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ORIGINAL PAPER

Sleep and Behavioral Problems in Children with Autism Spectrum Disorder

Micah O. Mazurek[1] · **Kristin Sohl**[2]

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Abstract Children with autism spectrum disorder (ASD) are at high risk for sleep disturbance and behavioral dysregulation. However, the relationships between these difficulties are not fully understood. The current study examined the relationships between specific types of sleep and behavioral problems among 81 children with ASD. Sleep problems were significantly associated with physical aggression, irritability, inattention, and hyperactivity. In multivariate analyses, distinct sets of sleep problems accounted for between 22 and 32 % of the variance in behavior problems across models. These results indicate that sleep disturbance is associated with behavioral dysregulation among children with ASD. Of note, night awakenings had the most consistently strong association with daytime behavior problems, even after controlling for the effects of age and sex.

Keywords Autism · Autism spectrum disorder · Sleep · Aggression · Hyperactivity · Inattention · Behavior problems

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by primary impairments in social and behavioral functioning (American Psychiatric Association 2013) and accompanied by frequent co-occurring medical and psychiatric conditions (Bauman 2010; Kielinen et al. 2004; Leyfer et al. 2006; Simonoff et al. 2008). Children with ASD are at particularly high risk for sleep disturbance, with prior studies indicating that between 50 and 80 % of children with ASD experience problems with sleep (Couturier et al. 2005; Krakowiak et al. 2008; Richdale and Schreck 2009; Souders et al. 2009). Most research shows that as a group, children with ASD most commonly experience problems falling asleep and night awakenings. However, parasomnias are also frequently experienced (see for review Malow and McGrew 2008; Richdale and Schreck 2009). Sleep disturbance contributes to decreased quality of life for both children with ASD and their families (Delahaye et al. 2014; Hodge et al. 2013; Hoffman et al. 2008). However, the relationship between sleep problems and behavioral functioning in children with ASD has not been well-characterized. This is an important consideration, given that children with ASD experience significant difficulties regulating both behavior and attention (Frazier et al. 2001; Gadow et al. 2005; Mayes et al. 2012).

Sleep and Behavior in Typically Developing Children

A large body of literature has demonstrated that sleep disturbance is associated with behavior problems among typically developing (TD) children (Gregory and Sadeh 2012; Lavigne et al. 1999). For example, prior studies have found that sleep disturbance in typically developing children is associated with parent- and teacher-reported aggression and conduct problems (Ali et al. 1993; Aronen et al. 2000; Chervin et al. 2003). Longitudinal studies have also found that sleep problems in childhood predict

✉ Micah O. Mazurek
mazurekm@missouri.edu

[1] Department of Health Psychology, Thompson Center for Autism and Neurodevelopmental Disorders, University of Missouri, 205 Portland Street, Columbia, MO 65211, USA

[2] Department of Child Health, Thompson Center for Autism and Neurodevelopmental Disorders, University of Missouri, Columbia, MO, USA

aggression later in childhood (Hall et al. 2007), adolescence (Gregory and O'Connor 2002) and young adulthood (Gregory et al. 2008). There is also some evidence to suggest that the relationship between problem behaviors and sleep may be bidirectional among TD children (see Kelly and El-Sheikh 2014; Gregory and Sadeh 2012). For example, sleep problems both predicted and were predicted by oppositional and defiant behaviors in a recent longitudinal study (Shanahan et al. 2014).

A number of prior studies have also found that sleep problems are associated with symptoms of inattention and hyperactivity (Dahl et al. 1991; Owens 2008). Specifically, prominent difficulties with inattention and hyperactivity have been found in children with sleep disorders (Ali et al. 1993; Chervin et al. 1997) and sleep-disordered breathing (Chervin et al. 2002; Guilleminault et al. 1982; O'Brien et al. 2003). Disrupted or restricted sleep has been found to result in daytime attention problems (Anders et al. 1978; Fallone et al. 2001; Guilleminault et al. 1982; Weinberg and Brumback 1990), irritability, and poor impulse control (Dahl 1996). Shorter sleep duration has also been highly correlated with hyperactivity among children in prior cross-sectional studies (Touchette et al. 2009), and longitudinal research has found that reduced sleep duration prior to age three is a predictor of hyperactive/impulsive behavior and poor cognitive performance at age six (Touchette et al. 2007).

There are many potential reasons for the connection between sleep and behavior problems in childhood, and most research suggests that the directions of these relationships are likely to be complex (see for review Gregory and Sadeh 2012). In addition to potential shared genetic and environmental influences, neural and psychological processes may also explain the effects of sleep deprivation on behavioral dysregulation (Walker and van der Helm 2009). For example, prior experimental studies have found that sleep deprivation results in increased amygdala response to negative emotional stimuli and weaker connectivity between the amygdala and prefrontal cortex (Yoo et al. 2007), as well as effects on glucose metabolism in the prefrontal cortex (Horne 1993). Thus, sleep loss may result in negative effects on neurocognitive function, and subsequent impairment in attention and behavioral regulation (Gregory and Sadeh 2012). At a more basic level, sleep loss results in daytime fatigue and associated irritability (Baum et al. 2014), which may make aggressive or challenging behaviors more likely to occur.

Sleep and Behavior in ASD

Children with ASD are at high risk for behavioral regulation difficulties, including aggression (Farmer and Aman 2011; Kanne and Mazurek 2011; Mazurek et al. 2013), irritability (Green et al. 2000; Mayes and Calboun 1999), inattention and hyperactivity (Frazier et al. 2001; Gadow et al. 2005; Lecavalier 2006; Mayes et al. 2012). Surprisingly, however, the relationship between sleep and behavior problems in children with ASD has received relatively little empirical attention, as noted in a recent review (Cohen et al. 2014).

Some studies have used broad-band scales of behavioral and emotional functioning to examine the relations among sleep and daytime behaviors. For example, Fadini et al. (2015) found that sleep disturbance was correlated with the Total Problems and Thought Problems scores on the Child Behavior Checklist (CBCL) in a sample of 45 children with ASD; however, other subscales were not significantly associated with sleep. Hollway and colleagues (2013) also examined subscale scores from the CBCL in their study of correlates of sleep problems in children with ASD. Using hierarchical linear modeling, they examined 45 potential predictors of sleep disturbance, including CBCL syndrome scale scores. Mayes and Calhoun (2009) also utilized a broad-band scale, the Pediatric Behavior Scale (PBS) to assess both sleep disturbance and behavior in a sample of 477 children with ASD. Their findings indicated that the sleep disturbance subscale scores were significantly correlated with both internalizing and externalizing symptoms on the PBS.

Other studies have examined the relations among sleep problems and item-level indicators of behavior problems. For example, in a study of adults with ASD and intellectual impairment, item-level correlations indicated significant associations between "difficulty getting to sleep" and some items assessing challenging behaviors, including "throwing objects at others" and "yelling or shouting at others" (Matson et al. 2008). In a sample of 42 children with ASD, Goldman et al. (2009) found that poor sleepers (as reported by parents) demonstrated greater problems on attention and hyperactivity items from the Parent Concerns Questionnaire (PCQ). In a larger sample of 1784 children with ASD, these findings were replicated (using the same PCQ items), and additional significant differences were found for additional items assessing challenging behavior, including aggression and self-injurious behavior (Goldman et al. 2012a).

In one of the few studies using a specific measure of problem behaviors, May et al. (2015) examined the associations between sleep and behavior problems in children with high functioning ASD. The Conners Third Edition was used to measure symptoms of impulsivity and aggression, and the CSHQ was used as a measure of sleep disturbance. The results indicated significant correlations between sleep disturbance and both aggression and hyperactivity. However, the sample was limited to 7–12 year old children with high functioning ASD. Thus, it is not clear whether these results generalize to the larger ASD population.

There are theoretical reasons to predict that the relationships between sleep and behavior may be bidirectional. For example, Hollway and Aman (2011) proposed a comprehensive theoretical framework for understanding sleep disturbance, in which a bidirectional relationship between externalizing behaviors and insomnia was predicted. As described above, evidence to date on sleep and behavior among children with ASD has been primarily cross-sectional, meaning that directionality and causality cannot be determined. However, findings from the general population provide some evidence for the bidirectionality assumption (e.g., Kelly and El-Sheikh 2014; Shanahan et al. 2014).

Current Study

In summary, previous research provides preliminary support for the idea that sleep disturbance and behavioral difficulties are associated in children with ASD. However, prior studies have not fully characterized the associations between specific types of sleep problems and specific challenging behaviors in children with ASD. Thus, the purpose of the current study was to examine the relationships between distinct types of sleep problems and behavioral problems. The specific behavior problems selected for examination were aggression, irritability/hostility, inattention, and hyperactivity, given their particular clinical relevance in the ASD population. The primary hypothesis was that sleep problems would be associated with daytime behavioral disturbance among children with ASD. The secondary research aim was to identify the specific types of sleep symptoms that were most closely related to each behavioral problem.

Methods

Participants

Participants included parents of 81 children with ASD. Participants were recruited through an academic medical center specializing in diagnosis and treatment of children with ASD and other neurodevelopmental disorders. All participants had been previously evaluated and diagnosed by an interdisciplinary team, comprised of a physician and psychologist. Evaluations included administration of standardized diagnostic tools (i.e., ADOS or ADOS-2), cognitive and adaptive skill assessment, clinical interview, and other measures deemed appropriate based on presenting concerns. Three hundred and sixty-nine parents were recruited for the current study by email, which included a brief description of the study and a link to an online survey platform. Interested participants reviewed an informed consent document, and indicated consent to participate before being directed to the survey. All measures were then completed online using a web-based survey platform. Parent respondents included biological mothers (72.8 %), followed by biological fathers (9.9 %), adoptive parents (8.6 %), or other guardians (7.4 %). Children ranged in age from 3.6 to 19.6 years ($M = 10.3$, $SD = 3.8$). The majority of children in the study were male (86.4 %), Caucasian (93.6 %), and not Hispanic or Latino (92.6 %). Most children lived with both biological parents (66.7 %).

Measures

Parents completed a demographic survey developed for the current study, which included child age, sex, race, ethnicity, and family composition. Additional specific measures of sleep and behavior were also collected, as described below.

Sleep Problems

The *Children's Sleep Habits Questionnaire (CSHQ)* (Owens et al. 2000) was used to examine different domains of sleep disturbance. The CSHQ is a parent-report measure of sleep that has demonstrated good psychometric properties (Owens et al. 2000) and is frequently used in studies of children of ASD (Goldman et al. 2012b; Souders et al. 2009). The CSHQ includes a Total Sleep Disturbance score as well as subscale scores in 8 different sleep domains: Bedtime Resistance, Sleep Onset Delay, Sleep Duration, Sleep Anxiety, Night Wakings, Parasomnias, Sleep Disordered Breathing, and Daytime Sleepiness. Item anchors were modified for the current study in order to capture the full range of variability in sleep behaviors. Specifically, the original CSHQ wording instructs parents to rate how often each sleep behavior occurs on a three-point scale, as follows: 1 = "rarely" if the behavior occurred never or one time per week, 2 = "sometimes" if the behavior occurred two to four times per week, or 3 = "usually" if the behavior occurred five to seven times per week. In the current study, parents were asked to rate the frequency of the same behaviors on a 7-point scale, using the full range of possible responses (i.e., ranging from never to 7 times per week.).

Physical Aggression

The Physical Aggression subscale of the *Children's Scale for Hostility and Aggression: Reactive/Proactive (C-SHARP)* (Farmer and Aman 2009) was used as a measure of physical aggression. The C-SHARP is a comprehensive measure of aggression developed specifically

for children with developmental disabilities. It has shown sound psychometric properties in prior studies (Farmer and Aman 2010) and has been used to characterize different subtypes of aggression among children with ASD, specifically (Farmer et al. 2015; Farmer and Aman 2011). The C-SHARP is comprised of five empirically-derived subscales. The Physical Aggression subscale contains 8 items assessing behaviors inflicting physical harm, such as biting, pinching, etc. Items are rated on a 4-point scale, ranging from 0 = *does not happen,* to 3 = *severe and/or very frequent problem.*

Irritability/Hostility

The Hostility subscale of the *C-SHARP* (Farmer and Aman 2009) was used to assess irritability/hostility. This subscale includes nine items assessing behaviors reflective of hostility, anger, and irritability. Examples include being quick to anger, being grouchy, reacting suddenly or impulsively to minor provocations, etc. Items are rated on a 4-point scale, ranging from 0 = *does not happen,* to 3 = *severe and/or very frequent problem.*

Inattention

The Inattention subscale of the *Vanderbilt Attention Deficit/Hyperactivity Disorder Parent Rating Scale (VADPRS)* (Wolraich et al. 1998) was used to assess attention problems. The VADPRS is a parent-report measure of ADHD symptoms, has good internal consistency, validity, and reliability (Wolraich et al. 2003) and has been used to assess inattention and hyperactivity in previous ASD research (Mazurek and Engelhardt 2013a; b). The Inattention subscale includes nine items rated on a 4-point scale, ranging from 0 = *never* to 3 = *very often*. Items assess behaviors such as being easily distracted and having trouble sustaining attention.

Hyperactivity/Impulsivity

The Hyperactivity subscale of the VADPRS (Wolraich et al. 1998) was used to assess symptoms of hyperactivity and impulsivity. The subscale is comprised of nine items rated on a 4-point scale, and assesses behaviors such as fidgeting and running about or climbing excessively.

Data Analysis Plan

Descriptive statistics were calculated to characterize the sample, including mean, standard deviation, range, and percentage. Preliminary analyses were conducted to test for potential associations between study variables and demographic variables. Specifically, for categorical demographic variables we conducted one-way analysis of variance (ANOVA) to examine potential differences in continuous study variables, and we used Pearson's correlation coefficients to examine potential associations between continuous demographic variables and continuous study variables. Bivariate relationships between sleep problems and behavior problems (primary hypothesis) were examined using Pearson's correlation coefficients. To determine the specific sleep problems most closely associated with each behavior problem, a series of linear regression models were conducted for each of the four behavior problems of interest: physical aggression, irritability, inattention, and hyperactivity. A backward stepwise approach was used to determine the most parsimonious model for prediction of each dependent variable. Sleep variables that were significantly related to the outcome of interest in bivariate analyses were entered into the first step of each model, and variables were eliminated in a stepwise fashion (criteria for entrance: $p < .05$; criteria for removal: $p \geq .01$).

Results

Initial Analyses

Initial ANOVAs were conducted to test for potential differences in study variables with regard to categorical demographic variables [i.e., sex, race (white vs. other), or family composition (living with both biological parents vs. not)]. Girls demonstrated greater scores than boys ($ps < .05$) on inattention (M = 18.0, SD = 4.8 vs. M = 13.0, SD = 5.9), hyperactivity (M = 15.5, SD = 8.5 vs. M = 10.9, SD = 6.5), hostility (M = 14.9, SD = 8.6 vs. M = 7.2, SD = 5.8), bedtime resistance (M = 21.1, SD = 14.1 vs. M = 14.1, SD = 9.1), and parasomnias (M = 19.3, SD = 8.7 vs. M = 13.7, SD = 6.4). No statistically significant group differences (in race or family composition) were observed with regard to any sleep or behavioral variables. Age was negatively correlated with hyperactivity ($r = -.267$, $p = .016$) and parasomnias ($r = -.334$, $p = .002$). In contrast, age was not significantly associated with other sleep or behavioral variables. Based on these results, age and sex were included as covariates in subsequent multivariate analyses.

Bivariate Relationships Between Sleep and Behavior

To test the hypothesis that sleep and behavior problems would be strongly associated, Pearson's correlations were computed between CSHQ subscale scores and scores on each of the following behavior problem scales: C-SHARP Physical Aggression, C-SHARP Hostility, VADPRS

Table 1 Means, standard deviations and correlation coefficients

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11
Behavior variables													
(1) Physical aggression[a]	1.6	3.2											
(2) Hostility[b]	8.3	6.7	.54***										
(3) Inattention[c]	13.7	6.0	.38***	.37***									
(4) Hyperactivity[d]	11.5	7.0	.33**	.53***	.49***								
Sleep variables[e]													
(5) Bedtime resistance	15.1	10.1	.03	.20	−.01	.18							
(6) Sleep onset delay	3.7	2.7	.19	.07	.08	.07	.42***						
(7) Sleep duration	7.5	5.2	.26*	.32**	.27*	.24*	.37**	.38**					
(8) Sleep anxiety	10.9	8.4	.08	.28*	−.04	.22*	.84***	.31**	.24*				
(9) Night wakings	7.1	5.4	.46***	.40***	.37**	.44***	.42***	.42***	.48***	.39***			
(10) Parasomnias	14.4	7.0	.40***	.40***	.29*	.46***	.46***	.34**	.49***	.42***	.76***		
(11) Sleep disordered breathing	4.3	3.0	.09	.22	.18	.16	.19	.22*	.30**	.17	.34**	.27*	
(12) Daytime sleepiness	17.8	8.7	.19	.25*	.02	−.11	.30**	.43***	.29**	.21	.32**	.30**	.17

* $p < .05$; ** $p < .01$; *** $p < .001$

[a] Children's Scale for Hostility and Aggression: Reactive/Proactive (C-SHARP) Physical Aggression subscale score

[b] C-SHARP Hostility subscale score

[c] Vanderbilt Attention Deficit/Hyperactivity Disorder Parent Rating Scale (VADPRS) Inattention subscale score

[d] VADPRS Hyperactivity subscale score

[e] Subscale scores from the Children's Sleep Habits Questionnaire (CSHQ)

Inattention, and VADPRS Hyperactivity. Consistent with predictions, statistically significant correlations were found between several sleep and behavioral indicators (see Table 1).

Multivariate Models

To determine the specific sleep problems most closely associated with each behavior problem, a series of four linear regression analyses were conducted. Each respective behavior problem (i.e., physical aggression, hostility, inattention, or hyperactivity) was included as the dependent variable in each model. Demographic variables found to be associated with primary variables in the initial analyses (i.e., age and sex) and specific sleep problems (i.e., CSHQ subscales scores) were entered as independent variables. A backward stepwise approach (criteria for entrance: $p < .05$; criteria for removal: $p \geq .01$) was used to determine the combination of sleep variables that best predicted each behavior problem.

The results of each model are as follows: (1) in the model predicting physical aggression, the linear combination of bedtime resistance and night wakings was significantly related to the outcome ($p < .001$) and accounted for 24 % of the variance. (2) In the model predicting hostility, the linear combination of sex, bedtime resistance, sleep duration, sleep anxiety, and night wakings was significantly related to hostility ($p < .001$), accounting for 32 % of the variance. (3) In the model predicting inattention, the linear combination of sex, bedtime resistance, and night wakings was significantly related to the outcome ($p < .001$) accounting for 22 % of the variance. (4) Finally, in the model predicting hyperactivity, the linear combination of night wakings, parasomnias, and daytime sleepiness was significantly related to the outcome ($p < .001$) and accounted for 31 % of the variance. The results of the first and final step of each model are presented in Table 2, including standardized regression coefficients (βs) for each predictor.

Discussion

These results add to the growing body of literature demonstrating a strong association between sleep disturbance and daytime functioning in children with ASD. This was the first study to examine which specific types of sleep problems are most closely associated with the most common specific types of behavioral problems in children with ASD. Consistent with our predictions, both bivariate and multivariate analyses revealed significant associations between specific sleep problems and problem behaviors, with small to moderately large effect sizes.

Table 2 Backward stepwise linear regression models: sleep variables predicting behavior

Variable	Physical aggression		Hostility		Inattention		Hyperactivity	
	Step 1 Adjusted $R^2 = .204$ β	Final step Adjusted $R^2 = .218$ β	Step 1 Adjusted $R^2 = .275$ β	Final step Adjusted $R^2 = .277$ β	Step 1 Adjusted $R^2 = .168$ β	Final step Adjusted $R^2 = .186$ β	Step 1 Adjusted $R^2 = .251$ β	Final step Adjusted $R^2 = .285$ β
Age	−.16		−.02		.15		−.13	
Sex	.10		.32**	.34**	.23*	.25*	.14	
Bedtime resistance	−.49*	−.189	−.43*	−.44*	−.13	−.22	−.17	
Sleep onset delay	.05		−.18		−.08		−.04	
Sleep duration	.13		1.9	.20	.16		.08	
Sleep anxiety	.22		.47*	.47*	−.07		.17	
Night wakings	.36*	.54***	.14	.22	.35*	.39**	.28	.30*
Parasomnias	.07		.09		.07		.20	.31*
Sleep disordered breathing	−.04		.10		.03		.06	
Daytime sleepiness	.11		.17		−.14		−.27*	−.31**

Standardized regression coefficients (βs) are shown for each predictor on the step in which it was included in the model

* $p < .05$; ** $p < .01$; *** $p < .001$

The results showed that sleep duration, night awakenings, and parasomnias were significantly correlated with all four behavior problems examined. Additionally, sleep anxiety was positively correlated with both irritability and hyperactivity, while daytime sleepiness was positively correlated with irritability, but not with other behavioral difficulties.

Of particular note, night awakenings appear to have the most consistently strong association with daytime behavior problems in both bivariate correlations and in linear regression models, even after controlling for the effects of age and sex. Specifically, night awakenings were positive correlated with physical aggression, hostility, inattention, and hyperactivity. In addition, night awakenings were retained as primary predictors of behavior problems across all four regression models. This indicates that night awakenings have a significant impact on daytime functioning for children with ASD regardless of age, suggesting that it should be an especially important treatment target. Many widely-used treatments for sleep disturbance in ASD are primarily effective for sleep onset delay (e.g., melatonin, see for review Guénolé et al. 2011). Although the availability of extended-release melatonin is promising, more specific examination of its effectiveness in addressing night awakenings in children with ASD is needed. Behavioral treatments for sleep disturbance have shown success in addressing night awakenings in some prior studies; however, most evidence has been drawn from case studies or single-subject designs (see for review Turner and Johnson 2013; Vriend et al. 2011). The current study suggests that night awakenings warrant additional attention in future empirical and clinical research among children with ASD.

Although sleep duration was significantly correlated with all four behavior problems, it was not retained in three of four stepwise regression models. In other words, other types of sleep disturbance (particularly night awakenings) appear to have a relatively stronger association with aggression and ADHD symptoms. However, sleep duration emerged as one of five variables that accounted for the most variance in predicting irritability. Of those, sleep anxiety had the strongest association with irritability. Given that prior research has also shown that anxiety is associated with sleep disturbance in children with ASD (Mazurek and Petroski 2015; Richdale and Baglin 2013), these results may reflect a broader relationship between sleep disturbance, arousal, mood (assessed here as irritability/hostility).

Although insomnia is a primary feature of sleep disturbance in ASD (Malow and McGrew 2008; Richdale and Schreck 2009) the current results indicate that parasomnias may also warrant consideration, given their relationships to clinically relevant behavioral disturbances. Specifically, parasomnias were significantly correlated (small to moderately large effects) with each of the four behavior problems examined. Furthermore, parasomnias were significant predictors of hyperactivity in linear regression analyses. This suggests that future research would benefit from more careful study of atypical sleep behaviors and their relation to daytime functioning in children with ASD.

Interestingly, bedtime resistance and sleep onset delay were not significantly correlated with any of the behavior problems in bivariate analyses. However, when examined within multivariate models accounting for additional sleep and demographic variables, bedtime resistance was a significant cross-sectional predictor of irritability. Surprisingly, the relationship between these variables was negative, suggesting of a suppressor effect. In other words, while bedtime resistance had a weak nonsignificant positive correlation with irritability, when additional variables were taken into account, lower bedtime resistance was associated with greater irritability.

The current results suggest that careful assessment of sleep quality and sleep behaviors should be an important consideration for clinicians targeting behavioral problems in children with ASD. Similarly, the strong associations between sleep disturbance and behavioral dysregulation highlight the fact that children with ASD and sleep disturbance are more clinically complex and may benefit from comprehensive treatment modalities in order to fully manage these comorbidities.

Limitations and Future Directions

It should be noted that the results describe cross-sectional relations among variables, meaning that casualty cannot be inferred. Future longitudinal research is needed to more carefully examine predictors, consequences, and long-term relationships between sleep and behavior. Treatment-outcome research would also be beneficial to determine whether treatment for one condition (e.g., sleep or behavior) results in improvements in the other. As noted previously, there is evidence to suggest that the relationships between sleep and behavior are complex and potentially bidirectional (Hollway and Aman 2011; Kelly and El-Sheikh 2014; Shanahan et al. 2014). Future studies should carefully investigate the timing and directionality of these relationships in order to more fully inform our understanding of the etiology and most effective treatments for these conditions.

Another limitation is that our sample represented a very wide age range, from early childhood through late adolescence. Although age was included as a covariate in our primary analyses, further research among larger samples would allow for the examination of potential developmental shifts in the relations among these variables. Additionally, participants were recruited by email and completed measures online. Thus, the extent to which our findings generalize to the larger ASD population, including families without internet access, is not known. Future studies would also benefit from including comprehensive measures of additional sample characteristics, such as ASD symptom severity and level of cognitive, language and adaptive functioning.

The study was also limited by the use of parent report for all measures of interest. An additional limitation was that our measure of inattention and hyperactivity has not been specifically validated for use in children with ASD. More work is needed to examine extent to which the measurement properties of existing behavior scales are adequate when applied to children with ASD. Future studies among ASD samples are needed to test the construct validity and measurement invariance of the VADPRS and other measures designed for use among TD individuals. In addition, although the CSHQ has been widely-used in studies of children and adolescents with ASD, it was not developed for use among adolescents and has not been specifically validated among children with ASD. Future research would also benefit from objective measures of sleep and behavior, such as actigraphy, polysomnography, and/or direct behavioral observation.

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Author Contributions MM and KS conceptualized and designed the study and coordinated and supervised data collection. MM conducted the analyses and drafted the initial manuscript. KS critically reviewed and edited the manuscript, and both authors approved the final manuscript as submitted.

Compliance with Ethical Standards

Conflict of interest Dr. Mazurek declares that she has no conflict of interest. Dr. Sohl declares that she has no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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