ADHD (Berlin et al., 2004; Brocki et al., 2010; Thorell & Wåhlstedt, 2006). Thus, more sleep difficulties experienced by individuals with DS may give rise to the atypical function/structural prefrontal cortex which proceed to greater EF challenges, and finally result in a higher rate of ADHD symptoms.

The high rates of sleep problems (Breslin et al., 2011; Carter et al., 2009; Esbensen, 2016), EF difficulties (Daunhauer et al., 2020; de Weger et al., 2021; Iralde et al., 2020; Manrique-Niño et al., 2020; Schworer et al., 2020; Tungate & Conners, 2021), everyday memory challenges (Pennington et al., 2003; Spanò & Edgin, 2017), and ADHD symptoms (Ekstein et al., 2011; Oxelgren et al., 2017) in individuals with DS presents a need for additional research to examine how these sets of difficulties are linked. Specifically, it is crucial to explore whether EF mediates the relation between sleep and both everyday memory and ADHD symptoms.

Examining EF as a mechanism through which sleep problems affect attention and memory function in individuals with DS is critical for both theoretical knowledge and refining clinical interventions. However, to our knowledge, no study has empirically studied this mediation model.

Current Study

In this study, we conducted a path analysis to (1) replicate the finding that higher rates of sleep problems are significantly associated with greater difficulty in EF, everyday memory, and ADHD symptoms, (2) replicate previous studies that report a significant relation between EF and both everyday memory and ADHD symptoms, and (3) test the hypothesis that EF mediates the relation between sleep problems and both everyday memory and ADHD symptoms. Based on previous findings, we hypothesized that sleep would have a significant effect on EF, everyday memory, and ADHD symptoms and that EF would predict both everyday memory and ADHD symptoms. Further, we hypothesized that EF would mediate the relation between sleep and both everyday memory and ADHD symptoms.

Method

Study Design

All study procedures were approved by the Institutional Review Board (IRB) and the Streamlined, Multisite, Accelerated Resources for Trials (SMART) IRB platform at the supervising medical center. Participants were recruited through a pediatric medical center, and local Down syndrome associations to participate in a longitudinal natural history study of outcome measures. Both direct measures of cognition and parent-report measures were collected across five time points. To participate, youth were required to have a diagnosis of DS and an approximate developmental age of at least three years in order to complete other neuropsychology assessments in the larger study (Schworer et al., 2021; Will et al., 2021). Inclusion criteria also required English be the primary language of the family. Exclusion criteria were having a history of blindness, deafness, and serious motor problems that would impair performance in the larger study. Information on the child's demographics and daily EF abilities was provided by one parent at the study visit (either in a clinic or university laboratory setting). Parent-report data from only the first time point were included in the current analyses.

Participants

Participants included 96 children and youth with DS and their parents who were engaged in a multi-site community-based natural history study based in Midwestern and Western US cities. The age of participants ranged from 6 to 17 years (*M* = 12.5, *SD* = 3.2), with approximately equal distributions by sex (49 [51%] males, 47 [49%] females). Participants were predominantly White (87.5%), with other participants identifying as Black (5.2%), Asian (4.2%), and other races (3.1%). Stanford-Binet Intelligence Scales, Fifth Edition (SB-5) (Roid, 2003) abbreviated IQ composite scores of the participants ranged from 47 to 76 (*M* = 40.1, *SD* = 5.2). Participants were diagnosed with co-occurring conditions of ADHD (16.8%), anxiety (15.6%), autism spectrum disorder (4.3%), gastrointestinal concerns (32.3%), heart defect (33.3%), recurrent otitis media (22.9%), sleep disorder (40.6%), and thyroid problems (29.5%).

Measures

Sleep*. Children's Sleep Habits Questionnaire (CSHQ).* The CSHQ is a parent-report screening tool that measures pertinent childhood behavioral and physiological sleep problems occurring over a "typical" recent week including bedtime resistance, night walking, sleep duration, sleep anxiety, parasomnias, sleep onset delay, sleep-disordered breathing, and daytime sleepiness (Owens et al., 2000). It encompasses 33 items rated on a 3-point Likert scale from rarely (0-1 time) to usually (5-7 times). Some items are required to be reverse scored and higher scores indicate more sleep challenges. The CSHQ demonstrated acceptable internal consistency, adequate validity, and adequate test-retest reliability for both clinical and non-clinical samples (Owens et al., 2000). Adequate psychometric properties and convergence of CHSQ were reported for identifying sleep problems in children with DS (Esbensen & Hoffman, 2017). The total score on the CSHQ was used in analyses.

Executive Functioning. *Behavior Rating Inventory of Executive Function, second edition (BRIEF-2).* Everyday EF skills were assessed using the BRIEF-2 parent form. The measure is designed for children 5-18 years old and includes 63 items rated by parents on a three-point scale (i.e., never, sometimes, often) (Gioia et al., 2015). Scores are age and gender standardized, with a mean t-score of 50 and standard deviation of 10. Higher scores represent more challenges with EF. The BRIEF-2 is comprised of nine subdomains of EF: Inhibition, Self-Monitor, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Task-Monitor, and Organization of Materials. The BRIEF-2 also provides index scores: Behavioral Regulation Index (BRI), Emotional Regulation Index (ERI), Cognitive Regulation Index (CRI), and a Global Executive Composite (GEC). Test-retest reliability is moderate to excellent (0.67 to 0.92) (Gioia et al., 2015) and internal consistency is generally good for children with DS (Esbensen et al., 2019). Overall, the BRIEF-2 is recommended for use in studies that include children and youth with DS (Esbensen et al., 2017). The BRIEF2 GEC was used in analyses.

Everyday Memory. *Observer Memory Questionnaire-Parent Form (OMQ-PF).* The OMQ-PF is a 27-item questionnaire designed to measure child memory function in everyday scenarios from a parent's perspective (Gonzalez et al., 2008). Each item is scored on a 5-point Likert scale and includes reverse-scored items. Higher scores are indicative of better memory function. The OMQ-PF demonstrates sound internal consistency among typically developing children (Gonzalez et al., 2008), adequate psychometric properties, and sound sensitivity to track the status of everyday memory function in participants with DS, ages 3-35 (Liogier d'Ardhuy et al., 2015; Spanò & Edgin, 2017). The OMQ-PF total score was used in analyses.

Inattention and Hyperactivity. *Vanderbilt Attention Deficit/Hyperactivity Disorder Parent Rating Scale (VADPRS).* The VADPRS is a DSM-based scale that includes all 18 of the DSM-IV and DSM-5 criteria for both subtypes of ADHD (Markowitz et al., 2020; Wolraich et al., 2003). Parents are asked to rate the severity of each behavior on a 4-point scale: never, occasionally, often, and very often to create a summed score of the 18 items. Higher scores indicate more challenges with ADHD symptoms. The VADPRS showed acceptable internal consistency and adequate reliability for measuring ADHD in both clinical and research settings (Wolraich et al., 2003). Furthermore, the VADPRS is among the common clinical outcome assessments in pediatric ADHD (Markowitz et al., 2020) and has been used to demonstrate differences among children with DS with and without ADHD (Esbensen, Epstein, et al., 2021). The total summed score on the VADPRS was used in analyses.

Cognition. *Stanford-Binet Intelligence Scales, Fifth Edition (SB-5).* The SB-5 is a wide-ranging, individually administered test battery (Roid, 2003). Norms were designed for ages 2 through 85+ years and the subtests cover five cognitive factors including Fluid Reasoning, Knowledge (crystallized ability), Quantitative Reasoning, Visual-Spatial Processing, and Working Memory in both the verbal and nonverbal domains (Roid & Barram, 2004). Excellent internal consistency, test-retest reliability, and content validity were reported (Roid, 2003). To reduce the significant floor effects observed when utilizing the SB-5 with individuals with intellectual disabilities, SB-5 IQ deviation scores have been developed using the method of raw *Z* score transformation (based on general population norms) which provide standardized scores below the floor of the measure (Sansone et al., 2014). Typically, the floor of the SB-5 is 40. Deviation scores are computed using online scoring software and compute scores below 40 (Roid, 2003). In the current study, we used SB-5 ABIQ Standard Scores to report the mean IQ of the sample, and deviation ABIQ scores to control for cognitive effects on everyday memory and ADHD symptoms in the model.

Data Analyses

Age- and gender-standardized mean t-scores were calculated for EF. Raw scores were used for sleep, everyday memory, and ADHD symptoms as t-scores are not available for these measures. Data were screened for univariate and multivariate outliers. No data points were identified as univariate outliers (Z Scores $<|3.29|$) and no participants were identified as multivariate outliers by inspection of Mahalanobis distance ($p > .001$). Descriptive data analyses were performed for each variable and Pearson correlation coefficients were calculated between each pair of the variables. A path model was constructed to examine the effect of sleep on everyday memory and ADHD via EF as a mediator. Full mediation would be present if the effect of sleep on everyday memory and ADHD was reduced to non-statistical significance, and partial mediation would be present if the effect was reduced but still statistically significant. Age and IQ were included in the model as control variables. The model was analyzed using IBM SPSS Amos v.26 with maximum likelihood estimation.

Results

Table 1 provides the mean, standard deviation, range, skewness, and kurtosis of all variables, and Table 2 represents Pearson correlation coefficients between each pair of variables. The values of skewness and kurtosis were between +1 and -1 showing univariate normality of all variables. Most correlation coefficients presented in Table 2 were statistically significant except for the correlations between age and sleep, EF, everyday memory, and ADHD symptoms, and there was no multicollinearity between variables (VIF < 3).

Table 3 presents the unstandardized estimates, standard errors, standardized estimates, and *p* values of the direct effects of sleep on EF, everyday memory, and ADHD symptoms as well as direct effects of EF on everyday memory and ADHD symptoms. Table 3 also provides unstandardized estimates, standard errors, standardized estimates, and 95% bootstrap confidence interval of total and indirect effects of sleep on everyday memory and ADHD symptoms. Regarding the direct effect of sleep on EF and its total effects on everyday memory and ADHD symptoms, higher rates of sleep problems were associated with greater difficulty with EF ($\beta = .43$, $p < .001$), everyday memory ($\beta = -.22$, *95% Bootstrap CI* excludes zero), and ADHD symptoms ($\beta = .35$, *95% Bootstrap CI* excludes zero). Regarding the direct effects of EF, greater difficulty with EF was associated with more challenges with everyday memory ($\beta = -.44$, $p < .001$) and higher rates of ADHD symptoms ($\beta = .59$, $p < .001$).

As Table 3 shows, examining the mediatory role of EF, all estimates were statistically. As hypothesized, sleep had significant indirect effects on everyday memory (β = -.18, *95% Bootstrap CI* excludes zero) and ADHD symptoms (β = .25, *95% Bootstrap CI* excludes zero). This finding indicated that EF fully mediated the relation between sleep and both everyday memory and ADHD symptoms. In other words, after controlling the effect of EF, sleep was no longer significantly correlated with everyday memory and ADHD symptoms. Regarding the effects of age and IQ, there were no significant direct effects of age on both everyday memory (β = .05, *p* = .55) and ADHD symptoms (β = -.12 *p* = .11). IQ had a significant direct effect on EF (β = -.20, *p* = .04), but not on everyday memory (β = .09. *p* = .41) and ADHD symptoms (β = -.10, *p* = .22).

Discussion

Given the high rates of sleep problems, EF difficulties, everyday memory challenges, and ADHD symptoms reported in children and youth with DS, a path analysis was conducted to examine how these sets of difficulties are linked. Specifically, we explored whether EF mediated the relation between parent-reported sleep and both everyday memory and ADHD symptoms. The study findings were consistent with previous research in DS (Chen et al., 2013; Esbensen & Hoffman, 2018; Esbensen et al., 2018; Joyce et al., 2020; Lukowski & Milojevich, 2017; Lukowski et al., 2020) and provide additional evidence supporting the association between sleep problems and difficulties with EF, memory, and ADHD symptoms among individuals with DS. Further, the results were theoretically in line with a growing body of research that underlines EF as a mechanism through which different environmental or physiological based disorders affect a variety of cognitive and behavioral functions, such as attention and memory function, academic performance, daily activities, and behavioral problems (Bindman et al., 2015; Engel-Yeger & Rosenblum, 2021; Fatima & Sheikh, 2014; Fernandez-Prieto et al., 2021; O'Bryant et al., 2011; Parks et al., 2011; Roman et al., 2016; Schmidt et al., 2017; Sulik et al., 2015; Visier-Alfonso et al., 2020; Whittingham et al., 2014).

The significant mediatory role of EF on the association between sleep and both everyday memory and ADHD symptoms in children with DS may be justified by referring to the multidimensional model initially proposed by Beebe and Gozal (2002). As noted earlier, the model highlights potential damaging effects of sleep disturbance on the prefrontal cortex as a prominent brain region involved in EF. It posits that sleep-related restorative processes are disrupted by sleep disturbance, which may lead to chemical and structural cellular injury in the prefrontal brain regions expressed as EF challenges that, consequently, results in some behavioral and cognitive daily dysfunctions such as everyday memory problems and inattention symptoms (Beebe & Gozal, 2002).

Although most variance of ADHD symptoms was explained indirectly via EF, our findings showed an approaching significance direct relation between sleep and ADHD symptoms. There are multiple explanations for this small effect. First, it may show that poor sleep directly impacts inattention and hyperactive behavior in children and youth with DS. Sleep disturbances may also affect brain regions associated with ADHD without involving EF. For instance, it has been reported that sleep deprivation may have a damaging effect on the cerebellum (Song & Zhu, 2021), which is a prominent brain region involved in ADHD (Goetz et al., 2014). OSA, commonly reported in the DS population (Carter et al., 2009), also causes decreased cerebellar volume and cerebellar malfunction (Desseilles et al., 2008) and therefore may be impacting the relation between sleep and ADHD symptoms. Second, difficulties with morning awakenings and daytime sleepiness resulting from sleep deprivation may negatively affect parent-child interaction and lead parents to score greater concerns on ADHD questionnaires. Furthermore, parents may interpret daytime sleepiness and fatigue as ADHD symptoms.

As noted earlier, age and IQ were included in the model to control for their effects on EF, everyday memory, and ADHD symptoms. Although their common variances were partialed out, age and IQ have no significant effects on everyday memory and ADHD symptoms, but IQ had a significant effect on EF. Unlike some previous studies which have supported the relative effects of age and cognitive ability on memory and ADHD symptoms in different clinical and non-clinical samples (Foley et al., 2009; Frazier et al., 2004; Holland & Sayal, 2019; Kuntsi et al., 2004; Mackinlay et al., 2009; Ratcliff et al., 2011), the current study provided no evidence for such associations in this sample of children and youth with DS. However, the significant relation between IQ and EF observed was in line with the results reported by a large growing body of research in typically developing children (Ardila Ardila, 2018; Arffa, 2007; Decker et al., 2007; Frischkorn et al., 2019), and children with intellectual disabilities (Erostarbe-Pérez et al., 2021).

Clinical Implications

The findings highlight the need for treatments to target sleep in children and youth with DS using specific behavior modification techniques and/or pharmacological interventions. Parents may need to use some behavioral sleep management programs specifically recommended for children with DS, such as establishing clear and regular routine sleep behaviors, providing safe and secure physical, social, and emotional environments, and rewarding good bedtime behaviors (Wood & Sacks, 2004). Further, findings indicate that ADHD or memory interventions in DS would benefit from addressing sleep intervention and education to optimize outcomes. The current findings also support a need for communication between home and school on sleeping patterns to help parents and teachers understand a child's daily performance in memory and attention. Finally, given the significant mediatory role of EF, specific interventions are also necessary for accommodating and supporting EF difficulties of children at home and school to moderate the potentially damaging effects of sleep problems on daily functions and school behaviors. Parents need to be provided a better understanding of their child's EF challenges, modify the home environment to reduce overloading, teach EF skills directly, and motivate the child to use EF skills. Schools can create an EF culture in the classrooms to address EF difficulties, foster EF strategies use and motivation, and broaden the scope of academic goals to include education that supports EF.

Limitations and Recommendations

While the present study provided evidence regarding the connections between a set of difficulties commonly experienced by children and youth with DS and specifically highlighted the prominent role of EF, some limitations need to be acknowledged. First, given the cross-sectional nature of the study, no causal implications can be made. Longitudinal research is recommended to support the specific directions proposed in the model. Next, only parent-report measures were used in the study. Although the parent-report measures were appropriate for use among individuals with DS (Esbensen & Hoffman, 2017; Esbensen et al., 2017; Liogier d'Ardhuy et al., 2015; Spanò & Edgin, 2017; Esbensen et al., 2021), using only parental perspective introduces bias by relying on the same respondent across all measures. Further studies are needed to support the proposed model using teacher rating, performance-based measures, and neuroimaging. Additionally, given the number of participants, we analyzed the proposed model using only observable variables. To partial out the errors from the variables' variance, further research using latent variables with a larger sample size is recommended. To avoid model complexity, we also only used BRIEF-2 GEC, a composite score. Given the growing body of research supporting the prominent role of EF as a mediation variable, it is suggested that future studies investigate the mediation role of specific EF subdomains in the association between sleep and both everyday memory and ADHD symptoms. Finally, in DS, EF may have a mediation effect in the relation between sleep and other cognitive or daily functions not investigated in the current study. Future work should investigate the mediatory role of EF on the link between sleep and other cognitive and daily functions such as adaptive functioning, social behaviors, and academic performance.

Conclusions

This study provides additional evidence regarding the relation between sleep problems commonly experienced by individuals with DS and some cognitive functions, such as everyday memory and ADHD symptoms. Specifically, it highlights the significant role of EF in mediating these associations. These findings indicated that greater difficulties with EF experienced by individuals with DS may exacerbate the effect of sleep problems on cognitive and behavioral functioning, and children with lower EF abilities may be more impacted by sleep disturbances.

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Table 1. Mean, Standard Deviation, Range, Skewness, and Kurtosis of the Variables

Variable	Mean	SD	Range	Skewness	Kurtosis
CSHQ	44.46	7.21	33 - 71	.64	.82
BRIEF-2 GEC	59.26	8.88	38 - 81	.10	-.50
OMQ-PF	87.45	11.78	59 - 115	-.05	-.15
VADPRS	17.15	8.95	2 - 44	.60	-.20
Age	12.52	3.24	6 - 17	-.45	-.85
SB5-ABIQ (deviation)	34.63	14.91	-4 - 77[a]	.03	.71

n=96; SD: Standard Deviation; [a]Negative deviation scores represent scores that are more than 3.33 standard deviations below the mean SB-5; BRIEF-2 GEC: Behavior Rating Inventory of Executive Function, second edition, Global Executive Composite; CSHQ: Children's Sleep Habits Questionnaire; OMQ-PF: Observer Memory Questionnaire-Parent Form; SB5-ABIQ: Stanford Binet, fifth edition, Abbreviated Battery Intelligence Quotient (deviation); VADPRS: Vanderbilt Attention Deficit/Hyperactivity Disorder Parent Rating Scale

Table 2. Pearson Correlation Coefficients

	1	2	3	4	5
1. CSHQ					
2. BRIEF-2 GEC	.41**				
3. OMQ-PF	-.27**	-.41**			
4. VADPRS	.42**	.68**	-.25**		
5. Age	-.03	-.08	.10	-.20	
6. SB5-ABIQ (deviation)	-.30**	-.29**	.23*	-.35**	.35**

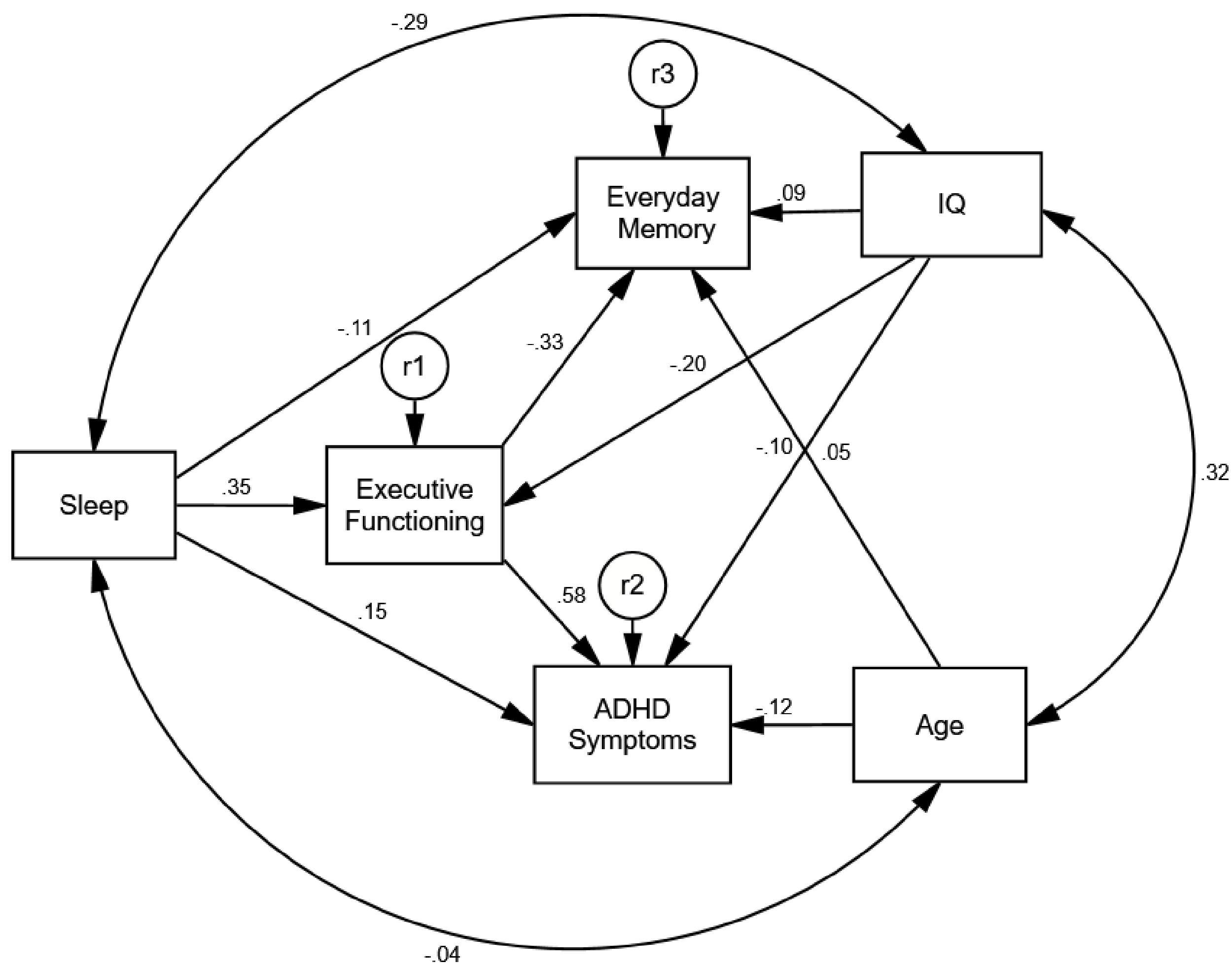
*p < .05, ****** p < .01; BRIEF-2 GEC: Behavior Rating Inventory of Executive Function, second edition, Global Executive Composite; CSHQ: Children's Sleep Habits Questionnaire; OMQ-PF: Observer Memory Questionnaire-Parent Form; SB5-ABIQ: Stanford Binet, fifth edition, Abbreviated Battery Intelligence Quotient (deviation); VADPRS: Vanderbilt Attention Deficit/Hyperactivity Disorder Parent Rating Scale.

Table 3. Parameter Estimates of Total, Indirect, and Direct Effects

Parameter			*Estimate*	*SE*	β	*p Value*	*95% Bootstrap CI*		*Sig.*
Total Effect									
Sleep[a]	→	Everyday Memory[b]	-.36	.17	-.22	-	(-.79	-.03)	Yes
Sleep	→	ADHD Symptoms[c]	.43	.10	.35	-	(.28	.62)	Yes
Indirect Effect									
Sleep	→	Everyday Memory	-.18	.09	-.11	-	(-.44	-.04)	Yes
Sleep	→	ADHD Symptoms	.25	.08	.20	-	(.13	.42)	Yes
Direct Effect									
Sleep	→	EF	.43	.12	.34	<.001	-	-	Yes
Sleep	→	Everyday Memory	-.18	.17	-.11	.29	-	-	No
Sleep	→	ADHD Symptoms	.18	.10	.15	.06	-	-	No
EF[d]	→	Everyday Memory	-.44	.13	-.33	<.001	-	-	Yes
EF	→	ADHD Symptoms	.59	.08	.58	<.001	-	-	Yes
Age	→	Everyday Memory	.19	.34	.05	.55	-	-	No
Age	→	ADHD Symptoms	-.32	.20	-.12	.11	-	-	No
IQ[e]	→	Everyday Memory	.07	.08	.09	.41	-	-	No
IQ	→	ADHD Symptoms	-.06	.05	-.10	.22	-	-	No
IQ	→	EF	-.12	.06	-.20	.04	-	-	Yes

EF: Executive Functioning; SE: Standard Error; β*: Standardized Estimate; CI: Confidence Interval*
[a]Sleep was measured by *CSHQ total score;* [b]*Everyday Memory was measured by OMQ-PF total score;* [c]*ADHD Symptoms were measured by VADPRS summed total score;* [d]*EF was measured by BRIEF-2 GEC t-score;* [e]*IQ was measured by SB5-ABIQ (deviation) standard score.*

Figure 1. Diagram of the Model with Standardized Estimates


-.29
r3
Everyday Memory
.09
IQ
-.11
-.33
r1
-.20
-.10
.05
.32
Sleep
.35
Executive Functioning
.58
r2
.15
ADHD Symptoms
-.12
Age
-.04