Snoring, Sleep Quality, and Sleepiness Across Attention-Deficit/Hyperactivity Disorder Subtypes

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Study Objectives: To characterize the relationship between pediatric attention-deficit/hyperactivity disorder (ADHD) subtypes, chronic snoring, and indexes of sleep quality and daytime sleepiness.

Design: A cross-sectional design with planned comparisons of ADHD (all subtypes) versus general community controls; ADHD Predominantly Inattentive Type (ADHD-I) versus a group with both ADHD Predominantly Hyperactive/Impulsive Type (ADHD-HI) and ADHD Combined Type (ADHD-C); and ADHD-HI versus ADHD-C.

Setting: Subjects recruited from a pediatric clinic, a university psycholgy clinic, and the general community.

Participants: Caretakers of 74 children (45 with ADHD, 29 community controls; 53 boys, 21 girls; mean age, 9.6 years; age range, 6 to 16 years). Thirty-two (71.1%) of the children with ADHD were taking stimulant medication and 7 (15.5%) were taking hypnotic medication.

Interventions: N/A.

Measurements and Results: Caretakers completed the Pediatric Sleep Questionnaire (PSQ) and the Children's Sleep-Wake Scale (CSWS). Only the ADHD-HI diagnosis was associated with an increased likelihood of chronic snoring. Sleep quality was poorer among children with ADHD than controls; however, there were no differences in sleep quality across ADHD subtypes. Sleepiness was greater in children with ADHD, especially the ADHD-I Type.

Conclusions: Chronic snoring may be a correlated feature in only a subgroup of the ADHD population, possibly those more likely to be diagnosed with ADHD-HI. Although children with ADHD have poorer sleep quality and greater daytime sleepiness, these 2 features of ADHD are not closely related.

Key Words: ADHD subtypes, snoring, sleep-disordered breathing, sleep quality, sleepiness, children

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INTRODUCTION

ATTENTION-DEFICIT/HYPERACTIVITY DISORDER (ADHD) IS AMONG THE MOST COMMON OF THE PSYCHOLOGICAL DISORDERS AFFECTING SCHOOL-AGED CHILDREN, WITH PREVALENCE ESTIMATES RANGING FROM 4% TO 12%.[1] The cardinal features of ADHD include inattention, hyperactivity, and impulsivity. The pathophysiology of ADHD is not yet well understood but may involve abnormal functioning of dopaminergic, glutamatergic, and other neurotransmitter systems in the prefrontal cortex and additional brain regions.[2,3] There are also reports of reduced regional brain volume in children with ADHD relative to healthy controls, with the volume reduction in some brain areas correlated with symptom severity.[3] The *Diagnostic and Statistical Manual, Fourth Edition* (DSM-IV) identifies 3 subtypes of ADHD: Predominantly Inattentive Type (ADHD-I), Predominantly Hyperactive-Impulsive Type (ADHD-HI), and Combined Type (ADHD-C).[4] Children with ADHD-I have greater problems with persistence of effort and sustained attention than would be expected for normal children of the same age and sex. Children with ADHD-HI have greater difficulties with excessive and inappropriate activity and with impulse control. Children with ADHD-C meet diagnostic criteria for both ADHD-I and ADHD-HI. Subtype classification of ADHD has been a controversial issue. One of several concerns is that ADHD-I may not actually be a subtype of ADHD but, rather, a separate clinical entity.[5]

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Children with sleep disorders characterized by inadequate or poor quality sleep display ADHD-like symptoms.[6-10] A recent review of research on childhood obstructive sleep apnea syndrome by a subcommittee of the American Academy of Pediatrics[11] led to the conclusion that sleep-disordered breathing is associated with an almost 3-fold increase in cognitive and behavioral abnormalities, including hyperactivity, inattention, and sleepiness. Interestingly, in several of the reviewed studies, snoring was found to be a significant factor. Chronic snoring in children is a symptom of obstructive sleep apnea syndrome and other forms of sleep-disordered breathing[12] but may occur independently. In a recent study of snoring and hyperactivity in a general pediatric sample, 22% of habitual snorers versus 12% of nonhabitual snorers had a clinically significant elevation on a standardized measure of hyperactivity.[13]

Overlap in the cognitive and behavioral symptoms of ADHD and sleep-related breathing disorders has led some investigators to suggest that breathing disorders may underlie ADHD diagnosis in a significant number of cases.[14,15] For instance, Chervin and colleagues[14] found that habitual snoring (snoring more than half the time) was more common among children diagnosed with ADHD (33%) than among control children from a psychiatry clinic and a pediatric clinic (9% and 11%, respectively). The authors concluded that, "If a causal effect is present,…25% of all children with ADHD could have their ADHD eliminated if their habitual snoring and any associated SRBD [sleep-related breathing disorder] were effectively treated."[14p1185] Further research on this relationship is needed. One important issue is whether nocturnal breathing disturbances are related to each of the ADHD subtypes. Because the majority of studies reviewed in the American Academy of Pediatrics' report[11] and other studies[16] indicate that snoring and sleep-disordered breathing are strongly linked to hyperactivity, one might expect that nocturnal breathing disturbances would be most strongly related to ADHD with a predominant hyperactivity component.

The primary purpose of this study was to determine whether chronic snoring is found in relation to each of the ADHD subtypes. Following the lead of Chervin et al,[14] children with ADHD (all subtypes) were first

compared to children from the general community. A comparison was then made between the ADHD-I type and that of the remaining 2 subtypes taken together to determine whether chronic snoring is a significant factor only among children with an ADHD diagnosis that includes hyperactivity [ADHD-HI and ADHD-C (ADHD-HI/C)]. A further comparison was made between the ADHD-HI and ADHD-C types. The rationale for this comparison is based on the body of findings showing that snoring is strongly associated with behavioral problems (hyperactivity) but weakly, if at all, related to attention problems (attention deficits). It is possible that the link between nocturnal breathing disturbance and ADHD may involve only the ADHD-HI subtype.

The present study also addressed issues concerning the relationship between sleep quality, daytime sleepiness, and subtypes of ADHD. Children with ADHD not differentiated by subtype are commonly reported by caretakers to have low standing on many behavioral dimensions of sleep quality, including going to bed,[17-19] falling asleep,[17,19-23] maintaining undisturbed sleep,[17-23] returning to sleep after awakening,[20] and returning to wakefulness in the morning.[17,20] Both caretaker reports[24,25] and objective assessments[26,27] suggest that children with ADHD also have significantly greater levels of daytime sleepiness. There are several concerns, however, about how these findings on sleep quality and daytime sleepiness should be interpreted. Although polysomnographic evaluation of a small number of cases provided evidence that sleep disturbance is less likely in ADHD without hyperactivity,[28] little has been done to assess whether sleep quality and daytime sleepiness vary across ADHD subtypes. Additionally, the roles of comorbid disorders and use of stimulant medications are not fully understood.[24,29,30] The subjective reports of increased sleep-onset latencies and increased frequency and duration of nocturnal awakenings have not been consistently verified in studies using objective measures.[17,26,31-35] Moreover, caretaker reports are inconsistent and sometimes contradictory with regard to the features of sleep that are problematic. Corkum and colleagues[32] identified several factors that make the existing literature on the sleep of children with ADHD difficult to interpret. These include across-study differences in diagnostic criteria and diagnostic procedures, studies with low statistical power, and studies with a variety of methodologic and procedural limitations. The across-study differences in caretaker reports are at least partially due to the marked differences in the instruments used to assess sleep quality.

Sleep quality in the present study was measured using the Children's Sleep-Wake Scale (CSWS),[36, 37] which presents an assessment of sleep across 5 different behavioral dimensions (going to bed, falling asleep, maintaining sleep, reinitiating sleep, and returning to wakefulness). It was anticipated that the CSWS would (*a*) provide confirming evidence of an abnormal sleep-quality profile of children with ADHD, (*b*) identify possible differences in sleep quality related to ADHD subtypes, and (*c*) be useful in quantitative analyses of factors associated with poor sleep quality.

METHODS

Participants

Caretakers of 108 children who were enrolled in a study about working memory and ADHD[38] were asked to participate in an additional investigation concerning their children's sleep. Data from 74 children were included in the present analyses. Of the 34 excluded cases, 13 failed to complete at least 1 of the questionnaires, and 21 refused to participate. Children in the ADHD group were recruited from 2 clinical sources: a university school psychology clinic and a local pediatric clinic. The assessment process at both clinics met DSM-IV guidelines[4] and Barkley's[5] suggestions for appropriate assessment practices in the diagnostic process for ADHD. The assessment protocols were multi-method (behavioral observations, clinical interviews, administration of standardized rating scales, IQ tests, and achievement tests) and multi-informant (caretaker, teacher, and child). To receive an ADHD diagnosis, the primary behaviors associated with ADHD (impulsivity, distractibility, and inattentiveness) must have been evidenced across settings, typically home and school. A team of professionally trained personnel conducted all assessments, and clinic directors (pediatrician or psychologist) made all diagnoses. All children with ADHD met DSM-IV criteria. Children with ADHD and comorbid learning disorders were not recruited for inclusion into the working-memory study[38] to allow for the independent assessment of memory processing associated with ADHD. Children with learning disorders were defined as those who qualified under an intelligence-achievement discrepancy model (eg, measure of IQ greater than 85, measure of achievement less than 90, and at least a 15-point discrepancy between IQ and achievement scores). Thus, children with ADHD and a history of learning disorders were also excluded from participation in the present study. Children with other comorbid psychiatric diagnoses and chronic medical conditions were not excluded.

The control group consisted of children from the local community who were neither referred nor receiving treatment for any behavioral, learning, or psychiatric disorders and who were not taking any medications known to affect sleep (eg, stimulants, antihistamines). Control children were recruited from the local community by information posters and through personal referrals made by existing participants.

Table 1 presents the number and characteristics of children with ADHD (all subtypes) and control children. The overall sample consisted of 74 participants (56 males, 18 females) aged 6 to 16 years (mean, 9.6 ± 2.7 years). Ninety-six percent of the children were Caucasian, and 4% were African-American. The ADHD group included a significantly higher proportion of boys than the control group. Only children with ADHD were taking stimulant medication (71.1%), hypnotic medication (15.6%), or both (8.8%). The number of children with chronic illnesses (eg, asthma, allergies) was similar for ADHD and control children and across ADHD subtypes. A positive history of tonsil and adenoid infections, however, was significantly more likely in children with ADHD-I (42.8%) than in children with ADHD-HI/C (16.7%). A total of 5 children

Table 1—Sample characteristics for attention-deficit/hyperactivity disorder and control groups

Characteristic	Comparison A		Comparison B		Comparison C			
	ADHD (n = 45)	Control (n = 29)	ADHD-I (n = 21)	ADHD-HI/C (n = 24)	ADHD-HI (n = 8)	ADHD-C (n = 16)	Statistical Analysis	Significant Comparisons
Mean age, y (SD)	9.8 (2.8)	9.2 (2.5)	10.4 (2.8)	9.4 (2.8)	8.6 (2.3)	9.8 (3.0)		
Boys, %	84.4	62.1	90.5	79.2	87.5	75.0	$\chi^2 = 4.8$, $P < .05$	A
Caucasian, %	93.3	100.0	90.5	95.8	87.5	100.0		
Medications								
Stimulant	32	0	17	15	6	9	$\chi^2 = 36.3$, $P < .001$	A
Hypnotic	7	0	3	4	0	4	FET, $P < .05$	A
Chronic illness (asthma, allergies)	3	2	1	2	2	0		
History of T&A infections, no.	13	4	9	4	2	2	$\chi^2 = 3.7$, $P = .05$	B
Mean BMI (SD)	18.8 (3.7)	17.5 (3.1)	19.4 (4.6)	18.1 (2.4)	17.1 (2.2)	18.6 (2.4)		

ADHD refers to attention-deficit/hyperactivity disorder; ADHD-I, inattentive subtype; ADHD-HI/C, hyperactive/impulsive and combined subtypes; ADHD-HI, hyperactive/impulsive subtype; ADHD-C, combined subtype; FET, Fisher's exact test; T&A, tonsil and adenoid; BMI, body mass index.

with ADHD had comorbid psychiatric diagnoses, including depression, obsessive-compulsive disorder, oppositional defiant disorder, and bipolar disorder. There were no significant differences in the number of children with comorbid psychiatric disorders across ADHD subtypes A(DHD-HI [n = 1], ADHD-I [n = 2], ADHD-C [n = 2]). Referral sources (psychology and pediatric clinics) yielded approximately the same number of children diagnosed with each ADHD subtype.

MEASURES

Pediatric Sleep Questionnaire

The Pediatric Sleep Questionnaire (PSQ) is a pencil-and-paper screening tool that assesses symptom complexes associated with sleep-related breathing disorders in 2- to 18-year-old children.[39] Using the past month as a reference period, caretakers report either "yes," "no," or "don't know" to questions measuring symptom domains, including snoring, daytime sleepiness, and inattentive/hyperactive behavior. Chervin et al[39] presented reliability and validity data for 3 scales: snoring (4 items), sleepiness (4 items), and behavior (6 items). The scale scores represent the proportion of items with an affirmative response (0 to 1). The scales have adequate internal consistency ($\alpha = 0.66$ to $\alpha = 0.89$) and test-retest reliability ($r = 0.66$ to $r = 0.92$) for research instruments and effectively discriminate between children with and without sleep-related breathing disorders.

Chervin and colleagues[14] found that mean scores on the 4-item PSQ Snoring scale did not reliably differentiate between children with and without ADHD. The PSQ Snoring scale contains items assessing both frequency (*snores more than half the time; always snores*) and quality of snoring (*snores loudly*; *heavy breathing*).[39] Several reports[13,14,40] have shown that snoring frequency is associated with ADHD and hyperactive behavior. Furthermore, Guilleminault and Pelayo[12] have opined that chronic snoring is clinically significant because of its association with reduced daytime functioning. Thus, the present analysis focused exclusively on the 2 PSQ items measuring frequency of snoring (chronic snoring).

Given that a factor analysis[39] supports use of a 2-item sleepiness scale (caretaker- and teacher-reported sleepiness) and that the remaining 2 PSQ Sleepiness items (*waking unrefreshed in the morning; hard to wake up*) are highly redundant with the CSWS Returning to Wakefulness subscale (see below), sleepiness in the present study was evaluated without the latter 2 items.

Children's Sleep-Wake Scale

The CSWS is a 40-item pencil-and-paper research instrument that assesses children's sleep quality along 5 behavioral dimensions: going to bed, falling asleep, maintaining sleep, reinitiating sleep, and returning to wakefulness. By design, the scale does not inquire about symptoms of pediatric sleep disorders (eg, obstructive sleep apnea syndrome, periodic limb movements). The CSWS subscales and the CSWS total sleep quality scale (average of the subscale scores) have adequate internal consistency for research instruments ($\alpha = 0.84$ to $\alpha = 0.90$). Details concerning the model upon which the scale is based, scale development, content validity, internal consistency, and construct validity issues are presented in earlier reports.[36,37] The version of the CSWS used in this study required parents to report how frequently during the past month their child exhibited different sleep-related behaviors using a 5-point response set (*never, not often, sometimes, often, always*). A *do not know* response was an option. Scores on each of the 5 CSWS subscales and the CSWS total Sleep Quality scale range from 1 (poor sleep quality) to 5 (good sleep quality). Four of the CSWS items require parents to quantitatively estimate (in minutes) the following: (*a*) time bedtime is delayed, (*b*) sleep-onset latency, and (*c*) time to fully return to wakefulness in the morning. Parents are also asked to report their children's typical weekday and weekend bedtimes and rise times.

Procedure

Student researchers made face-to-face or telephone contact with potential participants and asked for help with a study about differences in the sleep patterns of children with and without ADHD. Caretakers who decided to participate signed an institutional review board-approved consent form and completed a general demographics questionnaire, the PSQ, and the CSWS. All data were collected between August 2000 and May 2001.

Analysis

Statistical analyses included 3 sets of planned orthogonal comparisons (*a*) ADHD (all subtypes) versus control children, (*b*) ADHD-I versus ADHD-HI/C, and (*c*) ADHD-HI versus ADHD-C type. Where appropriate, summary measures were presented as means and SD. Comparisons involving continuous variables were made using *t* or Mann-Whitney U tests. Categorical data were analyzed using a χ^2 test or a Fisher's exact test. The significance level for the described comparisons was set at .05. All unplanned comparisons were conducted with a significance level of .01.

RESULTS

Behavior Scale of the PSQ

Caretakers of children with ADHD endorsed a greater proportion of items on the PSQ Behavior scale than did caretakers of control children (see Table 2). All ADHD subtype comparisons for the PSQ Behavior scale were nonsignificant. That is, the same high level of endorsement of the PSQ Behavior scale items was found for the Inattentive, Hyperactive, and Combined subtypes.

Chronic Snoring and ADHD Subtypes

Table 2 presents the proportion of subjects in each group with chronic snoring (ie, *snore more than half the time* or *always snore*). Although children in the ADHD group were more likely to have chronic snoring (22.5%) than children in the control group (10.7%), and chronic snoring was more common in the ADHD-HI/C group (31.8%) than in the ADHD-I group (11.1%), these differences were not statistically significant. The difference between the ADHD-HI group and the ADHD-C group, however, was significant ($P < .05$). That is, chronic snoring was found in 62.5% of children with ADHD-HI and only 14.3% of children with ADHD-C.

Table 2—Group and subgroup comparisons of item responses and scale scores on the Pediatric Sleep Questionnaire

	Comparison A		Comparison B		Comparison C			
PSQ Subscales	ADHD n = 45	Control n = 29	ADHD-I n = 21	ADHD-HI/C n = 24	ADHD-HI n = 8	ADHD-C n = 16	Statistical Analysis	Significant Comparisons
Mean Behavior (SD)	.79 (.21)	.26 (.32)	.78 (.20)	.81 (.21)	.88 (.19)	.77 (.22)	T = 7.9, $P < .001$	A
Chronic Snoring, %	22.5 (9/40)	10.7 (3/28)	11.1 (2/18)	31.8 (7/22)	62.5 (5/8)	14.3 (2/14)	FET, $P < .05$	C
Sleepiness, %	40.9 (18/44)	7.1 (2/28)	52.4 (11/21)	30.4 (7/23)	25.0 (2/8)	33.3 (5/15)	FET, $P < .001$	A

ADHD refers to attention-deficit/hyperactivity disorder; ADHD-I, inattentive subtype; ADHD-HI/C, hyperactive/impulsive and combined subtypes; ADHD-HI, hyperactive/impulsive subtype; ADHD-C, combined subtype; FET, Fisher's exact test

Daytime Sleepiness and Sleep Quality

Table 2 shows the proportion of children in each group reported by either a caretaker or a teacher as sleepy. Sleepiness was significantly more common among children with ADHD than among control children (40.9% versus 7.1%; $P < .001$), and this effect remained even when the 7 ADHD children using hypnotic medication were removed from the analysis (32.4% versus 7.1%; $\chi^2 = 6.0$, $P < .05$). Although sleepiness was more likely to be reported in children with ADHD-I (52.4%) than in those with ADHD-HI/C (30.4%), this difference was not significant. It should be noted, however, that both a caretaker and a teacher reported 11 of the children with ADHD as sleepy. Of these 11 children, 9 were diagnosed with ADHD-I (42.9% of all ADHD-I children) and 2 were diagnosed with ADHD-HI/C (8.7% of all ADHD-HI/C children). This difference was significant ($P < .05$). Statistical significance was also found for this relationship after excluding children taking hypnotic medication (Fisher's exact test, $P < .05$). Daytime sleepiness in children with ADHD was not significantly correlated (Spearman correlation coefficient) with any of the CSWS subscales.

Bedtime and wake time on weekdays and weekends were statistically the same across all groups (see Table 3). Children with ADHD (all subtypes) were rated significantly lower by caretakers on the Going to Bed, Falling Asleep, and Returning to Wakefulness subscales of the CSWS than were children in the control group (See Table 3). The differences in the ADHD and control groups on the Maintaining Sleep subscale approached significance ($P = .055$). Ratings were especially low on the Going to Bed and Falling Asleep subscales, where 59.1% and 56.8%, respectively, of the children with ADHD were below the first quartile for the control children. As shown in Table 3, caretaker estimates of sleep-onset latency were also longer for children with ADHD (24.7 minutes) than for control children (14.9 minutes; $P < .01$), and Problems Returning to Wakefulness were further indicated by a longer estimated time to fully awaken in the morning (19.3 minutes versus 10.4 minutes, respectively; $P < .05$). No CSWS subscale differences were found between children with ADHD taking (n = 31) and not taking (n = 13) stimulant medication. Children with ADHD who were taking hypnotic medication (n = 7), however, had significantly lower scores on the Maintaining Sleep subscale than did those not taking hypnotic medication (n = 37) (2.9 versus 3.6; $P < .05$). Although there were no significant differences across ADHD subtypes on the CSWS subscales, the difference between the ADHD-HI and ADHD-C groups on the Going to Bed subscale approached significance ($P = .065$). The CSWS Sleep Quality subscale scores of children with ADHD who chronically snore (n = 8) were compared to those of the remaining children (n = 31) to assess whether the presence of snoring accounted for sleep-quality differences. Differences were found only on the CSWS Maintaining Sleep subscale: the mean score for chronic snorers was about 1 SD lower than that of children who did not chronically snore (3.0 versus 3.7; $t = 2.86$, $P < .01$).

DISCUSSION

In summary (*a*) reports of chronic snoring did not differ between ADHD and control children but were more common among children with ADHD-HI relative to other subtypes and to non-ADHD controls; (*b*) in comparison to controls, sleep quality was described as poorer among children with ADHD; however, there were no differences in sleep quality across ADHD subtypes; (*c*) reported sleepiness was more common in children with ADHD than in controls; (*d*) sleepiness reports by both a caretaker and teacher were more likely among children with ADHD-I than among other subtypes; and (*e*) the lower sleep quality of children with ADHD was related to but not fully explained by snoring and use of medications.

The finding of greater prevalence (62.5%) of chronic snoring among children diagnosed with ADHD-HI is based upon a small sample, and further studies with larger samples are needed. This relationship is not surprising, given compelling evidence that hyperactivity and behavioral problems are linked to snoring in children.[11,13] The causal significance of the link between snoring and hyperactivity is not fully understood. Studies describing favorable changes in behavioral assessments and improved academic performance following adenotonsillectomy suggest that sleep-disordered breathing has a negative and reversible effect on daytime functioning in children.[41,42] Chronic snoring independent of OSAS may also have significant negative effects on behavior.[43] Nevertheless, it cannot be ruled out that snoring and mild sleep-disordered breathing are simply features of ADHD. That is, the pathophysiology underlying daytime hyperactivity and impulsivity related to ADHD may involve areas of the brain also involved in regulation of the upper airway during sleep. This appears to be the case in other central nervous system disorders that are associated with an increased prevalence of sleep apnea.[44]

The ADHD subtype comparisons in this study suggest that chronic snoring may not be related to the Inattentive and Combined subtypes of ADHD. Notably, the prevalence of chronic snoring for the ADHD-I and

Table 3—Group and subgroup comparisons of sleep schedules and measures of sleep quality from the Children's Sleep-Wake Scale

	Comparison A		Comparison B		Comparison C			
	ADHD n = 45	Control n = 29	ADHD-I n = 21	ADHD-HI/C n = 24	ADHD-HI n = 8	ADHD-C n = 16	Statistical Analysis	Significant Comparisons
SLEEP SCHEDULE (min)								
Weekday bedtime	21:06 (:40)	20:57 (:46)	21:04 (:44)	21:09 (:37)	21:08 (:37)	21:10 (:38)		
Weekday wake time	6:29 (:35)	6:34 (:24)	6:32 (:33)	6:26 (:37)	6:24 (:20)	6:28 (:43)		
Weekend bedtime	22:21 (:54)	22:06 (1:01)	22:27 (1:00)	22:16 (:47)	22:00 (:30)	22:24 (:53)		
Weekend wake time	8:26 (1:13)	8:07 (:56)	8:33 (1:14)	8:20 (1:12)	7:51 (:28)	8:34 (1:23)		
CSWS								
Total sleep quality	3.5 (.6)	4.0 (.4)	3.5 (.6)	3.5 (.6)	3.3 (.6)	3.6 (.6)	$t = -3.7$, $P < .001$	A
Going to bed	3.1 (.9)	3.7 (.8)	3.1 (.9)	3.0 (.9)	2.4 (.9)	3.2 (.9)	$t = -2.8$, $P < .01$	A
							$t = -1.95$, $P = .065$	Marginal C
Falling asleep	3.6 (1.0)	4.2 (.7)	3.6 (1.0)	3.6 (.9)	3.3 (.7)	3.6 (1.0)	$t = -3.0$, $P < .01$	A
Maintaining sleep	3.5 (.9)	3.8 (.6)	3.4 (1.0)	3.5 (.9)	3.4 (1.2)	3.5 (.7)	$t = -1.95$, $P = .055$	Marginal A
Reinitiating sleep	4.5 (.6)	4.6 (.5)	4.3 (.7)	4.5 (.5)	4.4 (.7)	4.5 (.4)		
Returning to wakefulness	3.0 (1.0)	3.5 (.8)	3.1 (1.1)	3.0 (.9)	3.1 (1.0)	3.0 (.9)	$t = -2.2$, $P < .05$	A
OTHER SLEEP-QUALITY MEASURES								
Bedtime delay, min	30.7 (21.0)	23.5 (15.3)	27.8 (19.2)	33.4 (22.6)	33.3 (22.5)	33.5 (23.5)		
Sleep-onset latency, min	24.7 (17.8)	14.9 (9.6)	26.8 (23.3)	22.8 (10.9)	17.9 (7.0)	24.9 (11.8)	$t = 3.0$, $P < .01$	A
Minutes to fully wake	19.3 (23.0)	10.4 (5.7)	22.8 (30.7)	16.0 (12.4)	18.6 (19.5)	14.9 (8.4)	$t = 2.4$, $P < .05$	A

Data are displayed as mean (SD).
ADHD refers to attention-deficit/hyperactivity disorder; ADHD-I, inattentive subtype; ADHD-HI/C, hyperactive/impulsive and combined subtypes; ADHD-HI, hyperactive/impulsive subtype; ADHD-C, combined subtype; CSWS, Children's Sleep-Wake Scale.

ADHD-C groups (11.1% and 14.3%, respectively) approximated reports among (*a*) the community control group in the present analysis (10.7%), (*b*) the clinical control groups in the Chervin et al[14] study (9% and 11%), and (*c*) the study groups reviewed by Schechter et al.[11] Additionally, the prevalence of chronic snoring in the current study was statistically the same in the ADHD group (all subtypes) and in the control group. This finding is consistent with the reports of other investigators who failed to find a relationship between increased snoring and undifferentiated ADHD[19,25] but is at variance with the results of Chervin and colleagues.[14] In their study, children with ADHD not differentiated by subtype were approximately 3 times more likely to habitually snore (ie, snore more than half the time) than control children. The discrepant outcomes may be related to differences in sampling strategies. That is, Chervin et al's sample included preschool children, and the link between snoring and hyperactivity is reportedly stronger in younger children (specifically, in boys less than 8 years of age).[13] The ADHD-HI diagnosis is also more common among younger children.[45-47] Thus, the greater difference in habitual snoring between ADHD and control groups in the Chervin et al study (33% versus 9% or 11%) and the present study (22.5% versus 10.7%) may be due to differences in the representation of young children.

Children with ADHD had lower scores (more difficulty) on the Going to Bed, Falling Asleep, Maintaining Sleep, and Returning to Wakefulness subscales of the CSWS and reportedly took longer to fall asleep at the beginning of the night and to return to wakefulness in the morning. These findings are consistent with those in many earlier reports that ADHD is associated with sleep problems.[17-23] The present study provides no clear indication that sleep quality varies across ADHD subtypes. The sleep-quality differences between ADHD and control children cannot be fully explained by snoring, which was related only to the Sleep Maintenance subscale. The lower standing on the Sleep Maintenance subscale is consistent with previous findings that snoring is related to restless sleep.[48] In some children, primary snoring or sleep-disordered breathing may lead to poor sleep maintenance (ie, increased arousals and awakenings), or restless sleep may predispose some children to snoring.

Use of stimulant medications cannot be ruled out as an important influence on sleep quality in the present study. Although no differences were found between children with ADHD who were taking and those not taking stimulant medication, assessing medication effects requires an experimental design with adequate sample size. Previous reports have found that use of stimulants by children is associated with at least mildly disturbed sleep, especially prolonged sleep latency.[29,30,32,49] The failure to find a stimulant effect here for the Falling Asleep, Maintaining Sleep, and Reinitiating Sleep subscales may be due to a small effect coupled with the limited number of nonmedicated cases. Notably, other investigators using caretaker and self reports, as well as objective measures, have found evidence of disturbed sleep in unmedicated children with ADHD.[19,35]

The common reports of more sleepiness among ADHD than among control children is consistent with findings from previous studies.[24-27] Poor sleep quality was not an explanatory factor in the present analysis. It is not clear from the present study why children with ADHD-I were more likely to receive sleepiness ratings by both a caretaker and a teacher than were children with the other ADHD subtypes. Clinically, this finding is not surprising when considering the behavioral presentation of the Inattentive subtype. Children with ADHD-I are most often described as passive, drowsy, sluggish, or a combination thereof when compared to children with hyperactivity.[50] In addition, teachers have reported children with ADHD-I as lethargic and daydreamy in class and slower in completing academic tasks.[51,52]

This study has several limitations. The degree to which clinicians adhere to DSM-IV criteria in the diagnosis of ADHD is known to vary greatly.[53] Although the referring clinicians in the present study were experienced and based their ADHD diagnoses on extensive and multimodal assessments, their strict adherence to DSM-IV criteria was not objectively established. It is possible that clinical practices such as a reluctance to consider an ADHD diagnosis in children suspected of having obstructive sleep apnea syndrome may have resulted in an underrepresentation of habitually snoring children in our sample. With regard to the ADHD-group versus control-group comparisons, there is a concern that the differences observed may be related to unequal sex distribution in the 2 groups. The small number of children with ADHD-HI presents another limitation. The prevalence rate of ADHD-HI is the lowest of the ADHD subtypes.[54] Although our finding of increased snoring with this subtype is consistent with the literature showing a snoring-hyperactivity relationship, a larger sample will be needed to obtain an accurate estimate of the prevalence and severity of chronic snoring. The use of medication by children in the ADHD group is a further limitation. Medication status is unlikely to fully account for the altered amount and pattern of sleep quality associated with ADHD; however, further study of this complex relationship is needed. Finally, this study used caretaker reports to assess sleep, sleepiness, and daytime functioning, which raises well-known validity issues. The discrepancies between subjective and objective assessments of sleep problems are not fully understood.[32] Also, the sleepiness measure from the PSQ was especially limited because presence but not severity of sleepiness was assessed and, further, the scale was based on only 2 items.

In summary, this study examined the relationship between sleep, sleepiness, and ADHD subtypes, with emphasis on investigating the prevalence of chronic snoring among these clinical groups. The data presented were consistent with clinical perceptions and laboratory findings that sleep quality and daytime sleepiness may be abnormal in children with ADHD. Furthermore, it was demonstrated that chronic snoring and daytime sleepiness vary as a function of ADHD subtype. These findings have important relevance for both researchers and clinicians. Researchers may further the understanding of the complex relationship between sleep and ADHD by accounting for clinical subtypes in their investigations or by utilizing measures that are independently sensitive to both the hyperactive-impulsive and inattentive symptoms of the disorder. Clinically, this study confirms the importance of incorporating measures of sleep-disordered breathing and sleepiness into the assessment of ADHD.

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REFERENCES

1. Brown RT, Freeman WS, Perrin JM, et al. Prevalence and assessment of attention-deficit/hyperactivity disorder in primary care settings. Pediatrics 2001;107:E43.
2. Carlsson ML. On the role of cortical glutamate in obsessive-compulsive disorder and attention-deficit hyperactivity disorder, two phenomenologically antithetical conditions. Acta Psychiatr Scand 2000;102:401-13.
3. Castellanos FX, Lee PP, Sharp W, et al. Developmental trajectories of brain volume abnormalities in children and adolescents with attention-deficit/hyperactivity disorder. JAMA 2002;288:1740-8.
4. Diagnostic and Statistical Manual of Mental Disorders. 4th ed. Washington, DC: American Psychiatric Association; 1994.
5. Barkley RA, ed. Attention Deficit Hyperactivity Disorder: A Handbook for Diagnosis and Treatment. 2nd ed. New York: Guilford Press; 1998.
6. Guilleminault C, Winkle R, Korobkin R, Simmons B. Children and nocturnal snoring: evaluation of the effects of sleep related respiratory resistive load and daytime functioning. Eur J Pediatr 1982;139:165-71.
7. Dahl RE, Pelham WE, Wierson M. The role of sleep disturbances in attention deficit disorder symptoms: A case study. J Pediatr Psychol 1991;16:229-39.
8. Kotagal S, Hartse KM, Walsh JK. Characteristics of narcolepsy in preteenaged children. Pediatrics 1990;85:205-9.
9. Ali NJ, Pitson D, Stradling JR. Sleep disordered breathing: effects of adenotonsillectomy on behaviour and psychological functioning. Eur J Pediatr 1996;155:56-62.
10. Walters AS, Mandelbaum DE, Lewin DS, Kugler S, England SJ, Miller M. Dopaminergic therapy in children with restless legs/periodic limb movements in sleep and ADHD. Dopaminergic Therapy Study Group. Pediatr Neurol 2000;22:182-6.

11. Schechter MS. Technical report: diagnosis and management of childhood obstructive sleep apnea syndrome. Pediatrics 2002;109:e69.
12. Guilleminault C, Pelayo R. Sleep-disordered breathing in children. Ann Med 1998;30:350-6.
13. Chervin RD, Archbold KH, Dillon JE, et al. Inattention, hyperactivity, and symptoms of sleep-disordered breathing. Pediatrics 2002;109:449-56.
14. Chervin RD, Dillon JE, Bassetti C, Ganoczy DA, Pituch KJ. Symptoms of sleep disorders, inattention, and hyperactivity in children. Sleep 1997;20:1185-92.
15. Dahl RE, Puig-Antich J. Sleep disturbances in child and adolescent psychiatric disorders. Pediatrician 1990;17:32-7.
16. Smedje H, Broman JE, Hetta J. Parents' reports of disturbed sleep in 5-7-year-old Swedish children. Acta Paediatr 1999;88:858-65.
17. Corkum P, Tannock R, Moldofsky H, Hogg-Johnson S, Humphries T. Actigraphy and parental ratings of sleep in children with attention-deficit/hyperactivity disorder (ADHD). Sleep 2001;24:303-12.
18. Ball JD, Tiernan M, Janusz J, Furr A. Sleep patterns among children with attention-deficit hyperactivity disorder: a reexamination of parent perceptions. J Pediatr Psychol 1997;22:389-98.
19. Owens JA, Maxim R, Nobile C, McGuinn M, Msall M. Parental and self-report of sleep in children with attention-deficit/hyperactivity disorder. Arch Pediatr Adolesc Med 2000;154:549-55.
20. Kaplan BJ, McNicol J, Conte RA, Moghadam HK. Sleep disturbance in preschool-aged hyperactive and nonhyperactive children. Pediatrics 1987;80:839-44.
21. Trommer BL, Hoeppner JB, Rosenberg RS, Armstrong KJ, Rothstein JA. Sleep disturbance in children with attention deficit disorder. Ann Neurol 1988;24:322.
22. Day HD, Abmayr SB. Parent reports of sleep disturbances in stimulant-medicated children with attention-deficit hyperactivity disorder. J Clin Psychol 1998;54:701-16.
23. Ring A, Stein D, Barak Y, et al. Sleep disturbances in children with attention-deficit/hyperactivity disorder: a comparative study with healthy siblings. J Learn Disabil 1998;31:572-8.
24. Marcotte AC, Thacher PV, Butters M, Bortz J, Acebo C, Carskadon MA. Parental report of sleep problems in children with attentional and learning disorders. J Dev Behav Pediatr 1998;19:178-86.
25. Carskadon MA, Pueschel SM, Millman RP. Sleep-disordered breathing and behavior in three risk groups: preliminary findings from parental reports. Childs Nerv Syst 1993;9:452-7.
26. Lecendreux M, Konofal E, Bouvard M, Falissard B, Mouren-Simeoni MC. Sleep and alertness in children with ADHD. J Child Psychol Psychiatry 2000;41:803-12.
27. Palm L, Persson E, Bjerre I, Elmqvist D, Blennow G. Sleep and wakefulness in preadolescent children with deficits in attention, motor control and perception. Acta Paediatr 1992;81:618-24.
28. Ramos Platon MJ, Vela Bueno A, Espinar Sierra J, Kales S. Hypnopolygraphic alterations in Attention Deficit Disorder (ADD) children. Int J Neurosci 1990;53:87-101.
29. Corkum P, Moldofsky H, Hogg-Johnson S, Humphries T, Tannock R. Sleep problems in children with attention-deficit/hyperactivity disorder: impact of subtype, comorbidity, and stimulant medication. J Am Acad Child Adolesc Psychiatry 1999;38:1285-93.
30. Mick E, Biederman J, Jetton J, Faraone SV. Sleep disturbances associated with attention deficit hyperactivity disorder: the impact of psychiatric comorbidity and pharmacotherapy. J Child Adolesc Psychopharmacol 2000;10:223-31.
31. Ball JD, Koloian B. Sleep patterns among ADHD children. Clin Psych Rev 1995;15:681-9.
32. Corkum P, Tannock R, Moldofsky H. Sleep disturbances in children with attention-deficit/hyperactivity disorder. J Am Acad Child Adolesc Psychiatry 1998;37:637-46.
33. Gruber R, Sadeh A, Raviv A. Instability of sleep patterns in children with attention-deficit/hyperactivity disorder. J Am Acad Child Adolesc Psychiatry 2000;39:495-501.
34. Dagan Y, Zeevi-Luria S, Sever Y, et al. Sleep quality in children with attention deficit hyperactivity disorder: an actigraphic study. Psychiatry Clin Neurosci 1997;51:383-6.
35. Konofal E, Lecendreux M, Bouvard MP, Mouren-Simeoni MC. High levels of nocturnal activity in children with attention-deficit hyperactivity disorder: a video analysis. Psychiatry Clin Neurosci 2001;55:97-103.
36. LeBourgeois M, Hancock M, Harsh J. Validation of the Children's Sleep-Wake Scale (CSWS). Sleep 2001;24:A219.
37. LeBourgeois M, Harsh J. A new research measure for children's sleep. Sleep 2001;24:A213.
38. Avis K. ADHD, Working Memory, and Disinhibition: Testing Barkley's Theory of ADHD. Hattiesburg, MS: The University of Southern Mississippi; 2000.
39. Chervin RD, Hedger K, Dillon JE, Pituch KJ. Pediatric sleep questionnaire (PSQ): validity and reliability of scales for sleep-disordered breathing, snoring, sleepiness, and behavioral problems. 2000;1:21-32.
40. O'Brien LM, Holbrook CR, Mervis CB, Klaus CJ, Bruner JL, Raffield TJ, et al. Sleep and neurobehavioral characteristics of 5- to 7-year-old children with parentally reported symptoms of attention-deficit/hyperactivity disorder. Pediatrics 2003;111:554-63.
41. Goldstein NA, Post JC, Rosenfeld RM, Campbell TF. Impact of tonsillectomy and adenoidectomy on child behavior. Arch Otolaryngol Head Neck Surg 2000;126:494-8.
42. Gozal D. Sleep-disordered breathing and school performance in children. Pediatrics 1998;102:616-20.
43. Rosen CL. Clinical features of obstructive sleep apnea hypoventilation syndrome in otherwise healthy children. Pediatr Pulmonol 1999;27:403-9.
44. Harsh J, Peszka J, Hartwig G, Mitler M. Night-time sleep and daytime sleepiness in narcolepsy. J Sleep Res 2000;9:309-16.
45. Applegate B, Lahey BB, Hart EL, et al. Validity of the age-of-onset criterion for ADHD: a report from the DSM-IV field trials. J Am Acad Child Adolesc Psychiatry 1997;36:1211-21.
46. Loeber R, Green SM, Lahey BB, Christ MAG, Frick PJ. Developmental sequences in the age of onset of disruptive child behaviors. J Child Fam Studies 1992;1:21-4.
47. Hart EL, Lahey BB, Loeber R, Applegate B, Frick PJ. Developmental change in attention-deficit hyperactivity disorder in boys: a four-year longitudinal study. J Abnorm Child Psychol 1995;23:729-49.
48. Ali NJ, Pitson DJ, Stradling JR. Snoring, sleep disturbance, and behaviour in 4-5 year olds. Arch Dis Child 1993;68:360-6.
49. Ahmann PA, Waltonen SJ, Olson KA, Theye FW, Van Erem AJ, LaPlant RJ. Placebo-controlled evaluation of Ritalin side effects. Pediatrics 1993;91:1101-6.
50. Carlson CL, Mann M. Attention-deficit/hyperactivity disorder, predominantly inattentive subtype. Child Adolesc Psychiatr Clin N Am 2000;9:499-510.
51. Lahey BB, Schaughency EA, Strauss CC, Frame CL. Are attention deficit disorders with and without hyperactivity similar or dissimilar disorders? J Am Acad Child Psychiatry 1984;23:302-9.
52. Lahey BB, Schaughency EA, Frame CL, Strauss CC. Teacher ratings of attention problems in children experimentally classified as exhibiting attention deficit disorder with and without hyperactivity. J Am Acad Child Psychiatry 1985;24:613-6.
53. Clinical practice guideline: diagnosis and evaluation of the child with attention-deficit/hyperactivity disorder. American Academy of Pediatrics. Pediatrics 2000;105:1158-70.
54. Wolraich ML, Hannah JN, Baumgaertel A, Feurer ID. Examination of DSM-IV criteria for attention deficit/hyperactivity disorder in a county-wide sample. J Dev Behav Pediatr 1998;19:162-8.