Risk Factors and Natural History of Habitual Snoring*

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Study objective: **It has been suggested that habitual snoring (HS) has adverse health outcomes in children. We aimed to identify risk factors for HS and determine its natural history in primary school children.**

Design: **Cross-sectional, population-based cohort study.**

Setting: **Twenty-seven primary schools located within the city limits of Hannover, Germany.**

Participants: **Third-grade primary school children.**

Measurements and results: **Snoring frequency and potential risk factors were investigated using parental questionnaires. Unadjusted and adjusted odds ratios (ORs) for HS and their 95% confidence intervals (CIs) were calculated. One year after the initial contact, snoring status was re-evaluated in habitual snorers. In total, 1,760 children were contacted, and 1,144 parents and their children (49% were girls) agreed to participate and returned a completed questionnaire. A body mass index ≥ 90th percentile (OR, 3.5; 95% CI, 1.8 to 7.1), low maternal education (OR, 2.3; 95% CI, 1.1 to 4.7), regular daytime mouth breathing (OR, 7.4; 95% CI, 3.5 to 15.6), and a higher frequency of sore throats (OR, 17.6; 95% CI, 6.4 to 48.8) were independent risk factors for HS. Parental smoking and frequent infections were significantly but not independently associated with HS. The association of low maternal education and HS was higher in boys (OR, 4.4; 95% CI, 1.5 to 13.6; vs OR, 1.2; 95% CI, 0.4 to 3.6), while that of sore throats and HS was higher in girls (OR, 52.7; 95% CI, 6.0 to 460.2; vs OR, 13.3; 95% CI, 3.0 to 58.5). At follow-up, 39 of 80 eligible habitual snorers (48.8%) still snored regularly. Children who continued to snore differed significantly in maternal education, household smoking, snoring loudness, and prior ear, nose, throat surgery from those who had ceased to snore habitually.**

Conclusions: **Socioeconomic status, obesity, signs of nasal obstruction, and pharyngeal problems were independent risk factors for HS in these primary school children. The expression of HS varied considerably over time.**

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Key words: child; mouth breathing; nasal obstruction; obesity; risk factor; snoring; socioeconomic status; sore throat

Abbreviations: BMI = body mass index; CI = confidence interval; ENT = ear, nose, and throat; HS = habitual snoring; OR = odds ratio; OSA = obstructive sleep apnea; SDBQ = sleep-disordered breathing questionnaire; SES = socioeconomic status

Habitual snoring (HS) [*ie*, snoring on most nights] is increasingly recognized as an important public health problem in adults, especially since a large population-based study[1] revealed a high prevalence of HS (23%), and an association with daytime sleepiness independent of the frequency of obstructive sleep apnea (OSA) and cortical arousal. Thus, not only HS combined with OSA and daytime sleepiness (*ie*, OSA syndrome) or with multiple cortical arousals and daytime sleepiness (*ie*, upper airway resistance

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syndrome), but also primary snoring (*ie*, HS without OSA or multiple cortical arousals) appears to be linked to impaired daytime functioning in adults.

In contrast, HS seems to be less frequent in preschool children,[2] school children,[3–5] and adolescents,[6] affecting approximately 1 in 10. Similar to adults, however, children with primary snoring and/or upper airway resistance syndrome also appear to exhibit impaired daytime functioning and may benefit from intervention. Studies demonstrated significant impairments in children with primary snoring and/or upper airway resistance syndrome[7,8] and improvement in daytime functioning after surgical treatment for these conditions.[8,9] As in adults, primary snoring and/or upper airway resistance syndrome, as well as OSA, may be important public health burdens in children. Thus, population-based, cross-sectional, and cohort studies are needed to further investigate risk factors and the natural history of HS. Identifying modifiable risk factors would give the opportunity for interventions by public health campaigns.

We recently performed a cross-sectional study[5] on the prevalence of sleep-disordered breathing and its association with poor academic performance on a large cohort of primary school children. This included a questionnaire on most of the currently known risk factors for HS. In this report on that study, we determined the value of these factors in predicting HS and investigated its natural history. We focused on gender differences in associations between risk factors and HS, and speculated that gender differences are uncommon in this age group.

Materials and Methods

Subjects

The recruitment strategy and basic characteristics of the study sample are described elsewhere.[5,10] In short, 27 of 59 regular primary schools located within the city limits of Hannover, Germany were selected, using a stratified random selection procedure. Following approval by the institutional review board and the regional directorate of education, all children attending the third grade (n = 1,760) were identified. Pupils were contacted in their classrooms by two investigators, and study goals were presented to the children. A cover letter explaining the study, an informed consent form, and a questionnaire on signs and symptoms of sleep-disordered breathing were given to the children to be filled in by their parents. A telephone hotline was set up to respond to any question concerning the study. After being returned to school, questionnaires were collected by the classroom teacher and picked up by a study crewmember 1 to 2 weeks after the initial visit. Finally, 1,144 children (65.0%) participated in the study. Comparisons to all eligible third graders (n = 1,760) and the underlying source population of third graders (n = 3,809) revealed good-to-excellent representativeness concerning gender distribution, socioeconomic status (SES), academic performance, and diagnosis of asthma.[10]

Sleep-Disordered Breathing Questionnaire

Children were screened for signs and symptoms of sleep-disordered breathing using a widely used and validated questionnaire, the sleep-disordered breathing questionnaire (SDBQ).[11–14] This questionnaire was translated into German and extended with questions concerning gender, metric data (*ie*, age, height, and weight), current health status (*ie*, history of adenotomy, adenotonsillectomy, asthma, allergies, and frequency of infections), household smoking, and parental education.[15] Race was not recorded, because the prevalence of nonwhites among participants was < 5%. According to Gozal[13] most questions were rated on a 5-point rating scale (never, rarely, occasionally, frequently, and almost always); but for the purpose of this study, the categories "frequently" and "almost always" were collapsed into the category "frequently."

Body mass index (BMI) was calculated using a standard formula. Household smoking was investigated with the question: "How many cigarettes are smoked in your household per day?" Answers were rated on a 3-point scale (none, 1 to 10 cigarettes, and > 10 cigarettes).[15] Parental education was investigated separately for either parent. The highest graduation was defined on a 4-point scale (no graduation/primary school, level 1; secondary school, level 2; high school, level 3; and college/university, level 4). For the purpose of this study, graduation from high school and college/university were grouped together as level 3.

Snoring was investigated with the question: "Does your child snore?" and rated on a 4-point scale (never, occasionally, frequently, and always).[11] Children were classified as habitual snorers if the answers were "frequently" or "always," and as nonsnorers if the answers were "never" or "occasionally." Nose obstruction was investigated with the questions "Is your child a daytime mouth breather?"[12] and "Has your child a diagnosis of allergy or chronic rhinitis? If yes, please specify." Based on the responses to the allergy question, children were classified as having respiratory allergies (including chronic rhinitis), nonrespiratory allergies, or no allergy. Pharyngeal problems were investigated with the question "How often does your child have a sore throat?"[12] Infections were addressed as follows: "How often did your child have infections (*eg*, rhinitis, bronchitis, otitis) during the past 12 months?" Answers were rated on a 2-point scale (one to seven times, or eight times or more).[15] Asthma was investigated with the following question: "Does your child have any chronic lung disease (*eg*, asthma)? If yes, please specify." Based on the responses children were classified as suffering from asthma or not. Ear, nose, and throat (ENT) surgery was evaluated using the following questions: "Have the adenoids been taken out in your child?" and "Have the tonsils been taken out in your child?"

Follow-up

Approximately 1 year after the initial survey, current snoring status and associated symptoms were re-evaluated in all habitual snorers found among the initial study sample (n = 114). A cover letter emphasizing our continuous interest in the child's breathing and a short version of the SDBQ were mailed to the children's homes. Parents were asked to fill in the questionnaires and send them back using a provided stamped and addressed envelope. Nonresponders were contacted twice by telephone.

Statistics

All analysis was done with statistical software (Statistical Package for the Social Science, release 11.0 for Windows; SPSS; Chicago, IL). Descriptive statistics were used to summarize subject characteristics and questionnaire data. Comparison between groups was done using Student t test for continuous variables and the Mann-Whitney U and Pearson's χ^2 tests and χ^2 test for trend for discrete variables where appropriate. Collinearity was tested using the Kendall-Tau correlation coefficient for discrete variables. All significance tests were two sided, and a $p < 0.05$ was considered statistically significant. Unadjusted odds ratios (ORs) and their 95% confidence intervals (CIs) for HS were calculated using unconditional logistic regression. Adjustments were made following a two-step procedure. Firstly, adjustments were made only for personal characteristics (*ie*, gender, age category, BMI category, parental education, and household smoking [model A]). Secondly, adjustments were made for personal characteristics and clinical factors being related to HS in univariate analysis (*ie*, daytime mouth breathing, sore throats, frequent infections [model B]).

Results

Study Sample

Detailed information on basic characteristics of the study sample has been given elsewhere.[5,10] In short, there were 559 girls (48.9%); mean age and body mass index (BMI) were 9.6 years (SD, 0.7) and 17.5 (SD, 2.9), respectively. Most children (n = 681; 59.5%) were 9 years old, but 213 children (18.6%) and 250 children (21.9%) were < 9 years or > 9 years old, respectively. The 75th and 90th percentiles of the BMI were 19.0 and 21.4 for the study sample, 19.5 and 21.8 for boys, and 18.5 and 20.8 for girls, respectively. These percentiles were used to form categories (*ie*, < 75th percentile, 75th to 89th percentile, and ≥ 90th percentile) for all further analyses.

Proportions of HS and other related factors are provided in Table 1. Parental information on snoring was available for 1,129 children (98.7%). Of these, 410 children (36.3%) and 605 children (53.6%) were reported to snore "never" or "occasionally," respectively, and were grouped as nonsnorers. Eighty-nine children (7.8%) and 25 children (2.2%) snored "frequently" or "always," and were categorized as habitual snorers. Among the 114 children with HS, snoring loudness was rated mildly quiet, medium loud, loud, and very loud in 7 children (6.2%), 71 children (62.8%), 25 children (22.1%), and 10 children (8.8%). There was no significant difference in

Table 1—*Prevalence of Snoring and Related Factors in the Study Sample and Stratified by Gender**

Snoring-Related Factor Definition	Study Sample	Boys	Girls	Boys vs Girls, p Value
Snoring status				NS
Nonsnoring	1,015 (89.9)	524 (91.1)	491 (88.6)	
Habitual snoring	114 (10.1)	51 (8.9)	63 (11.4)	
Household smoking, cigarettes/d				0.009
None	560 (50.6)	266 (47.1)	294 (54.3)	
1–10	228 (20.6)	119 (21.1)	109 (20.1)	
> 10	318 (28.8)	180 (31.9)	138 (25.5)	
Daytime mouth breathing				< 0.001
Never	280 (25.2)	125 (22.1)	155 (28.4)	
Rarely	383 (34.5)	185 (32.7)	198 (36.3)	
Occasionally	244 (22.0)	134 (23.7)	110 (20.2)	
Frequently	204 (18.4)	122 (21.6)	82 (15.0)	
Sore throats				0.004
Never	162 (14.4)	98 (17.0)	64 (11.6)	
Rarely	704 (62.5)	358 (62.0)	346 (62.9)	
Occasionally	207 (18.4)	103 (17.9)	104 (18.9)	
Frequently	54 (4.8)	18 (3.1)	36 (6.5)	
Infections, /yr				NS
0–7	1,026 (94.7)	530 (95.3)	496 (94.1)	
> 7	57 (5.3)	26 (4.7)	31 (5.9)	
Allergies				< 0.001
None	903 (84.9)	439 (80.7)	464 (89.2)	
Nonrespiratory	32 (3.0)	17 (3.1)	15 (2.9)	
Respiratory	129 (12.1)	88 (16.2)	41 (7.9)	
Asthma				NS
No	1,017 (95.1)	516 (94.9)	501 (95.4)	
Yes	52 (4.9)	28 (5.1)	24 (4.6)	
ENT surgery				NS
No	824 (73.7)	410 (71.1)	414 (76.5)	
Only AT	243 (21.7)	141 (24.4)	102 (18.9)	
ATE	45 (4.0)	22 (3.8)	23 (4.3)	

*Data are presented as No. (%). NS = not significant; AT = adenotomy; ATE = adenotonsillectomy.

this distribution between girls and boys. Girls were significantly less exposed to household smoking and had less daytime mouth breathing and allergies reported, while they were significantly more likely to complain about sore throats (Table 1).

Personal Characteristics and HS

Unadjusted ORs for HS stratified by personal characteristics are given in Table 2. Obesity was the most important factor within this group of risk factors. Children with a BMI $\geq$ 90th percentile had more than four times the risk for HS than those with a BMI < 75th percentile. Approximately one in four obese boys and girls snored habitually. A statistically significant association between an increased BMI and HS was also found in girls with a BMI within the 75th to 89th, but not in boys with the corresponding gender-specific BMI range. There was a significant association between maternal education and HS. The prevalence of HS decreased with increasing education. This was found in both sexes, but was only significant for boys. Household smoking was the third personal characteristic that was significantly associated with HS. In both sexes, the prevalence of HS was higher in children exposed to household smoking of > 10 cigarettes per day than in children not exposed to smoking. Again, this association was only significant for boys. While boys showed a steady decrease in HS along the age categories, there was an increase with age in girls. Girls who were $\geq$ 10 years old had twice the risk for HS than girls $\leq$ 8 years old, or than boys of similar age. This tendency, however, did not reach statistical significance. Within the age group $\geq$ 10 years, however, girls had a significantly higher risk for HS in univariate analysis than boys (OR, 2.5; 95% CI, 1.1 to 5.7).

Clinical Factors and HS

Unadjusted ORs for HS stratified by clinical factors are given in Table 3. Among the clinical factors, daytime mouth breathing, sore throats, and frequent infections were significantly associated with HS, while a history of allergies, asthma, and ENT surgery were not. This was found in the total study sample and separately for boys and girls. The strongest association was found between sore throats and HS. While there were quite similar ORs for HS in boys and girls regarding the factors daytime mouth breathing and frequent infections, we found a remarkable gender difference for sore throats. Girls complaining frequently about sore throats had a five-times-higher risk for HS than comparable boys. Moreover, occasionally complaining about a sore throat was only significantly associated with HS in girls, but not in boys.

Table 2—*Prevalence and Unadjusted ORs for HS Stratified by Personal Characteristics and Gender*

	Study Sample			Boys			Girls		
Characteristics	No.	%	OR (95% CI)	No.	%	OR (95% CI)	No.	%	OR (95% CI)
Gender									
Boys	51	8.9	Reference						
Girls	63	11.4	1.3 (0.9–1.9)						
Age, yr									
< 9	19	9.0	Reference	9	9.8	Reference	10	8.3	Reference
9	68	10.1	1.1 (0.7–2.0)	31	9.3	0.9 (0.4–2.1)	37	10.9	1.4 (0.7–2.8)
> 9	27	11.0	1.3 (0.7–2.3)	11	7.4	0.7 (0.3–1.8)	16	16.7	2.2 (0.9–5.1)
BMI, percentile									
< 75	50	7.3	Reference	22	6.3	Reference	27	7.8	Reference
75–89	19	13.6	2.0 (1.1–3.5)	8	11.3	1.9 (0.8–4.4)	11	16.2	2.3 (1.1–4.8)
≥ 90	22	22.9	3.8 (2.2–6.6)	11	23.4	4.5 (2.0–10.1)	12	26.1	4.1 (1.9–8.9)
Maternal education									
High	28	7.3	Reference	8	4.2	Reference	20	10.5	Reference
Medium	41	10.3	1.4 (0.9–2.4)	21	10.0	2.5 (1.1–5.9)	20	10.6	1.0 (0.5–2.0)
Low	39	13.9	2.0 (1.2–3.4)	18	13.2	3.5 (1.5–8.2)	21	14.6	1.5 (0.8–2.8)
Paternal education									
High	41	9.4	Reference	19	8.6	Reference	22	10.2	Reference
Medium	27	9.0	1.0 (0.6–1.6)	11	7.5	0.9 (0.4–1.9)	16	10.5	1.0 (0.5–2.0)
Low	32	12.1	1.3 (0.8–2.2)	12	8.5	1.0 (0.5–2.1)	20	16.3	1.7 (0.9–3.3)
Household smoking, cigarettes/d									
No	50	9.0	Reference	18	6.8	Reference	32	10.9	Reference
1–10	17	7.7	0.8 (0.5–1.5)	8	7.0	1.0 (0.4–2.4)	9	8.3	0.7 (0.3–1.6)
> 10	45	14.4	1.7 (1.1–2.6)	23	13.0	2.0 (1.1–3.9)	22	16.2	1.6 (0.9–2.8)

Table 3—*Prevalence and Unadjusted ORs for HS Stratified by Clinical Factors and Gender**

Clinical Factors	Study Sample			Boys			Girls		
	No.	%	OR (95% CI)	No.	%	OR (95% CI)	No.	%	OR (95% CI)
Daytime mouth breathing									
Never	12	4.3	Reference	4	3.2	Reference	8	5.2	Reference
Rarely	17	4.5	1.0 (0.5–2.2)	5	2.7	0.8 (0.2–3.2)	12	6.1	1.2 (0.5–3.0)
Occasionally	27	11.4	2.9 (1.4–5.8)	14	10.7	3.6 (1.1–11.2)	13	12.3	2.6 (1.01–6.4)
Frequently	56	27.7	8.5 (4.4–16.4)	27	22.5	8.7 (2.9–25.8)	29	35.4	10.0 (4.3–23.2)
Sore throats									
Never	7	4.4	Reference	6	6.3	Reference	1	1.6	Reference
Rarely	41	5.9	1.4 (0.6–3.1)	20	5.7	0.9 (0.4–2.3)	21	6.1	4.0 (0.5–30.4)
Occasionally	36	17.6	4.7 (2.0–10.8)	15	14.9	2.6 (0.97–7.1)	21	20.4	15.8 (2.1–120.4)
Frequently	29	53.7	25.2 (10.0–63.7)	9	50.0	15.0 (4.3–51.8)	20	55.6	77.2 (9.7–617.1)
Infections, per yr									
0–7	89	8.8	Reference	41	7.8	Reference	48	9.8	Reference
> 7	20	35.7	5.8 (3.2–10.4)	7	28.0	4.6 (1.8–11.6)	13	41.9	6.7 (3.1–14.5)
Allergies									
None	84	9.5	Reference	34	7.9	Reference	53	11.5	Reference
Nonrespiratory	4	12.5	1.3 (0.5–3.9)	1	5.9	0.7 (0.1–5.7)	3	20.0	1.9 (0.5–7.0)
Respiratory	16	12.0	1.1 (0.6–2.0)	9	10.9	1.4 (0.6–3.0)	4	9.8	0.8 (0.3–2.4)
Asthma									
No	102	10.2	Reference	43	8.5	Reference	59	11.9	Reference
Yes	4	7.8	0.8 (0.3–2.1)	2	7.4	0.9 (0.2–3.8)	2	8.3	0.7 (0.2–2.9)
ENT surgery									
No	75	9.2	Reference	33	8.2	Reference	42	10.2	Reference
Only AT	30	12.6	1.4 (0.9–2.2)	16	11.7	1.5 (0.8–2.8)	14	13.7	1.4 (0.7–2.7)
ATE	4	8.9	1.0 (0.3–2.8)	1	4.5	0.5 (0.1–4.1)	3	13.0	1.3 (0.4–4.6)

*See Table 1 for expansion of abbreviations.

Multivariate Analysis

Results of the multivariate analyses are presented in Table 4. After adjusting for personal characteristics (model A), the strength of association between household smoking and HS was reduced and significance lost. Tests for collinearity between covariates included in the model showed weak but significant correlation coefficients for the association between household smoking and BMI category ($r = 0.19$; $p < 0.001$) and between household smoking and maternal education ($r = -0.316$; $p < 0.001$). As done in univariate analysis, the association between gender and HS was re-examined after stratification by age. This revealed a still significant association between female sex and HS in children ≥ 10 years old (OR, 2.6; 95% CI:, 1.1 to 6.2).

After adjusting for personal characteristics and clinical factors (model B), the strength of association between frequent infections and HS was reduced and significance lost. Tests for collinearity between covariates showed a weak but significant correlation between frequent infections and daytime mouth breathing ($r = 0.15$; $p < 0.001$) or sore throats ($r = 0.2$; $p < 0.001$). Regarding the association between female sex and HS in children ≥ 10 years old, statistical significance was lost in this multivariate model although the strength remained quite stable (OR, 12.3; 95% CI, 0.8 to 6.9).

Follow-up

Follow-up data were available for 80 habitual snorers (70.2%). The mean interval between filling in the initial SDBQ and the follow-up SDBQ was 13.5 months (SD 2.9). Follow-up participants had higher educated mothers compared to nonparticipants (prevalence of low, medium, and high maternal education: 31.3%, 38.8%, and 30.0% in follow-up participants, vs 50.0%, 35.7, and 14.3% in nonparticipants, respectively). Other personal characteristics (*ie*, gender, age, BMI, and paternal education) were similar between groups. At follow-up, only 39 of 80 former habitual snorers (48.8%) still snored habitually. Thirty-nine children (48.8%) now snored only occasionally, and 2 children (2.5%) had ceased snoring. Three children (4.2%) had increased their snoring. Based on the follow-up results, habitual snorers were grouped in ex-habitual snorers (n = 41) and long-term habitual snorers (n = 39).

To find predictors for long-term HS, both groups were compared by personal and clinical characteristics derived from the initial SDBQ (Table 5). This revealed maternal education, household smoking, snoring loudness, and ENT surgery since the initial survey (two tonsillectomies and two adenotonsillectomies) to be significantly different between both groups (Table 5).

Table 4—*Adjusted ORs for HS Stratified by Significant Snoring-Related Factors and Gender**

Snoring-Related Factors	Model A†			Model B‡		
	Study Sample	Boys	Girls	Study Sample	Boys	Girls
BMI, percentile						
< 75	Reference	Reference	Reference	Reference	Reference	Reference
75–89	2.0 (1.1–3.5)	1.9 (0.8–4.5)	2.0 (0.9–4.4)	1.7 (0.9–3.3)	2.0 (0.7–5.2)	1.4 (0.5–3.6)
≥ 90	3.4 (1.9–6.1)	3.7 (1.6–8.8)	3.5 (1.6–8.0)	3.5 (1.8–7.1)	4.6 (1.6–12.9)	3.3 (1.2–8.8)
Maternal education						
High	Reference	Reference	Reference	Reference	Reference	Reference
Medium	1.6 (0.9–2.9)	2.8 (1.1–7.2)	1.0 (0.4–2.1)	1.5 (0.8–2.9)	2.3 (0.8–6.1)	1.1 (0.5–2.8)
Low	2.0 (1.03–3.7)	4.2 (1.5–11.7)	0.9 (0.4–2.2)	2.3 (1.1–4.7)	4.4 (1.5–13.6)	1.2 (0.4–3.6)
Household smoking, cigarettes/d						
No	Reference	Reference	Reference	Reference	Reference	Reference
1–10	0.7 (0.4–1.3)	0.8 (0.3–2.1)	0.7 (0.3–1.5)	0.8 (0.4–1.6)	0.9 (0.3–2.5)	0.7 (0.3–1.8)
> 10	1.3 (0.8–2.1)	1.6 (0.8–3.4)	1.1 (0.6–2.2)	1.1 (0.6–2.0)	1.4 (0.6–3.3)	1.0 (0.5–2.3)
Daytime mouth breathing						
Never	Reference	Reference	Reference	Reference	Reference	Reference
Rarely	1.0 (0.5–2.3)	0.7 (0.2–2.9)	1.1 (0.4–2.9)	1.0 (0.5–2.4)	0.5 (0.1–2.2)	1.4 (0.5–3.9)
Occasionally	3.1 (1.5–6.3)	3.5 (1.1–11.7)	2.4 (0.9–6.1)	2.4 (1.1–5.3)	2.7 (0.8–9.4)	1.9 (0.6–5.5)
Frequently	9.5 (4.8–18.9)	9.5 (3.0–30.0)	8.9 (3.7–21.3)	7.4 (3.5–15.6)	6.3 (1.9–20.4)	7.9 (2.9–21.6)
Sore throats						
Never	Reference	Reference	Reference	Reference	Reference	Reference
Rarely	1.4 (0.6–3.2)	1.0 (0.4–2.7)	3.9 (0.5–30.2)	1.3 (0.5–3.0)	1.0 (0.4–3.0)	3.1 (0.4–24.6)
Occasionally	4.4 (1.9–10.5)	2.8 (0.96–8.3)	15.0 (1.9–116.1)	2.9 (1.2–7.2)	1.6 (0.5–5.0)	10.3 (1.3–83.1)
Frequently	26.0 (9.9–68.1)	18.1 (4.5–73.4)	84.9 (10.2–702.7)	17.6 (6.4–48.8)	13.3 (3.0–58.5)	52.7 (6.0–460.2)
Infections, per yr						
0–7	Reference	Reference	Reference	Reference	Reference	Reference
> 7	5.5 (3.0–10.2)	3.8 (1.3–10.7)	7.6 (3.3–17.3)	2.0 (0.9–4.1)	2.2 (0.6–7.5)	1.9 (0.7–5.2)

*Data are presented as OR (95% CI).
†Model A = ORs are adjusted for personal characteristics (sex, age category, BMI category, maternal education, paternal education, household smoking).
‡ Model B = ORs are adjusted for personal characteristics and clinical factors (daytime mouth breathing, sore throats, frequent infections).

Discussion

In adults, population-based cohort studies revealed age, obesity, smoking, asthma, and nasal congestion as independent risk factors for self-reported HS.[16] In addition, a marked gender difference in the expression of HS and OSA was found.[17–19] Some studies[3,20–22] have specifically addressed risk factors for HS in children, but none focused on gender differences. Corbo et al[20,21] investigated snoring in two studies with a combined sample size of 3,824 school children. These authors postulated three major risk factors for snoring: obesity (*ie*, BMI > 90th percentile), nasal obstruction (*eg*, septal deviation, rhinitis) and pharyngeal problems (*eg*, hypertrophy of tonsils, adenotomy without tonsillectomy, otitis).[21] Our study concurs with these findings and adds some new aspects.

We found a BMI ≥ 75th percentile, low maternal education, household smoking of > 10 cigarettes per day, daytime mouth breathing, sore throats, and more than seven infections a year to be predictive of HS in our population-based cohort study among primary school children. After adjusting for potential confounders, obesity (BMI ≥ 90th percentile), low maternal education, daytime mouth breathing, and sore throats remained significant and independent risk factors for HS in these children. Gender-separated analyses showed obesity and daytime mouth breathing equally related to HS in boys and girls. Low maternal education, however, played a more important role in boys, while sore throats were more closely associated with HS in girls. In addition, we found HS to be more frequent in girls > 9 years old than in boys of similar age, and this association was independent of other basic characteristics. Thus, maternal education, sore throats, and age as risk factors for HS seem to play different roles in boys and girls. To our knowledge, these are the first data indicating differences in the risk for HS between boys and girls. Considering these differences could lead to a deeper understanding of snoring in childhood.

Obesity is a well-known risk factor for snoring and sleep-disordered breathing in children,[21,23] adoles-

Table 5—*Snoring-Related Factors in Ex-Habitual Snorers and Long-term Habitual Snorers**

Snoring-Related Factors	Ex-Habitual Snorers (n = 41)	Long-term Habitual Snorers (n = 39)	p Value
Gender			NS
Boys	18 (43.9)	14 (35.9)	
Girls	23 (56.1)	25 (64.1)	
Mean age at initial survey (SD), yr	9.5 (0.7)	9.7 (0.8)	
Mean BMI at initial survey (SD)	17.8 (3.8)	19.1 (4.2)	
Maternal education			0.003
High	18 (43.9)	5 (12.8)	
Medium	14 (34.1)	17 (43.6)	
Low	8 (19.5)	15 (38.5)	
Household smoking at initial survey, cigarettes/d			0.042
No	23 (56.1)	15 (38.5)	
1–10	7 (17.1)	5 (12.8)	
> 10	10 (24.4)	19 (48.7)	
Snoring loudness at initial survey			0.026
Mildly quiet	3 (7.3)	1 (2.6)	
Medium loud	29 (70.7)	21 (53.8)	
Loud	7 (17.1)	11 (28.2)	
Very loud	2 (4.9)	6 (15.4)	
ENT surgery since initial survey			0.040
No	35 (85.4)	39 (100.0)	
Yes	4 (9.8)	0 (0.0)	

*Data are presented as No. (%) unless otherwise indicated. See Table 1 for expansion of abbreviation.

cents,[24] and adults,[16,18] and was found to be a strong and independent predictor for HS in our study. As obesity is correlated with increased neck circumference,[25] external compression of the pharynx by superficially located fat is proposed as the underlying cause of snoring and sleep-disordered breathing in obese humans.[26] One study[17] revealed gender as an important effect modifier of the association between obesity and OSA in adults. Although having a higher BMI, obese women were less likely to exhibit OSA than obese men. Thus, there may be inherent structural and/or functional differences in upper airway mechanics during sleep between men and women.[17,27] Our finding of equally strong associations between obesity and HS in both sexes supports the hypothesis that these differences are not yet present in childhood.

Daytime mouth breathing was also strongly and independently associated with HS in our study. Mouth breathing is a consequence of increased nasal resistance.[28] One cause of increased nasal resistance is chronic nasal congestion at night, a well-known and potentially modifiable risk factor for snoring in adults.[16] It can also be related to enlarged tonsils and adenoids, but mouth breathing *per se* may lead to tonsillar hypertrophy due to irritation of tissues. Interestingly, daytime mouth breathing was less common in girls. This may be explained by the fact that girls were less reported to have respiratory allergies, a factor that is associated with nasal obstruction. A history of respiratory allergies, however, was only weakly associated with HS in our study. Thus, it remains unclear which nasal factor contributed to snoring in these children. Due to the design of our study, children were not examined locally, and we therefore could not determine the cause(s) for mouth breathing.

Having a higher frequency of sore throats was the strongest factor associated with HS in our study. This symptom can be caused by pharyngitis, recurrent tonsillitis, or tonsillar hypertrophy. Tonsillar hypertrophy, as well as other pharyngeal problems such as angina, could narrow the pharyngeal airway, and were associated with snoring in children.[20,21,29] Interestingly, the association between a higher frequency of sore throats and HS was stronger than the association between daytime mouth breathing and HS, and this association was independent of the presence of daytime mouth breathing. This concurs with others[21] and underscores the potential role of pharyngeal problems in the snoring child. As mentioned above, mouth breathing may lead to the breathing of unfiltered air, which may also cause a sore throat. Collinearity between daytime mouth breathing and sore throats was only weak in our study ($r = 0.21$; $p < 0.001$), but adjusting for collinear covariates is problematic in logistic regression and could lead to pseudoindependent associations. Thus, it cannot be excluded that the independent association found in our study may be artificial. Also, a sore throat can be one symptom of a common cold. The latter diagnosis, however, was separately addressed, with both being related to HS (see below). Finally, a higher frequency of sore throats could be a cause (*eg*, tonsillar hypertrophy) or consequence (*eg*, due to snoring-induced vibrations) of snoring. To clarify this question, an observational cohort study or an interventional study is needed. Unfortunately, there are no data available on this issue. Frequent sore throats were twice as common in girls than in boys, and the association with HS was four times stronger in girl than in boys. Two reasons could be suggested for this finding. Firstly, a "true" gender difference could be present, indicating that pharyngeal problems as predictors for HS could be more important in girls and should receive more attention. Secondly, a reporting bias could have occurred. Compared to boys of similar age, girls likely have a different perception of pain and could therefore overreport the occurrence of a sore throat. However, this finding needs further research before establishing an accurate interpretation.

Interestingly, we found an independent association between low maternal education and HS in boys, but not in girls. An association between SES and symptoms of sleep-related obstructed breathing has been reported.[30] That study, however, did not report gender differences, and the presented association between a low SES and symptoms of sleep-related obstructed breathing lost its significance after adjusting for parental smoking.[30] In our study, the situation was reverse. The association of household smoking and HS lost its significance after adjusting for maternal education, while maternal education remained a significant predictor for HS in the multivariate models. Several reasons could account for our findings. Firstly, lower SES may be associated with household crowding. As the perception of snoring depends on the presence of a family member within the child's bedroom during the night, household crowding may lead to a more accurate reporting of snoring. Thus, snoring may tend to remain unrecognized or underreported in single-child or upper-class families, where children are more likely to sleep alone.[20] Secondly, parents could have underreported their household smoking. This would have led to misclassification and lowering of associated risks. At the same time, they may have accurately reported their education, which would then better correlate with their "true" smoking habit. Thus, education may be a surrogate variable for smoking in our study, and the results for education may be rather attributable to smoking. Thirdly, smoking may be related to SES (and thus to education) and the concurrent inclusion of colinear variables into a logistic model could result in overadjustment and artificially lower associated risks. Finally, a yet-unknown, specific snoring-related factor or behavior may be present in families with poorly educated mothers. However, why this factor should contribute to snoring only in boys remains unknown.

Having experienced more than seven infections during the preceding year was found to be an important predictor for HS in univariate analysis, and remained significant after adjusting for demographic variables. An association between infections of the upper respiratory tract (*eg*, adenotonsillitis or otitis media) and snoring has been reported.[21,29,31] Enhanced growth of lymphatic tissue within the upper airway promoted by viral infections is the suggested mechanism for this association.[31] This would result in increased upper airway resistance and snoring. According to this hypothesis, daytime mouth breathing (due to adenoidal hypertrophy) and sore throats (due to tonsillar hypertrophy) would be the consequences of frequent infections. In our study, tests for collinearity and the results of adjustments for daytime mouth breathing and sore throats in multivariate analysis supported this assumption. Thus, frequent infections may be an independent risk factor for HS and daytime mouth breathing and sore throats may be two intervening variables.

Regarding the total study sample, we did not find an association of HS with sex or age, as described by other authors.[20,21,32,33] Although not statistically significant, we observed a steady decrease in HS with age in boys and an increase in girls. A significant difference between the sexes was only found for the age group $\geq$ 10 years old. In this group, girls had a significantly higher risk for HS than boys, and this association remained significant even after adjusting for other demographic variables. This finding is different from a previous study[21] showing gender differences in the prevalence of HS to occur not before 15 years of age and male sex as the predominant risk factor in this age group. We suggest that in our age group of $\geq$ 10 years old some girls already had entered puberty. The change in hormonal status and passage from prepuberty to early puberty, which occurs earlier in girls than boys, may promote snoring at an earlier age in girls and lead to the higher prevalence of HS in women compared to girls.[34] However, little is known about estrogen and testosterone effects on airway mechanics in children, and more studies are needed in this field.

At follow-up 1-year after the initial survey, 51% of habitual snorers had ceased to snore habitually. Although this variance in HS over time was also found in a previous cohort study,[35] these population-based data do not concur with case studies on the natural history of primary snoring, revealing HS in 69 to 80% of former habitual snorers.[36,37] The latter studies, however, included children who had been referred to a sleep center. Thus, it is likely that these children were more severe snorers, which may account for the greater persistence of snoring in those groups. As mentioned above, the perception of snoring may depend on the number of household members (which is inversely associated with SES) and on the expression of snoring (*eg*, loudness) itself. The observed variance of HS with time in our study could thus be the result of methodologic shortcomings of surveys as well as of true changes in expression. Further studies using objective measures of snoring are thus needed to clarify this point.

In addition, we found significantly lower maternal education, more household smoking, louder snoring, and less ENT surgery in children who continued with HS. Thus, SES and parental smoking may play the same role in prolonging HS, as they seem to play in establishing HS (see above). Of interest was the fact that children with long-term snoring had snored more loudly at the initial survey. Thus, loud snoring seems to be a more stable symptom than quiet snoring. This could help to detect children who are prone to long-term snoring in future studies. Not surprising was the fact that ENT surgery, *eg*, tonsillectomy or adenotonsillectomy, had more often been performed in children who had ceased to snore. This underscores the important role of adenotonsillar hypertrophy as a risk factor for snoring and adds further evidence for a causal relationship between adenotonsillar hypertrophy and snoring in children.

Limitations

It cannot be excluded that some of our findings may be attributable to study limitations, including sampling bias, unreliable data collection, or incomplete control for confounding factors. Sampling bias would require the overrepresentation of habitual snorers exhibiting mainly those risk factors found to be significantly associated with HS in our study. Comparisons in demographic variables between our study sample and the underlying population showed a good overall representativeness of the study sample. Thus, it is difficult to explain how a sampling bias could account for the strong associations found in our study.

Misclassification of snoring, BMI, maternal education, daytime mouth breathing, and sore throats is possible, because these measures relied solely on parental report and were not based on objective data. Parental history, for example, was found to be poorly predictive of whether a child snored during a single night.[38] Another study[30] reported that only one third of children with parentally reported HS actually snored at a specific night. Despite this, a recent study[32] on children attending kindergartens showed a significant and independent association between parentally reported HS and objectively measured pathologic snoring. In addition, high test-retest reliability measures of sleep-disordered breathing questionnaires have been reported, suggesting a high reproducibility of parental assessments of their children's breathing during sleep.[14,31] To our knowledge, however, there have been no studies on the accuracy of parental assessment of BMI, maternal education, daytime mouth breathing, or sore throats.

Misclassification of snoring or associated risk factors, if random, would result in underestimation of the true magnitude of association in this study. However, if misclassification was differential to one of the exposure or outcome variables with respect to the other, then an unpredictable bias could result. Such a situation would arise if there were a tendency of parents whose children snore to exaggerate any other conditions, including those risk factors under study. Unfortunately, we were not able to address this potential bias, as objective measures were not used.

Although we could account for several potential confounding factors, it is possible that an unknown factor related to HS and the risk factors under study is responsible for part or all of the associations reported herein. Such a factor, however, would have to be extremely influential to account for the relatively high ORs found and, therefore, would have been most likely identified in preceding studies.

Conclusion

Our findings on obesity, SES, household smoking, nasal obstruction, pharyngeal problems, and frequent infections as risk factors for HS concur with others and underscore the relevance of these factors for snoring in children. Some factors cannot be modified (*eg*, SES), but most factors can easily be recognized and may be modified by intervention. As an example, nasal obstruction may be controlled pharmacologically (*eg*, nasal steroids for congestions or adenoidal hypertrophy),[16,39] surgically (*eg*, adenoidectomy for adenoidal hypertrophy or turbinectomy for enlarged turbinates),[40] or by promising new methods (*eg*, radiofrequency ablation).[41] The role of some factors, however, remains unclear. Reducing the frequency of upper airway infections in children would likely lead to a decrease in HS by adenotonsillar hypertrophy, but intervention strategies to reach that goal are not established.

If the associations found in our study were causal, the magnitude of the ORs, in conjunction with the high prevalence of some risk factors, suggests that intervention may result in a significant reduction of

HS (and other sleep-related obstructive breathing disorders) in children. At present, however, no data from randomized controlled trials are available testing the efficacy of interventions to reduce HS in childhood. Thus, continuing efforts to investigate modifiable risk factors for snoring in children are needed.

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