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Snoring in preschool children: prevalence, severity and risk factors

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Abstract

Epidemiological data on snoring from preschool children are scarce, although habitual snoring (snoring on almost all nights) has been associated with poor long-term outcomes. In a population survey of 6811 children aged 1-4 years (Leicestershire, UK) we determined prevalence, severity and risk factors for snoring, especially habitual snoring.

For 60% of the children parents reported snoring in the last 12 months, including 7.9% with habitual snoring and 0.9% with habitual snoring and sleep disturbance. Prevalence of habitual snoring increased with age from 6.6% in 1-year olds to 13.0% in 4-year olds. Habitual snoring was associated with: one and two smoking parents (adjusted odds ratio 1.46 and 2.09 respectively), road traffic (1.23), single parent (1.60) and in white but not in south Asian children, socioeconomic deprivation (1.25 and 2.03 for middle and upper thirds of Townsend score). Respiratory tract symptoms related to atopic disorders and to respiratory infections were strongly associated with snoring, body mass index was not.

In conclusion, habitual snoring is common in preschool children with one third of cases attributable to avoidable risk factors. The strong association with atopic disorders, viral infections and environmental exposures suggests a complex aetiology, based on a general vulnerability of the respiratory tract.

Keywords

Ethnicity, South Asian

Predictors, risk factors

Prevalence

Preschool child

Snoring

Wheeze, asthma

Introduction

Snoring in children indicates increased upper airway resistance during sleep and is the cardinal symptom of sleep-disordered breathing (SDB).[1, 2] The complications of SDB are potentially severe and include neurobehavioral and cardiovascular complications and growth inhibition.[1] Habitual snoring (HS), snoring on almost all nights in so called primary snorers, has been associated with behavioural problems and poor academic performance even in the absence of intermittent hypoxia, possibly due to increased sleep fragmentation.[3-5]

Despite its clinical importance, the epidemiological literature on snoring in childhood is sparse. Population-based studies are few, often based on small samples and only rarely including preschool children.[6-16] Published results are heterogeneous with the prevalence of habitual snoring ranging from 3% to 12% and the total prevalence of snoring from 21% to 68%. Some studies reported an association between habitual snoring and male sex,[7, 11, 15] overweight,[12, 17, 18] parental smoking,[6, 13, 14] breastfeeding,[18] and low socioeconomic status,[5, 7, 19] while others did not confirm these findings. Some of these discrepancies might be due to age differences between study populations.[20] An excess of respiratory symptoms related to atopic diseases has been reported.[6, 7, 12, 17, 18, 21]

Using a large population-based sample of preschool children we aimed to determine prevalence and severity of snoring in preschool children, describe environmental and sociodemographic factors associated with snoring in this age-group and study the association between snoring and other respiratory symptoms. A special focus of our analysis was on habitual snoring, the clinically most significant category.

Methods

Study design and population

We used the Leicestershire Health Authority Child Health Database, which includes both the birth notification and perinatal data with mother's self-reported ethnic origin, religion, country of birth and language, to select an age-stratified random sample of white and south Asian (mother self-identified as Indian, Pakistani, Bangladeshi or other) children aged 1 to 4 years with complete birth records. From this database we extracted a random sample of 6100 white and 2600 south Asian children (5400 aged 1, 1100 aged 2, 3 and 4 years respectively).[22] The Leicestershire Health Authority Research Ethics Committee approved the study.

Questionnaire

Parents were sent a single questionnaire including questions on wheeze, cough and upper respiratory symptoms during the past 12 months.[23-25] The questions for one-years olds and their repeatability have been published.[25] The questionnaire for 2-5-year olds was almost identical and is available from the authors. The following questions related to snoring: 'Over the past 12 months, has your child snored at night? if yes how often? (only with a cold/sometimes even without a cold/almost always)' and 'Did the snoring disturb your child's sleep? (not at all/a little/a moderate amount/a lot)'.[6, 7]

The questionnaire also contained sections on diagnoses, healthcare utilisation and treatments for wheeze, environmental exposures, breastfeeding, pets, nursery care, siblings and household members, parental history of atopic diseases, ethnicity and language. We measured socioeconomic factors at family level (duration of parental education, number of people per room, single parenthood) and area level (Townsend score, 1991 census data). Height and weight measurements were available through the Leicestershire Health Authority Child Health Database, assessed in a standardised way by health visitors at birth and at the ages of 8, 20, 40 and 60 months. For the analysis, we used the measurements at birth, and those made nearest to the date of the questionnaire. The standard deviation score (SDS) for the body mass index (BMI) was calculated from British growth reference curves.[26]

International BMI cut offs were used to define underweight, overweight and obesity in children.[27] The ponderal index (cube root of body mass (in kilograms) divided by height of the children in centimetres) was also calculated.

Statistical analysis

Analyses were performed with Stata, version 8.2 (Stata Corporation, Austin, Texas). Based on reported frequency of snoring, children were grouped into four categories: non-snorers, children snoring only with colds, children snoring also apart from colds, and children snoring almost always. The latter were classified as habitual snorers.[1, 6, 7] We used descriptive analysis to summarise characteristics of the subjects according to snoring category.

To quantify associations between potential risk factors and different categories of snoring we used multivariable logistic regression models. The main analysis compared habitual snorers with non-snorers. Because we hypothesised that the aetiology of habitual snoring might differ from the aetiology of less frequent snoring separate logistic regression models were used to compare the other two snoring categories with non-snorers.

In addition to age, sex and ethnicity, the following variables were considered for inclusion in the models: a) environmental exposures, including maternal smoking during pregnancy (yes/no), current parental smoking (none, one parent, both parents), electrical cooking (yes/no), central heating (yes/no), reported exposure to road traffic (moderate-dense/little-none), household pets (cats, dogs, birds, small furry pets, all categorised as yes/no), number of siblings, nursery care (yes/no) and breastfeeding (>6 months); b) socioeconomic factors, including the Townsend score, paternal and maternal education (completed full-time education at ≤16 years), single parenthood, overcrowding (>1person/room); and c) clinical features and symptoms including parental history of atopic disease, upper and lower respiratory symptoms in the child, prevalence and frequency of wheeze, chronic cough, chronic rhinitis, frequency and severity of colds, eczema, birth weight, BMI and ponderal index at the time of the questionnaire. We also asked about ‘posseting’ in the first year of life (regurgitation, a common form of gastro-oesophageal reflux in infants).

To explore potential causal pathways, we developed three logistic regression models with increasing complexity. First a simple model, adjusted only for age, sex and ethnic group (Tables 2 and 3, Base model). Second, a model which was adjusted for all environmental and socioeconomic factors (Table 2, Partially adjusted model I) and a model which was adjusted for other clinical and biological features (Table 3, Partially adjusted model II). Third, a model adjusting for environmental, social and clinical conditions simultaneously (Table 2 and 3, Fully adjusted model). All variables associated with prevalence of HS ($p<0.05$) in one model were included in the next modelling step, except when the information contained in two or more variables was so similar (colinear) that only one could be taken into the next modelling step. This was, for instance, the case for paternal and maternal education, current maternal smoking and smoking during pregnancy, and Townsend score and household size (crowding). Results are presented as odds ratios (OR) with 95% confidence intervals (95% CI). Based on the literature and previous findings from our cohort,[28] we hypothesised that risk factors might differ between ethnic groups (south Asians /whites), between boys and girls and between age groups (one-year olds/ 2-5-year olds). Therefore stratified analyses were performed and evidence for heterogeneity between groups was tested for using interaction terms. Because south Asian children and one-year olds had been oversampled we also performed weighted analyses, which accounted for the sampling scheme. As the results were similar to the main analysis, we report unweighted results for simplicity.

The population-attributable risk fraction, or proportion of HS that could be prevented if the associations were causal and the risk factors were eliminated completely from the population, was calculated from the logistic regression framework by using the aflogit command in STATA,[29] which allows confounders to be taken into account.

Results

The overall response rate was 80% (6811 of the 8500 families with a valid address), higher in white (4986, 84%) than in south Asian (1825, 72%) families, corresponding to 16% and 29% of white and south Asian children aged 1-5 years living in Leicestershire at the time. Children with missing information on frequency of snoring (n=69, 1%) were excluded from further analyses, leaving 6742 children.

Prevalence and severity of all categories of snoring

In total, parents of 4028 children (59.7%) reported that their child had snored in the last 12 months, including 1862 children (27.6%) snoring only with colds, 1635 (24.2%) snoring sometimes apart from colds and 531 (7.9%) snoring almost always (habitual snoring, HS). Habitual snoring was more common in boys, white children and 2-4-year olds compared to younger children (**Table 1**, and **Online Tables E1A and E1B**).This was similar for snoring 'sometimes without colds', while 'snoring only with colds' was reported more often for younger children, with no gender difference. For 44 children, an operation to remove adenoids and/or tonsils was reported (none of the 1-year olds, and 4 (0.5%), 13 (1.5%) and 27 (3.0%) of children aged 2, 3 and 4 years respectively). Moderate or severe sleep disturbance due to snoring was reported most often for habitual snorers (60/530, 11.3% of all HS), while mild sleep disturbance was reported more often for children snoring only with colds (**Figure 1**). In total, parents of 60 children (0.9%) reported habitual snoring with moderate or severe sleep disturbance. Otitis media in the past 12 months was reported by 34.6% of non-snorers, 42.2% of children snoring only with colds, 48.1% of children snoring sometimes without colds and 52.5% of habitual snorers (p trend<0.001). For recurrent otitis media, these figures were 13.4%, 17.0%, 21.3% and 27.3% respectively (p trend<0.001).

Association between habitual snoring and environmental and socioeconomic factors

Adjusting only for age, sex and ethnic group (base model), habitual snoring was reported more often in children exposed to air pollutants: environmental tobacco smoke, reported road traffic, absence of central heating and of electric cooking (**Table 2**). In the fully adjusted model, only the effect of parental smoking remained significant with odds ratios for HS of

1.43 if one and 2.06 if both parents smoked. The association was stronger in 1-year olds than in older children (OR 2.10 and 3.14 in 1-year olds, and 1.22 and 1.47 in 2-4-year olds for one and two smokers respectively, p for interaction=0.010). Maternal smoking during pregnancy was also strongly associated with habitual snoring (OR in base model 2.10 (1.66-2.67), p<0.001). Because the same women smoked during pregnancy and at the time of the survey, it was not possible to disentangle the effects of prenatal and current smoke exposure, and only one variable (we chose for current smoking) could be included in the adjusted models. Longer breastfeeding was associated with a lower prevalence of snoring (OR in base model: 0.73 (0.57-0.95)), but the association disappeared after adjustment for parental smoking and was not age-dependent.
Habitual snoring was reported more often for children from disadvantaged families, with a single parent, overcrowded households or low paternal or maternal education. The area-based deprivation measure (Townsend score) was associated with HS in white, but not in south Asian preschool children (p for interaction<0.001). Adjusting simultaneously for environmental exposures and socioeconomic factors, parental smoking, traffic exposure, single parenthood and Townsend score in whites remained independent predictors of HS (**Table 2**, Partially adjusted model I). When adjusting additionally for clinical features (**Table 2**, Fully adjusted model) the strength of the association (OR) between snoring and environmental exposures decreased, but did not disappear. When children with current wheeze or asthma were excluded from the analysis, the associations with environmental factors were similar to the model including all children (data not shown).

Using a statistical approach which allowed multiple risk factors to be taken into account,[29] a total of 33.4% of HS could be attributed to air pollutants (20.0% to parental smoking, 14.7% to exposure to road traffic and 3.0% to lack of central heating).

We repeated these analyses for the less severe categories of snoring. ‘Snoring sometimes without colds’ was associated, although less strongly, with the same environmental exposures as habitual snoring (**Online Table E2A**). ‘Snoring only with colds’ was only weakly associated with current parental smoking and reported road traffic, but not with the other exposures (**Online Table E2B**).

Association between habitual snoring and clinical and biological features

Habitual snoring was strongly associated with a large number of clinical conditions. This included conditions potentially related to atopy, such as maternal history of asthma and a personal history of wheeze, eczema, chronic night cough and chronic rhinitis. However, snoring was also independently associated with symptoms related to viral infection such as frequency of colds and otitis media, and with posseting (regurgitation) in the first year of life (**Table 3,** Base model and Partially adjusted model II). These associations remained essentially unchanged after additional adjustment for environmental exposures and socioeconomic factors, suggesting that they were not explained by confounding with exposures such as parental smoking, which increase the risk for both snoring and other respiratory conditions (**Table 3,** Fully adjusted model).

Body mass index was not associated with HS, either when analysed as a continuous variable (OR 1.03 (95% CI 0.95-1.12), by standard deviation score p=0.42) or as a categorical variable [27] (**Table 3**, Base model). Similarly, we found no association between HS and ponderal index at the time of the study (p=0.46 when analysed as a continuous variable, p= 0.57 when analysed as tertiles), or birth weight (p=0.93 and p=0.88 respectively when analysed as a continuous or categorical variable).

These analyses were repeated comparing the milder categories of snorers with non-snorers. For children snoring sometimes apart form colds (**Online Table E3A**) the results were very similar to those habitual snoring. For children snoring only with colds (**Online Table E3B**) the associations with other respiratory symptoms and posseting were similar to those for more severe snoring, while the association with atopic disorders was less consistent.

Sensitivity analyses

The associations with environmental exposures and clinical features were similar for girls and boys, and for white and south Asian children (all p values for interaction terms >0.01)

Similarly, a weighted analysis adjusting for oversampling of young children and those of south Asian origin gave similar results to the main analysis.

Discussion

In this large representative survey, 60% of preschool children were reported to have snored in the past year, 8% were habitual snorers and 11% of these (almost 1% of the cohort) were habitual snorers with significant sleep disturbance, a group at risk of long-term neurobehavioral problems.[3-5] Assuming a causal association, about one-third of cases with habitual snoring might be attributable to avoidable environmental exposures (parental smoking and traffic exposure). Snoring was associated both with clinical features of atopic disease and with symptoms caused by viral infections.

Methodological issues

This cross-sectional survey is the largest community-based study of snoring in under-fives and the only one covering the age range 1-4 years. Most other publications focused on 3-5-year olds and included only a few hundred subjects.[9-12] We studied a community-based sample of children, had a good response rate and included south Asians, the largest ethnic minority group in the UK. The results therefore should be representative of UK toddlers. A large number of environmental exposures, socioeconomic factors and clinical features were assessed.

A limitation shared with other community-based surveys is the lack of objective outcomes. In this cohort, we assessed whether the families understood the different respiratory symptoms listed in our questionnaire and although we found that some parents confused ‘wheeze’ with rattly breathing or cough, ‘snoring’ was clearly distinguished both by white and south Asian parents.[24] Moreover, a recent study showed that parental reports of frequent snoring were highly sensitive and specific when compared with overnight polysomnography.[2] Although the latter remains the ‘gold standard’ for the diagnosis of obstructive sleep apnea syndrome and sleep disordered breathing [1] it is clearly impractical for a large population survey, as are methods such as overnight pulse oximetry, audio and videotaping. Several recent studies have shown strong associations between reported habitual snoring in children and adults and adverse behavioural and academic outcomes, even in the absence of intermittent hypoxia.[1, 4, 5, 30] This may be due to increased sleep fragmentation. Considering all this, we believe that parent-reported habitual snoring can be used as a simple indicator of clinically relevant disease.

Prevalence of snoring in preschool children

As assessment of snoring by questionnaire has not been standardised, differences in reported prevalence between studies are unavoidable. In common with other surveys [6, 7] we used a question on snoring frequency in the past 12 months, with the answer categories ‘never’, ‘only with colds’, ‘sometimes apart from colds’, ‘almost always’. Other studies asked if snoring occurred ‘never’, ‘rarely’, ‘frequently’ or ‘always’, without differentiating between snoring with or without colds. In spite of these differences in wording, the prevalence of habitual snoring in our study (7% in 1-year olds, increasing to 13% in 4-year olds) was comparable to data from 4-5-year olds in the UK (12%),[10] from 2-5-year olds in Australia (11%),[12] and from schoolchildren (5 to 10%).[6, 7, 9, 31] The total prevalence of snoring in our sample (60%) was similar to data from preschool children (70%) [10] and schoolchildren (35-64%).[6, 7, 9, 31] An increasing prevalence of habitual snoring from age 1 to 4 years has not previously been reported and might be due to age-dependent increments in adenoid size which peak at age 7-10 years.[32] In adults the prevalence of habitual snoring is higher in males. For children, published data are less consistent, with some studies reporting a sex difference [7, 14-16, 18] and others none.[6, 8, 11] We found a slightly higher prevalence in boys (OR 1.33).

Studies from the US report an increased prevalence in African Americans compared to whites.[17, 19] In our study, south Asian children, the largest ethnic minority group in the UK, had a lower crude prevalence. This difference remained after adjusting for other clinical conditions, (Table 3, Partially adjusted model II) but disappeared after adjustment for differences in parental smoking and socioeconomic factors (Table 3, Fully adjusted model). This suggests that the differences in prevalence between ethnic groups might be caused by differences in environmental exposures rather than biological factors.

Association with environmental exposures and socioeconomic factors

An association between snoring and passive smoking has been demonstrated for adults [33] and children,[7, 18] sometimes disappearing after adjustment for social class.[17] We confirmed a strong and dose-dependent effect of parental smoking (2 vs. 1 smoking parent) on frequency of snoring even after adjustment for socioeconomic factors. This dose-response relationship and the fact that the association was stronger in younger children who spend more time at home and who might be more vulnerable support a causal association. Our analysis suggests that about one in five cases of habitual snoring could be avoided if parents did not smoke. Because of the close correlation between prenatal and postnatal smoke exposures it was not possible to disentangle their effects.

Habitual snoring was also more common in households that had no central heating, used gas for cooking and were exposed to greater road traffic. These are new findings. Although we found that some of these effects disappeared after adjustment for the Townsend score, this might be an over-adjustment because area-based deprivation scores are closely associated with housing conditions and air pollution. The increased prevalence of snoring in children from disadvantaged families was only partially explained by a higher exposure to parental smoking and air pollutants. Other unmeasured lifestyle variables, such as nutrition, must also play a role.

Association with clinical features

We found a strong association between snoring and other upper and lower respiratory symptoms. This was not only the case for symptoms associated with atopy (wheeze, eczema, maternal asthma), which has been reported by others,[6, 12, 18, 34] but also for symptoms which are usually associated with infection (frequent colds, otitis media).

We therefore hypothesise that, as in other airway disorders, snoring might result from an interaction between underlying host predisposition, various intrinsic mechanisms and external triggers, which together lead to a similar endpoint. We propose a tentative model (Figure 2), which will be revised as further evidence accumulates. Chronic snoring in children might arise via several inflammatory pathways which independently affect upper airway resistance or compliance. For some mechanisms (such as atopy), there is a simple explanation for the association between upper and lower airway vulnerability. Increased susceptibility to viral respiratory infection may be another. A hypothetical mechanism for such susceptibility has been proposed.[35] The authors provide evidence that early exposure to respiratory syncytial virus (RSV) might induce neuro-immunomodulatory changes within adenotonsillar tissue, predisposing to an accelerated proliferative response and hence enlargement when exposed to other stimuli such as viruses or allergens.

An association between HS and gastro-oesophageal reflux has been reported for adults.[36] For children an association with posseting is a new finding. This physiological form of gastro-oesophageal reflux is largely confined to the first year of life, and cannot therefore be directly related to snoring later in childhood. However, one may speculate that intermittent contact with gastric juices leads to chronic pharyngeal inflammation, possibly predisposing to snoring by altered compliance or calibre of the upper airways.

We found no association, between snoring and overweight or obesity, whether assessed by BMI or ponderal index. This is unlikely to be due to lack of statistical power. However, there are data suggesting that the association between obesity and snoring might change with age [20] and that BMI might play a minor role in the aetiology of snoring in preschool children, in contrast to adolescence and adulthood.[12, 17, 18] In young children, with relatively non-collapsible upper airways, obesity per se might not elicit the noise of snoring.

Conclusions

We found that 60% of preschool children had snored during the past 12 months, with 8% snoring habitually and nearly 1% reporting habitual snoring with sleep disturbance, the latter representing children at risk of adverse consequences. Risk factors for habitual snoring in this age group were exposure to parental smoking, other air pollutants and socioeconomic deprivation, but not overweight. The strong association with a number of other upper and lower respiratory symptoms, both those associated with atopy and those associated with viral infection, suggests common pathways such as increased host susceptibility in the respiratory tract.

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Competing interests

There are no competing interests.

References

1. Schechter MS. Technical report: diagnosis and management of childhood obstructive sleep apnea syndrome. *Pediatrics* 2002: 109:e69.
2. Montgomery-Downs HE, O'Brien LM, Holbrook CR, Gozal D. Snoring and sleep-disordered breathing in young children: subjective and objective correlates. *Sleep* 2004: 27:87-94.
3. O'Brien LM, Mervis CB, Holbrook CR, Bruner JL, Klaus CJ, Rutherford J, Raffield TJ, Gozal D. Neurobehavioral implications of habitual snoring in children. *Pediatrics* 2004: 114:44-49.
4. Urschitz MS, Eitner S, Guenther A, Eggebrecht E, Wolff J, Urschitz-Duprat PM, Schlaud M, Poets CF. Habitual snoring, intermittent hypoxia, and impaired behavior in primary school children. *Pediatrics* 2004: 114:1041-1048.
5. Urschitz MS, Guenther A, Eggebrecht E, Wolff J, Urschitz-Duprat PM, Schlaud M, Poets CF. Snoring, intermittent hypoxia and academic performance in primary school children. *Am J Respir Crit Care Med* 2003: 168:464-468.
6. Corbo GM, Fuciarelli F, Foresi A, De Benedetto F. Snoring in children: association with respiratory symptoms and passive smoking. *BMJ* 1989: 299:1491-1494.
7. Corbo GM, Forastiere F, Agabiti N, Pistelli R, Dell'Orco V, Perucci CA, Valente S. Snoring in 9- to 15-year-old children: risk factors and clinical relevance. *Pediatrics* 2001: 108:1149-1154.
8. Ferreira AM, Clemente V, Gozal D, Gomes A, Pissarra C, Cesar H, Coelho I, Silva CF, Azevedo MH. Snoring in Portuguese primary school children. *Pediatrics* 2000: 106:e64.
9. Gottlieb DJ, Vezina RM, Chase C, Lesko SM, Heeren TC, Weese-Mayer DE, Auerbach SH, Corwin MJ. Symptoms of sleep-disordered breathing in 5-year-old children are associated with sleepiness and problem behaviors. *Pediatrics* 2003: 112:870-877.
10. Ali NJ, Pitson DJ, Stradling JR. Snoring, sleep disturbance, and behaviour in 4-5 year olds. *Arch Dis Child* 1993: 68:360-366.
11. Castronovo V, Zucconi M, Nosetti L, Marazzini C, Hensley M, Veglia F, Nespoli L, Ferini-Strambi L. Prevalence of habitual snoring and sleep-disordered breathing in preschool-aged children in an Italian community. *J Pediatr* 2003: 142:377-382.
12. Lu LR, Peat JK, Sullivan CE. Snoring in preschool children: prevalence and association with nocturnal cough and asthma. *Chest* 2003: 124:587-593.
13. Owen GO, Canter RJ, Robinson A. Snoring, apnoea and ENT symptoms in the paediatric community. *Clin Otolaryngol Allied Sci* 1996: 21:130-134.
14. Brunetti L, Rana S, Lospalluti ML, Pietrafesa A, Francavilla R, Fanelli M, Armenio L. Prevalence of obstructive sleep apnea syndrome in a cohort of 1,207 children of southern Italy. *Chest* 2001: 120:1930-1935.

15. Kaditis AG, Finder J, Alexopoulos EI, Starantzis K, Tanou K, Gampeta S, Agorogiannis E, Christodoulou S, Pantazidou A, Gourgoulianis K, Molyvdas PA. Sleep-disordered breathing in 3,680 Greek children. *Pediatr Pulmonol* 2004: 37:499-509.
16. Mitchell EA, Thompson JM. Snoring in the first year of life. *Acta Paediatr* 2003: 92:425-429.
17. Redline S, Tishler PV, Schluchter M, Aylor J, Clark K, Graham G. Risk factors for sleep-disordered breathing in children. Associations with obesity, race, and respiratory problems. *Am J Respir Crit Care Med* 1999: 159:1527-1532.
18. Chng SY, Goh DY, Wang XS, Tan TN, Ong NB. Snoring and atopic disease: A strong association. *Pediatr Pulmonol* 2004: 38:210-216.
19. Montgomery-Downs HE, Jones VF, Molfese VJ, Gozal D. Snoring in preschoolers: associations with sleepiness, ethnicity, and learning. *Clin Pediatr (Phila)* 2003: 42:719-726.
20. Kaditis AG, Alexopoulos EI, Hatzi F, Karadonta I, Chaidas K, Gourgoulianis K, Zintzaras E, Syrogiannopoulos GA. Adiposity in relation to age as predictor of severity of sleep apnea in children with snoring. *Sleep Breath* 2007: doi:10.1007/s11325-007-0132-z.
21. Gozal D, Pope DW, Jr. Snoring during early childhood and academic performance at ages thirteen to fourteen years. *Pediatrics* 2001: 107:1394-1399.
22. Kuehni CE, Brooke AM, Strippoli M-PF, Spycher BD, Davis A, Silverman M. Cohort profile: The Leicester Respiratory Cohorts. *Int J Epidemiol* 2007: in press:doi:10.1093/ije/dym1090.
23. Kuehni CE, Davis A, Brooke AM, Silverman M. Are all wheezing disorders in very young (preschool) children increasing in prevalence? *Lancet* 2001: 357:1821-1825.
24. Michel G, Silverman M, Strippoli M-PF, Zwahlen M, Brooke AM, Grigg J, Kuehni CE. Parental understanding of "wheeze" and its impact on asthma estimates. *Eur Respir J* 2006: 28:1124-1130.
25. Strippoli M-PF, Silverman M, Michel G, Kuehni CE. A parent-completed respiratory questionnaire for one-year olds: repeatability. *Arch Dis Child* 2007: 92:861-865.
26. Cole TJ, Freeman JV, Preece MA. British 1990 growth reference centiles for weight, height, body mass index and head circumference fitted by maximum penalized likelihood. *Stat Med* 1998: 17:407-429.
27. Cole TJ, Flegal KM, Nicholls D, Jackson AA. Body mass index cut offs to define thinness in children and adolescents: international survey. *BMJ* 2007: published online 25 June 2007:doi:10.1136/bmj.39238.39944.39255.
28. Kuehni CE, Strippoli M-PF, Low N, Brooke AM, Silverman M. Wheeze and asthma prevalence and related health-service use in white and south Asian pre-school children in the UK. *Clin Exp Allergy* in press: doi:10.1111/j.1365-2222.2007.02784.x.
29. Brady AR. sbe21-Adjusted population attributable fractions from logistic regressions. *STB Reprints* 1998: 7:137-143.

30. Gottlieb DJ, Yao Q, Redline S, Ali T, Mahowald MW. Does snoring predict sleepiness independently of apnea and hypopnea frequency? *Am J Respir Crit Care Med* 2000: 162:1512-1517.
31. Schlaud M, Urschitz MS, Urschitz-Duprat PM, Poets CF. The German study on sleep-disordered breathing in primary school children: epidemiological approach, representativeness of study sample, and preliminary screening results. *Paediatr Perinat Epidemiol* 2004: 18:431-440.
32. Vogler RC, Ii FJ, Pilgram TK. Age-specific size of the normal adenoid pad on magnetic resonance imaging. *Clin Otolaryngol* 2000: 25:392-395.
33. Franklin KA, Gislason T, Omenaas E, Jogi R, Jensen EJ, Lindberg E, Gunnbjornsdottir M, Nystrom L, Laerum BN, Bjornsson E, Toren K, Janson C. The influence of active and passive smoking on habitual snoring. *Am J Respir Crit Care Med* 2004: 170:799-803.
34. Sulit LG, Storfer-Isser A, Rosen CL, Kirchner HL, Redline S. Associations of obesity, sleep-disordered breathing, and wheezing in children. *Am J Respir Crit Care Med* 2005: 171:659-664.
35. Goldbart AD, Mager E, Veling MC, Goldman JL, Kheirandish-Gozal L, Serpero LD, Piedimonte G, Gozal D. Neurotrophins and tonsillar hypertrophy in children with obstructive sleep apnea. *Pediatr Res* 2007: 62:489-494.
36. Janson C, Gislason T, De Backer W, Plaschke P, Bjornsson E, Hetta J, Kristbjarnason H, Vermeire P, Boman G. Daytime sleepiness, snoring and gastro-oesophageal reflux amongst young adults in three European countries. *J Intern Med* 1995: 237:277-285.

Figure legends

Figure 1 - Prevalence of reported sleep disturbance associated with snoring in the past 12 months (%), by frequency of snoring

Reported sleep disturbance: ■ moderate/severe, ▒ mild, □ none

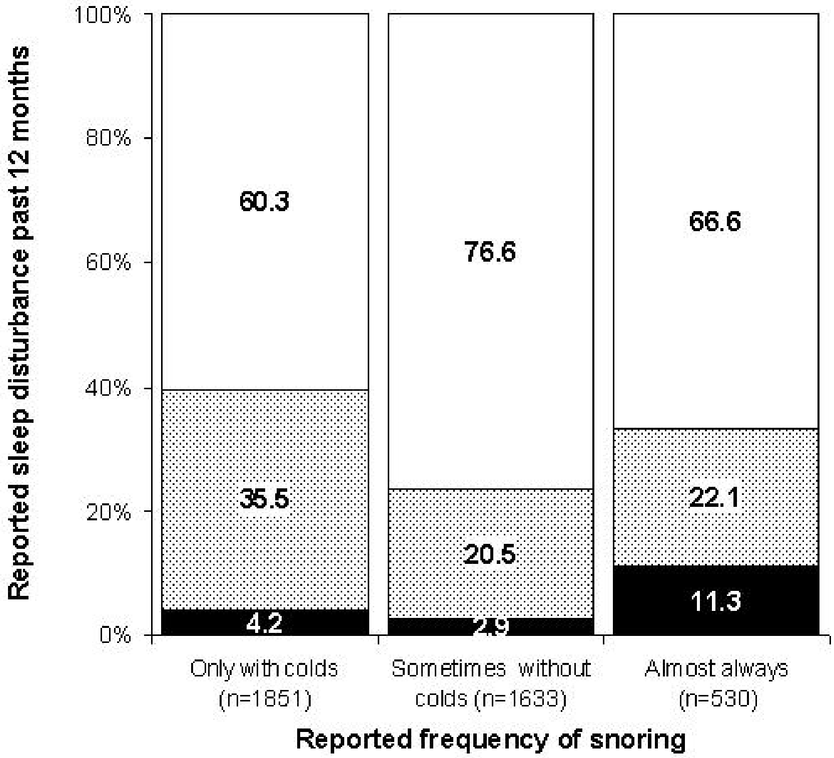

Figure 2 - Schematic illustration of potential pathways leading to chronic snoring in young children

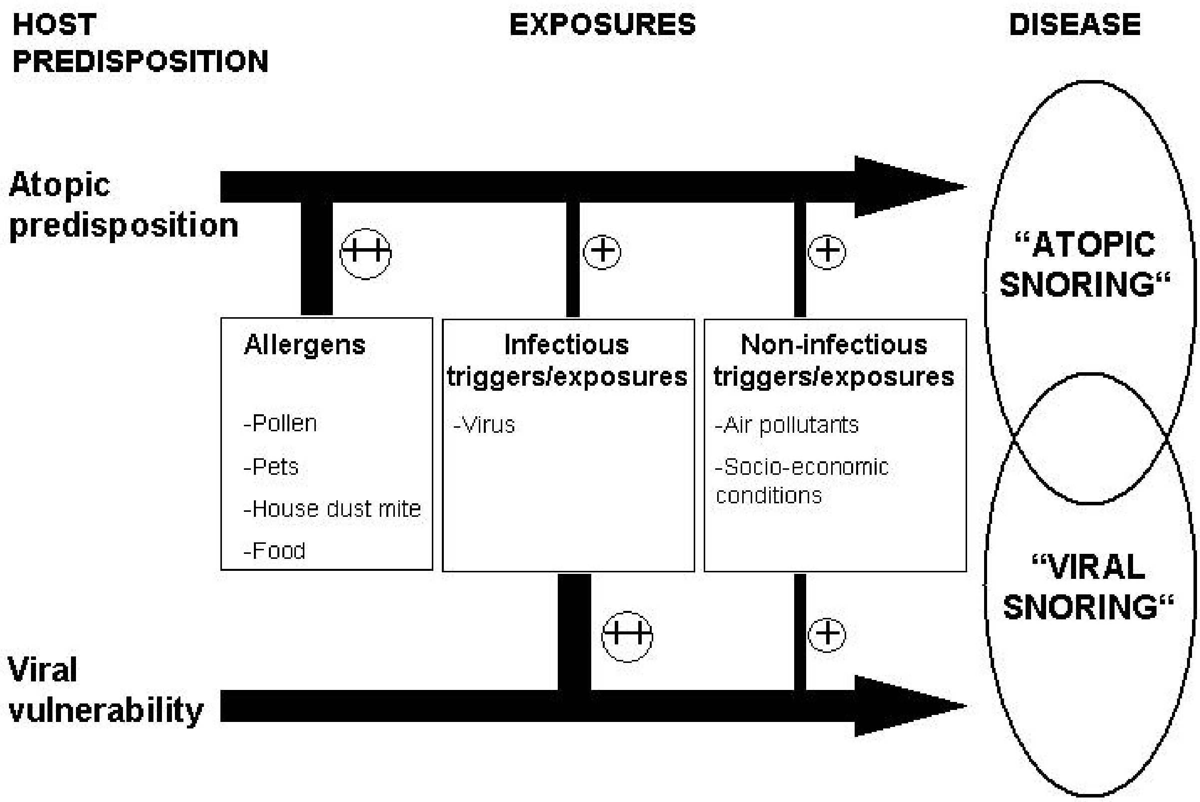
HOST
PREDISPOSITION
EXPOSURES
DISEASE
Atopic
predisposition
"ATOPIC
SNORING"
Allergens
-Pollen
-Pets
-House dust mite
-Food
Infectious
triggers/exposures
-Virus
Non-infectious
triggers/exposures
-Air pollutants
-Socio-economic
conditions
"VIRAL
SNORING"
Viral
vulnerability

Table 1 - Reported frequency of snoring in the last 12 months in children aged 1-4 years, by age, sex, ethnicity and selected covariates (N=6742)

	Reported frequency of snoring											
	Never			**Only with colds**			**Sometimes without colds**			**Almost always**		
	n	%	(95 CI)	n	%	(95 CI)	n	%	(95 CI)	n	%	(95 CI)
Total	2714	40.3	(39.1-41.4)	1862	27.6	(26.6-28.7)	1635	24.2	(23.2-25.3)	531	7.9	(7.2-8.5)
Age (years)												
1	1719	40.9	(39.4-42.3)	1259	29.9	(28.5-31.3)	953	22.7	(21.4-23.9)	276	6.6	(5.8-7.3)
2	319	39.5	(36.1-42.9)	225	27.9	(24.7-30.9)	208	25.7	(22.7-28.8)	56	6.9	(5.2-8.7)
3	331	38.5	(35.2-41.7)	198	23.0	(20.2-25.8)	245	28.5	(25.5-31.5)	86	10.0	(8.0-12.0)
4	345	39.8	(36.5-43.1)	180	20.8	(18.1-23.5)	229	26.4	(23.5-29.3)	113	13.0	(10.8-15.3)
Sex												
Female	1387	43.0	(41.3-44.7)	897	27.8	(26.3-29.4)	708	22.0	(20.5-23.4)	234	7.3	(6.4-8.1)
Male	1327	37.7	(36.1-39.3)	965	27.5	(26.0-28.9)	927	26.4	(24.9-27.8)	297	8.5	(7.5-9.4)
Ethnicity												
White	1907	38.6	(37.3-40.0)	1390	28.2	(26.9-29.4)	1229	24.9	(23.7-26.1)	412	8.3	(7.6-9.1)
South Asian	807	44.7	(42.4-47.0)	472	26.2	(24.1-28.2)	406	22.5	(20.6-24.4)	119	6.6	(5.4-7.7)
Smoking by parents												
None	1878	43.0	(41.5-44.5)	1209	27.7	(26.4-29.0)	990	22.7	(21.4-23.9)	290	6.6	(5.9-7.4)
One parent	621	36.3	(34.0-38.6)	471	27.5	(25.4-29.6)	461	26.9	(24.8-29.0)	158	9.2	(7.9-10.6)
Both parents	215	32.4	(28.8-35.9)	182	27.4	(24.0-30.8)	184	27.7	(24.3-31.1)	83	12.5	(10.0-15.0)
Townsend score												
Low deprivation	1020	41.4	(39.4-43.3)	715	29.0	(27.2-30.8)	572	23.2	(21.5-24.9)	159	6.5	(5.5-7.4)
Medium deprivation	894	39.5	(37.5-41.5)	647	28.6	(26.7-30.5)	546	24.1	(22.4-25.9)	175	7.7	(6.6-8.8)
High deprivation	750	39.5	(37.3-41.7)	469	24.7	(22.8-26.7)	487	25.7	(23.7-27.6)	191	10.1	(8.7-11.4)

Table 2 - Environmental and socioeconomic factors associated with habitual snoring in the last 12 months (N=3245)

	Base model			Partially adjusted model I			Fully adjusted model		
	OR	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**
A- Environmental factors									
Parental smoking									
One parent *vs*. none	1.66	(1.34- 2.06)		1.46	(1.17- 1.83)		1.43	(1.13- 1.82)	
Both parents *vs.* none	2.43	(1.82- 3.25)	<0.001	2.09	(1.53- 2.84)	<0.001	2.06	(1.48- 2.87)	<0.001
Exposure to road traffic	1.38	(1.14- 1.68)	0.001	1.23	(1.00- 1.50)	0.048			
No electric cooking	1.22	(0.99- 1.50)	0.065						
No central heating	1.50	(1.09- 2.05)	0.012						
Breast feeding > 6 months	0.73	(0.57- 0.95)	0.019						
B- Socioeconomic factors									
Single parent	1.97	(1.46- 2.66)	<0.001	1.60	(1.16- 2.22)	0.004	1.41	(0.99- 2.00)	0.058
Poor maternal education (≤ 16 yrs)	1.29	(1.07- 1.56)	0.009						
Poor paternal education (≤ 16 yrs)	1.39	(1.13- 1.70)	0.002						
Townsend score (tertiles)									
Whites									
Medium deprivation *vs.* low	1.38	(1.07- 1.79)		1.25	(0.96- 1.62)		1.29	(0.98- 1.71)	
High deprivation *vs.* low	2.78	(2.11- 3.66)	<0.001	2.03	(1.51- 2.73)	<0.001	1.69	(1.23- 2.33)	0.005
Asians									
Medium deprivation *vs.* low	0.94	(0.52- 1.71)		0.87	(0.48- 1.58)		1.01	(0.54- 1.89)	
High deprivation *vs.* low	0.86	(0.49- 1.50)	0.838	0.73	(0.42- 1.29)	0.502	0.92	(0.51- 1.65)	0.907

Base model: adjusted for age, sex and ethnic group

Partially adjusted model I: adjusted for age, sex, ethnic group and all environmental and socioeconomic factors (variables in Table 2)

Fully adjusted model: adjusted for age, sex, ethnic group and all environmental and socioeconomic factors and clinical features simultaneously (variables in partially adjusted model of Table 2 and partially adjusted model of Table 3 simultaneously)

p-values refer to Wald test for the whole variable included in the model

Table 3: Clinical and biological features associated with habitual snoring in the last 12 months (N=3245)

	Base model			Partially adjusted model II			Fully adjusted model		
	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
Demographic variables									
Male sex	1.33	(1.10- 1.61)	0.003	1.25	(1.02- 1.52)	0.033	1.27	(1.03- 1.55)	0.025
Age ≥ 2 years	1.74	(1.43- 2.10)	<0.001	1.94	(1.57- 2.40)	<0.001	2.01	(1.62- 2.49)	<0.001
South Asian ethnicity	0.61	(0.49- 0.77)	<0.001	0.70	(0.55- 0.89)	0.004	1.00	(0.57- 1.72)	0.985
Atopic disorders									
Attacks of wheeze* (1-10 attacks *vs.* none)	2.52	(2.04- 3.11)		1.48	(1.17- 1.87)		1.36	(1.07- 1.73)	
(>10 attacks *vs.* none)	9.70	(5.80- 16.16)	<0.001	3.27	(1.85- 5.79)	<0.001	2.61	(1.45- 4.70)	0.001
Eczema ever	1.67	(1.38- 2.02)	<0.001	1.20	(0.98- 1.48)	0.082	1.25	(1.01- 1.54)	0.039
Maternal history of wheeze or asthma	1.99	(1.59- 2.49)	<0.001	1.37	(1.07- 1.75)	0.012	1.33	(1.03- 1.71)	0.027
Other respiratory symptoms									
Cough at night*	3.32	(2.72- 4.05)	<0.001	1.85	(1.48- 2.31)	<0.001	1.79	(1.43- 2.26)	<0.001
Frequency of colds* (4-6 colds *vs.* <4 colds)	2.15	(1.72- 2.68)		1.46	(1.15- 1.85)		1.56	(1.22- 1.98)	
(≥7 colds *vs.* <4 colds)	4.19	(3.26- 5.37)	<0.001	1.83	(1.37- 2.44)	<0.001	1.94	(1.44- 2.61)	<0.001
Chronic rhinitis*	2.98	(2.46- 3.62)	<0.001	1.85	(1.49- 2.29)	<0.001	1.73	(1.39- 2.15)	<0.001
Otitis media* (1 episode *vs.* none)	1.60	(1.27- 2.02)		1.38	(1.08- 1.76)		1.42	(1.10- 1.82)	
(>1 episode *vs.* none)	2.70	(2.138- 3.43)	<0.001	1.65	(1.27- 2.14)	<0.001	1.69	(1.29- 2.20)	<0.001
Body mass index									
Underweight *vs.* normal	0.86	(0.51- 1.44)							
Overweight *vs.* normal	1.16	(0.88- 1.52)							
Obese *vs.* normal	1.03	(0.64- 1.68)	0.663						
Posseting† during 1st year of life									
A little *vs.* none	1.72	(1.36- 2.19)		1.43	(1.11- 1.85)		1.43	(1.11- 1.85)	
A lot *vs.* none	2.80	(2.08- 3.77)	<0.001	1.68	(1.22- 2.32)	0.003	1.65	(1.19- 2.30)	0.005

*during the past 12 months; † regurgitation, a common form of gastro-oesophageal reflux in infants

Base model: adjusted for age, sex and ethnic group.

Partially adjusted model II: adjusted for age, sex, ethnic group and all other clinical and biological features (variables in Table 3)

Fully adjusted model: adjusted for age, sex, ethnic group, all other clinical and biological features and all environmental and socioeconomic factors simultaneously (variables in partially adjusted model of Table 3 and partially adjusted model of Table 2 simultaneously)

p-values refer to Wald test for the whole variable included in the model