Actigraphy and Parental Ratings of Sleep in Children with Attention-Deficit/Hyperactivity Disorder (ADHD)

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All research was conducted at the Hospital for Sick Children, Toronto, Ontario, Canada.

Study Objectives: To assess various sleep parameters in latency-aged children with ADHD and their normally developing peers through the use of multiple sleep measures.

Design: Six sleep parameters were evaluated for two groups of children, ADHD and normal comparison. Each group consisted of 25 children (20 males, 5 females) who ranged in age from 7 to 11 years. All children underwent rigorous diagnostic procedures and the ADHD subjects were selected only if they displayed pervasiveness in their symptomatology and were medication naive. Parents completed a retrospective questionnaire which evaluated sleep problems over the past six months. Additionally, each child wore an actigraph for seven consecutive nights, and the child's parents completed a sleep diary during this time period.

Setting: N/A

Patients or Participants: N/A

Interventions: N/A

Results: Based on the findings from the questionnaire, parents of children with ADHD reported significantly more sleep problems than parents of normally developing children. However, the majority of these sleep differences were not verified through actigraphy or sleep diary data, with the exception of longer sleep duration for children with ADHD and parent reports that describe increased bedtime resistence. It was also found that child-parent interactions during bedtime routines were more challenging in the ADHD group.

Conclusions: Despite the possibility of intrinsic sleep problems such as longer sleep duration, results indicate that many of the sleep problems of children with ADHD may be due to challenging behaviours during bedtime routines. The reason for discrepancies among sleep studies employing objective measures as well as between retrospective and prospective measures are discussed.

Key words: Attention-deficit/hyperactivity disorder; children's sleep; actigraphy

INTRODUCTION

NUMEROUS AUTHORS HAVE COMMENTED ON THE PARALLELS BETWEEN THE EFFECTS OF SLEEP DEPRIVATION IN CHILDREN AND the symptoms of attention-deficit/ hyperactivity disorder (ADHD).[1-6] Children with ADHD and children suffering from sleep deprivation share a similar cognitive, behavioral and emotional profile.[1,7] Both groups have been found to experience difficulties on tests of executive functioning, exhibit problems with attention, impulsivity, and restlessness, and have difficulties regulating their emotions (e.g., increased irritability). Paradoxically, sleep-deprived children can display these symptoms without demonstrating overt sleepiness. Although the effects of sleep deprivation in children is based primarily on anecdotal reports, these are supported by a small body of controlled studies (e.g., [8, 9]), as well as by studies examining the effects of sleep deprivation in adults and animals.[10,11]

Treatment studies also provide supporting evidence for a potential link between sleep disturbances and ADHD. For example, a case study of chronotherapy treatment for a latency-aged girl diagnosed with ADHD and a delayed sleep phase insomnia resulted in improvements in ADHD symptomatology and learning that were both sustained over 18 months.[2] Also, improvements in ADHD-like symptoms have been demonstrated in children who have been treated for sleep apnea[3, 12] and who have been treated for periodic limb movement disorder (PLMD).[4] Finally, the mainstay treatment for ADHD, stimulant medication, is also indicated for the treatment of sleepiness in patients with narcolepsy (a primary sleep disorder).

The relationship between sleep disturbances and ADHD is further supported by numerous parental reports of sleep problems in children with ADHD. Based on subjective measures of sleep (e.g., questionnaires), parents of children with ADHD report that their children have more difficulty falling asleep, more night awakenings, shorter naps, more frequent motor movements during sleep, and increased tiredness upon waking when compared to parental reports from normal comparison groups.[13,14] However, objective measures (e.g., polysomnographs, actigraphy) yield little consistent evidence of differences in sleep between ADHD and normal samples. In our recent review of the literature, only three moderately consistent findings across studies were found. Compared to normal controls, children with ADHD had similar sleep durations, more movements during sleep, and had their sleep negatively affected by stimulant medication.[15] However, conclusions based on this literature are difficult as there are numerous methodological issues (e.g., small sample sizes, unclear medication status, and inadequate control procedures). Of particular concern are the inconsistent diagnostic criteria and procedures that were employed across the studies. This is important as different diagnostic procedures may identify

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different children as ADHD, and therefore, findings would not generalize to the larger population of children being diagnosed as ADHD.

Recently, the issue of specificity of sleep problems in children with ADHD has begun to be addressed.[16, 17] In a large-scale study[16] that conducted a factor analysis of a sleep questionnaire completed by parents, it was found that in comparison to normal controls, ADHD children were reported to show more problems in the areas of dyssomnias (e.g., bedtime resistance, sleep onset difficulties, problems with morning awakening) and sleep-related involuntary movements (e.g., restlessness, jerky movements, sleep talking, teeth grinding), but not parasomnias (e.g., night terrors, sleep walking, night waking). However, sleep problems found in the ADHD groups were also evident in a clinical comparison group. Moreover, in the ADHD group dyssomnias were found to be related to a diagnosis of oppositional defiant disorder and stimulant medication use rather than to an ADHD diagnosis. Although involuntary movements were found to be related to a diagnosis of ADHD, they were even more highly associated with a diagnosis of an anxiety disorder.

To date, there exists no theory which specifies the relationship between sleep and ADHD. However, it has been proposed that sleep deprivation in these children could be the result of a primary sleep disorder or be related to dysregulation of arousal mechanisms, which has been implicated in the etiology of ADHD.[18] Both of these explanations indicate that sleep problems are intrinsic to children with ADHD (i.e., physiological in nature and specific to ADHD). Another possible explanation may be that sleep problems are extrinsic to ADHD (i.e., are related to behavioral/environmental factors, and related to general psychopathology). If sleep problems are intrinsic to ADHD, then it would be predicted that sleep problems reported by parents of children with ADHD could be verified through the use of objective measures. However, if sleep problems are extrinsic to ADHD, then reported sleep problems in this population would not be confirmed on objective measures of sleep.

The purpose of the current study was to test whether sleep problems in children with ADHD could be verified across multiple measures of sleep (i.e., questionnaire, sleep diary, and actigraphy). The study examines six sleep parameters in a group of rigorously diagnosed, medication naive ADHD children and a normal comparison group. The six parameters chosen are some of the most common parent-reported sleep problems in children with ADHD. These include difficulties with: 1) sleep duration; 2) sleep onset latency; 3) night awakenings; 4) arising in the morning; 5) motor activity during sleep; and 6) bedtime resistance. Whenever possible, these variables were examined separately for weekdays and weekends, as there are substantial differences between sleep and waking routines during these days. These differences have been shown to directly effect sleep duration.[19] Also, it has been found that children with ADHD evidenced significant increased motor activity during sleep in comparison to normal controls only during school nights, not on weekends.[20]

METHOD

Subjects

The current sample consisted of 50 children, 25 children comprising the ADHD group and 25 children comprising the normal comparison group. There were 20 boys and 5 girls in each group, who ranged in age from 7.1 to 11.10 years. These children are a subsample from a study of parental report of sleep problems in ADHD, clinical and normal comparison groups.[16] All children in the ADHD group were medication naive and reached diagnostic criteria for pervasiveness of ADHD symptoms (i.e., children demonstrated symptoms of ADHD in both the home and school environment). The normal comparison group is a non-referred community sample and none of the children were receiving any treatment for attentional, behavioral, psychiatric, or learning difficulties. Exclusion criteria for participation included the following child variables: Verbal IQ and Performance IQ of less than 80, brain injury, pervasive developmental disorder, autism, psychosis, post-traumatic stress disorder, or a primary disorder of anxiety or affect.

Each child underwent a rigorous diagnostic assessment, including parent and teacher diagnostic interviews and a comprehensive child psycho-educational assessment.[16] In general, the diagnostic evaluation consisted of a face-to-face parent interview, a telephone interview with the child's teacher, and a comprehensive child assessment. The parent and teacher interviews were based on DSM IV[21] criteria for childhood externalizing and internalizing disorders and were administered by trained clinicians. These semi-structured interviews have been demonstrated to be reliable measures for use in diagnosing child psychopathology based on the DSM-III-R,[22] and evaluation of reliability for DSM-IV is in progress. In addition to the diagnostic interviews, parents and teachers completed a number of questionnaires to provide supportive information. The child assessment consisted of various measures of cognitive processing, academic achievement, and psychosocial functioning. The study was approved by the institutional ethics board and both parental consent and child assent were obtained.

Subject Characteristics

Table 1 presents subject characteristics as well as the number of children in each group who reached diagnostic criteria for the various subtypes of ADHD and for other externalizing and internalizing disorders. As per experimental design, the groups did not differ in their gender or age distributions. The mean age was 9.1 years for the ADHD group and 9.7 years for the normal comparison group. As is typically found, the normal comparison group had statistically significant higher IQ scores than the ADHD group, although all were within the normal range. Also, children in the ADHD group were more likely to have a comorbid learning disability (LD), which was defined by a standard score of at least 1.5 standard deviations below the age mean on either the reading or arithmetic subtests of the Wide Range Achievement Test-3.[23] Given the most recent practice parameters for diagnosing a learning disability, an IQ-achievement discrepancy score was not employed.[24]

Due to the fact that the DSM-IV does not specify an algorithm for pervasiveness or combining information across informants, this study employed a "6/4" algorithm to classify ADHD subtypes. For this algorithm, both the parent and teacher interviews were given equal weight. To ensure pervasiveness across settings, the child had to exhibit a minimum of four symptoms in at least one cluster (i.e., inattention or hyperactivity-impulsivity) on

both interviews. To meet diagnostic criteria for ADHD, the child also had to exhibit six symptoms of inattention or hyperactivity-impulsivity on either the parent or teacher interview, or on both interviews. For example, the combined subtype required evidence of at least six symptoms of inattention and six symptoms of hyperactivity-impulsivity, plus evidence of pervasiveness (i.e., at least four symptoms in one of the areas on the other interview). By design of the study, none of the children in the normal comparison group reached criteria for any subtype of ADHD. In the ADHD group, the combined subtype was the most common diagnosis (see Table 1).

A diagnosis of oppositional defiant disorder (ODD) and/or conduct disorder (CD) was given if the child reached diagnostic criteria for these disorders on either the parent and/or teacher interview. A diagnosis of generalized anxiety disorder (GAD), separation anxiety disorder (SAD), and/or major depressive episode (MD) was given if the child reached diagnostic criteria on the parent interview and/or was given a rating of "marked abnormality" on the screen included on the teacher interview. The ADHD group had more children with diagnoses for all externalizing and internalizing disorders; however, only differences in CD and MD reached statistical significance.

Measures

The Child Sleep Questionnaire: Parent Version

The Child Sleep Questionnaire: Parent Version (CSQ-P) provides an assessment of sleep problems and sleep-related issues for elementary school-aged children.[25] It was used previously in a community sample of 972 children between the ages of 5 to 12 years[25] and in a study of parental report of sleep problems in ADHD children.[16] The CSQ-P employs a predominantly multiple choice format and assesses sleep routines, sleep practices, and current sleep problems over the past six months. The questionnaire is divided into four sections that focus on: 1) initial sleep; 2) middle sleep; 3) sleep termination; and 4) sleep-related issues (e.g., assessment/treatment for sleep problems).

A number of sleep indices have been previously developed;[16] however, for the current study only information pertaining to six preselected sleep parameters was utilized. Five questions from the CSQ-P addressed specific sleep disturbances of interest (i.e., sleep onset difficulties, night waking, difficulties arising, restlessness, and bedtime resistance). Two of these items (sleep onset and night awakenings) were rated on a six-point scale (0 "never" to 5 "every night"), one item (bedtime resistance) was rated on a five-point scale (0 "never" to 4 "every night"), one item (difficulty arising) was rated on a four-point scale (0 "no" to 3 "extreme") and one item (restlessness) was rated on a two point scale (yes/no). The child's total time in bed was calculated from questions about the child's typical bedtime and wake time. Of the above six sleep parameters, two items asked the parent to provide information separately for weekdays and weekends (sleep duration and difficulty arising).

Actigraphy

Actigraphs are used in sleep assessment to discriminate between sleep-wake states through documentation of body movements. The actigraphs used in the current study were Basic Mini-Motionloggers from Ambulatory Monitoring, Inc. These actigraphs employ a piezoelectric beam sensor and have a fixed sensitivity at 2-3 Hz and detect accelerations greater than 0.01 g force. The mechanism is encased in a metal, waterproof case and has a 32K memory with a sampling rate of 10Hz. The actigraphs were initialized to employ zero-crossing mode using an auto actigraph interface with a built in comparator (i.e., a magnetically generated calibration signal for comparison of instrument perfor-

Table 1—Subject and diagnostic characteristics

Characteristics	ADHD group (N = 25)	NC group (N = 25)	F-Value/χ^2
age (years, months)	9.12 (1.42 SD)	9.72 (1.31 SD)	1.88
IQ	99.0 (16.10 SD)	114.08 (15.11 SD)	11.66**
LD	8	1	6.64**
Diagnoses			
Hyp-Imp	5	0	5.56*
InA	6	0	6.82**
Combined	14	0	19.44**
ODD	7	2	3.39
CD	8	0	9.52**
GAD	4	1	2.00
SAD	3	1	1.09
MD	3	0	9.52**

Notes: Unless otherwise specified the data indicates the number of children with the diagnosis. ADHD = attention-deficit/hyperactivity disorder; NC = normal comparison group; SD = standard deviation; IQ = intelligence quotient; LD = learning disabled; Hyp-Imp = hyperactivity-impulsivity subtype of ADHD; InA = inattentive subtype of ADHD; Combined = combined subtype of ADHD; ODD = oppositional defiant disorder; CD = conduct disorder; GAD = generalized anxiety disorder; SAD = separation anxiety disorder; MD = major depression.

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

mance over time and between units). The data was extracted using the ACT operational software and summary analyses were computed using the ACTIONW2 software that employed a validated sleep estimation algorithm.[26] Prior to analyzing the data, they were visually inspected to reject any epochs where the actigraph had been removed. The actigraph has been found to have good face validity and its reliability has been documented in numerous studies.[27] Studies have found a high rate of agreement (85—90%) between actigraphy and polysomnography, and actigraphs have been found to distinguish between sleep disturbed and control children with success.[28]

Four variables were computed using the actigraphic data (i.e., total sleep duration, sleep onset, number of night awakenings, and restlessness). Total sleep duration was defined as the number of minutes from sleep onset to wake onset. Sleep onset was measured in minutes from the time the parent indicated "lights out" by pressing the event marker to sleep onset which was defined automatically by the program as the first 20-minute block with greater than 19 minutes of sleep. The number of night awakenings was defined as the number of blocks of contiguous wake epochs between the time of sleep onset and wake onset. Restlessness during sleep was defined as the mean frequency of motor movements per epoch from sleep onset to wake onset. All four sleep parameters were computed separately for weekday and weekend, using the occurrence of school attendance the next day as the definition of weekday (weekday: Sunday, Monday, Tuesday, Wednesday, Thursday; weekend—Friday, Saturday).

Child Sleep Diary

In the absence of any published sleep diaries for children, a comprehensive diary was developed specifically for this study. (A copy of the sleep diary can be obtained from the first author.) In general, sleep diaries are widely used in clinical settings and have been found to have reasonable face validity, high internal consistency, and good agreement with videotapes of children's sleep.[28] The diary collected information for a seven-day period with identical questions for each day. Similar to the CSQ-P, the diary was divided into four sections; 1) getting ready for bed; 2) initial sleep; 3) middle sleep, and 4) waking. In each section, there were questions assessing various sleep parameters, as well as questions assessing the parent-child interactions related to these sleep parameters. Five specific sleep parameters were assessed: 1) sleep duration (difference between the time of sleep onset and the time of arising); 2) sleep onset (the difference between time of lights out and the time the child was reported to have fallen asleep); 3) night awakenings (the reported number of times the child awoke during the night); 4) arising (difference between time of waking and the time of getting out of bed); and 5) bedtime resistance (difference between the time of the first call for bed and the time into bed). The definitions employed for identifying weekday and weekend sleep nights were the same as those used for actigraphy data.

In addition to the above measures, eight questions were completed by the parent who assessed the child-parent interactions during routines associated with sleeping and waking (see Table 5 for questions). All eight questions were answered either with a numerical value (e.g., the number of calls) or were rated on a three-point scale for each night, based on parents' responses in the sleep diary. For parental response the scale was: 0 = "limited or no response needed (e.g., call back to child)"; 1 = "moderate response needed (e.g., go to child's room to check on him/her)"; 2 = "a lot of response needed (e.g., stay in child's room, bring child to parent's bed)". For child response the scale was: 0 = "positive, no problems (e.g., no complaining, bargaining, etc.)"; 1 = "OK, a few problems"; 2 = "poorly, a lot of problems (e.g., lots of complaining, bargaining, etc.)".

Procedure

The parent most familiar with the child's bedtime and waking routines completed the CSQ-P during the initial diagnostic assessment. After completing the questionnaire, a research assistant scanned the questionnaire for missing data and the parent was asked to complete any missing information (this usually occurred over the telephone). If the family had provided consent to participate in the study, orientation to the actigraph and sleep diary occurred approximately one week after the diagnostic assessment.

The family and child were provided with general information on how the actigraph worked and then it was placed on the wrist of the child's non-dominant hand. Instructions were given to remove the actigraph only for showers/baths and when the child was to be engaged in contact sports or swimming. The format and use of the sleep diary was explained to the parent(s) of each child. Specifically, parents were instructed that the diary was to be completed by the parent responsible for bedtime and morning routines. It was to be completed as soon as possible after the child went to sleep and when the child got up in the morning. The actigraph was to be worn and the sleep diary completed for one full week. After the one-week period, the actigraph and sleep diary were collected from the family's home.

Analysis

The Statistical Package for Social Sciences (SPSS) was used for all analyses. The results of the study are presented in three sections: 1) sleep questionnaire; 2) actigraphy; and 3) sleep diary. All of the analyses of the sleep parameters based on data from the sleep diary and actigraphy used repeated measures ANCOVA with age as a covariate, group as the between subject factor, and day of the week (weekday vs. weekend) as the within subject factor. The majority of analyses based on the CSQ-P were not evaluated separately for weekday and weekend (i.e., bedtime resistance, sleep onset, night waking, restlessness), rather these variables were analyzed using an ACNOVA with age as a covariate. For restlessness, a chi square analysis was used to analyze the parents' responses. For items addressing child-parent interactions, information was analyzed by chi-square and one-way analysis of variance.

RESULTS

The Child Sleep Questionnaire: Parent Version

Compliance rates for completing the CSQ-P were 100%. Table 2 displays bedtimes and wake times as well as the descriptive and inferential statistics for each of the six sleep parameters on the CSQ-P. A significant difference between the groups was found on five of the six sleep parameters. The ADHD group was reported to have: longer sleep durations (weekdays: 27 minutes;

Table 2—Data based on parental response on The Child Sleep Questionnaire: Parent Version

Sleep Problem	Measurement	ADHD (n=25)	NC (n=25)	F-Values Group	Days	G X D
Bed time						
weekdays	time-PM (SD-min)	8:39 (41)	8:53 (33)	N/A	N/A	N/A
weekends		9:27 (50)	9:42 (41)			
Wake time						
weekdays	time-AM (SD-min)	7:18 (32)	7:01 (25)	N/A	N/A	N/A
weekends		7:57 (65)	7:51 (53)			
Duration						
weekdays	minutes (SD)	637.5 (25)	610.8 (41)	4.16*	0.47	0.27
weekends		628.8 (56)	609.6 (44)			
Onset	mean(SD)	1.56 (1.58)	0.60 (0.82)	6.03*	N/A	N/A
Awakenings	mean (SD)	0.56 (1.12)	0.24 (0.60)	1.00	N/A	N/A
Arising						
weekdays	mean (SD)	1.08 (0.91)	0.40 (0.65)	9.43**	23.89**	6.46**
weekends		0.32 (0.56)	0.16 (0.48)			
Restless sleep	# subjects with "yes" response	15	5	8.33**	N/A	N/A
Resistance	mean (SD)	2.56 (1.04)	1.04 (0.68)	37.34**	N/A	N/A

Notes: ADHD = attention-deficit/hyperactivity disorder; NC = normal comparison group; Group = main effect of group; Days = main effect for days of the week (weekdays versus weekend); G X D = group by days interaction; SD = standard deviation; N/A = not available for the analysis.
* p<.05 ** p<.01

weekends: 19 minutes), more difficulty with sleep onset, more difficulties awakening in the morning, more of the ADHD subjects were considered "restless sleepers," and more bedtime resistance. The two groups did not differ in the frequency of night awakenings. For the variable of difficulties arising there was a group-by-day interaction which indicated that the ADHD group had more difficulties arising on the weekdays compared to the normal comparison group.

Actigraphy

Of the 50 subjects included in the study, 36 subjects (80%) had actigraphic data for seven days, ten subjects had six days, three subjects had five days and one subject had four days. Of the 14 subjects (seven children from each group) who did not have seven days of actigraphic data, but who were still included in the study because they had completed the minimal requirement of at least four days, three stopped wearing the actigraphy early and the data was lost from the remaining 11 children because of actigraphic equipment failure. Two of the six sleep parameters were not available based on actigraphic data (i.e., bedtime resistance and difficulties arising).

Table 3 documents bedtimes and wake times as well as the descriptive and inferential statistics for the four sleep variables assessed by actigraphy. There were no group differences on any of the four sleep parameters. However, the results for sleep duration approached significance (p=.056), with the ADHD group sleeping an additional 17 minutes on the weekdays and 30 minutes on the weekends. A number of additional indices of motor activity (e.g., mode of activity, standard deviation of activity, percent quiet sleep) were examined; however, none were significant or even approached significance. Confirmatory analyses were conducted whereby only children with complete seven-day data were included (18 children in each group). These analyses resulted in similar findings as the initial analyses, with the exception of a significant main effect for days of the week (i.e., both the ADHD and normal comparison groups evidenced more motor movements during sleep on weekends, compared to weekdays).

Sleep Diary

The majority of subjects completed the sleep diary for the entire seven days (N = 44, 88% of the sample), with three subjects completing six days and three subjects completing four days. Of the six subjects who did not complete the sleep diary for seven days, three had discontinued both the actigraphy and the sleep diaries early, and the other three continued with the actigraphy, but did not complete the sleep diaries. All of the sleep parameters were available on the sleep diary, with the exception of a measure of restlessness (see Table 4). For the sleep parameters of onset, night waking and morning arising, there were no main effects for group or days of the week, or interactions. There was a significant group effect for sleep duration, with the ADHD group sleeping an additional 12 minutes on the weekdays and 18

Table 3—Actigraphy data

Sleep Problem	Measurement	ADHD (n = 25)	NC (n = 25)	Group	Days	G X D
Sleep Time	time-PM (SD-min)					
weekdays		9:48 (51)	10:08 (40)	N/A	N/A	N/A
weekends		10:22 (66)	10:51 (54)			
Wake Time	time-AM (SD-min)					
weekdays		7:12 (36)	7:13 (45)	N/A	N/A	N/A
weekends		7:45 (54)	7:42 (46)			
Duration	minutes (SD)					
weekdays		569.6 (33)	552.9 (41)	3.23	1.06	0.62
weekends		567.8 (53)	538.0 (54)			
Onset	minutes (SD)					
weekdays		22.4 (9)	25.2 (14)	2.56	0.60	0.93
weekends		17.9 (10)	26.5 (25)			
Awakenings	# of contiguous					
weekdays	wake epochs (SD)	15.1 (7.3)	16.6 (6.6)	2.01	0.20	0.12
weekends		15.0 (5.1)	16.5 (5.7)			
Restless Sleep	# movements (SD)					
weekdays		12.0 (5.0)	13.0 (4.9)	0.40	2.26	1.29
weekends		13.9 (6.3)	13.7 (4.0)			

Notes: ADHD = attention-deficit/hyperactivity disorder; NC = normal comparison group; Group = main effect of group; Days = main effect for days of the week (weekdays versus weekend); G X D = group by days interaction; SD = standard deviation; N/A = not available for the analysis.
* p<.05 ** p<.01

minutes on the weekends. There was also a significant group effect for bedtime resistance, with the ADHD children having a longer time between the first call to get ready for bed and the time of actually going to bed.

The child-parent interactions associated with bedtimes were found to be more problematic for the ADHD group (See Table 5). The ADHD children required twice as many calls for bed and three times the number of children with ADHD responded poorly to these calls on at least one night over the week. Also, parents of ADHD children were required to use at least moderate interventions on one or more nights in order for their children to go back to bed prior to sleep onset. There were no differences between the groups in the children's response to "lights out" or the level of interventions required for night awakenings. Also, the groups did not differ in the number of morning calls required to awaken the child. Moreover, the children in both groups did not differ on the number of mornings that they awoke spontaneously over the course of the week.

DISCUSSION

The current study indicates that in addition to the possibility that children with ADHD may have intrinsic sleep problems, there is a need to consider an alternative explanation—that some of the most commonly reported sleep problems may be extrinsic in nature. The majority of sleep parameters which were reported by the parents of ADHD children to be problematic were not verified through the use of sleep diaries or actigraphy. Based on these measures, the groups differed only in that the ADHD group had increased bedtime resistance and longer sleep durations. Supporting evidence for the role of challenging behaviors in sleep problems was found on a number of items that reflect difficulties in child-parent interactions during bedtime routines. Taken together these findings raise the possibility that some of the reported sleep problems may be related to challenging behaviors which often exist in children with ADHD.

Based on the questionnaire data, the ADHD group was reported to have more: bedtime resistance, difficulty with sleep onset, restlessness during sleep, difficulties arising in the morning, as well as a longer sleep duration. The finding that sleep in children with ADHD and their normally developing peers differs based on retrospective questionnaires is consistent with previous research.[13,14] The only sleep parameter examined on the questionnaire that did not differentiate between the ADHD and normal comparison groups was the frequency of night awakenings. This is not surprising, as night awakenings have been found to be problematic in preschool aged samples with ADHD, but not latency-aged samples.[13,14]

Similar to the finding on the questionnaire, the frequency of night awakenings did not differentiate between the ADHD and normal comparison groups based on actigraphy or sleep diary data. However, there were also no differences in the sleep diary or actigraphy for the sleep parameters measuring sleep onset latency, difficulties arising, or motor movements, despite the fact that these were reported sleep problems based on parental questionnaires. Previous research has been inconsistent in regard to differences in sleep onset latency, with shorter, longer, and similar sleep onset being found.[15] No other study has examined dif-

Table 4—Sleep diary

Sleep Problem	Measurement	ADHD (n = 25)	NC (n = 25)	Group	Days	G X D
Sleep Time	time-PM (SD-min)					
weekdays		9:21 (45)	9:14 (36)	N/A	N/A	N/A
weekends		10:01 (66)	9:59 (54)			
Wake Time	time-AM (SD-min)					
weekdays		7:20 (22)	7:02 (29)	N/A	N/A	N/A
weekends		7:50 (44)	7:32 (44)			
Duration	minutes (SD)					
weekdays		579.3 (37)	567.4 (44)	4.91*	3.43	0.12
weekends		568.8 (45)	550.5 (51)			
Onset	minutes (SD)					
weekdays		22.2 (14)	15.4 (8)	1.09	0.17	0.36
weekends		19.5 (24)	15.8 (17)			
Awakenings	# of episodes (SD)					
weekdays		0.16 (0.3)	0.19 (0.3)	0.39	0.01	0.08
weekends		0.14 (0.2)	0.20 (0.4)			
Arising	minutes (SD)					
weekdays		5.4 (4)	7.6 (8)	1.69	0.63	0.49
weekends		5.8 (8)	9.6 (11)			
Resistance	minutes (SD)					
weekdays		28.7 (14)	18.9 (11)	8.09**	2.35	.05
weekends		25.3 (16)	16.4 (12)			

Notes: ADHD = attention-deficit/hyperactivity disorder; NC = normal comparison group; Group = main effect of group; Days = main effect for days of the week (weekdays versus weekend); G X D = group by days interaction; SD = standard deviation; N/A = not available for the analysis.
* p<.05 ** p<.01

ficulties arising using actigraphy and/or sleep diaries.

The finding of similar motor movements during sleep in both the ADHD and normal comparison group is somewhat inconsistent with previous literature, with the majority of studies employing actigraphy finding that ADHD children move more frequently during sleep.[20,29,30] The reason for this discrepancy between previous research and our findings of similar motor movements during sleep may be related to measurement issues. For example, previous studies collected data for varying time periods (e.g., two to seven days), did not control for day of the week (weekday vs. weekend), used a variety of brands of actigraphs with different placements (e.g., wrist, waist), and analyzed the data using different sleep-wake algorithms. Another potential confound that has rarely been controlled for in previous research, is the past or current use of stimulant medication and the comorbidity of the subject sample. For example, stimulant medication and anxiety both have been found to be linked to increased motor movements. Although the findings in the current study are not consistent with the majority of past research, they are very similar to a study that used an analogous methodology in a sample with similar subject characteristics (e.g., medication naive).[31] The current findings are also comparable to a number of studies employing polysomnography.[32,33]

The two consistent findings across measures were that ADHD children showed more bedtime resistance and slept for a longer duration than children in the normal comparison group. On average, the questionnaire data indicated a 23-minute difference, the sleep diary data indicated a 17-minute difference, and the actigraphy data indicated a 20-minute difference. This finding is in contrast to the majority of findings from previous studies. For example, in our review of the literature[15] there was no difference in sleep duration in nine out of ten studies reviewed. The reason for this discrepancy may also be related to methodological issues. Many of the previous studies had small sample sizes and therefore may have not had the power to detect these differences. Also, many of these studies did not control for past or present use of stimulant medication. Controlling for the use of stimulants is important as findings have found that stimulant medication can reduce sleep duration in ADHD children.[31]

Although there was a significant main effect for group on sleep duration, there was no day of the week effect or day of the week by group interaction. This finding would indicate that the difference in sleep duration was similar for both weekdays and weekends. To extrapolate from this finding, there was no evidence that the ADHD sample were "catching up" on sleep during the weekend which could potentially have indicated that these children were sleep deprived. However, this finding needs to be interpreted with caution, as examination of waking times on weekends indicated that many of the children were continuing to awake at similar time as on weekdays. It is not possible with the

Table 5—Qualitative questions on the sleep diary

Question	Data Presentation	ADHD (n = 25)	NC (n = 25)	F-value
Bedtime Resistance				
"How many calls did it take before your child began to get ready for bed?"	mean # of calls per night (SD)	2.13 (1.01)	1.29 (0.37)	14.98 **
"How did your child react to the first call for bed?"	# of children who reacted poorly on at least one night	10	3	5.09*
Sleep Onset				
"How many times did your child call out or get out of bed after lights out and before falling asleep?"	mean # of incidents per night per child (SD)	.91 (1.50)	.47 (0.61)	1.88
"How did the parent respond?"	# of children who required at least moderate interventions on a minimum of one night	17	5	11.69**
Night Awakenings				
"How did the parent respond to night wakings?"	# of children who required at least moderate interventions on a minimum of one night	3	2	0.22
Morning Arising				
"How many calls to awaken him/her?"	mean # of calls per morning (SD)	0.82 (0.83)	0.64 (0.59)	0.87
"Did your child awake on his own this morning?"	# days awoke on own	3.7 (2.32)	4.12 (2.20)	0.39

Notes: ADHD = attention-deficit/hyperactivity disorder; NC = normal comparison group; # = number; SD = standard deviation.
* p<.05 ** p<.01

current data to determine if the weekend wake times were free from scheduled waking times (i.e., some children may have morning sports activities that compelled them to rise early, etc.). Another finding which does not support the notion of sleep deprivation is that both groups awoke spontaneously during the week on a similar number of days. It would be expected if the ADHD group were sleep deprived, they would awaken spontaneously less often than normal controls. An alternative explanation is that increased sleep duration may be related to increased need for sleep as a result of high daytime activity level exhibited in unmedicated ADHD children. Future research is important to replicate our findings and determine why ADHD children require more sleep.

The finding that the ADHD group have more bedtime resistance is a consistent finding in past research. The current study extended past findings by exploring the nature of challenging behaviours across both bedtime and wake time. The current study found that in the ADHD group, parents needed to call their children more frequently to get them ready for bed, received poorer response from their children for these bedtime calls, and their children require more adult attention to settle for the night. Interestingly, the challenging behaviors were not found during waking routines. The reason why challenging behaviors would only be evident at night time needs to be further investigated.

Overall, the findings of the current study provide supportive evidence of our previous findings[16] that indicated that sleep problems defined as dyssomnias (i.e., bedtime resistance, and difficulties with sleep onset and arising in the morning) are related to a diagnosis of oppositional defiant disorder, rather than to a diagnosis of ADHD. Oppositional defiant disorder has been found to be comorbid with a diagnosis of ADHD in up to 90% of these children. Also, the lack of verification of sleep problems through objective measures is consistent with our previous review of the literature.[15] The exact extent that oppositional behaviors affect parents' ratings of sleep problems needs to be further investigated. For example, when asked to rate how problematic sleep onset is for their children, are parents able to separate difficulties managing behaviors up to the time of sleep onset from actual difficulties with sleep onset?

The current study sought to address many of the methodological weaknesses of previous research. First, it used both subjective and objective measures that were separate and distinct from diagnostic and daytime behavior measures. Second, the study applied these sleep measures to a large sample of children who were all medication naive. Third, all subjects underwent rigorous diagnostic procedures and were diagnosed as having pervasive ADHD (i.e., ADHD symptoms in both the home and school environment). Fourth, the ADHD and comparison groups were equated on age and gender composition which is important given the developmental changes in sleep. Finally, the study also employed rigorous experimental procedures. For example, the goal of the current study was to collect sleep diary and actigraphy data for a total of seven days, which has been recommended in recent research.[34]

There are a number of limitations of the current research. First, there may have been a sampling bias, with participation being driven by sleep-related issues. However, it was found that families that chose to participate actually reported more current and past sleep problems for their child than those families who did not choose to participate in the study. This should have biased the study in the direction of finding more differences between groups. Secondly, the current study only assessed a circumscribed number of potential sleep problems and therefore is limited in the generalizability of the findings. Third, the measures employed in the study are not sensitive to all the dimensions of sleep (for a discussion of the limitations of actigraphy see reference [35]). For example, actigraphy does not measure EEG features of sleep. Moreover, the most commonly used actigraphs measure frequency of motor movements, but not other dimensions such as amplitude.

Future research should continue to explore reasons for discrepancies between parent reports of sleep problems and the lack of verification of these sleep problems on objective measures. Several explanations have been suggested to account for these discrepancies.[13,32,26,27,28] These explanations include that: 1) parents of children with ADHD may complete questionnaires with a negative response bias, leading them to over-report all behavioral problems; and 2) parents of children with ADHD may have a lower threshold for reporting difficulties. The current study suggests that rather than a perceptual bias, two additional hypothesis should be considered: 1) that "over-reporting" of sleep problems may be influenced by oppositional behaviors associated with sleep routines; and 2) that the differences are not between subjective and objective measures, but between retrospective and prospective measures. The first hypothesis was supported by the fact that parents of ADHD children consistently reported more challenging behaviors during sleep routines. Also, in comparison to parents of children in the control group, parents in the ADHD group provided closer estimates of sleep parameters on the sleep diary when compared to the actigraphy data, which indicates that they were not "over-reporting." Rather, these parents may be truly experiencing these as "sleep problems," albeit not necessarily intrinsic in nature. The second hypothesis is supported by the fact that findings were similar between sleep diary (a subjective measure) and actigraphy (an objective measure). However, differences in findings existed between retrospective accounts on a questionnaire which reflected problems over the past six months and prospective accounts (which reflected sleep problems over the past seven days).

Given the current research, the clinician would be well advised to focus on both extrinsic (i.e., behavioral) and intrinsic (physiological) components of sleep problems in children with ADHD. Particular attention should be paid to the length of sleep duration (which may need to be increased) and the consistency of parental limit-setting at bedtime. Further intervention studies are needed to clarify the most appropriate approach and to delineate the relative contributions of intrinsic and extrinsic influences on sleep problems in children with ADHD.

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