Characterizing Sleep in Children with Autism Spectrum Disorders: A Multidimensional Approach

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Study Objectives: To relate parentally reported sleep concerns in autism spectrum disorders (ASD) to polysomnographic (PSG) findings and measures of daytime behavior and autism symptomatology.

Design: Cross-sectional study involving validated questionnaires, sleep histories and diaries, 2 nights of PSG, and the Autism Diagnostic Observation Schedule (ADOS).

Setting: Vanderbilt University General Clinical Research Center Sleep Core

Participants: 21 children with ASD and 10 typically developing (TD) children, aged 4-10 years. Children were free of psychotropic medications, with no history of mental retardation or epileptic seizures.

Interventions: N/A

Measurements and Results: Children with ASD were defined as "good sleepers" (10 children) and "poor sleepers" (11 children) on the basis of parental report; the age-comparable TD children were all reported by their parents to be good sleepers. Poor sleepers with ASD showed prolonged sleep latency and decreased sleep efficiency on night 1 of PSG and differed on insomnia-related subscales of the Children's Sleep Habits Questionnaire (CSHQ; increased sleep onset delay and decreased sleep duration). The good sleepers with ASD did not differ from the TD children in sleep architecture or on CSHQ domains. As compared with ASD good sleepers, the ASD poor sleepers also had higher scores related to affective problems on the Child Behavior Checklist and more problems with reciprocal social interaction on the ADOS.

Conclusions: Parentally reported sleep concerns of insomnia in children with ASD are substantiated by validated sleep questionnaires and by PSG. Furthermore, good sleepers with ASD showed fewer affective problems and better social interactions than ASD poor sleepers.

Keywords: Insomnia, polysomnography, Children's Sleep Habits Questionnaire, Child Behavior Checklist, Autism Diagnostic Observation Schedule

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INTRODUCTION

AUTISM SPECTRUM DISORDERS (ASD) ARE NEURODEVELOPMENTAL DISORDERS CHARACTERIZED BY DEFICITS IN SOCIAL INTERACTION AND COMMUNICATION, with restricted interests and repetitive behaviors.[1] Parentally reported sleep concerns are common in ASD, with prevalence rates of 44%-83%.[2] Even in children with average intelligence, sleep problems in ASD have been reported to be more prevalent and severe than in to age- and sex-matched typically developing (TD) children.[3] Insomnia, defined as difficulty initiating or maintaining sleep, has been documented consistently in children with ASD in studies using parentally completed questionnaires, sleep diaries, or both.[2,4-7] Parental reports of daytime sleepiness, sleep disordered breathing, and parasomnias (e.g., head banging, sleep terrors) have also been reported, but with lesser frequency than insomnia, in comprehensive investigations of large numbers of children with ASD.[6]

While parental sleep concerns have been well documented in children with ASD, few studies have related these concerns to polysomnographic (PSG) findings. Documenting PSG abnormalities in children with ASD whose parents report sleep concerns provides objective evidence of disordered sleep in these children (i.e., sleep concerns do not simply reflect parental over reporting in this group of highly stressed caregivers). Furthermore, few investigators have examined the relation of both parental report and physiological sleep variables to measures of daytime behavior and autism symptomatology.

The goals of our study were (1) To determine whether parental reports of sleep concerns correspond to physiological measures of sleep, and (2) To examine the relation of parental and physiological measures of sleep to daytime behaviors and autism symptomatology. To accomplish these goals, we characterized sleep in children with ASD using multiple measures, including parental report, a validated sleep questionnaire, sleep histories, sleep diaries, and two nights of video-EEG-PSG. Validated measures of daytime behavior and autism symptomatology were also collected. To minimize effects of confounding factors, we limited our cohort to children with ASD 4-10 years of age who were medication-free and seizure-free and did not have mental retardation. Typically developing children 4-10 years of age were included as a comparison group.

METHODS

Participants

This study was approved by the Vanderbilt University Institutional Review Board, with parents of participating children providing consent and children providing assent. Principles of the

Disclosure Statement

This was not an industry supported study. Drs. Malow, Marzec, McGrew, Wang, Henderson, and Stone have indicated no financial conflicts of interest.

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Declaration of Helsinki were followed. From Vanderbilt subspecialty clinics as well as from the community (e.g., local autism society, public schools), we recruited children with a clinical history of autism spectrum disorders (autism, pervasive developmental disorder, not otherwise specified, or Asperger's disorder) as well as typically developing (TD) children of comparable ages. Participants received a clinical diagnosis of ASD from psychologists or clinicians based on parent interviews, child observation, and direct testing. These clinical diagnoses of ASD were verified using the Autism Diagnostic Observation Schedule.[8] All children were between the ages of 4 and 10 years, were not taking psychotropic medications, and did not have a history of epileptic seizures or mental retardation. Receptive language vocabulary skills were required to be within 1½ standard deviations of the mean. Parents were asked one item concerning sleep on a parental concerns checklist: "Please describe the extent to which sleep disturbance (does not fall asleep easily, wakes often, etc.) has been a problem for you within the last month on a scale from 1 to 4 (1 = no concerns; 2 = mild concerns; 3 = moderate concerns; 4 = severe concerns)." Those children with no or mild parental sleep concerns were classified as "good sleepers" and those children with moderate or severe parental sleep concerns were classified as "poor sleepers." Our TD group consisted only of those who were "good sleepers," since we wished to compare ASD good sleepers with TD good sleepers on a variety of sleep and behavioral measures to determine the contribution of ASD to these measures independent of sleep. Parents completed a demographic form containing information about parental occupation and education. This information was used to calculate socioeconomic status according to Hollingshead's Four Factor Index of Social Status.[9]

Sleep Related Measures

Children's Sleep Habits Questionnaire

Parents completed the Children's Sleep Habits Questionnaire (CSHQ),[10] a questionnaire validated in children ages 4-10 years. The CSHQ has been used to examine sleep behavior in children with a variety of conditions, including ASD.[3,5] Domains on the CSHQ include insomnia-related dimensions such as bedtime resistance, sleep anxiety, sleep onset delay, sleep duration, and night wakings, as well as daytime sleepiness, sleep disordered breathing, and parasomnias. Based on the literature of parental sleep concerns in ASD (see introduction for references), we hypothesized that the insomnia-related dimensions would show the greatest differences between groups.

Sleep Histories and Sleep Diaries

The first author (BAM), a neurologist and Diplomate of the American Board of Sleep Medicine, spoke with the parent of each child to obtain a sleep history prior to the sleep studies. This semistructured history was done after the parent completed the CSHQ and augmented the data provided from this questionnaire. The history included questions concerning the nature and duration of the sleep concern, the child's sleep patterns (bedtime, wake time, time to fall asleep, arousals from sleep), and the presence of sleep disordered breathing, parasomnias, and daytime sleepiness. In order to obtain a measure of the child's habitual bedtime and wake time, sleep diaries were collected for one week prior to the laboratory PSGs.

Laboratory Video-EEG-Polysomnography

The laboratory study consisted of 2 consecutive nights of video monitoring combined with EEG and polysomnography (PSG) in the Sleep Research Core of the General Clinical Research Center (GCRC) at Vanderbilt University. Video-EEG-PSG studies were performed on digital systems (Nihon-Kohden USA, Foothill Ranch, CA) and included digital video recordings time-locked to the PSG recording, 21 channels of EEG, 2 channels of EOG, 2 channels of EMG, thermistor and nasal pressure transducer monitoring to measure airflow, thoracic and abdominal wall motion to measure respiratory effort, oximetry to measure oxygen desaturations, ECG, and anterior tibialis (leg movement) monitoring. PSG technologists with pediatric expertise conducted the studies. Bedtime on the night of the laboratory studies was planned to be as close as possible to the child's habitual bedtime. Acclimation procedures were used to promote success with video-EEG-PSG studies, including a brochure with pictures of children undergoing sleep studies, and development of individualized strategies with the parents to relieve anxiety in their child related to the procedure.[11]

Laboratory PSGs were scored by a registered PSG technologist blinded to the child's identity and group (ASD good sleep, ASD poor sleep, TD) and to the order of the studies (laboratory night 1 vs 2). Studies were staged for sleep architecture and scored for respiratory events (apneas and hypopneas), leg movements, and nocturnal events (e.g., abnormal movements or behaviors). A sleep physician reviewed each study to ensure accuracy in scoring. Stages NREM 3 and 4 sleep were combined into one stage as is the practice in most sleep centers. Sleep efficiency was defined as time asleep/time in bed; sleep latency was defined as the time from lights out to sleep onset. An apnea was defined as a ≥90% decrease in airflow for ≥10 seconds with preservation of respiratory effort. A hypopnea was defined as a ≥50% decrease in the airflow for ≥10 seconds, associated with an EEG arousal[12] or an oxygen desaturation of ≥3%. Obstructive sleep apnea was defined by an apnea index (AI; apneas per hour of sleep) of ≥1 or an apnea-hypopnea index (AHI; number of apneas and hypopneas per hour of sleep) of ≥5.

Since insomnia is the most prominent sleep concern reported by parents of children with ASD, we hypothesized that sleep latency would be prolonged, sleep efficiency and total sleep time would be decreased, and night wakings would be increased in the ASD poor sleepers compared with the ASD good sleepers.

Behavioral Measures

Child Behavior Checklist (CBCL)

Parents completed the Child Behavior Checklist (CBCL).[13,14] The CBCL is a parentally completed questionnaire used to examine daytime behavior in children, including those with sleep problems.[15] Because separate CBCL forms spanned the age range of our participants (one for ages 1½-5 years and one for ages 6-18 years), we included scales common to both forms which we believed might be affected by poor sleep or ASD. These included the syndrome scales of anxious/depressed, somatic complaints, attention problems, and aggressive behavior, and the Diagnostic and Statistical Manual (DSM) scale of affective problems. By definition, T-scores of ≥70 (≥98th percentile) are in the clinical range, less than <65 (<93rd percentile) are in the normal range,

and between 65 and 70 (93rd – 98th percentile) are in the borderline clinical range.

Autism Diagnostic Observation Schedule (ADOS)

Children with a clinical diagnosis of ASD were given the ADOS[8] to validate the diagnosis. The ADOS module was chosen on the basis of participants' age and language skills, as specified in the manual, with 13 children receiving module 3, 7 children receiving module 2, and 1 child receiving module 1. A classification of autism or ASD was determined using algorithm items and specified cutoffs. The scores from the ADOS communication and socialization domains were also analyzed in relation to parental sleep concerns. Although the ADOS was not developed as a measure of autism symptomatology, it has been used to assess efficacy of treatment in autism clinical trials.[16]

To compare ADOS results quantitatively across participants who were given different modules, only the algorithm items that were common to ADOS modules 2 and 3 were used (the one child who received module 1 was excluded from this analysis). Three communication items were used in the analysis: (a) stereotyped/idiosyncratic use of words or phrases, (b) conversation, and (c) descriptive, conventional, instrumental, or informational gestures. Six items from the reciprocal social interaction domain were used: (a) unusual eye contact, (b) facial expression directed at others, (c) quality of social overtures, (d) quality of social response, (e) amount of reciprocal social communication, and (f) overall quality of rapport.

Peabody Picture Vocabulary Test (PPVT)

The PPVT-III[17] was given to ensure adequate receptive language understanding in order to facilitate comprehension and cooperation with PSGs. Standard Scores on the PPVT could not be more than 1½ standard deviations below the mean.

Statistical Analyses

Data were tabulated in a web-based database, and analyses were performed using SAS for Windows (version 9). All statistical comparisons were performed using two-sided tests at the 5% significance level. For small sample comparisons (sample size <20 per group), exact P-values were estimated using Monte Carlo estimation with 10,000 resamples.

For the sleep data (night 1 and night 2 PSGs and the CSHQ), our goal was to identify differences in the ASD groups (good sleepers vs poor sleepers). The TD children (all good sleepers) were included as a comparison group for the ASD good sleepers to determine if ASD good sleepers differ from typically developing children on sleep parameters (as has been shown in prior work[5]). For the CBCL data, our goal was to compare all three groups (ASD good sleep, ASD poor sleep, TD) since both ASD and sleep patterns may be associated with behavioral problems. Because inspection of the data revealed unequal variances in the groups, the nonparametric Kruskal-Wallis statistic was used for overall comparisons. Between-group comparisons, using the Mann-Whitney U test, were performed only for the PSG, CSHQ, and CBCL parameters that were significant overall. Although multiple sleep and behavior parameters were examined, each parameter was of interest in its own right, so we chose to report all individual P-values and make separate statements regarding them by interpreting each result in relation to our hypotheses. As recommended by Cook (1996), when multiple univariate test results have implications on specific responses, multiplicity corrections to control for the simultaneous correctness of all parameters do not necessarily need to be considered, as it is more relevant to know the strength of evidence for testing individual hypotheses on each parameter.[18]

The ADOS was performed only in children with ASD, with the Pearson-chi square test used to compare the frequency of diagnoses of autism vs PDD-NOS across the 2 ASD sleep groups. The Mann-Whitney U test was performed to compare the ADOS scores between the 2 groups. The 3 groups (2 ASD groups and TD group) were also examined on age, socioeconomic status, and PPVT score using the Kruskal-Wallis test for overall differences and the Mann-Whitney U test for group comparisons. Spearman correlations for nonparametric data were used to compare night 1 sleep latency with CBCL scales.

RESULTS

Participants

Between April 2004 and December 2005, 29 children with ASD met study criteria and completed ADOS and PPVT testing, with parents completing the CSHQ and CBCL. Of the 29 children eligible for the study, 13 (45%) were classified by parents as poor sleepers and 16 (55%) as good sleepers.

Parents of 21 of these children agreed to having their child participate in video-EEG-PSG studies. Eleven children were classified by their parents as poor sleepers and 10 as good sleepers. Ten age-comparable TD children, all good sleepers, also underwent PSGs. The nonparticipating children were compared on demographic (age, socioeconomic score, and PPVT), CSHQ, CBCL, and ADOS measures to the children with ASD who participated in the video-EEG-PSG testing. There were no group differences except for the CSHQ domain of sleep disordered breathing being higher in the participating children (P = .01).

Of the 31 children (21 ASD and 10 TD), all but one (ASD good sleeper) tolerated both nights of testing. In 2 children, one in the ASD good sleeper group and one in the TD group, electrode artifact or equipment malfunction precluded interpretation of the second night of study.

Demographics

Age in months and socioeconomic status did not differ among the 3 groups (ASD good sleep, ASD poor sleep, TD; Table 1). All groups were predominantly male (9 boys with ASD good sleep, 9 boys with ASD poor sleep, 8 TD boys); there were no significant differences.

PPVT standard scores were within 1 standard deviation of the mean (i.e., ≥85) in all but 2 participants. One ASD poor sleeper (age 6) had a PPVT standard score of 78 with a corresponding age equivalent of 4.1 years, and one ASD good sleeper (age 4) had a PPVT standard score of 82 with an age equivalent of 3.0 years.

The PPVT standard score was lower in the ASD poor sleepers than the TD children (P < .0001) but was not different from the ASD good sleepers. The values for the TD children were comparable to normative values for children of similar ages.[17]

Sleep Related Measures

Sleep Histories and Sleep Diaries

In the ASD poor sleepers, 7 parents rated their children as having moderate sleep problems and 4 parents reported severe sleep problems. The major sleep concern expressed by parents of children in the ASD poor sleep group was difficulty falling asleep, which was reported in 9 of 11 children. Children were described as taking a long time to wind down and were observed to engage in behaviors such as replaying cartoons in their heads or talking incessantly. Other children were described as anxious and scared of the dark or of seeing insects in their beds. On sleep diaries, only 2 children were noted to fall asleep within 20 minutes on most nights, with some children documented to take as long as 3-5 hours on occasional nights. Night wakings were of concern in 5 of 11 participants although only 2 parents considered night wakings to be the predominant sleep concern (as opposed to falling asleep). Children were described to wander from their rooms and be found asleep outside their bedrooms. Two children engaged in undesired behaviors such as attempting to get out of the house to visit a relative next door or sleep eating. Early morning wakings (without a return to sleep) were not observed. Two children were noted to be loud snorers and have restless sleep; one was diagnosed with obstructive sleep apnea on PSG as noted below and the other did not meet criteria for obstructive sleep apnea on PSG.

In the ASD good sleepers, 4 parents rated their children as having no sleep problems and 6 parents reported mild sleep problems. These problems included mild bedtime resistance, mild or infrequent sleep onset delay (one child was observed to talk to himself in his bedroom for hours but this occurred only once per month), or occasional night wakings with rapid return to sleep.

Table 1—Participant Characteristics

	Mean (SD)		
	ASD Poor Sleep	ASD Good Sleep	TD (Good Sleep)
	n = 11	n = 10	n = 10
Age, mo	74.7 (20.0)	77.2 (26.5)	91.4 (26.4)
Socioeconomic status	47.9 (8.7)	56.9 (9.7)	49.9 (7.1)
PPVT	92.6 (6.5)*	105.1 (17.9)	112.3 (13.8)

*ASD poor sleep vs TD; P< .0001
PPVT = Peabody picture vocabulary test; ASD = autism spectrum disorder; TD = typically developing
PS = poor sleep; GS = good sleep

Table 2—Sleep Parameters

	Mean (SD)			P-values		
	ASD Poor Sleep n = 11	ASD Good Sleep n = 10	TD (Good Sleep) n = 10	Overall	ASD PS vs GS	ASD GS vs TD
Night 1 PSG						
n1_total sleep time (min)	434.1 (66.5)	462.6 (68.7)	469.8 (28.7)	.5507		
n1_sleep efficiency (percent)	75.8 (9.3)	87.5 (9.0)	86.7 (4.1)	.0018	.0091	.3065
n1_sleep latency (min)	97.8 (71.2)	30.3 (17.7)	25.1 (19.4)	.0015	.0079	.5876
n1_WASO (min)	29.9 (19.2)	29.9 (27.1)	45.7 (28.4)	.2951		
n1_NREM stage 1 (percent)	9.1 (3.4)	11.6 (3.8)	11.2 (6.1)	.2740		
n1_NREM stage 2 (percent)	45.8 (7.1)	46.2 (7.6)	48.5 (4.2)	.5375		
n1_NREM stage 3_4 (percent)	32.6 (8.1)	25.1 (6.5)	24.1 (3.9)	.0215	.0446	.6650
n1_REM (percent)	12.5 (5.4)	17.1 (3.3)	16.2 (3.9)	.0275	.0226	.5667
n1_REM latency (min)	162.2 (54.2)	144.3 (40.8)	171.8 (73.9)	.5558		
Night 2 PSG						
n2_total sleep time (min)	465.8 (48.2)	475.5 (62.8)	484.9 (31.7)	.5483	.3800	
n2_sleep efficiency (percent)	85.0 (6.5)	88.2 (7.5)	87.7 (4.1)	.1652	.0928	
n2_sleep latency (min)	57.1 (50)	29.4 (38.6)	33.6 (22.1)	.1012	.0638	
n2_WASO (min)	24.0 (13.9)	21.6 (6.7)	32.3 (13.1)	.1473	.8247	
n2_NREM stage 1 (percent)	8.4 (4.4)	10.2 (5.6)	8.9 (3.5)	.8291	.4697	
n2_NREM stage 2 (percent)	47.4 (8.1)	45.1 (7.2)	46.6 (5.0)	.7469	.5221	
n2_NREM stage 3_4 (percent)	27.7 (9.3)	27.0 (7.3)	27.8 (4.3)	.9859	.9060	
n2_REM (percent)	16.6 (3.2)	17.8 (4.9)	16.8 (2.8)	.8681	.5952	
n2_REM latency (min)	162.0 (26.2)	148.9 (61.3)	150.7 (65.2)	.5558	.7922	
CSHQ						
Bedtime resistance	9.6 (3.0)	7.8 (2.6)	7.2 (1.6)	.0421	.0544	.5770
Sleep onset delay	2.2 (.9)	1.3 (0.5)	1.3 (0.7)	.0124	.0256	1.0000
Sleep duration	6.1 (1.4)	4.1 (1.3)	3.5 (1.3)	.0001	.0046	.1378
Sleep anxiety	7.6 (2.3)	5.7 (2.0)	4.4 (0.7)	.0002	.0566	.0749
Night wakings	5.5 (2.6)	4.0 (1.9)	4.0 (1.3)	.4485		
Sleep dis. breathing	4.27 (1.56)	3.5 (0.53)	3.20 (0.42)	.1362		
Daytime sleepiness	15.45 (3.56)	12.8 (4.29)	12.6 (3.13)	.1725		
Parasomnias	10.64 (2.62)	9.4 (2.27)	8.3 (1.16)	.0973		
Sleep total	57.64 (9.84)	45.7 (8.08)	42.1 (5.93)	.0001	.0085	.2464

n1 = night 1, n2 = night 2; WASO = wake time after sleep onset
ASD = autism spectrum disorder; TD = typically developing
PS = poor sleep; GS = good sleep; CHSQ = Children's Sleep Habits Questionnaire

Table 3—Child Behavior Checklist Scales

	Mean (SD)				P-values		
	ASD Poor Sleep n = 11	ASD Good Sleep n = 10	TD (Good Sleep) n = 10	Overall	ASD PS vs GS	ASD GS vs TD	ASD PS vs TD
Affective problems	72.3 (9.0)	62.5 (11.3)	53.1 (4.2)	.0001	.0405	.0249	.0001
Attention problems	69.8 (15.5)	61.8 (8.5)	53.6 (4.8)	.0010	.2795	.0184	.0013
Anxious/depressed	64.9 (14.2)	57.1 (9.1)	51.7 (2.5)	.0156	.1232	.2530	.0056
Aggressive behavior	59.8 (8.2)	56.1 (9.5)	51.9 (3.4)	.0665			
Somatic complaints	61.2 (10.1)	56.8 (7.5)	54.3 (5.4)	.1562			

ASD = autism spectrum disorder; TD = typically developing
PS = poor sleep; GS = good sleep

Table 4—Correlations between night 1 sleep latency and CBCL domains

	Correlation	P-value
Affective problems	0.631	.000
Attention problems	0.344	.068
Anxious/depressed	0.398	.032
Aggressive behavior	0.466	.011
Somatic complaints	0.108	.576

Several of the ASD good sleepers requested to go to bed, and one would get frustrated if bedtime did not occur on schedule. One child snored loudly but did not meet evidence for sleep apnea on PSG. On sleep diaries, only 2 children were noted to take ≥30 minutes to fall asleep (one took 30 minutes and one took 30-90 minutes).

Polysomnography

Night 1 PSG showed significant overall differences among the groups for sleep efficiency and sleep latency (Table 2; Figures 1 and 2). The ASD poor sleepers differed significantly from the ASD good sleepers and the TD children on both measures, having lower sleep efficiency and prolonged sleep latency. Night 1 PSG also showed decreased REM sleep and increased NREM stages 3 and 4 sleep in the ASD poor sleepers compared with the other groups. The ASD good sleepers and the TD children did not differ on any of the sleep architecture parameters. As described in the sleep histories, several ASD poor sleepers were observed to lie awake for hours, talking incessantly about a restricted topic.

Night 2 PSG did not show significant differences overall among the groups.

The values for the TD children were comparable to normative values for children of similar ages on all parameters, with the exception of REM latency being higher than typical pediatric norms.[19]

Only one child, a poor sleeper with a history of loud snoring, stoppage of breathing, and choking and gasping during sleep, met criteria for obstructive sleep apnea on PSG. After undergoing adenotonsillectomy, her sleep latency and efficiency improved as did her CSHQ and CBCL scores; ADOS remained unchanged. Her case has been published separately.[20] Periodic limb movements of sleep (> 5/hour) were noted in 2 children with ASD who were poor sleepers and 3 children with ASD who were good sleepers. No parasomnias or epileptic seizures were recorded. Tonic and phasic muscle tone during REM sleep was normal.

CSHQ

CSHQ dimensions of bedtime resistance, sleep onset delay, sleep duration, sleep anxiety, and total score differed significantly overall among the 3 groups (Table 2). The ASD poor sleepers differed from the ASD good sleepers on 2 of these dimensions, having higher scores on the scales related to sleep onset delay (longer) and sleep duration (shorter), as well as a higher total CSHQ scale. The ASD good sleepers did not differ from the TD children on any of these dimensions.

The CSHQ dimensions of night wakings, sleep disordered breathing, daytime sleepiness, and parasomnias did not differ significantly among the 3 groups.

A visual comparison of CSHQ subscale scores obtained in pre-

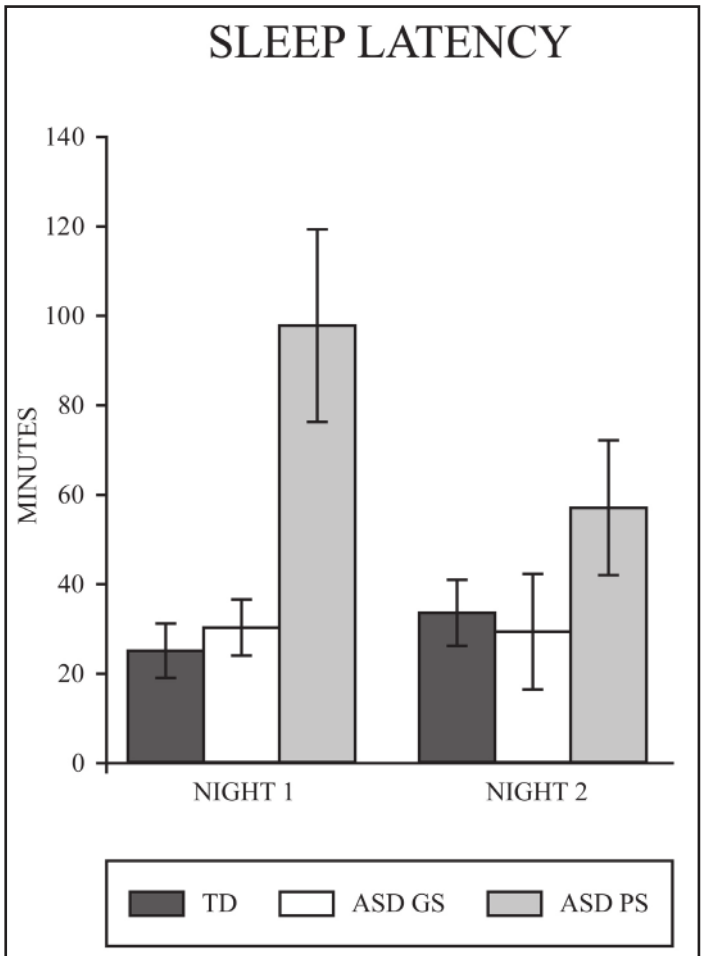

Figure 1—Night 1 sleep latency in the ASD poor sleepers was significantly worse compared with the ASD good sleepers and the TD children, who did not differ. There were no significant differences among groups on night 2. See Table 2 for sleep parameters and overall and group comparisons. Bars in figure are standard errors.

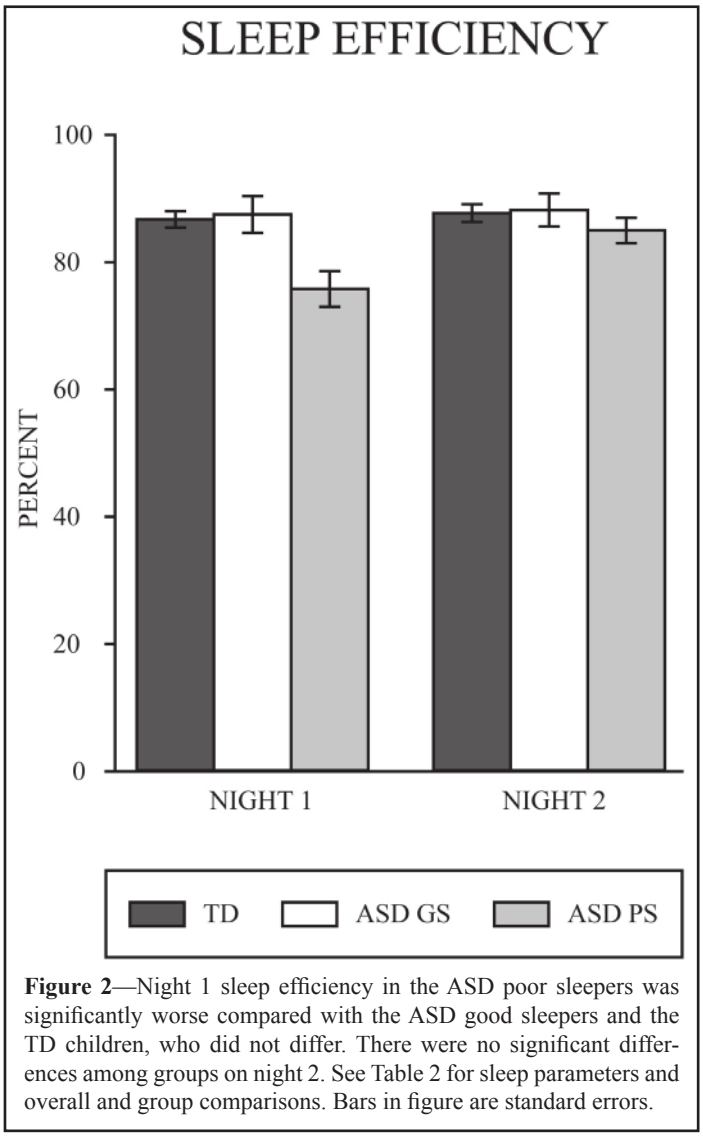

Figure 2—Night 1 sleep efficiency in the ASD poor sleepers was significantly worse compared with the ASD good sleepers and the TD children, who did not differ. There were no significant differences among groups on night 2. See Table 2 for sleep parameters and overall and group comparisons. Bars in figure are standard errors.

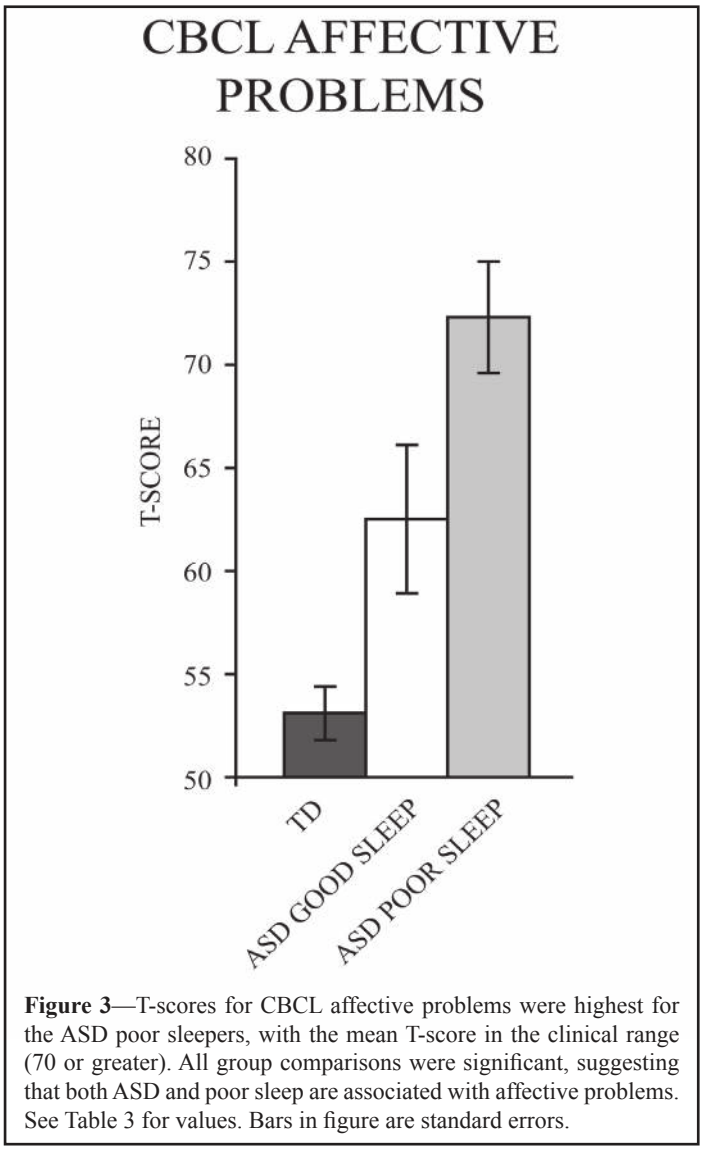

Figure 3—T-scores for CBCL affective problems were highest for the ASD poor sleepers, with the mean T-score in the clinical range (70 or greater). All group comparisons were significant, suggesting that both ASD and poor sleep are associated with affective problems. See Table 3 for values. Bars in figure are standard errors.

vious research, involving children with ASD who were seizure-free and who had average IQ scores, revealed mean values that were intermediate between those of our ASD poor sleep and good sleep groups, supporting the idea that our data are comparable to others.[3] In addition, the values for the TD children on the CSHQ subscales were comparable to normative values for children of similar ages.[10]

Behavioral Measures

CBCL

CBCL scales of affective problems, attention problems, and anxious/depressed differed significantly overall among the 3 groups (Table 3). For all 3 of these scales, T-scores were highest in the ASD poor sleepers, intermediate in the ASD good sleepers, and lowest in the TD children. On the affective problems scale (Figure 3), group comparisons (ASD good sleep vs poor sleep, and TD vs the 2 ASD groups) were all significant, with ASD poor sleepers having a mean T-score in the clinical range. Mean T-scores for the ASD good sleepers and the TD children were in the normal range. On the attention problems scale the ASD poor sleepers did not differ significantly from the ASD good sleepers, while both ASD groups differed significantly from the TD children. On the anxious/depressed scale the ASD poor sleepers differed from the TD children, but the ASD good sleepers did not differ from either group. CBCL dimensions of anxious/depressed, affective problems, and aggressive behavior correlated significantly with sleep latency on night 1 of PSG (Table 4).

The values for the TD children were comparable to normative values for children of similar ages.[13,14]

ADOS

In the 11 ASD poor sleepers, autism was diagnosed in 7 and PDD-NOS in 4. In the 10 ASD good sleepers, autism was diagnosed in 4 and PDD-NOS in 6. The distribution of autism vs PDD-NOS was not related to good vs poor sleep (P = .28), although compared with the ASD good sleepers, the ASD poor sleepers scored higher (worse) on the reciprocal social interaction (B) items (6.8 ± 1.9 vs 4.8 ± 1.5; mean ± standard deviation; P = .047). The communication (A) items and total (A + B) ADOS scores did not differ between ASD good and poor sleepers.

DISCUSSION

This study presents a multidimensional evaluation of parental sleep concerns in relation to PSG and measures of behavior and autism symptomatology in a group of children with ASD. We

found that children with ASD with moderate to severe parental sleep concerns (poor sleepers) differed from those children with ASD whose parents have no or only mild sleep concerns (good sleepers) on a variety of measures. Our study is unique in combining PSG findings with parent reports of sleep and daytime behavior as well as objective measures of autism symptomatology. We limited our cohort to children 4-10 years old who were free of psychotropic medications and epileptic seizures and without mental retardation, as these factors contribute to heterogeneity and can also affect sleep.[21-23] Given the limited work relating parental sleep concerns in ASD to PSG and behavioral measures, we made the decision to focus on a homogeneous sample. While studying a homogenous population is a relative strength, we recognize that one shortcoming of our work is that we cannot generalize our findings to children with ASD as a whole.

Sleep Findings in Relation to Parental Concerns

Children described as poor sleepers had higher scores on the CSHQ dimensions of sleep onset delay and sleep duration. However, poor sleepers did not have higher scores on other CSHQ dimensions, such as sleep disordered breathing, daytime sleepiness, or parasomnias. This finding supports an established literature documenting that the predominant sleep concern in ASD is insomnia (see introduction for references). Furthermore, parents did not globally report problems with their children's sleep but limited the problem area to insomnia. Although the CSHQ dimension of night wakings did not differ among groups, this finding may be explained by our cohort of children having more difficulties with sleep initiation rather than maintenance of sleep. The predominant concern of sleep-onset insomnia was also borne out in the sleep histories.

The objective findings of prolonged sleep latency and diminished sleep efficiency in the poor sleepers on night 1 of PSG further validate the ability of parents to differentiate their children as good sleepers and poor sleepers. This finding of increased sleep latency and decreased sleep efficiency in the poor sleepers was also noted on night 2 of laboratory PSG but did not reach statistical significance. The influence of night of study on group differences may be explained by an exaggerated first-night effect in the ASD poor sleepers, in which sleep is disrupted due to a participant's unfamiliarity with the sleep laboratory environment and the monitoring devices.[24] The ASD poor sleepers exhibited higher T-scores on the CBCL scale of anxious/depressed. It is possible, therefore, that the increased anxiety observed in the ASD poor sleepers contributed to a more pronounced first-night effect in this group. Night 2 may have represented a "catch-up" night in the ASD poor sleepers, who were more sleep-deprived on the first night of study than the other two groups, thereby minimizing group differences. The prolonged sleep latencies cannot be explained entirely by a first night effect, however, as review of sleep diaries in the poor sleepers showed that some children took 3 to 5 hours to fall asleep on some nights. An alternative possibility is that the combination of a first night effect and a small sample size precluded our detecting statistically significance on night 2, as compared to night 1. Future studies with a larger number of participants may bear out group differences on both nights. In addition, a third night of PSG may resemble the child's habitual sleep (e.g., no first night effect or "catch-up" effect) and may be appropriate to perform in future studies. Actigraphy is another option for estimating sleep parameters in the child's natural sleep setting that has been used in children with ASD. Results have been mixed, however, with actigraphy confirming parental report of sleep concerns in one study[25] but not others,[4,6] and further validation studies of actigraphy, possibly combined with video and/or PSG, may be warranted.

Most PSG studies of sleep in children with ASD have focused on abnormalities related to rapid eye movement sleep in ASD (decreased quantity, more undifferentiated sleep, more immaturity in the organization of eye movements into discrete bursts).[26,27] One group of investigators diagnosed REM sleep behavior disorder, with lack of muscle atonia during REM sleep in 5 of 11 children with ASD who had symptoms of disrupted sleep and nocturnal awakenings.[28] Although we noted decreased REM sleep on night 1, we did not observe abnormalities in muscle tone during REM sleep. The absence of such findings in our cohort may reflect that they were medication-free, as medications such as selective serotonin reuptake inhibitors may cause or contribute to lack of muscle atonia during REM sleep.[29]

Our study is also notable for documenting a relative absence of other sleep disorders on PSG, including sleep apnea, parasomnias, and sleep-related seizures. The CSHQ domain of sleep disordered breathing was higher in children undergoing PSGs than those who did not, raising the possibility that parents may have been motivated to have their children participate in the PSG testing because of concerns of obstructive sleep apnea. In fact, only one child had evidence of obstructive sleep apnea on PSG, and this child's mother had reported loud snoring, stoppage of breathing, and choking and gasping during sleep on the CSHQ, with confirmation of these symptoms during a sleep history.

Only one PSG study in children and adolescents with ASD documented abnormalities in parameters of sleep continuity in relation to behavioral instruments. These investigators found that total sleep time was negatively correlated with nonverbal communication on the Childhood Autism Rating Scale.[30] In adults with ASD, disrupted sleep continuity has been reported, with total sleep time correlating negatively with social and communication scales of the Autism Diagnostic Interview-Revised.[31] This comprehensive study in adults with ASD limited participants to those without mental retardation, epileptic seizures, psychiatric disorders, or psychotropic medications. Their findings are similar to ours in noting that individuals with ASD have prolonged sleep latency compared to age- and sex-matched controls; these investigators also noted more frequent nocturnal awakenings, lower sleep efficiency, increased duration of NREM stage 1 sleep and decreased deeper stages of NREM sleep. These investigators did not differentiate individuals with ASD who were relatively "good sleepers" from "poor sleepers," although no participants entered into the study had diagnosed sleep disorders.

Relation of Parental Sleep Concerns to Daytime Behavior and to Autism Symptomatology

The ASD poor sleepers had the highest T-scores on all scales of the CBCL examined, with significance reached for affective problems, attention problems, and the anxious/depressed scale, on which they differed from the TD children. On the affective problems scale, the ASD poor sleepers also differed from the good sleepers. These findings suggest that while ASD is related to problems in daytime behavior, disordered sleep may also be

a contributing factor. Alternatively, daytime behavior may influence sleep. Our findings cannot determine causality (e.g., whether good sleep is positively influencing behavior or vice versa), and will require further studies that intervene in children with ASD to improve sleep with measurements of behavior prior to and after treatment. Such studies have been done in TD children with obstructive sleep apnea prior to and after adenotonsillectomy and have documented improvements in behavior, particularly related to attention and hyperactivity.[32]

We had anticipated on the basis of these studies, that CBCL scales related to attention would be different in ASD good and poor sleepers. While attention problems did show group differences overall and between the ASD groups and the TD children, the ASD good and poor sleepers did not differ. In contrast, the good and poor sleepers were differentiated by the CBCL affective problems scale. Our findings may be explained by: (1) Differences in the scales used (Conners' Parental Rating Scales-Revised[33] and the Child Symptom Inventory-4: Parent Checklist[34]); (2) Differences in the effects of obstructive sleep apnea and insomnia on daytime behavior; and (3) Differences in the effects of sleep disruption on daytime behavior in children with ASD compared with TD children. While both OSA and insomnia result in disruption of sleep, sleep disordered breathing involves repetitive brief arousals with or without hypoxemia. In contrast, insomnia involves prolonged time to fall asleep and discrete awakenings without hypoxemia. Furthermore, children with ASD may be predisposed to affective problems, which are associated with insomnia.[35] Additional studies in ASD relating parental sleep concerns to daytime behavior will be needed to validate our findings.

Reciprocal social interaction scores on the ADOS, but not ADOS communication scores, were also lower for the ASD poor sleepers as compared to the ASD good sleepers. Unlike the CBCL findings, in which the response may have been influenced by parental perception of sleep (e.g., parents who responded that sleep was a problem were also more likely to respond that behavior was a problem), the ADOS was given by examiners not aware of the child's classification into the ASD good or poor sleeper groups, or results of the PSG studies. As with the CBCL findings, we cannot determine if good sleep is positively influencing autism symptomatology or whether children with higher levels of autism symptomatology demonstrate poorer sleep. Interventional studies will be necessary to determine causality in relation to sleep and behavior. Others have also reported a relation between sleep problems in children with ASD and daytime behaviors associated with autism symptomatology. Short sleep duration in children with ASD has been associated with stereotypic behavior, as well as inflated overall autism scores and social skills deficits.[36] Sleep problems in children with ASD have also been associated with repetitive behaviors and a desire for sameness, although this relation may be moderated by the level of cognitive ability.[37]

We found that a single question about a child's sleep from a parental concerns checklist, in which parents described the extent to which a sleep disturbance had been a problem for them within the last month, was a significant predictor of PSG findings. This question also correlated with behavior and autism symptomatology. Other investigations of developmental status have obtained similar findings, and underscore the importance of parental report in the assessment of sleep disturbances and other concerns in children with ASD.[38,39]

Our work demonstrates that some children with ASD sleep well—in fact a subset of children with ASD were identified by their parents as good sleepers and exhibited similar sleep patterns to age-comparable TD children. The observation that a subset of children with ASD may be good sleepers has not been emphasized in the literature, with most investigators combining all children with ASD into one group for comparison with non-ASD controls. Honomichl et al (2002) also observed that some children with ASD sleep well. In their study, 46% of children were reported not to have a sleep problem, in comparison to 55% of children in our sample reported to have no or mild sleep problems.[5] Understanding why certain subsets of children with ASD sleep relatively well may be helpful in defining the etiology of insomnia in this population. Insomnia in ASD is most likely multifactorial, with neurochemical (abnormalities in serotonergic transmission or melatonin levels), psychiatric (anxiety), and behavioral (poor sleep habits) causes implicated.[40]

In summary, our findings support that children with ASD and parental sleep concerns differ from those without parental sleep concerns on PSG measures, sleep duration and sleep onset delay, affective problems, and social interaction. Our work cannot establish whether sleep problems influence behavior and autism symptomatology or whether these factors adversely affect sleep. Interventional studies aimed at improving sleep through pharmacological therapies, behavioral treatments, or both will be necessary to determine if improving sleep in children with ASD can positively influence daytime behavior and autism symptomatology.

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