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Original Article

Prevalence of snoring and associated factors in infancy

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ABSTRACT

Introduction: In children aged 3–12 years snoring is associated with significant neurocognitive and behavioural deficits; however, there are few studies that have considered both the prevalence of snoring in infants and associated factors that may influence the development of snoring. The goal of the present study was to examine sleep, snoring and associated factors in a community sample of 0–3 month olds.
Methods: Previously validated infant sleep and parent sleep questionnaires were completed by parents of 457 term infants aged 1–13.9 weeks old (mean age = 4.6 weeks; *SD* = 2.7; 45% males) during a home-based nurse visit.
Results: Approximately 9% of infants were reported to snore habitually (snoring $\geqslant$ 3 nights/week). Habitual snoring was significantly associated with exclusive formula feeding (OR: 28.87; $p < .01$), maternal concern about child's breathing during sleep (OR: 3.91; $p = .01$) and restless sleep $\geqslant$ 3 nights/week (OR: 17.76; $p < .001$).
Conclusion: These results show that snoring is as common in infants as it is in older children. Given the known relationships between Sleep Disordered Breathing (SDB) and neurocognitive development, the effect of SDB developing early in childhood may have important consequences on future developmental outcomes.

1. Introduction

Snoring is a primary symptom of upper airway obstruction which ranges in severity from primary snoring (no evidence of ventilation abnormalities) to severe obstruction characterised by gas exchange abnormalities and frequent nocturnal arousals. This spectrum is collectively designated as Sleep Disordered Breathing (SDB). Snoring is common in children and it is estimated that 5–10% of school-aged children snore three or more nights per week [1]. Snoring is not benign and has been associated with a range of psychological and physiological deficits. For example, children with SDB utilise more health care services [2], experience higher cardiovascular morbidity [3,4] and demonstrate reduced neurocognitive and behavioural functioning [5–7]. However, despite its ubiquity, childhood SDB is infrequently reported by parents to primary physicians and often remains unrecognised and untreated. Details of the prevalence of snoring in childhood are based mainly on data collected in older children and the early natural history of snoring during the first year of life remains poorly described [8]. It is crucial to understand that brain growth is maximal in the first year of life [9], and the presence of any adverse events during this period, such as snoring, could significantly impair development.

Snoring estimates vary widely in infants with prevalence rates ranging from 5.6 to 26% [10–13]. This variation may be explained by several confounders, including the presence of colds, ethnicity and gender. As anticipated, higher rates of snoring are reported when studies include infants with colds [12]; ethnic groups at greater risk of upper airway obstruction due to craniofacial factors, such as African American and Pacific Islander infants [12,13]; and a higher proportion of male children [12,14].

Snoring has also been associated with a range of additional social and environmental factors, including maternal cigarette smoking [12,13], supine sleeping position [12], restless sleep [13], maternal concern about the child's breathing during sleep [13] and low socioeconomic status [8]. Although previously examined in isolation, these factors remain to be simultaneously examined in an omnibus investigation of the risk factors for snoring. Finally, there is a paucity of information in very young infants, with only the study of Montgomery-Downs and Gozal [13] evaluating snoring frequency in 0–1 month olds (although study numbers were relatively small ($n = 49$)). The limitations identified above remain

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to be addressed in a prospective community-based sample of infants.

The aim of the present study was to examine snoring prevalence and its association with potential risk factors in a community sample of predominantly Caucasian 0–3 month old infants.

2. Method

2.1. Participants

Participants were 457 term infants (253 females; 204 males) born in South Australia. Parents (99% mothers) completed a detailed questionnaire distributed by a paediatric trained nurse at their first well child visit from Child and Family Health (CFH) (conducted without charge in South Australia) between November 2008 and July 2009. Data were collected sequentially over an eight month period. Infants' ages ranged from 1 to 13.9 weeks old (mean age (*SD*) = 4.9 (2.7) weeks old). Mothers' ages ranged from 15.8 to 45.0 years old (Mean age (*SD*) = 32.0 (5.2) years). Parents were excluded if they were non-English speakers.

This study was approved by the Human Research Ethics Committees at the seven administering hospitals and by the University of Adelaide.

2.2. Measures

This was a questionnaire-based study and included items of parent and child demographics, infant sleep behaviours, parent sleep habits and parental wellbeing. The assessment of sleep dysfunction was obtained using an omnibus questionnaire, which incorporated items from previously validated questionnaires assessing: (a) sleep duration and timing [15], (b) respiratory problems (colds and runny nose) and (c) sleep disordered breathing [13,16,17]. Night time sleep was defined as between 1900 and 0700 h and day time sleep was defined as 0700 h and 1900 h.

The following demographic, social and medical information was collected; gender, birth date, birth weight, method of delivery (caesarean section or vaginal), breastfeeding status, birth order, length of gestation (<32 weeks, 32–36 weeks, >36 weeks), details of any medical condition, mother's medical conditions during pregnancy (for example pre-eclampsia and gestational diabetes), marital status, number of cigarettes smoked within the household, number of people smoking within the household, number of cigarettes smoked by the mother each day and number of cigarettes smoked each day during pregnancy. Socio-economic status (SES) was determined from the Australian Bureau of Statistics (ABS) Socio-economic index of relative socio-economic advantage and disadvantage (SEIFA: National mean = 1000; *SD* = 100). This estimates the social and economic conditions of a neighbourhood area, based on the information collected at the 2006 census (Australian Bureau of Statistics, 2006 Census data). A lower score indicates greater disadvantage.

2.3. Procedure

Child and Health (CFH) nurses distributed the omnibus questionnaires at the first well child visit to mothers in metropolitan Adelaide and six regional towns. Parents completed the questionnaire at the end of the visit or in subsequent days. The completed questionnaire and consent form were mailed to the Sleep Disorders Unit, Women's and Children's Hospital.

3. Statistical analyses

For univariate analyses a series of one-way analyses of variances (ANOVA) were used to test for the effect of snoring category for continuous variables and Chi-square analyses were used to test for categorical variables. Effect sizes were determined using partial eta squared values (η_p^2); 0.01 = small effect, 0.06 = medium effect, and 0.14 = large effect size (Cohen, 1988). For multivariate analyses, a logistic regression model using the dichotomous outcome variable: non-snoring and habitual snoring (snoring $\geqslant$ 3 nights/week) was performed to assess the associations with demographic, medical and social factors with snoring. It was hypothesised that risk factors associated with habitual snoring would differ for those associated with less frequent snoring, thus logistic regression analyses to compare infrequent snorers with non-snorers were also performed. However, none of the demographic, medical or social factors were associated with infrequent snoring, and these are therefore not reported further here. The final model included risk factors that held an association with the dichotomised non-snoring and habitual snoring outcome variable. The snoring item was recoded from four (not at all, 1–2 nights/week, 3–5 nights/week and $\geqslant$6 nights/week) to three (not at all, 1–2 nights/week and $\geqslant$3 nights/week) categories. The items were recoded because we considered the parent's ability to make a fine-graded judgment questionable and so the categories were made more disparate so that accuracy might be improved.

4. Results

Of the 515 surveys returned, 23 were excluded because they did not fit the age criteria (i.e. >12 weeks); and 35 because infants were born preterm (<37 weeks gestational age). The final sample consisted of 457 term infants (254 females; 203 males).

4.1. Prevalence of snoring

Twelve percent of children were reported to snore frequently ($\geqslant$3 nights/week) and 18% of children were reported to snore infrequently (1–2 nights/week). Overall, a greater proportion of infants reported to have a cold or nasal discharge were reported to snore (Table 1). In addition, a significantly higher proportion of children reported to have a current cold in the Winter/Autumn months were reported to snore than those reported in the Spring/Summer months (χ^2 = 6.64, p = .04) (see Table 2). To avoid confounding snoring with colds, for all subsequent analyses children reported to have a cold or nasal discharge were excluded from analyses. The final sample was n = 269. Table 1 details the parent and infant demographic information for snoring and non-snoring groups. When excluding all infants reported to have a cold or nasal discharge in the past week, 9% of infants were reported to snore habitually and 12% of infants were reported to snore infrequently.

A significantly greater proportion of older infants (i.e. 2–3 months old) were reported to snore habitually than younger infants (i.e. 0–1 months old) (χ^2 = 5.79, p = .02) (see Fig. 1).

4.2. Sleep for snoring group

There were no significant differences between snoring and non-snoring groups for night time sleep duration, day time sleep duration and number of nocturnal waking (Table 3).

4.3. Factors associated with snoring frequency

A logistic regression comparing non-snorers with habitual snorers was conducted. Due to small sample size, infrequent snorers were excluded. A significantly higher proportion of habitual snorers were formula fed and had parental report of restless sleep. Also, a significantly higher proportion of mothers of habitual snorers

Table 1
Demographic and sleep characteristics according to snoring frequency together with *F*-test/Chi-square results.

		Snoring frequency (% (*n*))			*F*-test (effect size (η_p^2))/Chi-square
		Not at all	1–2 nights/ week	⩾3 nights/week	
Maternal age (mean (SD))	32.0 (5.4)	30.1 (5.9)	32.9 (4.2)	*F* = 2.0 (.02)	
Socioeconomic status (mean (SD))	982.9 (72.0)	994.9 (85.7)	995.3 (56.8)	*F* = .6 (.01)	
Gestational age (mean (SD))	39.2 (1.2)	39.7 (1.1)	39.0 (1.1)	*F* = 2.9 (.02)	
Birth weight (mean (SD))	3.5 (.47)	3.6 (.45)	3.9 (.71)	*F* = 2.12 (.02)	
Birth length (mean (SD))	50.2 (4.1)	50.5 (2.6)	50.7 (2.8)	*F* = .23 (.00)	
Ethnicity	Caucasian	95 (203)	94 (31)	96 (22)	χ^2 = .13
	Other	5 (10)	6 (2)	4 (1)	
Type of delivery	Vaginal	68 (144)	70 (23)	48 (11)	
	Caesarean section	32 (69)	30 (10)	52 (12)	χ^2 = 3.8
Feeding	Breast milk only	75 (159)	79 (26)	52 (12)	
	Formula only	10 (22)	6 (2)	35 (8)	χ^2 = 13.2*
	Breast and formula	15 (32)	15 (5)	13 (3)	
Birth order	1st	48 (103)	58 (19)	62 (24)	
	2nd	32 (68)	36 (28)	22 (5)	χ^2 = 5.0
	⩾3	20 (42)	6 (15)	17 (4)	
Maternal education completed	High school or less	24 (51)	24 (8)	17 (4)	
	Technical qualification	26 (56)	24 (8)	39 (9)	χ^2 = 2.0
	University	50 (106)	52 (17)	44 (10)	
Paternal education completed	High school or less	24 (51)	30 (10)	39 (9)	
	Technical qualification	37 (77)	33 (11)	22 (5)	χ^2 = .3.4
	University	39 (82)	36 (12)	39 (9)	
Relationship status	Never married	2 (5)	0 (0)	0 (0)	
	Married	76 (260)	68 (21)	78 (18)	χ^2 = 2.9
	Living with partner	22 (46)	32 (10)	22 (5)	
Smoking in home	Yes	15 (32)	18(6)	13 (3)	χ^2 = .57
	No	85 (181)	82 (27)	87 (20)	
Sleep position	Supine	91 (193)	88 (29)	91 (21)	
	Side	9 (18)	12 (4)	9 (2)	χ^2 = .99
	Prone	1 (2)	0 (0)	0 (0)	
Sleep location	Parent bed/parent room	59 (125)	73 (24)	70 (16)	χ^2 = 3.1
	Own room/another room	41 (88)	27 (9)	30 (7)	
Restless sleep	Not at all	47 (98)	42 (13)	22 (5)	
	1–2 nights	38 (80)	36 (11)	30 (7)	χ^2 = 15.19**
	⩾3 nights	15 (32)	23 (7)	48 (11)	
Maternal concern about breathing	Not at all	71 (152)	61 (20)	43 (10)	
	Yes	29 (61)	39 (13)	57 (13)	χ^2 = 8.23**
Watched child breathing during sleep	Not at all	86 (182)	76 (25)	83 (19)	
	1–2 nights	11 (24)	12 (4)	17 (4)	χ^2 = 8.54
	⩾3 nights	3 (6)	12 (4)	0 (0)	
Colds[a]	Not at all	75 (274)	16 (57)	9 (34)	
	1–2 nights	52 (22)	26 (11)	21 (9)	χ^2 = 26.0**
	⩾3 nights	36 (9)	44 (11)	20 (5)	
Runny nose[a]	Not at all	77 (216)	13 (37)	9 (26)	
	1–2 nights	66 (68)	23 (24)	11 (11)	χ^2 = 34.7**
	⩾3 nights	41 (23)	34 (19)	25 (14)	

NB: *Denotes $p < .05$, **$p < .01$; ***$p < .005$ and ****$p < .001$.
[a] Entire sample ($N = 457$).

Table 2
Proportion (*n*) of children reported to have colds and snore for each of the seasons.

Snoring	Colds (% (*n*))					
	Yes			No		
	Winter/Autumn	Summer/Spring	Combined	Winter/Autumn	Summer/Spring	Combined
Yes	6 (26)	2 (10)	8 (36)	11 (49)	10 (42)	21 (91)
No	4 (17)	3 (14)	7 (31)	29 (125)	34 (149)	63 (274)

were concerned about their child's breathing during sleep (Table 1). Based on these significant mean group differences, a logistic regression was performed with the dichotomised outcome variable: non-snoring versus habitual snoring. Demographic factors such as maternal age that were not significantly related with snoring frequency were not entered into the regression model. In the fully adjusted model, exclusive formula feeding since birth (OR: 28.87; $p < .01$), restless sleep for three or more nights (OR: 17.76;

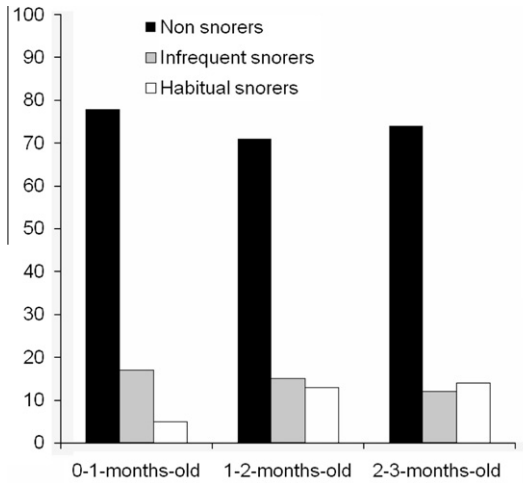

Fig. 1. Proportion of infants snoring for each age group and study group (non-snorers); Infrequent snorers (1–2 nights a week); Habitual snorers (⩾3 nights a week)).

$p < .001$) and increased maternal concern about the child's breathing during sleep at night (OR: 3.91; $p = .01$) were significantly associated with habitual snoring (Table 4).

5. Discussion

The main finding of this study is that the prevalence of snoring is significant in young infants. In a predominantly Caucasian sample aged 0–3 months old, habitual snoring in the absence of a parental-reported cold or nasal discharge was reported in 9% of infants. In addition, snoring prevalence increased with advancing age in the first three months of life and was associated with being formula fed, maternal concern regarding the infants breathing pattern and infant restlessness. As mild upper airway obstruction in older children was associated with neurocognitive deficits, the present findings suggest that a subset of otherwise healthy infants may also be at risk for developing daytime deficits, especially as brain growth and development is maximal at this age [18].

The snoring rate in the present study is consistent with the majority of studies, which have generally reported a low frequency of habitual snoring in infants, e.g., 4.5% of 0 to 4 months old [13], 5% of 2–4 months old [11], 5.1% of 6–12 months old [10] to 6.6% of 12 months old [8]. The exception is Mitchell and Thompson [12] who reported in New Zealand infants that 16% of 1 month old infants and 26% of 1–6 month olds snored in the past 2 weeks. However, that study did not adjust for seasonal colds and instead asked a global question about snoring frequency, which could explain the high estimate.

In the present study several methodological limitations were addressed that may have confounded previous estimates of snoring frequency, including small sample size [10,13], a failure to separately examine the interaction with ethnicity which is reported to be associated with SDB (Mitchell, personal communication 2009, 13), whether infants had a cold and season of testing. In this large sample of almost exclusively Caucasian children, as anticipated, a significantly higher proportion of children had colds in Winter/Autumn compared to Spring/Summer and a higher percentage of children who had colds also were reported to snore.

The second main finding of the present study was that a significantly larger proportion of older infants (i.e., 2–3 months old) were reported to snore habitually compared to younger aged infants. This may be a parenting-related factor, with parents needing time to familiarise themselves with their child's breathing (e.g., is it noisy, habitual and of concern). The capacity of parents to recognise and quantify snoring in children and how this might alter with child development is unknown. It will be important to validate

Table 3
Means and standard deviations (SD) for sleep variables according to snoring frequency, together with *F*-test results.

	Non-snorers		Infrequent snorers (1–2 nights/week)		Habitual snorers (⩾3 nights/week)		*F*-value (effect size (η_p^2))	
	Mean	SD	Mean	SD	Mean	SD		
Total sleep (h)	15.23	(2.97)	14.18	(3.47)	14.68	(3.41)	.17	(.01)
Night sleep (h)	8.43	(1.51)	7.94	(2.04)	8.43	(1.64)	.26	(.00)
Daytime sleep (h)	6.81	(2.12)	6.05	(2.19)	6.28	(2.59)	2.06	(.02)
No. of waking at night	2.31	(1.02)	2.56	(1.16)	2.22	(1.13)	.95	(.01)
Time to settle (min)	43.73	(37.32)	57.91	(44.12)	45.87	(42.50)	1.91	(.02)

NB: *Denotes $p < .05$, **$p < .01$; ***$p < .005$ and ****$p < .001$.

Table 4
The standardised beta coefficients for each variable predicting snoring frequency.

Variable	*n*	Unadjusted OR (95% CI)		Adjusted[a] OR (95% CI)	
Method of feeding					
Breastfeeding[b,c]	207	1 (–)		1 (–)	
Formula feeding	18	6.24**	(1.88, 20.73)	28.87**	(5.99, 139.19)
Maternal concern					
No[≠]	162	1 (–)		1 (–)	
Yes	75	3.50*	(1.47, 8.28)	3.91*	(.72, 14.07)
Restless sleep					
Not at all[≠]	103	1 (–)		1 (–)	
1–2 nights/week	87	1.72	(.52, 5.61)	3.19	(.72, 14.07)
⩾3 nights/week	44	7.35**	(2.41, 22.46)	17.76**	(3.68, 85.83)

[a] Odds Ratios (OR) adjusted for all other variables.
[b] Referent category.
[c] Denotes Coded as 1 = child ever formula fed since birth; 0 = never formula fed since birth.
* $p < .05$.
** $p < .01$.

parental-reported snoring in infants in future studies with objective data such as polysomnography [19].

The third main finding of the present study was that snoring frequency in young infants was associated with formula feeding, maternal concern about the child's breathing during sleep and restless sleep in the infant. The associations between habitual snoring and restless sleep [13], maternal anxiety about snoring in older children [22] and formula feeding [20,21] were expected. However, this study is the first to conduct a comprehensive analysis of the environmental and social variables associated with snoring frequency in this youngest age group, and the factors found to be important in increasing snoring prevalence are very similar to those found among older infants and children. It is of note that the reported associations were with *habitual* snoring and were not evident for infrequent snoring when compared to non-snoring infants.

In agreement with the study of Montgomery-Downs and Gozal [13], parental concern about the child's breathing during sleep was significantly associated with snoring frequency, with 65% of parents of habitual snorers, compared with 30% of non-snorers, reporting concern about their child's breathing during sleep. In addition, 31% of parents of habitual snorers reported watching their child sleep and worried that they might stop breathing. In studies with older children with SDB, it is common for parents to report concern that their child will stop breathing during sleep [22]. This may significant impact parental sleep and subsequent daytime functioning as they may feel the need to stay awake at night watching their child breathe [23]. It is also possible that at this young age the increased concern about the child's breathing during sleep is a result of the public health campaign that has raised parental concern about the risk of Sudden Infant Death Syndrome (SIDS) in young infants [38]. It was concerning though that, considering the prevalence of habitual snoring, 43% of parents of habitual snorers were not concerned about their child's breathing during sleep. This is consistent with other studies that have found that, although sleep problems are frequently reported by parents, they seldom discuss these concerns with their general practitioner [24].

A number of studies have demonstrated that factors that result in airway irritation may result in increased noisy breathing. For example, it has been suggested that parental smoking can induce swelling and narrowing of the upper airway passages in infants and result in increased noisy breathing [12]. In contrast to previous studies [8,12–14], snoring in this study was not associated with cigarette smoke within the household or maternal cigarette smoking during pregnancy. It may be that exposure to cigarette smoke has more of an impact on snoring when the child is exposed to it for a longer period of time. The same argument could be made for upper respiratory tract infections. In the current study parents were asked to report the number of cigarettes smoked "within the home" even if smoking occurred outside the house, for example, on a porch or patio. In future studies it might be important to specify whether smoking occurs within the home or outside the home. It is possible to speculate that if smoking occurs "outside" the home, children may not be directly exposed to the cigarette smoke. Thus, it is possible that these parents were more conscientious about not smoking around their infants or small children, which could explain the lack of relationship.

In the current study, a larger proportion of habitual snorers were formula fed. It has been suggested that breast feeding can provide immunologic protection against early exposures to infections that may cause swelling of the upper airways [20,21]. Montgomery-Downs et al. [21] found that children aged 6 years old had reduced SDB severity if they had been breastfed for at least two months. It has also been suggested that children with high palates and narrow arches may be more likely to develop SDB [25]. The mechanical aspects of bottle feeding have been proposed as an additional risk factor in developing SDB because they can alter the swallowing pattern of the infant which can lead to the development of facial and palatal structures that are more susceptible to narrowing and collapse during sleep [25]. The mechanisms by which the method of feeding the infant could reduce the development of SDB need to be explored further [21] but it is interesting that even after a relatively short time, there is a clear distinction between those who were formula versus breast fed.

Previous studies have shown that children from lower socioeconomic areas are more likely to be exposed to air pollution and to have a parent who smokes within the house [8], factors that are likely to contribute to snoring. However, in the current study, socioeconomic status, relationship status, maternal and paternal education, and maternal age were not related with snoring frequency. In the current sample more than half of both parents had completed some form of higher education. Thus, this sample was a better educated group compared with the general population, and this may explain why socioeconomic status was not associated with snoring. It has also previously been shown that prone sleep position is an important determinant of snoring in infants [12]. However, only four infants in the current study were reported to sleep in the prone position and therefore this analysis was obviously underpowered to test this question. It was also surprising that increased sleeping proximity to the infant (i.e. co-sleeping) was not associated with higher reported snoring frequency. It does seem likely that parents with children that sleep in their own room or in their own bed would be more aware of their child's breathing and snoring noises at night.

In the present study there were no significant gender differences in snoring. Most studies report a higher frequency of snoring in males [12,14,26–29], some no difference [13,27,30] and one a higher frequency in females [31].

In the current study the three snoring groups had similar total sleep duration, night sleep duration, daytime sleep duration and night waking. Similar to the current findings for sleep duration, studies with older children have found no significant differences between snorers and non-snorers for sleep duration [7,32]. In contrast to the present findings for night wakings, Weissbluth et al. [33] report that 4–8 month old infants who snored were more likely to wake frequently. Although they did not report more awakenings, a higher proportion of habitual snorers in the present study had restless sleep similar to studies in older children that have reported more restless sleep in habitual snorers [32,34,35]. It has been suggested that frequent arousals and restless sleep can lead to sleep fragmentation which may contribute to the neurocognitive deficits often reported in snorers [36].

A limitation of the present study is the reliance on parental report, which was deemed reasonable because the sleep characteristics for a large community sample of infants were of primary interest. The gold standard to assess snoring is polysomnography (PSG), but it is fiscally prohibitive in large samples. Previous studies have shown, however, that parental reports of snoring frequency are reliable when compared with PSG in children as young as 2 years old [16]. In addition, Greenfeld et al. [37] have validated snoring frequency as the main symptom for SDB in infants. It would be instructive to collect PSG data in future studies and thereby better understand the reliability of parental estimates of snoring in young infants and how that understanding is moderated by child age. The current study utilised standard questionnaires to assess snoring and colds in infants. It is possible that the duration of symptoms is equally important and this needs to be addressed in future studies. Due to distribution methods and restrictions on following respondents the response rate is unknown. Nevertheless, a strength of the present study is the inclusion of multiple measures of predictors of snoring in a predominantly homogenous community sample.

In summary, this study demonstrated that the prevalence of snoring, in the absence of parent reported colds and runny nose, in 0–3 month old infants is 8.3%. Restless sleep, maternal concern about the child's breathing during sleep, formula feeding and parental reported colds and runny nose were significantly predictive of increased snoring frequency. Future research is needed to clarify the natural history of snoring using longer longitudinal studies. The unanswered question is whether the neurocognitive sequelae seen in older children with snoring, even of mild degree, also occurs in infants who are potentially at a more critical period of brain development.

Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: doi:10.1016/j.sleep.2011.01.019.

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