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Inattention, Hyperactivity, and Symptoms of Sleep-Disordered Breathing

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ABSTRACT. *Objective.* **Inattention and hyperactivity are frequent among children with sleep-disordered breathing (SDB) and often improve when SDB is treated. However, the frequency of SDB symptoms among inattentive and hyperactive children has received little study.**

Design. **Cross-sectional survey.**

Setting. **Two university-affiliated but community-based general pediatrics clinics.**

Patients. **Patients consisted of $N = 866$ children (469 boys), aged 2.0 to 13.9 years (mean: 6.8 ± 3.2 years), with clinic appointments.**

Measures. **A validated Pediatric Sleep Questionnaire assessed for habitual snoring (1 item), snoring severity (a 4-item subscale), sleepiness (4 items), and overall risk of SDB (16 items). Parents also completed 2 common behavioral measures, an inattention/hyperactivity scale (IHS) derived from the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition*, and the hyperactivity index (HI, expressed as a *t* score) of the Conners' Parent Rating Scale.**

Results. **Habitual snoring was reported in 16% (95% confidence interval [CI]: 13, 19) of the participants. High HI scores (>60) were found in 13% (95% CI: 11, 16) of all participants, 22% (95% CI: 15, 29) of habitual snorers, and 12% (95% CI: 9, 14) of nonsnorers. Odds ratios between HI >60 and each of the following were: habitual snoring, 2.2 (95% CI: 1.4, 3.6); 1 additional positive symptom-item on the snoring scale, 1.3 (95% CI: 1.1, 1.5); 1 additional positive item on the sleepiness scale, 1.6 (95% CI: 1.4, 2.0); and a 1-standard deviation increase in the overall SDB score, 1.7 (95% CI: 1.4, 2.0; all odds ratios age- and sex-adjusted). Results were similar for high IHS scores (>1.25). Stratification by age and sex showed that most of the association with snoring (but not sleepiness) derived from boys <8 years old.**

Conclusions. **Inattention and hyperactivity among general pediatric patients are associated with increased daytime sleepiness and—especially in young boys—snoring and other symptoms of SDB. If sleepiness and SDB do influence daytime behavior, the current results suggest a major public health impact.** *Pediatrics* **2002;109: 449–456;** ***child, sleep, sleep disorders, snoring, sleep apnea, obstructive, disorders of excessive somnolence, Pediatric Sleep Questionnaire, attention, hyperactivity, attention deficit disorder with hyperactivity, child behavior disorders, neuropsychological tests.***

ABBREVIATIONS. ADHD, attention-deficit/hyperactivity disorder; SDB, sleep-disordered breathing; PSQ, Pediatric Sleep Questionnaire; *DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition*; IHS, inattention/hyperactivity scale; HI, hyperactivity index; CI, confidence interval.

Inattentive and hyperactive behavior are highly prevalent among school-aged children and are often associated with a clinical psychiatric syndrome such as attention-deficit/hyperactivity disorder (ADHD).[1] In many instances, unrecognized medical conditions underlie the problematic behavior.[2] One such medical condition may be obstructive sleep-disordered breathing (SDB).[3] Clinical series from sleep disorders centers report that inattentive and hyperactive behavior are common among children with obstructive sleep apnea or upper airway resistance syndrome[4,5] and that treatment of either form of SDB is often associated with improved behavior and decreased need for stimulant medication.[5,6]

Obstructive sleep apnea is estimated to affect between 1% and 3% of school-aged children.[7,8] The prevalence of upper airway resistance syndrome remains unknown, but may also be high.[9] Between 7% and 12% of children snore habitually and have a particularly high risk for SDB.[10] The high frequency of pediatric SDB, the possibility that most children (like adults[11]) remain undiagnosed, and evidence that SDB can influence daytime behavior all combine to suggest that occult SDB may have an important impact among children with inattentive and hyperactive behavior.

However, the frequency of SDB among inattentive and hyperactive children has received little study. Researchers found high frequencies of snoring among 14 children with ADHD,[12] among 31 children with ADHD or academic problems,[13] and among 27 ADHD patients at a child psychiatry clinic,[14] but not in a fourth sample of 21 ADHD children.[15] These studies were limited by small sample sizes, lack of validation for survey instruments, low subject participation rates, and variable definitions of snoring and ADHD. The sample sizes did not allow stratification—based on age, sex, or other variables—that could yield clues to why sleep and behavior might be linked. Published polysomnographic studies of hyperactive children involved even smaller samples,

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and most were performed before the importance of respiratory monitoring was realized. Results suggested either little or nonspecific sleep disturbance.[16–20]

To further assess whether symptoms of SDB are particularly frequent among children with inattentive and hyperactive behavior, we administered a previously validated instrument, the Pediatric Sleep Questionnaire (PSQ),[21] to a large sample of parents who brought their children to either of 2 general pediatric clinics. Parents also completed 2 validated measures of inattention and hyperactivity. We then compared the frequency of SDB symptoms among hyperactive and nonhyperactive children.

METHODS

Participants

Recruitment procedures for this cohort have been described previously.[22] Briefly, parents who brought their children to 2 general pediatrics clinics were asked to sign an institutional review board-approved informed consent for a study on "the sleep and daytime behavior of children." Study hypotheses were not described in more detail, in part to avoid influencing survey responses. Children >9 years old or able to understand the study were asked to sign an informed assent. Inclusion criteria were as follows: 1) age between 2.00 and 13.99 years, 2) parental ability to read and write, and 3) absence of mental or physical impairment severe enough to preclude interpretation of behavioral information collected. Participants were recruited between February 6, 1998, and May 1, 2000, by research assistants who attempted to approach all child-parent pairs at the clinics on designated days. Both clinics are owned by the same large public university health system, which only recently acquired one of the practices and now employs 9 pediatricians at the 2 sites. The clinic population at both sites is primarily community-based. Parents generally took between 20 and 30 minutes to complete the questionnaires. Data for each child were included in this report if at least two thirds of the items in the PSQ and each behavioral measure had been completed.

Measures

Parents, with encouragement to ask their children for help, completed the PSQ in waiting rooms. This instrument contains about 70 closed-question items with response options of "yes," "no," or "don't know." Instructions focused responses on behavior in general rather than recent days, during which the child may have been acutely ill. A 22-item SDB scale within the PSQ serves with adequate validity and reliability as a screen for polysomnographically defined obstructive sleep apnea and upper airway resistance syndrome.[21] The SDB score is calculated as the proportion of symptoms that are present. Among 27 sleep laboratory-referred children confirmed to have SDB and 54 children at a general pediatrics clinic, the SDB scale showed a sensitivity of 0.81 and a specificity of 0.87. Subscales for snoring (Appendix 1, items A2, A3, A4, and A5), excessive daytime sleepiness (items B1, B2, B4, and B6), and daytime behavior (6 *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* [*DSM-IV*]-derived category A symptoms of ADHD) each discriminated effectively between the children with and without SDB.[21] In the current study, the 22-item SDB scale was used without the 6 behavioral items to avoid artificial associations with hyperactive behavior. The shortened SDB scale appears in Appendix 1. Item A2, which asks about habitual snoring (defined as snoring more than half the time while asleep), also was analyzed separately, and snoring frequency was categorized according to parental indication that snoring occurred never, ever, more than half the time, or always.

Parents completed 2 measures of inattention and hyperactivity. The inattention/hyperactivity scale (IHS) asks parents to rate the extent to which the 18 *DSM-IV* category A symptoms of ADHD (Appendix 2) apply to their children. Assessment of behavior by this method has a long history and the validity of the instrument has been well-established.[23–25] The IHS has been used in previous studies of associations between childhood symptoms of SDB and inattentive and hyperactive behavior.[14] Responses are provided on a 4-point Likert scale from 0 to 3. In the current study, a mean item response (IHS score) greater than 1.25 was considered high. This threshold is somewhat arbitrary but corresponds to 12 or more positive responses ("2, applies quite a bit" or "3, definitely applies most of the time") among the 18 symptom-items. In the *DSM-IV*, 6 chronic symptoms among 9 that relate to inattention, plus 6 among 9 that relate to hyperactive/impulsive behavior, are required to support a diagnosis of ADHD, combined type.[26]

The short form of the Conners' Parent Rating Scale is a well-validated, 48-item instrument that can help to identify behavioral problems in children.[27] The instrument contains a Hyperactivity Index (HI), composed of the 10 most relevant items, that is one of the most widely used measures of the behavior. Symptoms are rated by parents on a 4-point scale, and raw scores are converted to age- and sex-adjusted t scores. These t scores range from 0 to 100 and average 50; scores that exceed this average by 1 standard deviation (10 points) to 2 standard deviations (20 points) are commonly considered to represent hyperactive behavior. In this study, HI >60 was considered to reflect hyperactive behavior.

Analysis

Data were summarized with means and standard deviations or by percentages and 95% confidence intervals (CIs). Logistic regression models of IHS >1.25 or HI >60 were used to test for associations with habitual snoring, snoring subscale scores, sleepiness subscale scores, and overall SDB scores. All odds ratios and their 95% CIs were adjusted for age and sex. To examine interaction of sleep-related symptoms with age and sex, the sample was stratified and analyses repeated. Covariance between IHS and HI was tested with the Spearman rank correlation coefficient ρ. Attributable risk percent and population attributable risk percent were calculated according to standard procedures[28] and contingent on 2 assumptions: that habitual snoring (or any associated SDB) can cause hyperactivity (HI >60), and that the pediatric clinic population prevalence of habitual snoring was that measured in the current study. The attributable risk percent and the population attributable risk percent then estimate, respectively, the proportion of snoring, hyperactive children, and the proportion of all hyperactive children whose behavioral problem could be eliminated by treatment of snoring or any associated SDB. Analyses were performed with SAS, version 6.12 (SAS Institute Inc, Cary, NC). The level of significance was set at $P < .05$.

RESULTS

Participants

Parents of approximately 1400 children were approached, and data from 866 children were included in these analyses. Among excluded children, parents of 349 failed to finish a sleep or behavior questionnaire, and the remainder refused to participate. The mean participant age was 6.8 ± 3.2 years, 469 (54%) of the participants were boys, and 397 (46%) were girls. These and other descriptive summaries of the sample are shown in Table 1. Hyperactive behavior was identified in similar proportions of the clinic sample by both the IHS and the HI. The correlation between these 2 scores ($\rho = 0.74$; $P < .0001$) suggested considerable but not perfect overlap between the measures.

Snoring, Sleepiness, SDB, and Associations With Behavior

Habitual snoring showed a trend toward an association with IHS >1.25 and a significant association with HI >60 (Table 2). Among habitual snorers, 22% (95% CI: 15, 29) had HI >60, whereas among nonhabitual snorers, only 12% (95% CI: 9, 14) had HI >60. The snoring, sleepiness, and SDB scores each showed significant associations with the 2 outcomes. The strength of these associations was not small. For

TABLE 1. Summary Measures (Mean ± Standard Deviation or Percentage and 95% CI) for Explanatory and Outcome Variables

Variable	All Participants (n = 866)	Hyperactive* (n = 98)	Not Hyperactive (n = 768)
Age (y)	6.8 ± 3.2	7.8 ± 3.3	6.6 ± 3.2
Male (%)	54 (51, 57)	73 (65, 82)	52 (48, 55)
Ever snores (%)	59 (56, 62)	62 (52, 72)	59 (55, 62)
Habitually snores (%)	16 (13, 19)	22 (13, 31)	15 (13, 18)
Always snores (%)	9 (7, 11)	14 (7, 21)	8 (6, 10)
Snoring score	0.17 ± 0.28	0.23 ± 0.34	0.17 ± 0.27
Sleepiness score	0.16 ± 0.24	0.31 ± 0.32	0.14 ± 0.22
SDB score	0.15 ± 0.15	0.24 ± 0.17	0.14 ± 0.14
IHS	0.54 ± 0.56	1.81 ± 0.47	0.38 ± 0.31
IHS >1.25 (%)	12 (10, 14)	100	0
HI	47 ± 13	71 ± 15	44 ± 9
HI >60 (%)	13 (11, 16)	69 (60, 79)	6 (5, 8)

* Participants with IHS above 1.25. (This measure was used to split results because it is, in contrast to the hyperactivity index, unadjusted for age and sex.)

TABLE 2. Conditional Logistic Regression Coefficients and Odds Ratios* for Hyperactive Behavior (IHS >1.25 or HI >60) and Symptoms of SDB†

Symptom	Change Modeled	IHS >1.25		HI >60	
		Regression Coefficient (Standard Error)	Estimated Odds Ratio (95% CI)	Regression Coefficient (Standard Error)	Estimated Odds Ratio (95% CI)
Habitual snoring	Present (vs absent)	0.52 (0.28)‡	1.6 (1.0, 2.8)	0.81 (0.25)	2.2 (1.4, 3.6)
Snoring score	One additional symptom	0.25 (0.09)	1.3 (1.1, 1.5)	0.27 (0.08)	1.3 (1.1, 1.5)
Sleepiness score	One additional symptom	0.60 (0.10)	1.8 (1.5, 2.2)	0.50 (0.09)	1.6 (1.4, 2.0)
SDB scale (normalized)	Increase by 1 standard deviation	0.60 (0.10)	1.8 (1.5, 2.2)	0.54 (0.09)	1.7 (1.4, 2.0)

* Adjusted for age and sex.
† IHS Derived from *DSM-IV* category A symptoms of ADHD, HI derived from Conners' Parent Rating Scale.
‡ P = .06. All other P < .01.

comparison, the unadjusted odds ratio for the long-recognized association[1] between male sex and hyperactive behavior—as reflected by IHS >1.25—was 2.7 (95% CI: 1.7, 4.3; adjustment for habitual snoring did not change this odds ratio substantially). A trend toward a dose-response relationship between reported snoring frequency and behavior is shown graphically in Fig 1. The attributable risk percent for habitual snoring and HI >60 was 53%, and the population attributable risk percent was 15%.

Associations Between Snoring and Sleepiness

Snoring scores correlated with sleepiness scores (ρ = 0.19; P < .0001). After accounting for sleepiness scores, the snoring scores showed somewhat less robust associations with behavioral measures. The odds ratio for HI >60 and habitual snoring was reduced from 2.2 (95% CI: 1.4, 3.6) to 1.8 (95% CI: 1.1, 3.0), and the odds ratio for HI and snoring score was reduced from 1.3 (95% CI: 1.1, 1.5) to 1.2 (95% CI: 1.0, 1.4). Conversely, after accounting for snoring scores, sleepiness scores showed essentially no reduction in association with behavioral measures.

Stratification by Age and Sex

Among the 469 boys in the sample, IHS and HI each showed significant associations with habitual snoring, snoring scores, sleepiness scores, and SDB scores. Among habitually snoring boys, 28% (95% CI: 17, 38) had HI >60, whereas among nonhabitually snoring boys, 12% (95% CI: 9, 16) had HI >60. Among the 397 girls, only 2 of the 4 explanatory variables—sleepiness scores and SDB scores—showed associations with behavioral measures. Results for HI are shown in Table 3. Logistic regression models showed that the interactions of sex with each of the 4 symptom variables failed to reach statistical significance.

Division of the sample into 6 subcategories based on age generally showed similar findings for the youngest 3 groups and similar findings for the oldest 3. Data, therefore, are reported here for children younger than 8 years in comparison with those 8 or more years old. Among the 565 younger children in the sample, IHS and HI each showed significant associations with habitual snoring, snoring score, sleepiness score, and SDB score. Among habitually snoring children <8 years old, 22% (95% CI: 14, 31) had HI >60, whereas among nonhabitually snoring children in this age group, only 9% (6, 12) had HI >60. Among the 301 children who were 8 or more years old, only 2 of the 4 explanatory variables—again sleepiness score and SDB score—showed associations with behavioral measures. Regression results for HI are shown in Table 4. Interaction models showed statistically significant effects of younger versus older age on the associations between behavior measures and habitual snoring (IHS only), snoring score, and SDB score, but not on the association between behavior measures and sleepiness scores (P > .10).

As suggested by the results for male children and

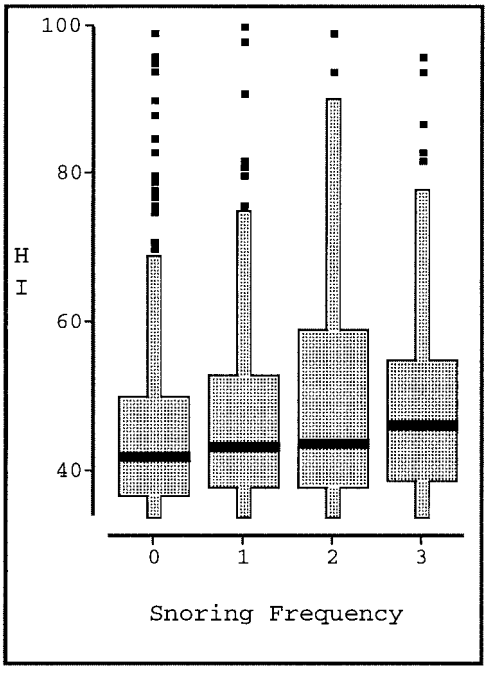

Fig 1. The frequency of snoring (0 = never, 1 = ever snores, 2 = snores more than half the time, 3 = always snores) and the HI showed a trend toward a dose-response relationship among all participants (logistic regression; $P = .09$). Box plots show medians and the 10th, 25th, 75th, and 90th percentiles.

those for younger children, the subgroup of 295 boys <8 years old showed substantially stronger associations between snoring measures and behavior than did the remaining 571 children (Table 5). The HI was associated with snoring frequency among young boys (Fig 2A) but not among young girls (Fig 2B), older boys (Fig 2C), or older girls (Fig 2D). Among habitually snoring young boys, 30% (95% CI: 17, 43) had HI >60, whereas among nonhabitually snoring young boys, only 9% (95% CI: 5, 13) had HI >60. Among all the young boys in this study, the attributable risk percent for habitual snoring and HI >60 was 77%, and the population attributable risk percent was 39%.

Among young boys, adjustment for sleepiness somewhat reduced the association between snoring and behavioral measures. For example, the odds ratio for HI >60 and habitual snoring was reduced from 4.3 (95% CI: 2.0, 9.1) to 3.5 (95% CI: 1.6, 7.6), and the odds ratio for HI >60 and snoring score was reduced from 1.8 (95% CI: 1.4, 2.3) to 1.6 (95% CI: 1.3, 2.1). Conversely, adjustment for snoring also somewhat reduced the association between sleepiness and behavioral measures. For example, adjustment for habitual snoring reduced the odds ratio for HI >60 and sleepiness from 1.8 (95% CI: 1.3, 2.5) to 1.7 (95% CI: 1.2, 2.4), and adjustment for snoring score reduced it to 1.5 (95% CI: 1.1, 2.1).

DISCUSSION

This cross-sectional study of children at 2 general pediatrics clinics shows substantial associations between several SDB symptoms and measures of inattention and hyperactivity. Inattentive and hyperactive children were reported to have more frequent snoring, more severe daytime sleepiness, and higher scores on an overall scale that identifies SDB with reasonable validity and reliability. The link between snoring measures and behavior resulted from a particularly strong association among young boys, and could not be demonstrated in children outside this group. In contrast, sleepiness and overall SDB scores showed similar associations with behavior among young boys and other age- and sex-defined groups. Although a correlative study design does not permit conclusions about causality, the current results suggest that SDB and daytime sleepiness may be important considerations in a large number children who exhibit inattentive and hyperactive behavior.

This study is distinguished from previous research on sleep in hyperactive children by its large sample size and by use of validated instruments to assess both explanatory and outcome variables. The current findings support previous suggestions that SDB is more common in hyperactive children,[12–14] and suggest that failure to reach the same conclusions in the past may have been attributable to methodological limitations.[15] The current study also allowed specification of the strength of the association, within relatively narrow CIs. Habitual snoring increased the chance of hyperactivity—as reflected by scores commonly considered abnormal on the Conners' Parent Rating Scale HI—from 12% to 22% among all the children (odds ratio: 2.2), and from 9% to 30% among young boys (odds ratio: 4.3).

Our study also showed that excessive daytime sleepiness is linked to inattention and hyperactivity.

TABLE 3. Stratification by Sex: Conditional Logistic Regression Coefficients and Odds Ratios* for Hyperactive Behavior (HI >60) and Symptoms of SDB†

Symptom	Change Modeled	Boys (n = 469)		Girls (n = 397)	
		Regression Coefficient (Standard Error)	Estimated Odds Ratio (95% CI)	Regression Coefficient (Standard Error)	Estimated Odds Ratio (95% CI)
Habitual snoring	Present (vs absent)	1.05 (0.31)	2.8 (1.5, 5.2)	0.39 (0.43)‡	1.5 (0.6, 3.3)
Snoring score	One additional symptom	0.37 (0.10)	1.4 (1.2, 1.8)	0.12 (0.13)‡	1.1 (0.9, 1.4)
Sleepiness score	One additional symptom	0.43 (0.12)	1.5 (1.2, 1.9)	0.62 (0.15)	1.9 (1.4, 2.5)
SDB scale (normalized)	Increase by 1 standard deviation	0.54 (0.12)	1.7 (1.4, 2.2)	0.55 (0.14)	1.7 (1.3, 2.3)

* Adjusted for age.
† HI derived from Conners' Parent Rating Scale.
‡ $P > .10$. All other $P < .001$.

TABLE 4. Stratification by Age: Conditional Logistic Regression Coefficients and Odds Ratios* for Hyperactive Behavior (HI >60) and Symptoms of SDB†

Symptom	Change Modeled	Age <8 Years (n = 565)		Age ≥8 Years (n = 301)	
		Regression Coefficient (Standard Error)	Estimated Odds Ratio (95% CI)	Regression Coefficient (Standard Error)	Estimated Odds Ratio (95% CI)
Habitual snoring	Present (vs absent)	1.02 (0.30)	2.8 (1.5, 4.9)	0.32 (0.46)‡	1.4 (0.5, 3.3)
Snoring score	One additional symptom	0.39 (0.09)	1.5 (1.2, 1.8)	−0.09 (0.17)‡	0.9 (0.6, 1.3)
Sleepiness score	One additional symptom	0.59 (0.12)	1.8 (1.4, 2.3)	0.37 (0.14)	1.5 (1.1, 1.9)
SDB scale (normalized)	Increase by 1 standard deviation	0.68 (0.12)	2.0 (1.6, 2.5)	0.30 (0.15)	1.4 (1.0, 1.8)

* Adjusted for age and sex.
† HI derived from Conners' Parent Rating Scale.
‡ P = .10. All other P < .05.

TABLE 5. Stratification by Age and Sex: Conditional Logistic Regression Coefficients and Odds Ratios* for Hyperactive Behavior (HI >60) and Symptoms of SDB†

Symptom	Change Modeled	Boys <8 Years Old (n = 295)		Remaining Children (n = 571)	
		Regression Coefficient (Standard Error)	Estimated Odds Ratio (95% CI)	Regression Coefficient (Standard Error)	Estimated Odds Ratio (95% CI)
Habitual snoring	Present (vs absent)	1.46 (0.38)	4.3 (2.0, 9.1)	0.33 (0.35)‡	1.4 (0.7, 2.7)
Snoring score	One additional symptom	0.58 (0.13)	1.8 (1.4, 2.3)	0.04 (0.12)‡	1.0 (0.8, 1.3)
Sleepiness score	One additional symptom	0.60 (0.16)	1.8 (1.3, 2.5)	0.46 (0.11)	1.6 (1.3, 2.0)
SDB scale (normalized)	Increase by 1 standard deviation	0.77 (0.16)	2.2 (1.6, 3.0)	0.44 (0.11)	1.5 (1.2, 1.9)

* Adjusted for age and (for remaining children) sex.
† HI derived from Conners' Parent Rating Scale.
‡ P > .10. All other P < .0001.

This finding is consistent with data from sleep-disordered (and often sleepy) children referred to sleep clinics,[4,5,29–33] neurophysiological evidence of hypoarousal in ADHD,[34] and improvement in behavior and hypoarousal among ADHD children treated with stimulants.[35,36] Our finding that adjustment for snoring did not greatly diminish the association between sleepiness and ADHD-like behavior is consistent with the fact that in many children, sleepiness is not a result of SDB. The most common cause of daytime sleepiness in school-aged children is insufficient sleep.[37] The desire of working parents to spend evenings with their children and still bring them to day care or school early in the morning may infringe on sleep time. Homework, computer games, television, sports, lessons, social commitments, and after-school jobs may all conspire to leave little time for sleep. An underlying tendency to have a delayed sleep phase, especially as adolescence approaches, may combine with early school start times to produce excessive sleepiness in many youngsters.

This study explored, for the first time, the influence of age and sex on associations between behavior and sleep-related symptoms. Sleepiness seems to be linked to hyperactive behavior in both boys and girls and throughout childhood and early adolescence. In contrast, the association between snoring and behavior seems to be stronger among younger children than among older children. Snoring might be predicted to be more common among children younger than 8 years—tonsils and adenoids are largest relative to upper airway size between ages 3 and 6[38]—but in our cohort, snoring frequency did not vary significantly between 6 different age groups.[39] Snoring and obstructive SDB may well be caused by anatomic and neurophysiological factors that differ between young children and adults.[40] Upper airways of older children may resemble those of adults more closely than those of young children. If so, habitual snoring may reveal different information depending on a child's age. Another possibility is that snoring or related SDB may have different consequences in younger and older children because of age-specific central nervous system vulnerabilities or sleep architecture.[41]

Snoring also differed from sleepiness in that it showed significant associations with behavior only among boys (although the difference between sexes did not reach statistical significance). Obstructive SDB is believed to occur in approximately equal proportions of boys and girls,[42] and snoring did not differ significantly with sex in our cohort.[39] However, ADHD is several times more common among boys than girls,[43] which raises the possibility of a sex-based vulnerability to any influence that SDB may have on behavior.

Several limitations of the current study must be considered in the interpretation of results. The PSQ SDB scale has good ability to predict sleep laboratory-confirmed SDB and is much easier to administer in large samples, but it cannot replace full polysomnography. Our results may have been subject to biases inherent to surveys. For example, parental rating levels for sleep and behavioral symptoms both may have been influenced in the same direction by parent-specific variables. Many potential third variables remained uncontrolled in this study, which used broad inclusion criteria, in an effort to maxi-

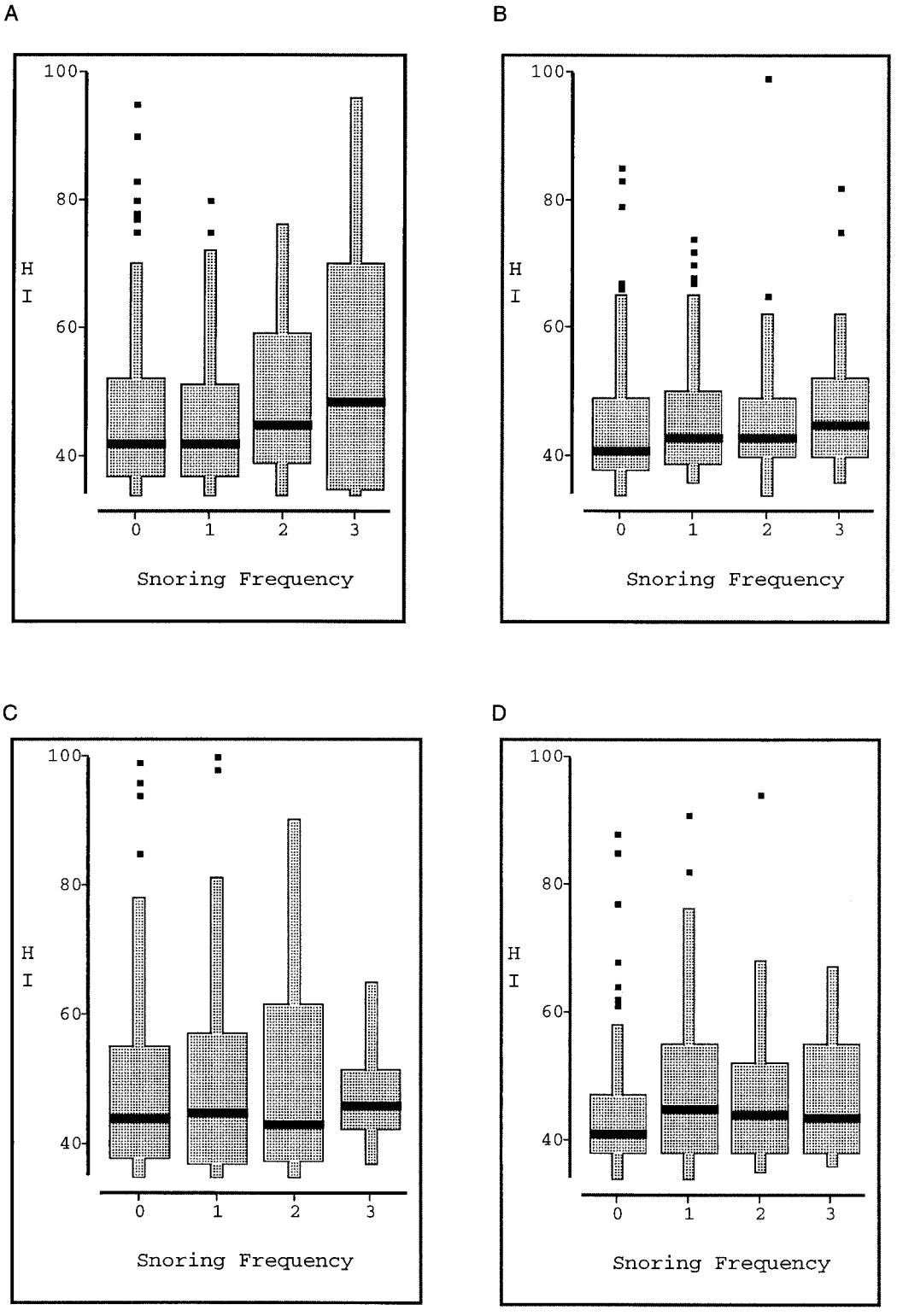

Fig 2. The frequency of snoring (see Fig 1 legend) and the HI showed a dose-response relationship among boys <8 years old ($P = .003$; A), but no significant association ($P > .10$) among girls <8 years old (B), boys ≥8 years old (C), or girls ≥8 years old (D).

mize generalizability, at the risk of introducing unsuspected confounds. This study purposefully focused not on diagnoses of ADHD, but on inattentive and hyperactive behavior as defined by well-validated measures. This choice improved uniformity in identification of the most hyperactive 12% or 13% of pediatric patients, but now prevents precise generalization of results to children who meet full *DSM-IV* criteria for ADHD.

Despite these considerations, the robust associations between SDB symptoms and hyperactivity are consistent with the possibility that the sleep disorder may contribute to the behavior in some children. The mechanism by which this may occur is uncertain, but

sleep disruption, sleep deprivation, inadequate oxygen saturation, and many other physiologic changes associated with SDB could play important roles. The association we identified between behavior and snoring was somewhat reduced after taking sleepiness into account: this suggests that sleepiness could act, to some extent, as an intermediary variable. Children who are sleepy may be more likely to shift their attention frequently and create stimulation to keep themselves awake, especially at young ages when wakefulness is essential to rapid learning.[15,32,44]

In adults, SDB is associated with significant cognitive changes and excessive sleepiness which show some correlation with levels of both sleep disruption and oxygen desaturation.[45,46] In children, experimental sleep deprivation impairs cognitive function,[47,48] and elementary school children with SDB achieve low grades that improve when the SDB is treated.[49] Cognitive changes associated with untreated SDB may promote inattentive and hyperactive behavior. At sleep laboratories, little work has been done to determine which polysomnographic features and physiologic variables are most closely associated with hyperactive behavior. Recent data from 113 children referred to our laboratory for suspected SDB suggest that apnea and hypopnea rates and minimum oxygen saturation do not predict HI.[50] However, sleepiness was not measured directly and may not be reflected adequately by the other SDB measures.[46] Data from adults show that sleep laboratory measures of SDB do not fully account for the association between snoring and sleepiness,[51] which suggests that sleep laboratory measures in children also may fail to account for the association between snoring and daytime behavior.

Alternatively, current findings could have resulted from the influence of an unstudied third variable. Our cross-sectional study did not determine whether hyperactivity or symptoms of SDB occurred first. The possibility that hyperactive behavior leads to some SDB symptoms cannot be excluded. Hyperactive children often have disturbed, restless sleep that potentially could explain increased daytime sleepiness.[52–55] However, no ready explanation has been proposed for how hyperactivity or restless sleep might increase snoring. Clinical series and one quasi-experimental study of children treated for SDB (by tonsillectomy) or for other surgical problems suggested that treatment for SDB improves inattention and hyperactivity.[5,6] Additional controlled trials and polysomnographic studies will be needed to clarify whether SDB does actually contribute to inattention and hyperactivity.

If habitual snoring or any underlying SDB is a cause of hyperactive behavior in some children, the population attributable risk percent suggests that a substantial percentage of children with HI >60 (15%) could be effectively treated by identification and treatment of habitual snoring and any underlying SDB. Among hyperactive young boys, this figure rises to 39%. In a previous smaller study that compared ADHD patients at a child psychiatry clinic to non-ADHD patients at a general pediatrics clinic, we estimated the population attributable risk percent for habitual snoring to be 25%.[14] These estimates can be misleading in case-control studies, but are more reliable to the extent that the sample is population-based. The current estimates, derived from a large sample in 2 predominantly community-based pediatric practices, suggest that SDB could constitute a substantial public health burden.

APPENDIX 1

Pediatric Sleep Questionnaire items from which explanatory variables were derived.

WHILE SLEEPING, DOES YOUR CHILD . . .
- A2 . . . snore more than half the time?
- A3 . . . always snore?
- A4 . . . snore loudly?
- A5 . . . have "heavy" or loud breathing?
- A6 . . . have trouble breathing, or struggle to breathe?

HAVE YOU EVER . . .
- A7 . . . seen your child stop breathing during the night?

DOES YOUR CHILD . . .
- A24 . . . tend to breathe through the mouth during the day?
- A25 . . . have a dry mouth on waking up in the morning?
- A32 . . . occasionally wet the bed?

DOES YOUR CHILD . . .
- B1 . . . wake up feeling unrefreshed in the morning?
- B2 . . . have a problem with sleepiness during the day?
- B4 Has a teacher or other supervisor commented that your child appears sleepy during the day?
- B6 Is it hard to wake your child up in the morning?
- B7 Does your child wake up with headaches in the morning?
- B9 Did your child stop growing at a normal rate at any time since birth?
- B22 Is your child overweight?

APPENDIX 2

The IHS question-items, derived from *DSM-IV* category A symptoms of ADHD.

THIS CHILD OFTEN . . .
- 1 . . . fails to give close attention to details or makes careless mistakes in schoolwork, work or other activities
- 2 . . . often has difficulty sustaining attention in tasks or play activities
- 3 . . . does not seem to listen when spoken to directly
- 4 . . . does not follow through on instructions and fails to finish schoolwork, chores or duties
- 5 . . . has difficulty organizing task and activities
- 6 . . . avoids, dislikes, or is reluctant to engage in tasks or activities that require sustained mental effort (such as homework or schoolwork)
- 7 . . . loses things necessary for tasks or activities (eg, toys, school assignments, pencils, books or tools)
- 8 . . . is easily distracted by extraneous stimuli
- 9 . . . is forgetful in daily activities
- 10 . . . fidgets with hands or feet or squirms in seat
- 11 . . . leaves seat in classroom or in other situations in which remaining seated is expected
- 12 . . . runs about or climbs excessively in situations in which it is inappropriate
- 13 . . . has difficulty playing or engaging in leisure activities quietly
- 14 . . . is "on the go" or often acts as if "driven by a motor"
- 15 . . . talks excessively
- 16 . . . blurts out answers before questions have been completed
- 17 . . . has difficulty awaiting his/her turn
- 18 . . . interrupts or intrudes on others (eg, butts into conversations or games)

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