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Predictors for Snoring in Children With Rhinitis at Age 5

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Summary. Snoring is often found in allergic diseases and may be an early manifestation of more serious sleep-disordered breathing. We aimed to investigate whether the risk factors for snoring among pre-school children with rhinitis are similar to those for allergic diseases in a birth cohort. The study cohort was drawn from participants in the Childhood Asthma Prevention Study (CAPS). This is a randomized controlled trial of dietary intervention and house dust mite avoidance during the first 5 years of life, aimed at reducing the risk of acquiring asthma and other allergic conditions in children at high-risk for allergic diseases. Parents of children with symptoms of rhinitis at age 5 years (n = 219 out of 516 cohort members) were asked if their child snored: 127 (60%) reported some snoring and 56 (26%) snored more than three times per week. Multiple logistic regression analyses indicated that children who were first-born (adjusted odds ratio, 2.50, 95% CI 1.20–5.21), were exposed to maternal tobacco smoke during the first year of life (2.40, 1.1–5.25), or who had asthma (2.51, 1.14–5.55) and/or eczema (2.29, 1.02–5.13) at age 5 years were more likely to snore. Birth-weight, body mass index at age 4.5, spirometry, and breastfeeding were not related to snoring. Risk factors for snoring are similar to risk factors for allergic disorders. Snoring may be part of the allergic spectrum of diseases. Our data may contribute to clinician's ability to effectively screen for snoring in preschool children. **Pediatr Pulmonol. 2007; 42:584–591.**

Key words: snoring; asthma; atopy; children; rhinitis; birth-order; environmental tobacco smoke exposure.

INTRODUCTION

In cross-sectional studies in children, snoring and more serious sleep disordered breathing are associated with impairment in neurobehavioral function and alterations in cardiovascular function.[1] These studies have examined the risk factors for snoring in pediatric populations and identified the strength of association with other medical conditions (e.g., asthma) and some potential causal risk factors (e.g., tobacco smoke). However, cross-sectional studies can only provide limited information regarding both the causes and consequences of snoring/sleep apnoea. Thus a recent consensus statement has called for cohort studies to investigate the outcomes of and antecedent risk factors for sleep disordered breathing in childhood.[2] It has also been recommended that primary care clinicians screen preschool children for snoring, in order to identify obstructive sleep apnoea.[3,4]

Snoring in population-based samples of children has often been associated with allergic or inflammatory conditions such as asthma,[5–7] atopy,[8] rhinitis,[5–7,9] and/or tonsillitis/adenoiditis.[5–7] Although snoring in adults is usually associated with obesity and/or anatomical abnormalities of the upper airway, in children, who have much smaller upper airways, mucosal inflammation may be more important.[1] If snoring is consistently found with other allergic conditions it might also share similar risk factors in its development. These risk factors may include

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breast-feeding, birth-order (which has been linked to the "hygiene hypothesis"[10]) and the already established risk for snoring of exposure to environmental tobacco smoke.[1,7,11–14]

The Childhood Asthma Prevention Study (CAPS) is a randomized controlled trial testing the effect of dietary modification and house dust mite avoidance, implemented during the first 5 years of life, on the risk of acquiring asthma and allergic disease.[15] We have utilized prospectively acquired data on environmental risk factors to test the hypothesis that snoring among children with rhinitis at age 5 years is associated with exposure to environmental tobacco smoke, short duration of breastfeeding and birth order. We also examined the association between snoring and the presence of atopy, asthma, eczema, and impaired lung function in children with rhinitis at 5 years.

MATERIALS AND METHODS

The study was approved by the human research ethics committees of the University of Sydney, the Children's Hospital at Westmead, and the Western Sydney and the South Western Sydney Area Heath Services. Informed consent was obtained from the parents.

Study Population and Questionnaire Data

Study design, recruitment and inclusion criteria, the data collection procedure and major findings of CAPS are described in detail elsewhere.[15–17] Briefly, pregnant women whose unborn child would have at least one parent or sibling with current asthma or frequent wheeze were recruited from antenatal clinics of six hospitals in Sydney, Australia. Of 7,171 pregnant women screened, 2,095 (29%) were eligible for inclusion and, of these, 616 (29% of those eligible and 9% of those initially screened) were finally enrolled. The subjects (49.4% girls, 50.6% boys) were born between September 1997 and January 2000. Women were randomized, using a factorial design, to active or control groups for both a house dust mite avoidance intervention and a dietary intervention prior to the first home visit at 36 weeks gestation.

Data on family history of asthma and allergy, maternal smoking in pregnancy, and the presence of older siblings and maternal and paternal education levels (minimum secondary, end of secondary or tertiary level) was obtained at interview with the mother during the perinatal period.

ABBREVIATIONS	
CI	confidence interval
ANOVA	analysis of variance
BMI	body mass index
CAPS	Childhood Asthma Prevention Study
DP	dermatophagoides pteronyssinus
ETS	environmental tobacco smoke
FEV1	forced expiratory volume in 1 sec
OR	odds ratio

Data on smokers in the household was collected at home visits conducted at 3 monthly intervals during the first 12 months and then once every 6 months until the child was aged 5 years. Information on breastfeeding was obtained from dietary questionnaires administered at these assessment times during the first 12 months.

Assessments

At 5 years, one or both parents were interviewed about symptoms and diagnoses relevant to asthma and allergic disease, and the children underwent skin prick tests to assess allergic sensitization and performed pre- and post-bronchodilator spirometry.

Spirometric function was measured before, and 10 min after, the administration of albuterol 200 μg via a large volume spacer using a Spirocard (QRS Diagnostic, LLC, Plymouth, MN) device linked to a laptop computer. The procedure was performed with the child standing, wearing a nose clip and in accordance with American Thoracic Society recommendations, except that a 6 sec expiratory time criterion was not applied. The highest value for forced expiratory volume in 1 sec (FEV1) from at least three acceptable manoeuvres was used for analysis.

Sensitization was measured using skin prick tests to the inhalant allergens Dermatophagoides pteronyssinus (DP, House Dust Mite), cockroach, cat, Alternaria alternata, rye grass and a grass mix and the ingested allergens salmon, peanuts, cow's milk, egg, and tuna (Hollister-Stier, Spokane, WA). Glycerine and histamine (6 mg/ml) were used as negative and positive controls, respectively. The weal size was measured, at 10 min, as the mean of the largest diameter and its perpendicular, each measured to the nearest mm. Weal sizes $\geq$2 mm and $>$negative control were defined as positive. Atopy was defined as the presence of any positive allergen weal.

Definitions of Symptoms, Exposure Variables, and Confounders

Rhinitis status was ascertained at age 5 years using the question "In the last 12 months has your child had a problem with itchy nose, sneezing or a runny or blocked nose which lasted for 1 week or more? (YES/NO)."

Snoring status was ascertained among children with rhinitis at age 5 years. Parents were asked whether their child snored (YES/NO) and, if so, how frequently. The responses were classified as "every night," "more than three nights per week," "more than once per week," and "less than once per week." For analysis, these responses were recoded into two dichotomous variables: "snorer" versus "non-snorer" (from the YES/NO question) and "habitual snorer" versus "not an habitual snorer" (where "every night" and "snoring at least three nights per week" was coded as habitual snorer and "snoring less frequently or not at all" was coded as not an habitual snorer). We also coded an ordinal scale which ranged from 0 = "No Snoring" to 4 = "Every night snoring" with other frequencies of snoring appropriately coded in-between.

We defined probable current asthma at age 5 years as parental report of any wheeze in the previous 12 months at age 5 years and either a parental report of diagnosed asthma at ages 18 months, 3 years, or 5 years or a >12% increase in FEV_1 after bronchodilator at age 5 years. Current eczema was defined as the presence of flexural eczema on inspection (by the assessment nurse) or by parental report of a history of itchy rash coming and going for a period of 3 months or more together with a history of seeking medical care for eczema and/or using steroid or emollient creams in the last 12 months.

Breastfeeding was classified as ever having been breastfed and as having been breastfed for 6 months or more. It was also measured as a continuous variable quantifying the duration of breastfeeding (up to 1 year).

Quantitative data on smoking within the home by the child's mother and by other household members was collected by parental interview at home during the pregnancy (at 36 weeks gestation), at 1, 3, 6, 9, and 12 months after the child's birth and then at 6 monthly intervals until the child was 5 years old. Three exposures to environmental tobacco smoke (ETS) were investigated for their risk of increasing snoring. These were any smoking during pregnancy, any smoking by the mother during the first year of life, and any exposure to ETS during the first 5 years of life.

Statistical Analyses

Analyses were undertaken in SAS v.9.1 (SAS Institute, Cary, NC). Contingency tables were constructed and logistic regression analyses were performed to estimate univariate and multivariate (adjusted) odds ratios.

In the multivariate models we included those variables that were significant in the univariate analyses as well as some other variables that had been shown in previous studies to be associated either with snoring or allergic disease or could conceivably confound the association with the main independent predictors and snoring. All multivariate models were also adjusted for the intervention group the child had been assigned to in the randomized controlled trial. Three multivariate models were tested. The first and second models (Table 1) investigated risk factors for any level of snoring versus no reported snoring. The second model excluded co-associated allergic outcomes (asthma, eczema, and atopy) in order to assess the effects of risk factors without these other allergic endpoints. The third model (Table 2) employed the same risk factors that were present in the first model but the dependent variable was habitual snoring status. Models presented in both tables were tested for the following two-way interactions between the covariates: mother's age by birth order, mother's age by breastfeeding, mother's age by mother's smoking during first 12 months, mother's smoking by breastfeeding and birth order by breastfeeding. Multi-colinearity was investigated using the variance inflation factor. Dose-response relationships between the severity of snoring and continuous variables were investigated by ANOVA.

The relationship between snoring status and spirometric function was analyzed using the general linear model with the child's height and gender as covariates.

RESULTS

Rhinitis

Of the 516 children who were assessed at age 5 years, 219 (42%) reported rhinitis within the last year. Information on snoring was available for 213 (97%) of these 219 children.

Snoring Prevalence

Any snoring was reported in 127 (59.6%) of 213 children. These included 38 (17.8%) who snored less than once a week, 33 (15.5%) who snored more than once a week, 31 (14.6%) who snored more than 3 nights a week, and 25 (11.7%) who snored every night.

Asthma, Eczema, and Atopy

Probable current asthma, current eczema and parental history of asthma were significant risk factors for snoring (Table 1). However, in multivariate models parental history of asthma was not an independent predictor, after inclusion of the child's current asthma status (Table 1). Skin prick test data were available for 202 of the 213 children. The presence of atopy was not a significant risk factor for snoring in these children with rhinitis OR 1.39 (95% CI 0.79–2.47).

Breastfeeding

Being breastfed for at least 6 months was not associated with snoring (Tables 1 and 2). The frequency of snoring was not related to the duration of breastfeeding ($P = 0.78$).

Birth-Order

Children who were first-born in their family were significantly more likely to be snorers than children who had older siblings (Table 1). However, being a first born child was not a risk factor for habitual snoring (Table 2).

Environmental Tobacco Smoke

Among the indices of ETS exposure, the largest and only significant univariate risk factor for snoring was maternal ETS exposure during the first year (OR 2.08 95% CI 1.05–4.11). Smoke exposure from the mother during pregnancy, during the first year of life, and during the first 5 years of life

TABLE 1— Predictors of Any Snoring at 5 Years of Age in Children With Rhinitis

Predictor	N	% who snored	Univariate odds ratio (95% CI)	Multivariate odds ratio[1] (95% CI) Model 1	Multivariate odds ratio[1] (95% CI) Model 2
Probable current asthma at 5 years					
No	152	52.6	Ref.	Ref.	
Yes	61	77.1	2.87 (1.42–5.80)	2.70 (1.23–5.93)	
Maternal asthma history					
No	93	54.8	Ref.		
Yes	120	63.3	1.39 (0.79–2.47) →		
Paternal asthma history				No = Ref.	
No	138	54.4	Ref.	→ 1.43 (0.64–3.20)	
Yes	75	69.3	1.75 (0.95–3.23)		
Atopy at 5 years					
No	106	56.6	Ref.	Ref.	
Yes	96	64.6	1.39 (0.79–2.47)	1.08 (0.55–2.13)	
Current eczema at 5 years					
No	162	54.9	Ref.	Ref.	
Yes	51	74.5	2.29 (1.13–4.66)	2.29 (1.02–5.13)	
Sex					
Female	106	64.2	Ref.	Ref.	Ref.
Male	107	55.1	0.66 (0.37–1.17)	0.57 (0.30–1.09)	0.58 (0.32–1.07)
Birth order					
Not first-born	140	52.9	Ref.	Ref.	Ref.
First-born	73	72.6	2.29 (1.23–4.27)	2.50 (1.20–5.21)	2.91 (1.45–5.82)
Maternal age at birth of child					
<25.1 years	50	64.0	Ref.		
25.1–29.1 years	56	64.3	0.82 (0.37–1.86)		
29.1–32.7 years	52	53.9	0.78 (0.34–1.79)		
>32.7 years	55	56.4	0.65 (0.29–1.45)		
Breastfeeding for ≥6 months					
Yes	87	56.3	Ref.	Ref.	Ref.
No	126	61.9	1.38 (0.77–2.45)	1.52 (0.79–2.94)	1.46 (0.78–2.72)
Mother smoked during pregnancy					
No	163	57.1	Ref.		
Yes	50	68.0	1.71 (0.84–3.46)		
Mother smoked during child's first year					
No	153	54.9	Ref.	Ref.	Ref.
Yes	56	71.4	2.08 (1.05–4.11)	2.51 (1.14–5.55)	2.43 (1.13–5.20)
Any smoke exposure in 5 years					
No	136	56.6	Ref.		
Yes	77	64.9	1.50 (0.82–2.74)		
Diet intervention					
Control	102	65.7	1.39 (0.79–2.47)		
Active	111	54.1	Ref.		
HDM intervention					
Control	103	62.1	1.26 (0.71–2.22)		
Active	110	57.3	Ref.		

[1]Adjusted for other variables in this column and also adjusted for dietary and house dust mite avoidance randomization groups and for maternal age. Ref., reference category.

were investigated independently in the multivariate models. These multivariate odds ratios for association with snoring were very similar to the univariate odds ratios. However due to colinearity among the ETS exposure variables odds ratios were markedly changed when they were analyzed together. The strongest predictor remained maternal ETS exposure during the first year. Therefore, we present maternal ETS exposure during the first year of life as the key ETS risk factor for later snoring.

Other Potential Risk Factors for Snoring

Increasing levels of snoring severity were not significantly associated with lower maternal age ($P = 0.23$), child's body mass index at age 4.5 years ($P = 0.34$), birth weight ($P = 0.87$) or either maternal or paternal education levels (both $P > 0.8$). The variability of body weight in the highest snoring category was higher than in other

TABLE 2— Predictors of Habitual Snoring (3+ Nights/Week) at 5 Years of Age in Children With Rhinitis

Predictor	N	% who snored	Univariate odds ratio (95% CI)	Multivariate odds ratio[1] (95% CI) Model 1
Probable current asthma at 5 years				
No	152	20.4	Ref.	Ref.
Yes	61	41.0	2.80 (1.44–5.45)	3.36 (1.57–7.23)
Maternal asthma history				
No	93	22.6	Ref.	
Yes	120	29.2	1.37 (0.72–2.59) →	
Paternal asthma history				No = Ref.
No	138	26.1	Ref.	0.47 (0.20–1.14)
Yes	75	26.7	0.99 (0.51–1.91) ↗	
Atopy at 5 years				
No	106	26.4	Ref.	Ref.
Yes	96	27.1	1.01 (0.54–1.89)	0.93 (0.44–1.95)
Current eczema at 5 years				
No	162	24.1	Ref.	Ref.
Yes	51	33.3	1.36 (0.68–2.74)	1.28 (0.58–2.85)
Sex				
Female	106	34.0	Ref.	Ref.
Male	107	18.7	0.50 (0.26–0.95)	0.48 (0.23–0.97)
Birth order				
Not first-born	140	25.0	Ref.	Ref.
First-born	73	28.8	1.16 (0.61–2.21)	1.24 (0.58–2.67)
Maternal age at birth of child				
<25.1 years	50	36.0	Ref.	
25.1–29.1 years	56	23.2	0.53 (0.22–1.26)	
29.1–32.7 years	52	26.9	0.73 (0.31–1.72)	
>32.7 years	55	20.0	0.42 (0.17–1.04)	
Breastfeeding for ≥6 months				
Yes	87	26.2	Ref.	
No	126	26.4	1.12 (0.59–2.13)	
Mother smoked during pregnancy				
No	163	23.9	Ref.	
Yes	50	34.0	1.82 (0.90–3.69)	
Mother smoked during child's first year				
No	153	23.5	Ref.	Ref.
Yes	56	35.7	1.90 (0.97–3.73)	1.70 (0.78–3.70)
Any smoke exposure in 5 years				
No	136	22.8	Ref.	
Yes	77	32.5	1.84 (0.97–3.48)	
Diet intervention				
Control	102	28.4	1.24 (0.66–2.32)	
Active	111	24.3	Ref.	
HDM intervention				
Control	103	27.2	1.06 (0.57–1.98)	
Active	110	25.5	Ref.	

[1]Employing exactly the same model used for any snoring (Table 1). Adjusted for other variables in this table and also adjusted for dietary and house dust mite avoidance randomization groups and for maternal age. Ref., reference category.

categories indicating the effect of a small number of obese, snoring children.

Forced expiratory volume over 1 sec (FEV_1) did not differ between snorers (mean 1.06 L) and non-snorers (mean 1.08 L, $P = 0.6$) nor between frequent snorers (mean 1.05 L) and less frequent or non-snorers (mean 1.08 L, $P = 0.5$), after controlling for gender and height.

The prevalence of snoring among children with rhinitis did not differ between active and control groups for the house dust mite avoidance intervention or the dietary intervention.

Multivariate Models

In the full multivariate model, being the first-born child, having been exposed to a mother who smoked during the child's first year of life, having asthma and having eczema at age 5 years were independent risk factors for reported snoring among children with rhinitis at age 5 years. In a more limited model, which excluded associated clinical outcomes at age 5 years, being the first-born child and having a mother who smoked during the child's first year of life both remained significant independent risk factors for snoring. In the model of habitual snoring (more than three nights per week) that used the same risk factors tested in the first model only asthma and female gender were significant independent risk factors.

DISCUSSION

Children in the CAPS cohort with rhinitis had a high prevalence of snoring at least once per week at age 5 years (59.6%). Independent risk factors for snoring include being a first-born child; exposure to environmental tobacco smoke, particularly from the mother during the child's first year of life; and the co-existence of asthma or eczema. The child's gender, the mother's age when the child was born, the parental history of asthma, the duration of breastfeeding and the child's body mass index, atopic status and lung function at age 5 years were not found to be independent risk factors for snoring in this cohort, although girls with rhinitis were more likely to have habitual snoring than boys with rhinitis.

The prevalence of habitual snoring among children with rhinitis in the CAPS cohort was 26.3%, which is much higher than the 10.5% reported in 2–5 year olds in rural Australia or the 15.2% reported in primary school children living in Perth, Western Australia.[6,7] The restriction of this cohort to children with rhinitis, an established risk factor for snoring,[5,7,9,11,12] is the probable explanation for the high prevalence of snoring.

We have demonstrated that snoring in children with rhinitis is associated with asthma and eczema and also with risk factors for asthma and allergic disease, specifically exposure to ETS and being a first-born child. The lack of association with atopy (previously reported[8]), measured by positive skin prick tests, is probably explained by the restriction of the cohort to children with rhinitis. We acknowledge that the association between asthma and snoring could be explained by misclassification of nocturnal wheeze as snoring, or vice versa and that the absence of an association between snoring and impaired lung function means that snoring is not associated with severe asthma. However, the association between snoring with eczema cannot be explained by this misclassification. These findings, together with the previously reported beneficial effect of leukotriene receptor antagonists in the treatment of children with mild sleep-disordered breathing,[18] are consistent with the view that snoring forms part of the spectrum of allergic diseases in childhood.

Breastfeeding might promote an oral cavity with a wide caliber that reduces the likelihood of upper airway occlusion during sleep.[19] However, the role of breastfeeding in protecting against snoring and sleep disordered-breathing has not been directly evaluated in previous studies. Our data do not provide support for the contention that breastfeeding protects against childhood snoring, at least in children with rhinitis.

Exposure to environmental tobacco smoke (ETS) has been found to be a risk factor for snoring in children.[1,7,11–14] Our prospective data in a subset of children with symptoms of rhinitis confirms those previous cross-sectional observations. Furthermore the relationship between maternal exposure to ETS in the first year is significant in both of the snoring models presented and remains elevated in the model of habitual snoring. A report from a 1-year-old birth cohort did not find an association between ETS exposure and snoring but concluded that "a critical duration of ETS exposure may be necessary before this association can be detected".[8] Our findings are congruent with this hypothesis. Our observations help to prospectively demonstrate that exposure to ETS, particularly via the mother in the first year, is a risk factor for snoring in children with rhinitis at age 5.

We found that first-born children are more likely to snore than children who have older siblings. However, this association does not apply to habitual snoring where being first born is not a risk factor. Although it is possible that this finding is explained by differential reporting due to parents being more sensitive to occasional snoring in their first-born child, first-born children have been consistently shown to be at higher risk of allergic diseases.[10] This was the first of several hygiene-related early life exposures that have been shown to be risk factors for asthma and allergic diseases.[20–22] The observed independent association between infrequent snoring and birth-order implies that hygiene-related immunological mechanisms may also play a part in the aetiology of snoring, even in children with rhinitis.

A recent review of the epidemiology of sleep-disordered breathing concluded that snoring in children was roughly equally prevalent in boys and girls.[23] We found a higher risk of habitual snoring in girls although the difference was not statistically significant for all snoring. Although, it is possible that the restriction of the cohort to children with rhinitis may have altered the gender association with snoring, this observation may be yet another important demonstration of gender differences in the course of allergic and airway diseases during childhood.

Although the association between obesity and snoring has been well established in adults[23] and school age children[11,14] our findings imply that body mass is not an important contributor to risk of snoring in pre-school age children. It seems likely that upper airway morphology and the manifestations of allergic disease are more important.

Two stages of selection applied to this study cohort will influence the generalizability of these findings. The CAPS cohort was selected to have a high risk of developing asthma and other allergic diseases due to all children having at least one first-degree relative with asthma. The analyses presented here are further limited to children whose parents reported that they had a ‘‘a problem with itchy nose, sneezing or a runny or blocked nose which lasted for 1 week or more’’ in the last year. We have labeled this condition as rhinitis although we acknowledge that other upper airway pathology may explain this symptom in children. This selection process means that prevalence estimates are not applicable to the general population. However, it will have less impact on the interpretation of the observed associations with risk factors, except that those characteristics or exposures that are strongly correlated with the presence of rhinitis or a family history of asthma may be under-estimated as potential risk factors for snoring.

The relatively small size of the study cohort means that non-significant associations need to be interpreted with caution. Tables 1 and 2 demonstrate that confidence intervals around the effect estimates are broad and do not exclude the possibility that a larger study would show clinically relevant, significant associations between snoring and additional risk factors.

The lack of any objective measure of snoring is an important potential limitation of these analyses. However, unlike adults and older children, children aged 5 years and younger are commonly observed during all stages of sleep by their parents and others and frequent or habitual snoring has been shown to be a highly sensitive and specific measure of in-laboratory measured snoring in preschool and early school-age children.[9] In that study, many children whose parents reported occasional snoring did not have snoring on polysomnography (low specificity). This is not unexpected, since the sleep study only measured one night and the parental report implies that the occurrences are episodic and may not have occurred on the night of the sleep study. Hence, parental report, as used in this study, is probably a valid measure of snoring in young children.

Obstructive sleep apnea syndrome is a common condition in childhood and can result in severe complications if left untreated. There are guidelines to enhance the primary care clinician's ability to recognize obstructive sleep apnea syndrome and our data may contribute to their ability to comply with recommendations to screen for snoring at well-child's visits.[3,4]

We have shown that snoring is common among children with rhinitis. In these children snoring is associated with asthma and eczema and shares some of the common risk factors for allergic diseases. Snoring in children may be regarded as part of the spectrum of allergic diseases.

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