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Snoring During Early Childhood and Academic Performance at Ages Thirteen to Fourteen Years

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Snoring During Early Childhood and Academic Performance at Ages Thirteen to Fourteen Years

David Gozal, MD, FAAP, and Dennis W. Pope Jr, REPSGT

ABSTRACT. *Objectives.* **Obstructive sleep apnea syndrome in young children is associated with an adverse effect on learning. However, the long-term impact of sleep-disordered breathing (SDB) during early childhood on learning remains unknown.**

Methods. **Questionnaires were mailed to seventh and eighth graders attending public schools whose class ranking was either in the top 25% (high performance [HP]) or bottom 25% of their class (low performance [LP]), and who were matched for age, gender, race, school, and street of residence. Snoring frequency and loudness at 2 to 6 years of age, tonsillectomy and adenoidectomy (T&A) for snoring or recurrent infection, school grades, and parental smoking and snoring were assessed.**

Results. **The questionnaire response rate was 82.8%. Because of ongoing snoring, 13 responders were excluded, such that 1588 questionnaires could be analyzed (797 in LP and 791 in HP group). Frequent and loud snoring during early childhood was reported in 103 LP children (12.9%) compared with 40 HP children (5.1%; odds ratio: 2.79; confidence interval: 1.88–4.15). Furthermore, 24 LP and 7 HP children underwent T&A for snoring (odds ratio: 3.40; confidence interval: 1.47–7.84), while 21 LP and 19 HP children required surgery for recurrent tonsillitis.**

Conclusions. **Children with lower academic performance in middle school are more likely to have snored during early childhood and to require T&A for snoring compared with better performing schoolmates. These findings support the concept that SDB-associated neurocognitive morbidity may be only partially reversible or that a "learning debt" may develop with SDB during early childhood and hamper subsequent school performance.** *Pediatrics* **2001;107:1394–1399;** ***obstructive sleep apnea, sleep, learning, snoring.***

ABBREVIATIONS. OSAS, obstructive sleep apnea syndrome; HP, high performance; LP, low performance; OR, odds ratio; *P*-NS, *P* value not significant; CI, confidence interval; ADHD, attention-deficit hyper activity disorder.

Although the neurocognitive implications of obstructive sleep apnea syndrome (OSAS) in children have been recognized for over a century,[1] it is only in the last decade that a more systematic exploration of this problem has been undertaken. Schooling problems have been repeatedly reported in case-series of children with OSAS, and in fact, may underlie more extensive behavioral disturbances such as restlessness, aggressive behavior, excessive daytime sleepiness, and poor neurocognitive test performances.[2] The separate contributions and potential interactions of sleep fragmentation, alveolar hypoventilation, and intermittent hypoxemia, the hallmarks of sleep-disordered breathing, on neural development are unknown, as is the correlation between the magnitude of physiologic alterations during sleep and the severity of daytime behavioral measures in children.[3,4] As an example that further emphasizes the complexity of these relationships, sleep architecture disturbances were identified in only 20% of children with either primary snoring or OSAS, suggesting that children with sleep-disordered breathing may be less prone to develop sleep fragmentation and subsequent behavioral and cognitive disturbances when compared with adults.[5]

It is currently estimated that 20% to 30% of children with either OSAS and/or with loud and frequent snoring may have clinically significant problems of inattention and hyperactivity.[6] This subgroup of "vulnerable" children may not have true attention deficit hyperactivity disorder but, rather, repeated sleep arousals, and intermittent hypoxic events may result in a lack of behavioral inhibition, with negative implications for working memory, motor control, and self-regulation of motivation and affect.[7] The attentional and behavioral problems observed in children with OSAS could certainly have a negative impact on cognitive and academic performances. Indeed, we have recently shown that improvements in school performance will occur with the remediation of OSAS in first-grade children who were experiencing substantial academic impairment in school-related activities.[8] However, to what extent the recovery process is complete after surgical treatment remains unknown. It is possible that the learning and behavioral deficit incurred by sleep-disordered breathing may be fully reversible; alternatively, long-term decreases in learning performance could represent a residual and irreversible neurocognitive deficit in children who experienced sleep-disordered breathing during a critical age associated with brain development. Thus, the present study was conducted to test the hypothesis that frequent and loud snoring during early childhood may

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lead to long-term decreases in overall school achievements.

METHODS

In the initial stages of this project, we identified 13- to 14-year-old children attending Jefferson County Public Schools who were ranked among the top or bottom quartiles of their class based on the computerized school database. Children were then matched for age, gender, race, school, and street of residence, the latter serving as a surrogate measure for socioeconomic status. When the street of residence could not be exactly matched, children residing in immediately contiguous streets within the same neighborhood were selected. Of the ~21 750 13- to 14-year-old children attending the public school system in Jefferson County, 1001 children were included in the high school performance group (HP), and correspondingly, an additional 1000 children were identified in the lower school performance group (LP).

A scannable questionnaire was prepared using Teleform software (Cardiff Software, San Marcos, CA) and mailed to the parents after the project received approval from the institutional experimental human subject committee. In addition to the informed consent cover letter, the questionnaire included the following items:

a. Child's name, address, telephone, gender, and race.
b. Does your child snore now?
c. Does the father snore?
d. Does the father smoke?
e. Does the mother snore?
f. Does the mother smoke?
g. Did the child snore between the ages of 2 to 6 years old?
h. Did the child have his/her tonsils and/or adenoids surgically removed? If yes, was this because of 1) recurrent throat infections? 2) snoring?
i. Does your child have any medical problem either now or in the past? If yes, what is/was the nature of the problem and what medications does/did your child receive?
j. What are the grades of your child in his/her last report card?

For questions b, c, e, and g, in the event of a positive answer, 2 additional questions addressed whether the snoring was quiet, mildly loud, loud, and very loud, and whether the snoring occurred occasionally (1–2 times week or less), frequently (3–4 times a week), very frequently (5–6 times a week), or always (every night). Each of these responses was assigned a numerical score of 1 to 4 points such that the maximal score indicating the greatest severity of snoring for both questions was 8 points. A negative response was assigned a score of 0.

The questionnaires included a stamped return envelope. To enhance the response rate to the questionnaire, efforts to contact all nonresponding parents were made at least on 2 separate occasions 2 and 3 months after the initial mail out. Among those parents who responded to the questionnaire, a telephone interview was conducted randomly in 125 households 1 month after receiving the filled questionnaire. The stability of the questionnaire was further tested and retested on an independent sample of middle school-aged children within a 1-month interval, and was found to be satisfactory. Indeed, the test-retest reliability of the snoring question was highly significant with a correlation coefficient of 0.94 for this parent cohort and 0.92 for the independent sample, respectively.

Data Analysis

Because the aims of this study were to determine the potential long-term impact of early childhood snoring, any responder whose child was a snorer at the time of filling the questionnaire was excluded from the HP and LP group comparisons. Frequent and loud snoring was defined as a cumulative snoring score of ≥ 4 points in which the snoring frequency reported had to be at least ≥ 3 times/week. We used Student's t test or Fisher's exact test to compare between LP and HP groups. Odds ratio (OR) and Cornfield's confidence intervals were derived from χ^2 tests for determination of differences in snoring among LP and HP. Multivariate logistic regression analysis was used to assess the association between the dichotomous variables environmental smoking exposure, early childhood snoring, and parental snoring, and the child's school performance in seventh or eighth grade. All P values reported are 2-sided, and statistical significance was set at $<.05$.

RESULTS

A total of 2001 questionnaires were mailed. Of these, 68 were returned because of wrong address. Of the 1933 potential responders, appropriately filled questionnaires were obtained from 1601 parents, representing a 82.8% overall response rate. Of the 1601 responders, 13 were reported to currently have loud and frequent snoring, ie, composite snoring scores ≥ 4 (Fig 1), and were, therefore, excluded from subsequent analysis. Of note, out of these 13 children, 8 children were in the LP group.

The remaining 1588 children with complete questionnaires included 797 children in the LP group and 791 children in the HP group (P value not significant [P-NS]). As expected from our cohort selection procedures, the average grades for LP children were 2.75 ± 0.12 in a 0 to 4 point scale, and significantly lower than for the HP children (3.78 ± 0.11; $P < .00001$). In the LP group, 52.6% were girls with 51.3% in HP group (P-NS). The racialdistribution of LP and HP children responding to the questionnaire was similar, and included 70.5% white, 22.3% black, 2.8% Hispanic, 1.2% Asian, and the remaining 3.2% were categorized as other. This ethnic distribution is similar to that of the metropolitan population of the city of Louisville. Smoking at least by 1 parent was present in the household of 247 LP children (31%) compared with 190 households with at least 1 smoker in the HP group (24%; $P < .003$). Fathers had higher smoking rates than did mothers (22% vs. 12%; $P < .00001$). Similarly, parental snoring was more frequent in the father with 38% of fathers reporting loud and frequent snoring compared with 22% of mothers ($P < .0001$). However, snoring frequencies among parents were similar in LP and HP groups.

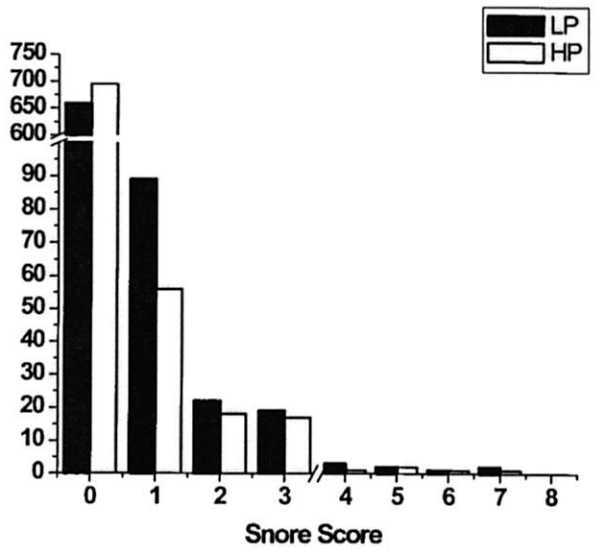

Fig 1. Distribution of snoring scores in 13- to 14-year-old HP and LP children. Snoring was categorized as none (0), quiet (1), mildly loud (2), loud (3), and very loud (4), as well as never (0), occasional (1), frequent (2), very frequent (3), or always (4). The snore score represent the arithmetical addition of the answers to these 2 items.

Frequent and loud snoring during early childhood was reported in 103 LP children (12.9%), whereas only 40 HP children had frequent and loud snoring as young children (5.1%; OR: 2.79; confidence interval [CI]: 1.88–4.15; $P < .00001$). Similarly, the mean snore score for the LP group was higher compared with the HP group (1.19 vs 9.56, $P < .03$; Fig 2). Interestingly, the mean snore score was significantly lower at ages 13 to 14 in both groups compared with the scores based on parental recall for ages 2 to 6 years (0.29 and 0.21 for LP and HP respectively; $P < .0001$). No differences were present between HP and LP at the latter age (*P*-NS).

Furthermore, 24 LP and 7 HP children underwent surgical removal of adenoids and tonsils because of snoring (OR: 3.40; CI: 1.47–7.84; $P < .003$). In contrast, 21 children in the LP group and 19 children in the HP group required this surgical procedure because of recurrent infections of the tonsils (*P*-NS). Among the 103 LP children who snored during early childhood, 56 lived in a cigarette-smoking household, the latter being reported in 17 HP children (*P*-NS). Thus, although smoking emerged as a very prominent risk factor for snoring (OR: 3.30; CI: 2.29–4.74; $P < .00001$), multivariate logistic regression analysis did not indicate that passive smoke exposure was an independent risk factor for lower school performance.

Allergic symptoms and asthma were reported in 38 HP and 45 LP children (*P*-NS). Interestingly, 51 of these children were also among those with loud and frequent snoring during early childhood ($P < .000001$). Similarly, attention-deficit hyperactivity disorder (ADHD) requiring pharmacotherapy was reported in 28 HP and 39 LP children (*P*-NS). Of the 67 children declared as having ADHD, 42 were also in the loud and frequent snorer group ($P < .000001$).

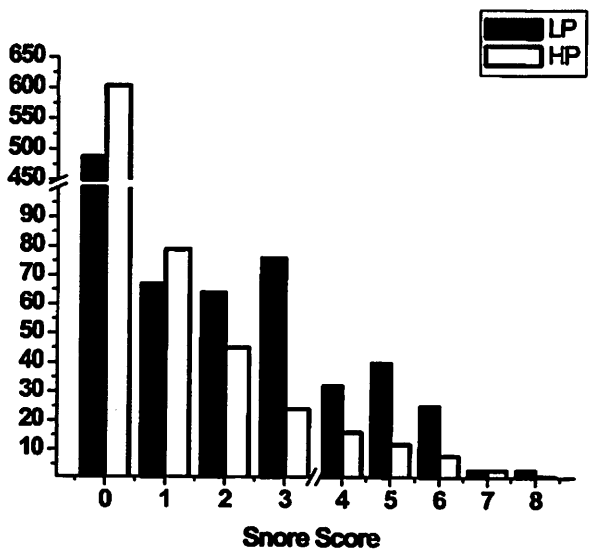

Fig 2. Distribution of snoring scores during early childhood in 13- to 14-year-old HP and LP children. (For details on the snore score, see Fig 1 legend.)

DISCUSSION

In this study, we found that early childhood snoring was more frequently reported among 13- to 14-year-old children who were ranked in the lower quartile of their class when compared with age-, gender-, race-, school-, and area of residence-matched children whose performance was in the upper quartile ranks. These findings suggest that children who experienced sleep-disordered breathing during a period traditionally associated with major brain growth and substantial acquisition of cognitive and intellectual capabilities may suffer from a partially irreversible compromise of their a priori potential for academic achievement.

The mechanisms underlying cognitive deficits in sleep-disordered breathing in both adults and children remain unclear. Three major components that result from the intermittent upper airway obstruction that occurs during sleep in children could theoretically contribute to such neurocognitive deficits, namely episodic hypoxia, repeated arousal leading to sleep fragmentation and sleep deprivation, and periodic or continuous alveolar hypoventilation. However, the relative contributions and possible interactions of these 3 elements in the pathophysiology of the neurocognitive deficits in the developing human brain are currently unknown. In adults with OSAS, excessive daytime sleepiness is very frequent,[9,10] but may not be solely attributable to sleep fragmentation. Indeed, in a study of 322 OSAS adult patients, Poceta and colleagues[11] found that the ability to maintain wakefulness was markedly disturbed, and was inversely correlated not only with the arousal index, but also with the degree of hypoxemia. Similar findings suggesting the combined effects of both sleep deprivation, particularly rapid eye movement sleep deprivation, and episodic hypoxemia on neurocognitive function have been reported.[12,13] In experimental healthy participants, rapid eye movement sleep deprivation produced no obvious deterioration of mental function and did not impair learning of simple verbal tasks, but elicited reduced retention of complex stories and inferior creative performance in humans.[14,15] However, Bedard and colleagues[16] found that reductions in general intellectual measures and executive and psychomotor tasks were attributable to the severity of hypoxemia, whereas other attention and memory deficits were related to impaired vigilance and sleep fragmentation.

An additional concern regarding the neurocognitive impairment relates to the reversibility of such impairments. Although there is clearly a paucity of information in this regard, 2 preliminary lines of published evidence suggest that the functional recovery may be only partial. Indeed, mountain climbers exposed to high altitude hypoxia exhibited intellectual impairments that persisted for long periods of time after return to lower elevations.[17] Similarly, short-term memory impairments and other neurobehavioral manifestations persisted in adult OSAS patients despite effective therapy.[18–20] Thus, the functional recovery following exposures of the mature

brain to the 3 aforementioned pathogenetic elements of neurobehavioral disturbances that characterize OSAS appears to be only partial.

Children with sleep disordered breathing tend to have behavioral problems similar to those observed in children with attention deficit hyperactivity disorder. For example, in a survey of 782 children, daytime sleepiness, hyperactivity, and aggressive behavior were documented in ~30% of children who snored.[21] Similar studies in smaller patient cohorts with proven OSAS have also documented parental reports of behavioral disturbances, and their improvement following treatment of OSAS,[22–25] whereas a study of 14 morbidly obese children with OSAS found inverse correlations between memory and learning performance and the apnea/hypopnea index.[26] Thus, snoring and OSAS are associated with significant behavioral disturbances in children.

The adverse consequences of OSAS on academic achievement were identified more recently in a large cohort of first graders who were failing in school. Indeed, a six- to ninefold increase in the incidence of OSAS was found in this group when compared with the predicted prevalence of OSAS in the general pediatric population.[8] More importantly, however, the overall school performance was significantly improved 1 year later in those children undergoing surgical removal of the hypertrophic adenotonsillar tissue.[8]Thus, although this particular study was not designed to assess the extent of reversibility for those neurocognitive elements underlying decreased learning performance, the improvement in grades after treatment would suggest that such deficits are at least partially correctable. The present results further extend on these observations, and suggest that residual deficits in learning performance may still be detected several years after snoring has resolved. Before addressing the possible implications of such findings, some methodological issues deserve comment. First and foremost, this study was a retrospective study using a questionnaire, and as such is potentially hampered by the parental ability to recall snoring symptoms in their children several years later. To partially circumvent this problem, we used a relatively stringent criterion for loud and frequent snoring that showed good sensitivity in a previous prospective study of 6-year-old children.[8] In addition, parents were not specifically informed of the link between snoring and school grades, such that a recall bias primarily occurring among the parents of LP children is unlikely. Age and gender were carefully matched in the initial participant selection procedures, and remained statistically similar on completion of the recruitment process. Because differences in ethnic distribution may be a confounder variable in school performance, the LP and HP groups were carefully matched in this regard. To further eliminate the potential bias introduced by different grading systems among the various public schools included in the survey, pairing of LP and HP participants was done within each school. However, we cannot exclude the possibility that an occasional child in any given class of a particular school may not qualify for such LP or HP group assignment in another class within the same school. Notwithstanding this consideration, it is highly unlikely that this factor may have skewed in any significant way the 2 population groups under study. An additional potential confounder pertains to the well-established observation that school performance is dependent on socioeconomic factors.[27–29] To overcome this potential problem, participant matching incorporated selection of children into the LP and HP groups such that whenever possible each pair resided in the same street of residence or at least in the immediately contiguous streets within the same neighborhood. Although this pairing procedure may not completely address confounding factors such as parental educational background or annual income status, it provides a robust estimate of such factors during participant selection, and allows for valid comparisons to be performed. However, because lower socioeconomic status has been associated with higher prevalence of smoking, a clear and significant finding among the parents of LP children in this study, caution needs to be exercised in the acceptance of street of residence as an ideal matching criterion for socioeconomic status. Thus, the higher rates of smoking in households of LP children could reflect either a true role of smoking in the pathogenesis of snoring in children, or alternatively indicate that the validity of the matching criterion may be somewhat compromised.

The prevalence of snoring in young children varies greatly between the various studies addressing this symptom, and ranges from 3.2% to 27% in 2- to 8-year-old children.[21,30–33] It is likely that such differences may reflect different cultural perceptions of snoring, rather than true differences in prevalence. The mean snoring prevalence among the 1588 children in our study was 9%. This relatively lower prevalence value could be attributable to more stringent criteria for inclusion in the "snorer" category being used in our study. However, because the hypothesis being tested assumed that loud and frequent snoring would behave as a surrogate marker for either the upper airway resistance syndrome or OSAS, higher stringency criteria in our questionnaire would lead to increased sensitivity and specificity in the detection of such conditions. Alternatively, because of the time elapsed between the actual snoring and the age at which the questionnaire was administered, the lower positive response rates for snoring in this cohort could in fact represent a reduced recall accuracy. It is, however, unlikely that such putative recall bias may have preferentially affected 1 of the 2 groups studied herein.

An interesting albeit somewhat anticipated finding in our study was the high frequency of smoking in the household among snoring children. Indeed, 73 of the 143 loud snorers during early childhood reported being exposed to a smoking home environment. Our findings are in close agreement with previous studies suggesting an increased risk for snoring among children exposed to cigarette smoking in the household.[33–35] The increase in snoring prevalence most

likely reflects the enhanced proliferation of lymphoid tissue induced by chemical irritation of the upper respiratory tract at an age that characteristically exhibits accelerated growth of tonsils and adenoids.[36]

Frequently recurring conditions such as asthma, allergies, and ADHD were more likely to be reported among the children with a history of early childhood snoring. Although the significance of these associations is unclear, it is conceivable that allergic predisposition may promote the hypertrophy of nasal mucosa leading to increased nasal airflow resistance and thereby increasing the tendency for snoring and its severity.[37] Similarly, the association between sleep disordered breathing and ADHD has been previously documented,[7] lending support to the concept that the behavioral disturbance in some of the ADHD children may be resolved by addressing and treating their sleep disturbance.

This study raises several important questions. First, what are mechanisms whereby sleep-disordered breathing during early childhood reduces the learning potential later in life? Second, does the effect of 1 or more disturbances in sleep fit a linear model when plotted against the corresponding learning deficit or is there a threshold to such effect? Third, are there particularly vulnerable populations among snoring children? Finally, does early recognition and intervention reduce or abolish the adverse outcome on learning and academic achievement? Obviously, definitive answers to these questions are not currently available, but the findings of this study clearly justify implementation of future research in these directions.

CONCLUSION

Young children who snore loudly and frequently during their sleep are at higher risk for exhibiting lower grades in school several years after the snoring has resolved. These findings substantiate the potential for adverse and sustained neurocognitive outcomes and diminished academic achievement being associated with sleep-disordered breathing, particularly when the latter occurs during critical phases of brain growth and development.

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"Nullius in verba (Take nobody's word for it)."

—Royal Society's motto

"It is easier to be critical than to be correct."

—Benjamin Disraeli

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