Sleep Medicine 84 (2021) 275–282

Contents lists available at ScienceDirect

Sleep Medicine

journal homepage: www.elsevier.com/locate/sleep

Original Article

Prevalence and evolution of snoring and the associated factors in two-year-old children

Maija Katila [a, b, *], Outi Saarenpää-Heikkilä [a, b], Marja-Terttu Saha [b], Nina Vuorela [a, b], Heini Huhtala [c], Laura S. Korhonen [d, e], Minna Lukkarinen [d, e], Jetro J. Tuulari [d, f, g, h], Linnea Karlsson [d, f, i], Hasse Karlsson [d, f, i], E. Juulia Paavonen [j, k]

[a] Department of Paediatrics, Tampere University Hospital, Tampere, Finland
[b] Tampere University, Faculty of Medicine and Health Technology, Tampere, Finland
[c] Faculty of Social Sciences, Tampere University, Tampere, Finland
[d] FinnBrain Birth Cohort Study, Department of Clinical Medicine, University of Turku, Turku, Finland
[e] Department of Paediatrics and Adolescent Medicine, Turku University Hospital and University of Turku, Turku, Finland
[f] Department of Psychiatry, Turku University Hospital and University of Turku, Turku, Finland
[g] Turku Collegium for Science, Medicine and Technology, University of Turku, Turku, Finland
[h] Department of Psychiatry, University of Oxford, UK (Sigrid Juselius Fellowship), United Kingdom
[i] Centre for Population Health Research, Turku University Hospital and University of Turku, Turku, Finland
[j] Pediatric Research Center, Child Psychiatry, University of Helsinki and Helsinki University Hospital, Helsinki, Finland
[k] Finnish Institute for Health and Welfare, Helsinki, Finland

ARTICLE INFO

Article history:
Received 8 March 2021
Received in revised form
1 June 2021
Accepted 3 June 2021
Available online 11 June 2021

Keywords:
Parental snoring
Prevalence
Sleep-disordered breathing
Socioeconomic status

ABSTRACT

Objectives: To evaluate the prevalence and persistence of snoring during the first two years of life in two Finnish birth cohorts and to assess the associated factors.
Study design: The study population comprised 947 children from the CHILD-SLEEP (CS) and 1393 children from the FinnBrain (FB) birth cohorts. Questionnaires were provided to both parents when the child was 24 months of age. The questionnaire consisted of parts concerning the child's sleep and environmental factors.
Results: The combined prevalence of habitual snoring in the two birth cohorts at the age of 24 months was 2.3% (95% CI 1.5–3.1), which is markedly lower than reported previously.
Children suffering from recurrent infections (CS odds ratio (OR) 3.9, 95% CI 1.2–12.5) or asthma (FB OR 4.3, 1.4–13.5) snored habitually more often. Both the mother's (CS OR 3.2, 1.2–9.0) and father's (CS OR 3.4, 1.4–8.0) snoring every night added to the risk of the child snoring. In the multivariate models, parental snoring (CS adjusted odds ratio (OR_a) 2.8, 1.1–6.8), the mother's lower level of education (CS OR_a 2.9, 1.2–7.5, FB OR_a 2.1, 1.0–4.5), and the mother's lower monthly income (FB OR_a 2.9, 1.3–6.3) associated with the child's habitual snoring.
Conclusions: The prevalence of habitual snoring in two Finnish birth cohorts is lower than reported previously. The independent risk factors for habitual snoring at the age of two years were the parents' snoring and the mother's low income and low education.

1. Introduction

Sleep disordered breathing (SDB) covers a range of breathing problems during sleep, from primary snoring to obstructive sleep apnea (OSA). Habitual snoring in children is generally defined as snoring three or more nights per week. The variation in the reported prevalence among young children is broad. Based on previous population-based reports, the condition affects approximately 10–20% of children aged 18–48 months [1–3]. However,

Abbreviations: OR_a, adjusted odds ratio; BNSQ, Basic Nordic Sleep Questionnaire; BMI, body mass index; BMI-SDS, body mass index standard deviation score; CI, confidence interval; CS, CHILD SLEEP; FB, FinnBrain; OR, odds ratio; OSA, obstructive sleep apnea; SES, socioeconomic status; SD, standard deviation; SDB, sleep disordered breathing; SDSC, Sleep Disturbance Scale for Children.

* Corresponding author. Department of Paediatrics, Tampere University Hospital, Central Hospital, P.O. Box 2000, FI-33521 Tampere, Finland.
E-mail address: maija.katila@tuni.fi (M. Katila).

https://doi.org/10.1016/j.sleep.2021.06.004
1389-9457/

approximately 10 years ago Liukkonen et al. reported a moderately lower habitual snoring prevalence of 6% among 1471 Finnish preschool-aged children in a questionnaire survey [4]. This inconsistency may partly be due to the variety in the definition of habitual snoring or the different prevalence of risk factors for snoring in the study populations. In addition, there are actual differences in study samples based on ethnicity. Reported studies on the prevalence of snoring have mostly focused on school aged children. There is clearly lesser data available concerning toddlers' SDB and most of these studies concern are relatively old or concern infants aged less than one year [1,3,5–10]. Furthermore, longitudinal studies describing the persistence and evolution of snoring during early childhood are infrequent [1,3].

The most common cause of children's snoring and OSA is large adenoids or tonsils blocking the upper airway. During adolescence, obesity has an important role in causing obstructive sleep disordered breathing [11]. Whether obesity plays a role in SDB in earlier childhood needs to be established considering that the number of overweight young children is increasing. Between the ages of 2 and 6 years, 24% of boys and 14% of girls are estimated to be overweight in Finland [12].

Snoring and OSA have been associated with a higher frequency of upper respiratory infections [13] and allergic diseases [14,15] during childhood. Children with gastroesophageal reflux disease seem to have a higher risk for snoring [16]. In addition, male sex [2,13,17,18], parental snoring [17–19], and passive smoking [17,19–21] have been reported to add to the risk of snoring among infants and toddlers.

The association between snoring and OSA and lower socioeconomic status (SES) has been well established [2,22,23]. In a Swedish study, a low level of familial income and parental education increased the risk of SDB [22]. Living in socio-economically disadvantaged neighborhoods in New Zealand and Canada added to the risk of habitual snoring among children under school age [2,23].

Even if snoring corresponds to an intermittent and partial obstruction of the airway and represents the milder end of the SDB spectrum, it is not a benign condition. Besides OSA, studies provide evidence that snoring is also associated with elevated blood pressure and neurocognitive and behavioral disturbances [2,24–27]. In addition, Li et al. found that more than one-third of snoring school-aged children progressed to OSA after a follow-up period of four years [28]. Considering the reported disadvantageous consequences of snoring already in childhood, it is essential for physicians to ask parents about snoring and routinely also screen the milder forms of SDB.

Compared to toddlers, the prevalence of habitual snoring during infancy has been estimated to be somewhat lower, ie, about 5.0–6.6% [9,29,30], although some studies report a prevalence of 9–14% [1,6]. We have previously reported that the prevalence rates of snoring at the age of three and eight months are as low as 3.2% and 3.0%, respectively [19]. However, it is not known whether Finnish children have a persistent low risk for habitual snoring, nor is it known what causes the low snoring prevalence in Finland. In addition, the reports of young children's snoring from European countries are scarce and longitudinal information not available. The objective of this study was to examine the current prevalence and persistence of snoring during the first two years of life and the associated factors. Gathering updated information is highly valuable, taking into account the well-characterized changes in the currency of risk factors for SDB as they may exert direct influences on the prevalence of snoring as well.

2. Methods

2.1. Study design and population

This study was conducted within two prospective, population-based birth cohort studies, CHILD-SLEEP (CS) [31] and FinnBrain (FB) [32]. The original sample was composed of 1679 families from the CS birth cohort and 3808 families from the FB cohort.

Recruitment of the CS cohort took place in Pirkanmaa Hospital District, Finland. The study protocol was approved by the Ethics Committee of Pirkanmaa Hospital District on March 9, 2011 (number R11032). The infants were born between April 2011 and February 2013. The baseline questionnaire was sent by mail to the parents before the babies were born, and the follow-up measurements took place at several time points. Questionnaires were provided to both mothers and fathers. The questionnaire concerning the child was filled out by the parents together. As the questionnaire was sent only to the Finnish-speaking population, the ethnic background of the participants is Finnish. The details of the recruitment procedure have been reported previously [31].

From the CS cohort, 950 families out of 1679 originally recruited families responded to the 24-month questionnaire concerning the child health and sleep, yielding a response rate of 56.8%. In 3 (0.3%) cases, the family did not answer the question about snoring. These cases were excluded from further analysis, leaving 947 (56.4%) families.

The FB cohort was a population-based sample gathered in Southwest Finland. A more detailed description of the characteristics of the sample and the recruitment process have been described previously [33]. The sample was recruited between December 2011 and April 2015 at maternal welfare clinics in a geographically defined area, comprising all women eventually referred to give birth at Turku University Hospital in the Southwest Finland Hospital District and the Åland Islands in Finland. The recruitment took place at the pregnancy ultrasound scan at gestational week 12. The study inclusion criteria were a sufficient knowledge of Finnish or Swedish and a normal ultrasound screening result. Initially, a total of 3808 mothers and 2623 fathers participated. At the child age of 24 months, 1454 families out of 3808 initially recruited families responded to the 24-months questionnaire, so the response rate was 38.2%. There were 61 (4.2%) responses missing information on the child's snoring status, leaving 1393 (36.6%) children in the final sample.

2.2. Questionnaire

In both cohorts, the parents filled in the first questionnaires before labor. In the CS cohort, the follow-up questionnaire was sent to the families when the child was three months, eight months, and 24 months old. The time points for the follow-up questionnaires in the FB cohort were six, 12, and 24 months after the child was born. The questionnaire consisted of parts concerning the child's sleep and environmental factors that may affect sleep.

The sleep questionnaires included questions from four screening tools: the Basic Nordic Sleep Questionnaire (BNSQ) [34], the Brief Infant Sleep Questionnaire [35], the Infant Sleep Questionnaire [36], and the Sleep Disturbance Scale for Children (SDSC) [37].

The SDSC [37] is a rating scale developed for the evaluation of sleep disorders in children. This questionnaire is divided into six subscales, including disorders of initiating and maintaining sleep, sleep-disordered breathing, disorders of arousal/nightmares, sleep–wake transition disorders, disorders of excessive somnolence, and sleep hyperhidrosis. In the CS cohort, the questionnaires at every measurement point included the SDSC scale. In the FB cohort, only the 24-month questionnaire comprised the questions of the SDSC scale.

To assess sleep-disordered breathing, we used questions from the SDSC scale's sleep disordered subscale. The answer options were *always* (daily), *often* (3–5 times per week), *sometimes* (once or twice per week), *occasionally* (once or twice per month or less), and *never*. In the analyses, we combined the frequency of snoring into a dichotomy as follows: habitual snorers, meaning snoring at least three nights per week, versus the others.

The total sleep time was calculated from the answers of the following questions: “What time does your child fall asleep?” and “What time does your child wake up?” The question “Has your child had recurrent infections?” was included in the 24-month questionnaire in both cohorts. This question was applied as a method to determine the children suffering from recurrent infections, because no absolute consensus exists on the number of infections per year that would define recurrent infections [38]. The frequency of parents' snoring was gathered from the questions of the BNSQ at the end of the pregnancy.

There were some variations in the questionnaires of the CS and FB cohorts. Information on whether the child was being breastfed or having only formula was available from the first three months of life in the CS cohort and the first four months in the FB cohort. In the CS cohort, we compared those parents who answered smoking today or less than six months ago in the 24-month questionnaire to those who had last smoked more than six months ago or had never smoked. In the FB cohort, we had information on whether the parent was smoking when the child was one year old. This information on smoking was gathered only from a subsample comprising 275 mothers and 168 fathers. In the CS cohort, the parental monthly income was inquired at the end of the pregnancy, whereas in the FB cohort, the information was gathered at the beginning of the pregnancy. Information on the parents' BMI was available from the 24-month questionnaire in the CS cohort and the 12-month questionnaire in the FB cohort.

2.3. Growth

The growth charts were collected from well-baby clinics. The body mass index standard deviation score (BMI-SDS) at the child age of two years was calculated based on Finnish growth references [39]. We used standardized Finnish classifications of overweight and obesity based on BMI-SDS information and combined classes into the dichotomy as follows: children with obesity or severe obesity versus overweight, normal weight, or underweight children [39].

2.4. Statistical analysis

Frequency analyses were performed first separately for both birth cohorts. We reported prevalence rates with 95% confidence intervals separately for the two cohorts and jointly. We also analyzed longitudinally the prevalence of persistent snoring. There were 856 children in the CS cohort with complete data on snoring from all three measurement points at three, eight, and 24 months. The positive and negative predictive values were calculated to evaluate the probability of snoring at eight and 24 months based on the child's snoring status at the age of three months. Next, we evaluated how snoring was related to parent-reported background factors. The comparisons were based on *t*-tests or the chi-squared test depending on the type of variable to be analyzed. The first logistic regression model was constructed in order to study which of the risk factors were significantly related to snoring when controlling for the children's age, sex, prevalence of asthma, and recurrent cycle of infections. The second model included the first model plus the maternal smoking status.

3. Results

The prevalence rates of snoring at the age of two years are shown in Fig. 1.

In the CHILD-SLEEP birth cohort, the prevalence of habitual snoring was 2.4% (95% CI 1.6–3.2). There were five children snoring every night based on the parental report. Some 9.2% (7.7–10.7) of the children snored at least weekly. There were 615 (64.9%, 61.9–67.9) children not snoring at all. In the FinnBrain cohort, the snoring prevalence was as low as in the CS cohort (Fig. 1). There were 31 children (2.2%, 1.4–3.0) snoring habitually, and only six of them snored every night. The prevalence of weekly snoring in the FB cohort was 8.3% (6.9–9.8). There were 905 children (65.0%, 62.5–67.5) who did not snore at all at the age of two years.

The combined prevalence of habitual snoring in these two birth cohorts was 2.3% (1.5–3.1).

In the CS cohort, there were 856 children whose SDSC scaling was available for every measurement point (see Fig. 2).

There were only six children (0.7%) snoring habitually throughout the first two years of life, ie, at the age of three, eight, and 24 months. Some 2.5% of the children (N = 21) snored at least once a week at all three measurement points. Of the 23 habitually snoring children, almost all had snored already previously. Only two children snored for the first time at 24 months. The remainder of the two-year-old habitual snorers snored at least occasionally at one or two additional measurement points. Of the 856 children, 47.0% (N = 402) did not snore at any measurement point.

When the infant snored at the age of three months, the positive predictive value of snoring at eight and 24 months was 84.6% (56.6–95.9) and 63.6% (37.1–83.8), respectively. The children not snoring at all during infancy seemed to have a persistent low risk for habitual snoring subsequently, as the negative predictive values were 98.3% (97.2–99.0) at eight months and 98.3% (96.8–99.2) at 24 months.

The associations of selected background factors and snoring are shown in Tables 1 and 2.

The parents reported six children with chronic illnesses potentially affecting the snoring status in the CS cohort [Goldenhar syndrome, Down syndrome, cleft palate, craniosynostosis, developmental disability (N = 2)] and nine children in the FB cohort (Beckwith-Wiedemann syndrome, Kabuki syndrome, Malan syndrome, Turner syndrome, Poland syndrome, laryngomalacia, scaphocephaly, tp63 gene mutation, neurometabolic syndrome). All the analyses were carried out excluding the children with illnesses, and the results remained virtually the same.

There were no statistically significant differences in the age, weight, height, BMI-SDS, gestational age, or total sleep time based on the parental reports between the habitually snoring children and the other children in either cohort. When analyzing the dichotomies “overweight” and “obesity” in the CS cohort, there was no significant difference between the weight status of snorers and the controls. However, in the FB cohort, there was a significantly

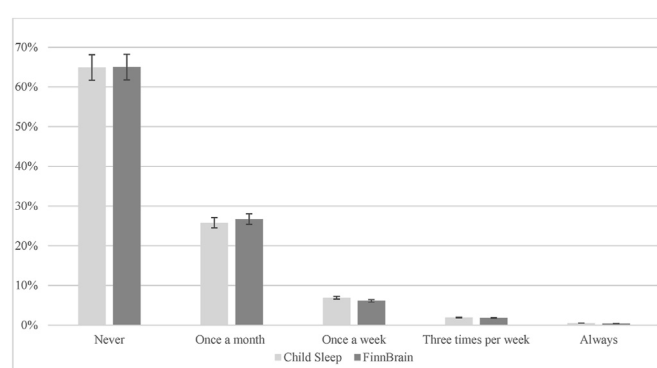

Fig. 1. Parent-reported snoring prevalence (%) for 24-month-old children. The bars display standard errors.

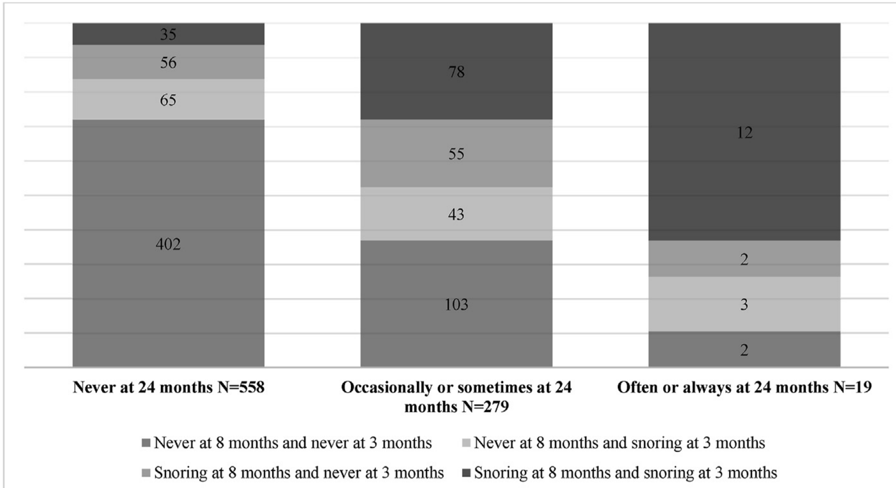

Fig. 2. Snoring at the age of 24 months (N = 856) and evolution of parent-reported snoring during the first two years of life in the CS cohort.

Table 1
The associations of parent-reported child's background factors and snoring.

	Child sleep N = 947						FinnBrain N = 1393					
	Controls N = 924		Snorers N = 23		*p*-value		Controls N = 1362		Snorers N = 31		*p*-value	
	Mean	SD	Mean	SD			Mean	SD	Mean	SD		
Age (yrs)	2.06	0.12	2.10	0.14	0.109		2.05	0.05	2.05	0.04	0.687	
Weight (kg)	12.35	1.90	12.65	1.89	0.483		12.67	1.47	13.06	1.85	0.164	
Height (cm)	86.61	6.26	87.25	5.45	0.652		87.81	3.67	88.12	3.21	0.664	
BMI	16.37	1.29	16.55	1.44	0.550		16.41	1.45	16.86	1.87	0.116	
BMI-SDS	0.07	1.06	0.26	1.06	0.505		0.10	1.10	0.36	1.32	0.214	
Gestational age (wk)	40.03	1.27	39.88	1.06	0.607		39.75	1.65	39.76	1.67	0.976	
Total sleep time (hr)	11.87	0.87	11.65	1.01	0.238		10.71	0.87	10.85	0.83	0.369	
	n	%	**n**	%	OR (95% CI)	*p*-value	n	%	n	%	OR (95% CI)	*p*-value
Male sex	486	52.6	13	56.5	1.17 (0.51–2.69)	0.833	728	53.5	23	74.2	**2.46 (1.11–5.46)**	**0.028**
Overweight	120	13.0	4	17.4	1.41 (0.47–4.22)	0.528	277	20.3	7	22.6	1.14 (0.49–2.68)	0.821
Obesity	21	2.3	1	4.3	1.96 (0.25–15.18)	0.421	54	4.0	6	19.4	**5.81 (2.29–14.76)**	**0.002**
Only formula in the first months[a]	98	10.6	5	21.7	2.34 (0.85–6.45)	0.095	48	3.5	2	6.5	1.89 (0.44–8.14)	0.307
Use pacifier at the age of two years	182	19.7	5	21.7	1.11 (0.41–3.05)	0.792	NA					
Milk allergy	30	3.2	2	8.7	2.72 (0.67–11.12)	0.180	NA					
Other allergy	63	6.8	3	13.0	2.00 (0.61–6.57)	0.212	NA					
Allergic rhinitis	NA						14	1.0	1	3.2	3.14 (0.46–21.59)	0.282
Atopic dermatitis	NA						289	21.1	11	35.5	1.89 (0.92–3.90)	0.085
Asthma	16	1.7	1	4.3	2.48 (0.36–17.40)	0.344	31	2.3	3	9.7	**4.30 (1.37–13.50)**	**0.037**
Recurrent cycle of infections	32	3.5	3	13.0	**3.91 (1.22–12.54)**	**0.049**	151	11.1	4	12.9	1.20 (0.41–3.48)	0.769
Gastroesophageal reflux	15	1.6	0	0	NA	1.000	8	0.6	1	3.2	5.64 (0.68–46.54)	0.184

BMI = body mass index; BMI-SDS = body mass index standard deviation score; CS=CHILD SLEEP; FB=FinnBrain; NA = not available. Bold font indicates statistical significance.
[a] CS the first three months of life, FB the first four months.

higher proportion of obese children in the snorer group (19.4% vs. 4.0%, OR 5.8, 95% CI 2.3–14.8, p = 0.002).

In the FB cohort, there were more boys in the group of habitual snorers compared to children snoring less (74.2% vs. 53.5%, OR 2.5, 1.1–5.5, p = 0.028). In the CS cohort, a recurrent cycle of infections was distinctly more common in the snorer group (3.5% vs. 13.0%, OR 3.91, 1.22–12.54, p = 0.049). Correspondingly in the FB cohort, there were proportionately more children suffering from asthma among habitual snorers (9.7% vs. 2.3%, OR 4.30, 1.37–13.50, p = 0.037).

In the FB cohort, the fathers of habitually snoring children had a higher BMI compared to fathers in the control group (27.95 vs. 25.97, p = 0.043). Between the snoring group and the controls, there was no statistically significant difference in the mothers' BMI in both cohorts nor in the fathers' BMI in the CS cohort.

In the CS cohort, the mother's (21.7% vs. 7.9%, OR 3.24, 1.17–8.97, p = 0.034) and father's (39.1% vs. 15.9%, OR 3.40, 1.44–8.00, p = 0.007) snoring every night was significantly more common in the habitual snorer group. In the group of habitual snorers in the CS cohort, there was more often someone smoking in the family (43.5% vs. 22.6%, OR 2.63, 1.14–6.09, p = 0.041).

In both birth cohorts, the educational level of mothers in the snorer group was more frequently lower compared to the mothers in the control group (43.5% vs. 20.3%, CS OR 3.01, 1.30–6.97, p = 0.016, FB 48.4% vs. 26.75%, OR 2.57, 1.26–5.25, p = 0.013). In the FB cohort, the mother's monthly income was more often below 2000 euros (35.5% vs. 14.3%, OR 3.29, 1.55–6.98, p = 0.003) in the habitual snorer group.

Table 2
The associations of parent-reported family background factors and snoring.

	Child sleep N = 947						FinnBrain N = 1393					
	Controls N = 924		Snorers N = 23		*p*-value		Controls N = 1362		Snorers N = 31		*p*-value	
	Mean	SD	Mean	SD			Mean	SD	Mean	SD		
Mothers' BMI (kg/m^2)[a]	24.59	4.31	25.70	4.88	0.221		24.66	5.14	25.72	5.66	0.300	
Fathers' BMI (kg/m^2)[a]	26.16	3.52	26.89	2.54	0.436		25.97	3.78	27.95	6.22	**0.043**	
	n	%	n	%	OR (95% CI)	*p*-value	n	%	n	%	OR (95% CI)	*p*-value
Maternal snoring every night	73	7.9	5	21.7	**3.24 (1.17–8.97)**	**0.034**	116	8.5	3	9.7	1.15 (0.35–3.84)	0.744
Paternal snoring every night	147	15.9	9	39.1	**3.40 (1.44–8.00)**	**0.007**	112	8.2	5	16.1	2.15 (0.81–5.70)	0.176
Maternal smoking during pregnancy	40	4.3	3	13.0	3.32 (0.94–11.68)	0.082	157	11.5	7	22.6	2.24 (0.95–5.28)	0.082
Paternal smoking during pregnancy	240	26.0	8	34.8	1.52 (0.37–3.63)	0.342	225	16.5	6	19.4	1.21 (0.49–2.99)	0.628
Smoking in the family during previous 6 months or at the age of one year[b]	209	22.6	10	43.5	**2.63 (1.14–6.09)**	**0.041**	74	5.4	2	6.5	1.20 (0.28–5.13)	0.685
Maternal lower level of education	188	20.3	10	43.5	**3.01 (1.30–6.97)**	**0.016**	364	26.7	25	48.4	**2.57 (1.26–5.25)**	**0.013**
Paternal lower level of education	283	30.6	10	43.5	1.74 (0.76–4.02)	0.252	364	26.7	7	22.6	0.80 (0.34–1.87)	0.686
Maternal monthly income < 2000 €[c]	621	67.2	18	78.3	1.78 (0.65–4.78)	0.368	195	14.3	11	35.5	**3.29 (1.55–6.98)**	**0.003**
Paternal monthly income < 2000 €[c]	312	33.8	12	52.2	2.14 (0.93–4.91)	0.076	258	18.9	5	16.1	0.82 (0.31–2.16)	0.820

BMI = body mass index; CS=CHILD SLEEP; FB=FinnBrain. Bold font indicates statistical significance.
[a] CS when the child was two years old, FB when the child was one year old.
[b] FB information from 275 mothers and 168 fathers, CS previous 6 months, FB when the child was one year old.
[c] CS at the end of pregnancy, FB at the beginning of pregnancy.

3.1. The adjusted risk

After controlling for age, sex, prevalence of asthma, and recurrent infections in the logistic regression models, parental snoring, the mother's lower level of education, and the mother's lower income associated with the child's habitual snoring (see Table 3).

In the CS cohort, parental snoring every night (OR_a 2.75, 95% CI 1.11–6.78, p = 0.028) added to the risk of habitual snoring after adjustment. In the FB cohort but not in the CS cohort, the association of the mother's lower income and the child's habitual snoring remained statistically significant in the multivariable model (CS OR_a 2.12, 0.70–6.47, p = 0.182, FB OR_a 2.88, 1.31–6.34, p = 0.009).

Considering that the educational level (CS 38.3% vs. 22.3%, p < 0.001, FB 51.3% vs. 26.5%, p = 0.001) and monthly income (CS 79.9% vs. 67.3%, p = 0.004, FB 38.5% vs. 14.1%, p < 0.001) of smoking mothers were more often lower compared to non-smoking mothers in both cohorts, we added the maternal smoking status into the second model. In the CS cohort parents' snoring every night (OR_a 3.66, 1.34–10.01, p = 0.011) and mother's lower level of education (OR_a 2.78, 1.01–7.65, p = 0.048) remained significantly related to the child's snoring. In the FB cohort, the association of mothers' lower income and the child's habitual snoring was statistically significant in the second model as well (OR_a 2.82, 1.27–6.23, p = 0.011), see Table 3.

4. Discussion

Our results show that the prevalence of habitual snoring in Finland was lower than reported previously in other countries. The combined prevalence of habitual snoring in the two large birth cohorts was 2.3%, and the prevalence rates were virtually identical in both populations: 2.4% in the CHILD-SLEEP cohort and 2.2% in the FinnBrain cohort. In the CS cohort, the children not snoring at all during infancy had a persistent low risk for habitual snoring during the first two years of life. Habitual snoring was associated with several health and environmental factors such as parents' snoring, mother's lower socioeconomic status (SES), child's exposure to smoking, recurrent respiratory infections and asthma. Many of these factors can be altered and may provide important means to diminish the risk of the child snoring.

The reason for the low prevalence of habitual snoring among Finnish infants [19] and toddlers in our cohorts is not known. Since breastfeeding is known to protect from snoring [1,19,40,41], the

Table 3
The adjusted risk for snoring of parent reported background factors.

	Child sleep N = 947			FinnBrain N = 1393		
	OR_a	95% CI	p	OR_a	95% CI	p
Model 1[a]						
Parental snoring every night	**2.75**	**1.11–6.78**	**0.028**	1.90	0.79–4.55	0.151
Maternal lower level of education	**2.93**	**1.15–7.46**	**0.024**	**2.14**	**1.01–4.51**	**0.047**
Maternal monthly income <2000 €	2.12	0.70–6.47	0.185	**2.88**	**1.31–6.34**	**0.009**
Model 2[b]						
Parental snoring every night	**3.66**	**1.34–10.01**	**0.011**	1.84	0.76–4.44	0.175
Maternal lower level of education	**2.78**	**1.01–7.65**	**0.048**	2.09	0.99–4.44	0.054
Maternal monthly income <2000 €	1.48	0.41–5.36	0.552	**2.82**	**1.27–6.23**	**0.011**

Bold font indicates statistical significance.
[a] Age, gender, recurrent cycle of infections and diagnosis of asthma controlled for.
[b] Age, gender, recurrent cycle of infections, diagnosis of asthma and mother's smoking status controlled for.

very high breastfeeding numbers in our country may explain some of this low snoring prevalence among infants.

Furthermore, in both our birth cohorts, the parents were relatively highly educated. Lower SES [2,22] is a risk factor for childhood snoring that has been identified in previous studies. In the CS cohort, the mother's lower monthly income associated with habitual snoring at two years. In addition, in both cohorts a lower maternal educational level was significantly related to the toddler's habitual snoring. We hypothesize that the low prevalence of snoring is connected to the fact that both of our cohorts are skewed toward higher socioeconomic classes. In line with this, Bonuck et al. reported a higher prevalence of snoring [1] where the proportion of mothers with lower education was considerably higher (62.3%) compared to our study populations (CS 20.9%, FB 27.2%). When we stratified the sample according to education, we found that the prevalence of snoring was 5.1% in the CS and 4.0% in the FB cohort in families with lower maternal education. These figures are somewhat closer to those reported previously, albeit at the lower end of the spectrum.

In addition, another explanation for the unexpectedly low prevalence of snoring among Finnish children could be the somewhat pure outdoor air, given the evidence that air pollution may affect the incidence of sleep-disordered breathing in children [42,43]. Further research is undoubtedly needed to clarify the background of the distinct SDB prevalence in different countries.

The first-line therapy for OSA in childhood is adenotonsillectomy. In our study population, adenoidectomy was performed in nine children in the CS cohort. None of these children were in the group of habitual snorers at the age of two years. In the FB cohort, there were 20 children who had had their adenoids removed, all of whom were in the group with no reported habitual snoring at 24 months. There was one child alone who snored habitually regardless of adenoidectomy. If we assume that all these aforementioned children would have snored without adenoidectomy, the prevalence of habitual snoring would have been 3.4% in the CS and 3.7% in the FB cohort. Even in this scenario, Finnish toddlers to date seem to snore markedly less than reported previously.

There are multifactorial mechanisms including environmental factors and genetic aspects behind childhood snoring. Additionally to socioeconomic status and environmental air quality, snoring in the family is a well-known risk factor for children's snoring [17–19] and these factors were established in our present study as well. In the CS cohort, parental snoring associated significantly with the toddler's habitual snoring. Inherited anatomic factors that determine facial structure and body composition explain the tendency to snore in some families. In addition, obesity runs in the family.

The high frequency of upper respiratory infections is a risk factor for snoring [13], and we found the same association in our study in the CS cohort, where children with a recurrent cycle of infection snored more often habitually compared to children without cyclic infections. However, the same association was not seen in the FB cohort. The prevalence of recurrent infections was markedly low (3.7%) in the CS cohort, considering that approximately 10% of children aged under two years are estimated to suffer from frequent infections [44]. In the FB cohort, the prevalence of recurrent infections was 11%. The more specific phenotype of these children with recurrent respiratory infections in the FB cohort has been reported previously [45]. Most of the children with cyclic infections had more than five respiratory infections before 2 years of age (77% vs. 16%) and more frequent antibiotic treatments compared to the comparison group in the FB cohort. In the CS cohort, information on antibiotic treatments was not available. Some 51% of the children with a recurrent cycle of infection had more than five infections. In total, a substantially limited proportion of children in the CS cohort had had more than five infections compared to the children in the FB cohort (4.8% vs. 26%) based on parental reports. The underlying reason for this difference remains unknown along with the lacking association of recurrent infections and children's snoring in the FB cohort.

Despite the absent association between infections and snoring, the diagnosis of asthma associated with habitual snoring in the FB cohort. Since the diagnosis of asthma is usually made based on a history of recurrent wheezing during respiratory infections, we think that the association of snoring and asthma in the FB cohort might reflect the association of snoring and cyclic infections in the CS cohort. However, the number of children with a diagnosis of asthma in both cohorts was rather low, so it is troublesome to establish the statistical significance.

Some studies have reported a higher incidence of snoring in boys compared to girls [13,17]. In the FB cohort, there were significantly more boys among the group of habitual snorers, but we did not find the same difference in the CS cohort. In our study, this can be explained by the fact that boys in the FB cohort were significantly more often overweight or obese than girls (25.4% vs 14.5%, OR 1.51, 1.27–1.80, $p < 0.001$). In the CS cohort the prevalence of overweight was somewhat lover (15.0% in boys and 11.0% in girls). The protective effect on female gender concerning childhood snoring remains to be established in further studies.

A meta-analysis of 24 studies among children indicates that tobacco smoke exposure increases the risk of habitual snoring [46]. The specific pathways by which exposure to tobacco smoke induces snoring are not known. It has been hypothesized that upper airway inflammation caused by chronic irritant exposure could be one explanation. In the CS cohort, the children of smoking parents snored habitually significantly more often compared to children living in smoke-free families. This association could serve as a supplementary tool for healthcare workers to be used in counselling and encouraging parents to quit smoking.

Previous longitudinal studies concerning snoring during early childhood are scarce. During the first two years of life, the prevalence of habitual snoring remained low among Finnish children in the CS cohort. The children not snoring at all during infancy seemed to have a persistent low risk for habitual snoring subsequently at the age of eight and 24 months, and vice versa. Overall, as many as half of the children (47%) in the CS cohort did not snore at any measurement point.

Despite the paucity of longitudinal information regarding toddlers' habitual snoring, there is a reasonable amount of data that parent-reported snoring may represent multiple phenotypes. Kamal et al. [16] reported four different SDB symptom trajectories up to two years of age; no-SDB, early SDB, late SDB, and persistent SDB. In every trajectory, they found different risk factors for SDB symptoms. Rhinitis and prior day-care seemed to add to the risk of snoring, daytime sleepiness, and attention deficit hyperactivity disorder symptoms in all trajectories. In addition, Freeman and Bonuck [47] defined five clusters during childhood; early snoring, early apnea, late snoring and mouth-breathing, normal, and all SDB after infancy. Children in the clusters of early snoring and early apnea alone developed the symptoms during the first two years of life. Some 50% of children were classified in the normal cluster, and these families were characterized by higher SES and a lower prevalence of smoking by the mothers.

The various phenotypes of SDB symptoms and the different risk factors in each cluster can explain the differences in the associations with habitual snoring in the CS and FB cohorts. Since the amount of habitually snoring children in our birth cohorts was limited (CS N = 23, FB N = 31) due to the low snoring prevalence, the evaluation of different phenotypes in our study population was not possible. Considering the low prevalence of snoring during early childhood in Finland, it would be interesting to study these phenotypes in a case control study in the future.

This study is based on comprehensive questionnaire surveys from two large birth cohorts, the CS (N = 947) and the FB (N = 1393). Further along in the CS cohort, we report the longitudinal aspect of snoring during early childhood. Comparable to our previous study covering snoring in infancy, the number of habitual snorers remained small in this study, and even larger samples or case–control study settings are needed in the future.

Polysomnography is considered to be the gold standard for diagnosing sleep disorders, and the absence of an objective measurement of snoring is a limitation in a community-based survey study. However, in this kind of large cohort study, overnight sleep recording is remarkably difficult to accomplish. We used standardized scales to assess the children's snoring in the questionnaires. As the snoring prevalence was practically identical in the two independent cohorts, we assume that the result of our study demonstrates rather accurately the prevalence of snoring among children in Finland.

In conclusion, our study suggests that the prevalence of habitual snoring among Finnish toddlers is notably lower (2.3%) than reported previously. Furthermore, risk for habitual snoring remained low from infancy to toddlerhood. Screening and administering preventive interventions for risk factors for snoring in early childhood may apply a tool to reduce the well-documented negative health consequences of SDB in later life.

Funding

The project was funded by the Academy of Finland (Linnea Karlsson: #308589 & Juulia Paavonen: #308588), the Signe and Ane Gyllenberg Foundation, the Yrjö Jahnson Foundation, the Foundation for Pediatric Research, the Finnish Cultural Foundation, the Competitive Research Financing of the Expert Responsibility Area of Tampere University Hospital, the Hospital District of Southwest Finland, the Arvo and Lea Ylppö Foundation, the Doctors' Association in Tampere, the Tampere Tuberculosis Foundation, and the Research Foundation of the Pulmonary Diseases.

Credit author statement

Maija Katila: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft. **Outi Saarenpää-Heikkilä:** Conceptualization, Investigation, Methodology, Writing – review and editing, Supervision. **Marja-Terttu Saha:** Writing – review and editing, Supervision. **Nina Vuorela:** Writing – review and editing. **Heini Huhtala:** Formal analysis, Writing – review and editing. **Laura S. Korhonen:** Data curation, Writing – review and editing. **Minna Lukkarinen:** Data curation, Writing – review and editing. **Jetro Tuulari:** Writing – review and editing. **Linnea Karlsson:** Data curation, Resources, Writing – review and editing. **Hasse Karlsson:** Writing – review and editing. **E. Juulia Paavonen:** Conceptualization, Data curation, Formal analysis, Methodology, Writing – review and editing, Supervision.

Conflict of interest

None declared.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2021.06.004.

References

[1] Bonuck KA, Chervin RD, Cole TJ, et al. Prevalence and persistence of sleep disordered breathing symptoms in young children: a 6-year population-based cohort study. Sleep 2011 Jul 1;34(7):875–84.
[2] Gill AI, Schaughency E, Galland BC. Prevalence and factors associated with snoring in 3-year olds: early links with behavioral adjustment. Sleep Med 2012 Oct;13(9):1191–7.
[3] Byars KC, Yolton K, Rausch J, et al. Prevalence, patterns, and persistence of sleep problems in the first 3 years of life. Pediatrics 2012 Feb;129(2):e276–84.
[4] Liukkonen K, Virkkula P, Aronen ET, et al. All snoring is not adenoids in young children. Int J Pediatr Otorhinolaryngol 2008 Jun;72(6):879–84.
[5] Katila M, Saarenpää-Heikkilä O, Saha MT, et al. Parental reports showed that snoring in infants at three and eight months associated with snoring parents and smoking mothers. Acta Paediatr 2019 Sep;108(9):1686–94.
[6] Piteo AM, Lushington K, Roberts RM, et al. Prevalence of snoring and associated factors in infancy. Sleep Med 2011 Sep;12(8):787–92.
[7] Kuehni CE, Strippoli MP, Chauliac ES, et al. Snoring in preschool children: prevalence, severity and risk factors. Eur Respir J 2008 Feb;31(2):326–33.
[8] Mitchell EA, Thompson JM. Snoring in the first year of life. Acta Paediatr 2003 Apr;92(4):425–9.
[9] Montgomery-Downs HE, Gozal D. Sleep habits and risk factors for sleep-disordered breathing in infants and young toddlers in Louisville, Kentucky. Sleep Med 2006 Apr;7(3):211–9.
[10] Li AM, Sadeh A, Au CT, et al. Prevalence of habitual snoring and its correlates in young children across the Asia Pacific. J Paediatr Child Health 2013 Feb;49(2):E153–9.
[11] Arens R, Marcus CL. Pathophysiology of upper airway obstruction: a developmental perspective. Sleep 2004 Aug 1;27(5):997–1019.
[12] Mäki P, Lehtinen-Jacks S, Vuorela N, et al. Data on prevalence of overweight among Finnish children available in an increasing number of municipalities through the Avohilmo Register. Suom Laakaril 2018;73(41):2336–41.
[13] Kukwa W, Guilleminault C, Tomaszewska M, et al. Prevalence of upper respiratory tract infections in habitually snoring and mouth breathing children. Int J Pediatr Otorhinolaryngol 2018 Apr;107:37–41.
[14] Wang X, Gao X, Yang Q, et al. Sleep disorders and allergic diseases in Chinese toddlers. Sleep Med 2017 Sep;37:174–9.
[15] Hu JM, Lin CS, Chen SJ, et al. Association between obstructive sleep apnea and atopic dermatitis in children: a nationwide, population-based cohort study. Pediatr Allergy Immunol 2018 May;29(3):260–6.
[16] Kamal M, Tamana SK, Smithson L, et al. Phenotypes of sleep-disordered breathing symptoms to two years of age based on age of onset and duration of symptoms. Sleep Med 2018 Aug;48:93–100.
[17] Kaditis AG, Finder J, Alexopoulos EI, et al. Sleep-disordered breathing in 3,680 Greek children. Pediatr Pulmonol 2004 Jun;37(6):499–509.
[18] Li AM, Au CT, So HK, et al. Prevalence and risk factors of habitual snoring in primary school children. Chest 2010 Sep;138(3):519–27.
[19] Katila M, Saarenpaa-Heikkila O, Saha MT, et al. Parental reports showed that snoring in infants at three and eight months associated with snoring parents and smoking mothers. Acta Paediatr 2019 Sep;108(9):1686–94.
[20] Ersu R, Arman AR, Save D, et al. Prevalence of snoring and symptoms of sleep-disordered breathing in primary school children in istanbul. Chest 2004 Jul;126(1):19–24.
[21] Zhu Y, Au CT, Leung TF, et al. Effects of passive smoking on snoring in preschool children. J Pediatr 2013 Oct;163(4):1158–62. e4.
[22] Friberg D, Lundkvist K, Li X, et al. Parental poverty and occupation as risk factors for pediatric sleep-disordered breathing. Sleep Med 2015 Sep;16(9):1169–75.
[23] Brouillette RT, Horwood L, Constantin E, et al. Childhood sleep apnea and neighborhood disadvantage. J Pediatr 2011 May;158(5):789–795.e1.
[24] Li AM, Au CT, Ho C, et al. Blood pressure is elevated in children with primary snoring. J Pediatr 2009 Sep;155(3):362–368.e1.
[25] Biggs SN, Vlahandonis A, Anderson V, et al. Long-term changes in neurocognition and behavior following treatment of sleep disordered breathing in school-aged children. Sleep 2014 Jan 1;37(1):77–84.
[26] Brockmann PE, Urschitz MS, Schlaud M, et al. Primary snoring in school children: prevalence and neurocognitive impairments. Sleep Breath 2012 Mar;16(1):23–9.
[27] Vlahandonis A, Yiallourou SR, Sands SA, et al. Long-term changes in blood pressure control in elementary school-aged children with sleep-disordered breathing. Sleep Med 2014 Jan;15(1):83–90.
[28] Li AM, Zhu Y, Au CT, et al. Natural history of primary snoring in school-aged children: a 4-year follow-up study. Chest 2013 Mar;143(3):729–35.
[29] Kelmanson IA. Snoring, noisy breathing in sleep and daytime behaviour in 2-4-month-old infants. Eur J Pediatr 2000 Oct;159(10):734–9.
[30] Gislason T, Benediktsdottir B. Snoring, apneic episodes, and nocturnal hypoxemia among children 6 months to 6 years old. An epidemiologic study of lower limit of prevalence. Chest 1995 Apr;107(4):963–6.
[31] Juulia Paavonen E, Saarenpaa-Heikkila O, Polkki P, et al. Maternal and paternal sleep during pregnancy in the Child-sleep birth cohort. Sleep Med 2017 Jan;29:47–56.
[32] Karlsson L, Tolvanen M, Scheinin NM, et al. Cohort profile: the FinnBrain birth cohort study (FinnBrain). Int J Epidemiol 2018 Feb 1;47(1):15–16j.
[33] Korja R, Nolvi S, Kataja EL, et al. The courses of maternal and paternal depressive and anxiety symptoms during the prenatal period in the FinnBrain Birth Cohort study. PloS One 2018 Dec 17;13(12):e0207856.
[34] Partinen M, Gislason T. Basic Nordic Sleep Questionnaire (BNSQ): a quantitated measure of subjective sleep complaints. J Sleep Res 1995 Jun;4(S1):150–5.

[35] Sadeh A. A brief screening questionnaire for infant sleep problems: validation and findings for an Internet sample. Pediatrics 2004 Jun;113(6):e570–7.
[36] Morrell JMB. The infant sleep questionnaire: a new tool to assess infant sleep problems for clinical and research purposes. Child Psychol Psychiatr Rev 1999 02/01;4(1):20–6. 2018/09.
[37] Bruni O, Ottaviano S, Guidetti V, et al. The Sleep Disturbance Scale for Children (SDSC). Construction and validation of an instrument to evaluate sleep disturbances in childhood and adolescence. J Sleep Res 1996 Dec;5(4):251–61.
[38] Nokso-Koivisto J, Pitkäranta A, Blomqvist S, et al. Viral etiology of frequently recurring respiratory tract infections in children. Clin Infect Dis 2002 Sep 1;35(5):540–6.
[39] Saari A, Sankilampi U, Hannila ML, et al. New Finnish growth references for children and adolescents aged 0 to 20 years: length/height-for-age, weight-for-length/height, and body mass index-for-age. Ann Med 2011 May;43(3): 235–48.
[40] Galbally M, Lewis AJ, McEgan K, et al. Breastfeeding and infant sleep patterns: an Australian population study. J Paediatr Child Health 2013 Feb;49(2): E147–52.
[41] Brew BK, Marks GB, Almqvist C, et al. Breastfeeding and snoring: a birth cohort study. PloS One 2014 Jan 8;9(1):e84956.
[42] Sanchez T, Gozal D, Smith DL, et al. Association between air pollution and sleep disordered breathing in children. Pediatr Pulmonol 2019 May;54(5):544–50.
[43] Kheirandish-Gozal L, Ghalebandi M, Salehi M, et al. Neighbourhood air quality and snoring in school-aged children. Eur Respir J 2014 Mar;43(3):824–32.
[44] Toivonen L, Karppinen S, Schuez-Havupalo L, et al. Burden of recurrent respiratory tract infections in children: a prospective cohort study. Pediatr Infect Dis J 2016 Dec;35(12):e362–9.
[45] Korhonen LS, Karlsson L, Scheinin NM, et al. Prenatal maternal psychological distress and offspring risk for recurrent respiratory infections. J Pediatr 2019 May;208:229–235.e1.
[46] Sun K, Zhang Y, Tian Y, et al. Environmental tobacco smoke exposure and risk of habitual snoring in children: a meta-analysis. J Epidemiol Community Health 2018 Nov;72(11):1064–70.
[47] Freeman K, Bonuck K. Snoring, mouth-breathing, and apnea trajectories in a population-based cohort followed from infancy to 81 months: a cluster analysis. Int J Pediatr Otorhinolaryngol 2012 Jan;76(1):122–30.