Sleep problems, behavioral problems, and neurocognitive functioning in snoring school-aged children

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Kati Hagström
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UNIVERSITY OF TAMPERE
School of Social Sciences and Humanities
Psychology

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Abstract

Purpose The aim of this study was to assess the sleep problems, behavioral problems, and neurocognitive functioning in snoring school-aged children (6-10 years old).

Methods Twenty-seven snoring children and 35 nonsnoring children attended the study. The parents completed the Sleep Disturbance Scale for Children (SDSC), an instrument assessing the frequency of sleep problems and snoring. Behavioral problems were assessed by parents with the Child Behavior Checklist (CBCL) and the Conners' Parent Rating Scale-Revised (CPRS-R) and by teachers with the Teacher Report Form (TRF) and the Conners' Teacher Rating Scale-Revised (CTRS-R). The neurocognitive functioning of the two groups was compared with the Wechsler Intelligence Scale for Children (WISC-III) and the Developmental Neuropsychological Assessment (NEPSY).

Results The snoring children had more sleep breathing disorders ($p < .001$), they had more problems in sleep-wake transition ($p < .01$), they were sleepier ($p < .05$), and they had more nighttime sweating ($p < .05$) than the nonsnoring peers. On the CBCL, the snoring children had more internalizing problems ($p < .05$) and total problems ($p < .01$) than the nonsnoring children, especially symptoms of anxious/depressed ($p < .01$), withdrawn/depressed ($p < .01$), and thought problems ($p < .01$). On the CPRS-R, the snoring children had more social problems ($p < .01$), they were more anxious and shy ($p < .01$), and they had more psychosomatic symptoms ($p < .05$) than the nonsnoring peers. Several associations between sleep quality parameters and behavior were found. Contrary to parents, teachers did not report any behavioral problems in snoring children. No differences were found between the two groups in the neurocognitive assessments.

Conclusions Snoring school-aged children are at risk for internalizing problems, thought problems, and social problems. Children with habitual snoring, sleep-related symptoms, and daytime problems should be referred to diagnostic assessment and possible treatment.

Keywords: snoring, sleep-disordered breathing, school-aged children, behavioral problems, neurocognitive functioning

INTRODUCTION

Sleep is a behavior characterized by recumbent posture, closure of the eyelids, a diminished responsiveness to sensory stimulation, and a low level of motor output. Sleep is regulated by the brain, occurs in the brain, and brain benefits most from it (Danker-Hopfe, 2011; Sheldon, 2005a). Sleep consists of two states; rapid eye movement (REM) and non-rapid eye movement (NREM) sleep (Carskadon & Dement, 2011). These two states are divided into five stages. A normal sleep cycle begins in NREM stage 1 and gradually deepens through stage 2, which indicates light sleep, to stages 3 and 4, which consist of deep sleep. During REM sleep (stage 5), brain activity is high and most dreaming occurs (Carskadon & Dement, 2011). Total sleep cycle lasts approximately 90 to 110 minutes and continues through the night in cyclic fashion (Carskadon & Dement, 2011). All stages of sleep are perceived during middle childhood (Sheldon, 2005b).

Although sleep has been studied for more than 100 years, its exact function remains elusive (Dahl, 1996). The function of sleep may be so complex that it proves to be a combination of several proposed hypotheses, including restoration of somatic function and the central nervous system, learning and unlearning, and memory (Sheldon, 2005a). Sleep is important to the well-being, growth, and development of children, and early disruption of sleep may have major cognitive and emotional consequences (Sheldon, 2005a). Although there are only some data addressing the specific effects of inadequate sleep and sleepiness on daytime function in children, the general pattern of results includes difficulties with focused attention, irritability, emotional lability, and low threshold for frustration and distress (Dahl, 1996).

Pediatric sleep disorders

Total sleep duration decreases from the newborn period to adolescence, from an average of 14 hours a day at six months of age to an average of eight hours at 16 years of age (Iglowstein, Jenni, Molinari, & Largo, 2003). During preadolescence, the need for sleep is about 9 to 10 hours (Saarenpää-Heikkilä, 2001). Longitudinal studies show that the prevalence of pediatric sleep disorders continues to rise and at the same time sleep duration declines (Dollman, Ridley, Olds, & Lowe, 2007; Iglowstein et al., 2003). One of the pediatric sleep disorders is sleep-disordered breathing (SDB), which impact on behavioral outcomes and neurocognitive functions has received growing attention in the last decade (Barnes et al., 2009; Owens, 2009). SDB is often viewed as a spectrum, with primary snoring (PS, i.e. snoring without apnea, hypoventilation or sleep fragmentation) being at the mild end, upper airway resistance syndrome (UARS, i.e. no gas exchange abnormalities, increased respiratory effort) in the middle, and obstructive sleep apnea syndrome (OSAS, i.e. various degrees of hypoxemia, hypercapnia, and sleep fragmentation) at the most severe end (Carroll & Loughlin, 1995a; McColley, 2005). Snoring is a primary and major

clinical symptom in all three categories. Snoring occurs in children of all ages, but snoring frequency is higher among preschool-aged children than among older children (Kaditis et al., 2004). In preschool-aged and prepubertal children, the prevalence of snoring seems to be similar between genders (Ali, Pitson, & Stradling, 1993; Ferreira et al., 2000), or slightly more common in boys (Kaditis et al., 2004). The prevalence of PS in children ranges from 3 to 12% while only 0.7-2.9% have OSAS (Ali et al., 1993; Brockmann, Urschitz, Schlaud, & Poets, 2012; Liukkonen, 2011). OSAS is most common in the preschool age group, due to adenotonsillar overgrowth, but is not caused by large tonsils and adenoids alone, since structural and neuromuscular factors also contribute to its existence (Marcus, 2001). UARS has not been described or defined by most pediatric snoring studies and its prevalence is largely unknown (McColley, 2005). SDB is diagnosed on the basis of parental reports, a subjective clinical history, or objective data from polysomnography (PSG) (Mitchell & Kelly, 2006). There are no universally accepted polysomnographic parameters for the diagnosis of pediatric SDB because of the continuum from normality to disease (Ali et al., 1993; Owens, 2009; Zhao, Sherrill, Goodwin, & Quan, 2008). Treatment for childhood SDB consists of surgical removal of adenoids and tonsils, while continuous positive airway pressure (CPAP) can be used for cases in which surgery is either contraindicated or unsuccessful (Beebe & Gozal, 2002). Primary snoring without interruption of normal sleep patterns and adverse consequences is common and does not usually require any treatment (McColley, 2005).

Associations between pediatric snoring and sleep problems have been studied to some extent. Eitner et al. (2007) found that snoring children have an increased prevalence of sleep problems, including sleep-onset delay, night awakenings, and nightmares. Blunden, Lushington, Kennedy, Martin, & Dawson (2000) found similar results, as well as poor sleep quality. Ferreira et al. (2000) reported increased bedtime struggles and fears, increased need for comforting activities to fall asleep, sleep talking, bruxism, night terrors, and increased daytime sleepiness associated with snoring.

SDB and behavioral problems

Associations between sleep-disordered breathing and behavior have been studied and there is evidence that childhood SDB is associated with parent-reported behavior problems. The strongest associations have been reported for externalizing behaviors, including hyperactivity, impulsivity, emotional lability, delinquency, conduct problems, aggressive behavior, and oppositional behavior (Arman et al., 2005; Barnes et al., 2009; Brockmann et al., 2012; Giordani et al., 2008; Gottlieb et al., 2003; Rosen et al., 2004; Urschitz et al., 2004; Zhao et al., 2008). Fewer studies have found that children with SDB have internalizing problems, showing more anxious/depressed mood, somatic complaints, withdrawal, thought problems, and social problems (Aronen et al., 2009; Bourke et al.,

2011; Kohyama, Furushima, & Hasegawa, 2003; O'Brien et al., 2004; Rosen et al., 2004; Zhao et al., 2008). A few studies have used teacher reports (Ali et al., 1993; Arman et al., 2005), showing that teachers report substantially fewer problems than parents. In a study by Ali et al. (1993) teachers estimated that the children in high risk group of sleep and breathing disorders were more hyperactive and inattentive than the controls. On the other hand, Arman et al. (2005) found no significant differences in behavioral scales at school setting between the two groups. In a study by McLaughlin Crabtree, Varni, & Gozal (2004), children's self-evaluations revealed that children with PS have more impairment in quality of life and more depressive symptoms than children who do not snore.

SDB and neurocognitive functions

Previous studies have reported on the significant associations between childhood SDB and a diffuse pattern of impairments in neurocognitive functions. Most studies report significant differences between snoring and nonsnoring children in intelligence, attention, and executive functions (Aronen et al., 2009; Blunden et al., 2000; Gottlieb et al., 2004; Kennedy et al., 2004; Kohler et al., 2009; Kohler, Lushington, & Kennedy, 2010; O'Brien et al., 2004). Less commonly reported deficits are in memory, visual-spatial ability, language skills, and sensomotor functions (Giordani et al., 2008; O'Brien et al., 2004). Despite these differences, it is notable that the mean intelligence quotient (IQ) and subtest scores for SDB children have usually been within the standardized normal range (for review, see Kohler et al., 2010). Poor academic performance has been found in snoring children (Brockmann et al., 2012), as well as higher risk for academic underachievement even after snoring has resolved (Gozal & Pope, 2001). However, not all studies support this association between SDB and cognition. Calhoun et al. (2009), for example, found in a large population-based study that children with mild SDB have no significant neurocognitive impairment compared with children without SDB. Studies investigating the association between snoring and both behavioral and neurocognitive implications are sparse (Aronen et al., 2009; Blunden et al., 2000; Giordani et al., 2008; Gottlieb et al., 2004; O'Brien et al., 2004).

Underlying mechanisms and SDB severity

The precise underlying mechanisms that explain how SDB is linked to behavioral and neurocognitive deficits remain unknown. Two primary mechanisms considered linking SDB to negative influences are 1) intermittent hypoxemia and 2) repeated episodic arousals from sleep leading to sleep fragmentation and resulting in daytime sleepiness (Beebe & Gozal, 2002; El-Ad & Lavie, 2005; Owens, 2009). Hypoxemia is usually defined as an arterial oxyhemoglobin saturation of less than 90 or 92%, and it is common in pediatric OSAS (Carroll & Loughlin, 1995a). Sleep

fragmentation is the interruption of any stage of sleep due to the appearance of another stage or to wakefulness, leading to disrupted NREM and REM sleep cycles (Carroll & Loughlin, 1995b). Intermittent hypoxemia, with or without sleep fragmentation, may cause adverse effects especially at a critical age for brain development (O'Brien & Gozal, 2002; O'Brien et al., 2004). Beebe & Gozal (2002) suggest that intermittent hypoxemia and sleep disruption prevent restorative features of sleep and cause disruption of cellular or chemical homeostasis, producing central nervous system cellular injury. These lead to dysfunction of prefrontal regions of the brain cortex inducing executive dysfunction. Executive dysfunction is proposed to affect cognitive abilities and result in maladaptive daytime behaviors. Hypoxemia though may not be an explanation applicable to children with PS (Brockmann et al., 2012) or to behavioral problems (Urschitz et al., 2004). Snoring has been associated with parent-reported daytime sleepiness in several studies (Ali et al., 1993; Gottlieb et al., 2003) and in adults with SDB, mood problems seem to be more reflected on the degree of daytime sleepiness than on the degree of nocturnal hypoxemia (for review see El-Ad & Lavie, 2005). The pathway from sleep patterns to sleep problems, to daytime sleepiness, and to deficits in performance and behavior may be complex and multifactorial (Goodlin-Jones, Tang, Liu, & Anders, 2009).

Only some studies have examined the associations between SDB severity and neurobehavioral implications. Majority of these have found no significant dose-response association. McLaughlin Crabtree et al. (2004) found no differences in quality of life or depressive symptoms among children with PS, mild SDB, or moderate to severe SDB. Increased problem behaviors and executive dysfunction as well as hyperactivity have been found in children with all severities of SDB spectrum (Bourke et al., 2011; Melendres, Lutz, Rubin, & Marcus, 2004). Rosen et al. (2004) found that the odds for borderline or clinically abnormal externalizing behavior were comparable in children with OSA and primary snoring. In behavior, SDB severity has been associated with increased aggression or oppositional behavior, depression, hyperactivity, and social problems (Beebe et al., 2004; Zhao et al., 2008). Kohler et al. (2010) critically reviewed the current literature and found only scarce evidence of an association between SDB severity and neurocognitive functions. The only finding with any consistency was between increased SDB severity and reduced executive function (Archbold, Giordani, Ruzicka, & Chervin, 2004; Beebe et al., 2004; O'Brien et al., 2004).

It might be that the deficits result from other definitions of exposure, including duration of SDB and severity during a sensitive developmental period, rather than the current SDB status (Beebe, 2006). Because of the relative difficulty of testing neurocognitive functioning in young children, SDB studies are usually restricted to children over 5 years (Kohler et al., 2010). However, the incidence

of snoring and other SDB symptoms peaks in preschool-aged children (Marcus, 2001). Therefore, for example, school-aged children may have had symptoms long before testing. It is possible that neurocognitive deficits secondary to SDB develop in early life explaining the lack of correlation between SDB severity and neurocognitive measures found later in life. Cumulative effects or earlier point of insult may result in greater severity and a range of deficits, especially during a period of rapid neural development (Kohler et al., 2010).

Taken together, the available, but limited literature suggests associations between SDB and increased behavioral problems (both internalizing and externalizing) and a diffuse pattern of reduced, yet within the normal range, neurocognitive functions. All studies have though not confirmed these associations. The inconsistencies in results are probably due to many factors that limit the interpretation and generalizability of these studies, for example, small sample sizes, lack of control groups, and inconsistent measurement tools (Calhoun et al., 2009).

Only some studies have concentrated on the mild end of the sleep-disordered breathing (PS) and studied its associations with behavioral problems and neurocognitive outcomes. Even fewer studies (Ali et al., 1993; Arman et al., 2005; O'Brien et al., 2011) have used both parent and teacher validated behavioral instruments, thus little is known about the behavior of snoring children in school environment. As mentioned earlier, only a few studies have extensively investigated snoring and neurobehavioral outcomes and none of these has concentrated entirely on school-aged children. Most studies have used broad age ranges and investigated also preschool-aged or younger children. Hence, to our knowledge, studies on snoring school-aged children and their neurocognitive functioning and parent- and teacher-reported behavior do not exist.

Aim of this study

The focus of this study was in school-aged children and the aim of the study was fourfold. First aim was to assess snoring and other sleep-related symptoms. Second aim was to assess the behavioral problems in snoring children. Third aim was to assess snorers' neurocognitive functioning. Fourth aim was to investigate associations between sleep-related problems and behavioral and neurocognitive implications. The main research questions were 1) Do snoring children have more sleep-related problems than nonsnoring peers? 2) Do snoring children differ from nonsnoring children in problem behavior? 3) Do snoring children differ from nonsnoring children with respect to neurocognitive functions? and 4) Are sleep-related problems associated with behavioral and neurocognitive outcomes?

Based on previous studies it was hypothesized that snoring school-aged children have many types of sleep problems (Eitner et al., 2007; Ferreira et al., 2000). School-aged snoring children were

expected to have elevated scores on problem behavior (Arman et al., 2005; Bourke et al., 2011; Brockmann et al., 2012; Rosen et al., 2004; Urschitz et al., 2004; Zhao et al., 2008). In addition, it was hypothesized that snoring school-aged children perform worse than nonsnoring peers in neurocognitive functioning, showing a diffuse pattern with various mild impairments in attention, executive function, verbal and global intelligence, and memory (Archbold et al., 2004; Kennedy et al., 2004). Finally, higher sleep-related problems were expected to be associated with elevated behavioral problems and reduced neurocognitive functioning (Blunden et al., 2000).

METHODS

Participants

This study is a part of a larger study evaluating sleep and sleep-related disorders in school-aged children. The larger study consisted of a sample of 1538 6- to 10-year-old children in Tampere, Finland. Seventeen primary schools of a total 32 located in the city of Tampere were selected. Three primary schools for deaf, motor skill disordered, specific language skill disordered, and mentally handicapped children were excluded. Parents of children enrolling in the first- or third-grade classes in selected schools received a detailed questionnaire about child's sleep, sleep-related breathing, and daytime functioning (SDSC, described later). The questionnaire was handed in physical examination by the school nurse or at class by the teacher. The sleep questionnaire included a question about snoring: "How often does your child snore?". The answering options were "never", "occasionally", "sometimes", "often", and "always". The child was classified as snorer, if the parent answered the child to snore "sometimes" (1 to 2 nights a week), "often" (3 to 5 nights a week) or "always" (every night). Nonsnoring children snored according to their parents "never" or "occasionally" (1 to 2 nights a month). The snoring and nonsnoring children were invited for overnight polysomnographic (PSG) assessment and neurocognitive tests. The study was approved by the Ethical Committee of Tampere University Hospital and the City of Tampere. Written informed consent was obtained from parents to participate in the study.

A total of 831 questionnaires were given to the first-graders and 190 were returned (23%). The third-graders received 707 questionnaires and 101 were returned (14%). Five children were excluded from the research data; four because of missing information about snoring prevalence rate, and one who was no longer in the first grade. Thus, the analyses included 186 first-graders and 100 third-graders (=286 children). The parents who had expressed willingness to participate in the clinical study were contacted by the clinical research assistant to make an appointment for the clinical tests. Finally, 62 children from the original target population of 1538 (4%) participated in the clinical part of this study and had PSG studies and psychological assessment at the Sleep Laboratory in Tampere University Hospital. The data was collected between September 2006 and August 2008. Data from the PSG studies will be reported elsewhere.

Snoring and other sleep-related symptoms

The parents completed the Finnish version of the Sleep Disturbance Scale for Children (SDSC), developed and validated by Bruni et al. (1996). SDSC is an instrument for assessing the frequency of sleep problems and snoring in school-aged children. It contains statements scored using a five point scale: 1=never, 2=occasionally (1 to 2 nights a month), 3=sometimes (1 to 2 nights a week),

4=often (3 to 5 nights a week), and 5=always (every night). SDSC consists of 26 items grouped into Total Disturbance scale (sum of all six factors) and six factors representing the most common types of sleep problems in children: 1) Disorders of Initiating and Maintaining Sleep (sleep duration, sleep latency, difficulties in falling asleep, going to bed reluctantly, falling asleep anxiety, night awakenings, difficulties in falling asleep after wakenings); 2) Sleep Breathing Disorders (frequency of snoring, sleep apnea, breathing problems); 3) Disorders of Arousal (sleepwalking, nightmares, sleep terrors); 4) Disorders of Sleep-Wake Transition (hypnic jerks, rhythmic movement disorders, hypnagogic hallucinations, nocturnal hyperkinesia, sleep talking, bruxism); 5) Disorders of Excessive Somnolence (difficulty in waking up, tired when waking up, sleep paralysis, daytime sleepiness, sleep attacks during the day); and 6) Sleep Hyperhydrosis (night sweating, falling asleep sweating). SDSC has been used extensively around the world and it has been translated into numerous languages (e.g. Blunden et al., 2000; Eitner et al., 2007; Simola et al., 2010).

Measurements of behavioral problems

Problem behaviors were identified using well-validated and internationally widely used assessment tools. Behavioral problems were assessed using the Problem Scales of the Child Behavior Checklist (CBCL, parent version) (Achenbach & Rescorla, 2001) and equivalent Teacher Report Form (TRF, teacher version) (Achenbach & Rescorla, 2001). The questionnaires have 113 questions with response options: 0=not true, 1=somewhat or sometimes true, and 2=very true or often true. The questionnaires yield 8 scales: Anxious/Depressed, Withdrawn/Depressed, Somatic Complaints (these three constitute index for Internalizing Problems), Social Problems, Thought Problems, Attention Problems, Rule-Breaking Behavior, Aggressive Behavior (last two constitute index for Externalizing Problems), and Total Problems. For description of the data, the raw scores of the CBCL and TRF are individually converted into *T*-scores. Scales have a mean *T*-score of 50 and a standard deviation of 10. The borderline is T = 65-69, and the clinical range is $T > 69$. The borderline range for Internalizing, Externalizing and Total Problems is T = 60-63 and clinical range $T > 63$. In this study the reliability (Cronbach alpha) for the CBCL was .945 and for the TRF .952.

The Conners' Parent Rating Scale-Revised (CPRS-R) (Conners, 1997) and the Conners' Teacher Rating Scale-Revised (CTRS-R) (Conners, 1997) were used to identify behavioral problems as well. The CPRS-R has 80 questions with response options: 0=not true at all, 1=just a little true, 2=pretty much true, 3=very much true, and yields 7 scales: Oppositional, Cognitive Problems/Inattention, Hyperactivity, Anxious-Shy, Perfectionism, Social Problems, and Psychosomatic and the indices Attention Deficit Hyperactivity Disorder (ADHD), Restless-Impulsive, Emotional Lability, Total Index, DSM-IV Inattentive, DSM-IV Hyperactive-Impulsive, and DSM-IV Total. The CTRS-R has 59 questions with the same response options and yields same

scales excluding Psychosomatic and has all the same indices. For description of the data, the raw scores of the CPRS-R and CTRS-R are individually converted into *T*-scores. The CPRS-R and CTRS-R scales and indices have a mean *T*-score of 50 and a standard deviation of 10. The borderline *T* = 56-60, and *T*-scores of 65 and above indicate a clinically significant problem. In this study the reliability (Cronbach alpha) for the CPRS-R was .964 and for the CTRS-R .959.

Parents completed their questionnaires at the Sleep Laboratory and teachers at school. The data for the CBCL and the CPRS-R scores was available for 27 snoring and 34 nonsnoring children. The data for the TRF was obtained for 23 snoring and 32 nonsnoring children and the data for the CTRS-R for 23 snoring and 30 nonsnoring children. On average, teachers reported to have taught the child for nine months, but the range was quite broad; from one month to 36 months. Most teachers reported that they knew the child pretty well, while eight teachers reported that they didn't. Achenbach & Rescorla (2001) suggest that the TRF can be used when a teacher has known a child for at least two months.

Neurocognitive assessments

Neurocognitive functions were assessed with standardized tests. The tests were chosen to measure both intellectual functioning and specific neurocognitive functions in five domains (attention and executive functioning, language, sensomotor, visuospatial, and memory and learning). Children's intellectual functioning was evaluated using the Finnish version of the Wechsler Intelligence Scale for Children (WISC-III) (Wechsler, 1999). Scores for Verbal Intelligence Quotient, Performance Intelligence Quotient, and Full Scale Intelligence Quotient were estimated by the following six subtests: Information, Similarities, Arithmetic, Picture Completion, Block Design and Object Assembly.

To evaluate specific neurocognitive functions the Developmental Neuropsychological Assessment (NEPSY, Finnish version) was used (Korkman, Kirk, & Kemp, 2000). The NEPSY subtests were chosen according to Korkman (2000) to obtain a comprehensive assessment of each domain for this age group. The five age-appropriate domains and their subtests were: Attention and Executive Function (Tower, Auditory Attention and Response Set, Visual Attention), Language Function (Phonological Processing, Comprehension of Instructions, Speeded Naming), Sensomotor Function (Fingertip Tapping, Imitating Hand Positions, Visuomotor Precision), Visuospatial Function (Design Copying, Arrows), and Memory and Learning Function (Memory for Faces, Memory for Names and Narrative Memory). For description of the data, the raw scores of the WISC-III and the NEPSY were individually converted into standard scores.

All children underwent a three hour neurocognitive evaluation (with one break) at the Sleep

Laboratory in Tampere University Hospital. A trained psychologist or a trained psychology student administered the standardized tests individually to each child. The examiner was unaware whether the child was a snorer or a nonsnoring one. A comprehensive assessment battery including both behavioral ratings and neurocognitive assessments was justified given the descriptive nature of the study and lack of previous studies in this area.

Statistical analysis

Analyses were done using the Statistical Package for the Social Sciences (SPSS) software (Version 18.0 for Mac OS X). Due to limited number of participants and skewed distributions, the nonparametric Mann-Whitney *U*-test and Kruskall-Wallis test were used to test for group differences in sleep-related symptoms, behavioral, and neurocognitive parameters. Chi square analyses were used to test for group differences in socio-economic variables. Correlation coefficients (Spearman's rho) were used to test the relationship between behavioral and neurocognitive parameters and SDSC factors. *P*-values less than 0.05 were considered statistically significant.

RESULTS

Demographics and background data

The demographics and background data of the participants are presented in Table 1. The data consisted of 27 snoring children (11 girls and 16 boys) and their 35 nonsnoring peers (17 girls and 18 boys). There were no significant differences for age, gender, asthma, tonsillectomy or adenoidectomy. The groups did not differ with respect to support received at school. No significant differences were found in parental educational status or parental smoking. The snoring children had significantly higher body mass index (BMI) than the nonsnoring peers ($U = 312.00$, $p = .023$).

Table 1 Demographics and background data for snoring and nonsnoring children

	Snoring children (N = 27)	Nonsnoring children (N = 35)	*P*-value
Mean age (SD)	7.8 (1.1)	8.1 (1.1)	ns
Mean body mass index (SD)	18.6 (3.4)	16.7 (2.4)	.023*
	n (%)	n (%)	
Gender			ns
Girls	11 (40.7)	17 (48.6)	
Boys	16 (59.3)	18 (51.4)	
Part-time special education or remedial teaching	7 (25.9)	7 (20.0)	ns
Asthma	3 (11.1)	3 (8.6)	ns
Tonsillectomy	3 (11.1)	2 (5.7)	ns
Adenoidectomy	9 (33.3)	9 (25.7)	ns
Maternal education			ns
Basic	0 (0)	2 (5.7)	
Vocational training	12 (44.4)	15 (42.9)	
High school	3 (11.1)	4 (11.4)	
Polytechnic	3 (11.1)	2 (5.7)	
University	6 (22.2)	11 (31.4)	
Unknown	3 (11.1)	1 (2.9)	
Paternal education			ns
Basic	3 (11.1)	3 (8.6)	
Vocational training	9 (33.3)	10 (28.6)	
High school	2 (7.4)	3 (8.6)	
Polytechnic	2 (7.4)	4 (11.4)	
University	8 (29.6)	14 (40.0)	
Unknown	3 (11.1)	1 (2.9)	
Parental smoking			ns
Mother	6 (22.2)	7 (20.0)	
Father	4 (14.8)	7 (20.0)	
Unknown	6 (22.2)	6 (17.1)	

*$p < .05$.

Snoring and sleep-related symptoms

On average, both snoring and nonsnoring children slept 9.7 hours per night. Parent-reported snoring and other SDB symptoms were significantly different in snoring and nonsnoring groups. Five (18%) of the snoring children snored every night, 21 (78%) snored 3 to 5 nights a week, and one (4%) child snored 1 to 2 nights a week. In the nonsnoring group 18 (51%) children never snored and 17 (49%) snored occasionally (1 to 2 nights a month).

Table 2 shows the results of the Sleep Disturbance Scale for Children. Analyses revealed that

snoring children had significantly more sleep breathing disorders and problems in sleep-wake transition. They also had higher incidence of sweating at night and daytime sleepiness. Their total SDSC score was significantly higher than in the nonsnoring group. No significant differences were found between the two groups in initiating and maintaining sleep and in disorders of arousal.

Table 2 Factors of the Sleep Disturbance Scale for Children in snoring and nonsnoring children

Sleep Disturbance Scale for Children (SDSC)	Snoring children (N = 27) Mean ± SD (Range)	Nonsnoring children (N = 35) Mean ± SD (Range)	*P*-value Mann-Whitney *U*-test
Factors			
Initiating and Maintaining Sleep	12.5 ± 3.1 (8-21)	11.7 ± 3.1 (7-19)	.331
Sleep Breathing Disorders	8.1 ± 2.2 (5-13)	3.7 ± 0.9 (3-7)	.000***
Disorders of Arousal[a]	4.6 ± 1.8 (3-9)	3.7 ± 0.9 (3-7)	.070
Disorders of Sleep-Wake Transition	10.6 ± 3.6 (5-18)	8.0 ± 2.0 (3-13)	.003**
Disorders of Excessive Somnolence	9.3 ± 2.7 (5-17)	7.9 ± 2.0 (5-14)	.030*
Sleep Hyperhydrosis	4.0 ± 2.2 (1-10)	3.0 ± 1.5 (1-8)	.036*
Total Score	48.8 ± 9.6 (34-75)	38.0 ± 7.0 (26-60)	.000***

[a]Data for one snoring child was unavailable.
*$p < .05$. **$p < .01$. ***$p < .001$.

Behavioral problems

As a group, snoring children had significantly more problems than nonsnoring children on several CBCL and CPRS-R subscales. When measured with the CBCL, internalizing problems and total problems were significantly more prevalent in the snoring group (Figure 1). On the Internalizing scale, 12 children (44%) of the snoring group and only one child in the nonsnoring group scored on the clinical range. Snoring children also had statistically higher scores than nonsnoring children on the following CBCL subscales: Anxious/Depressed, Withdrawn/Depressed and Thought Problems. No significant difference was found between the groups in the amount of externalizing problems.

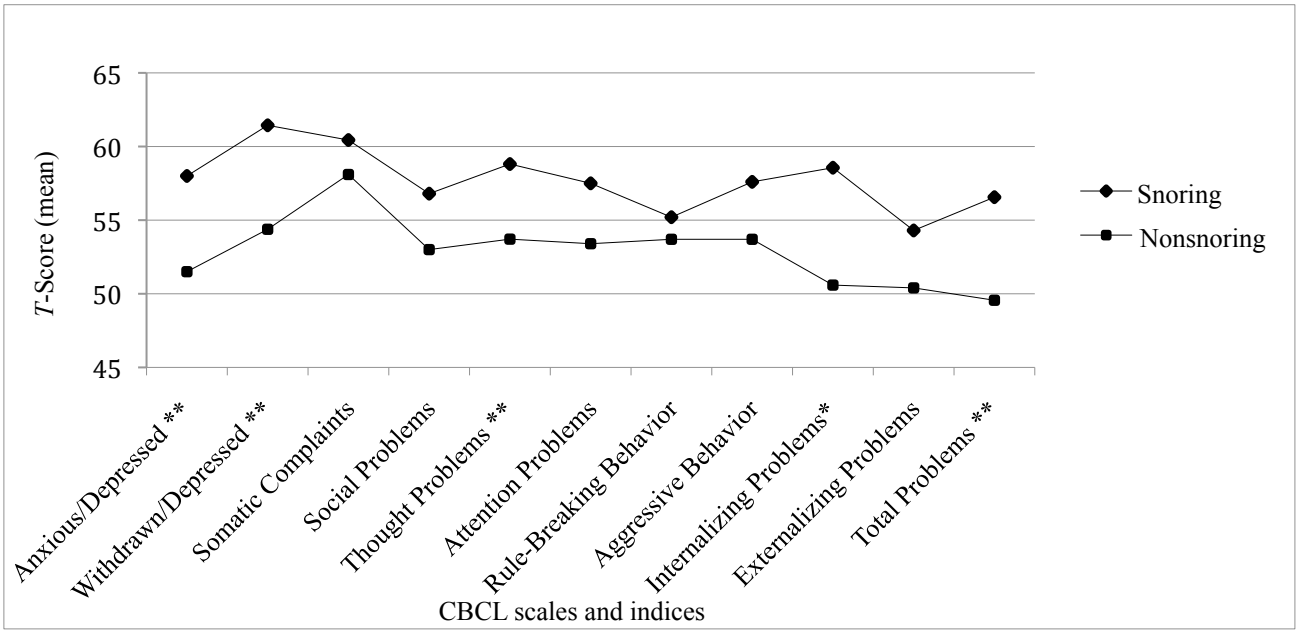

Figure 1. Scores on the Child Behavior Checklist for snoring and nonsnoring children.
*$p < .05$. **$p < .01$.

Based on the CPRS-R scores, snoring children were significantly more anxious and shy and had more social problems and psychosomatic symptoms than nonsnoring peers (Figure 2). Twelve snoring (44%) and 6 nonsnoring (18%) children scored on the borderline or clinical range on the Psychosomatic scale, 11 snoring (41%) and 3 nonsnoring (9%) children on the Social Problems scale and 9 snoring (33%) and 4 nonsnoring (12%) children on the Anxious-Shy scale.

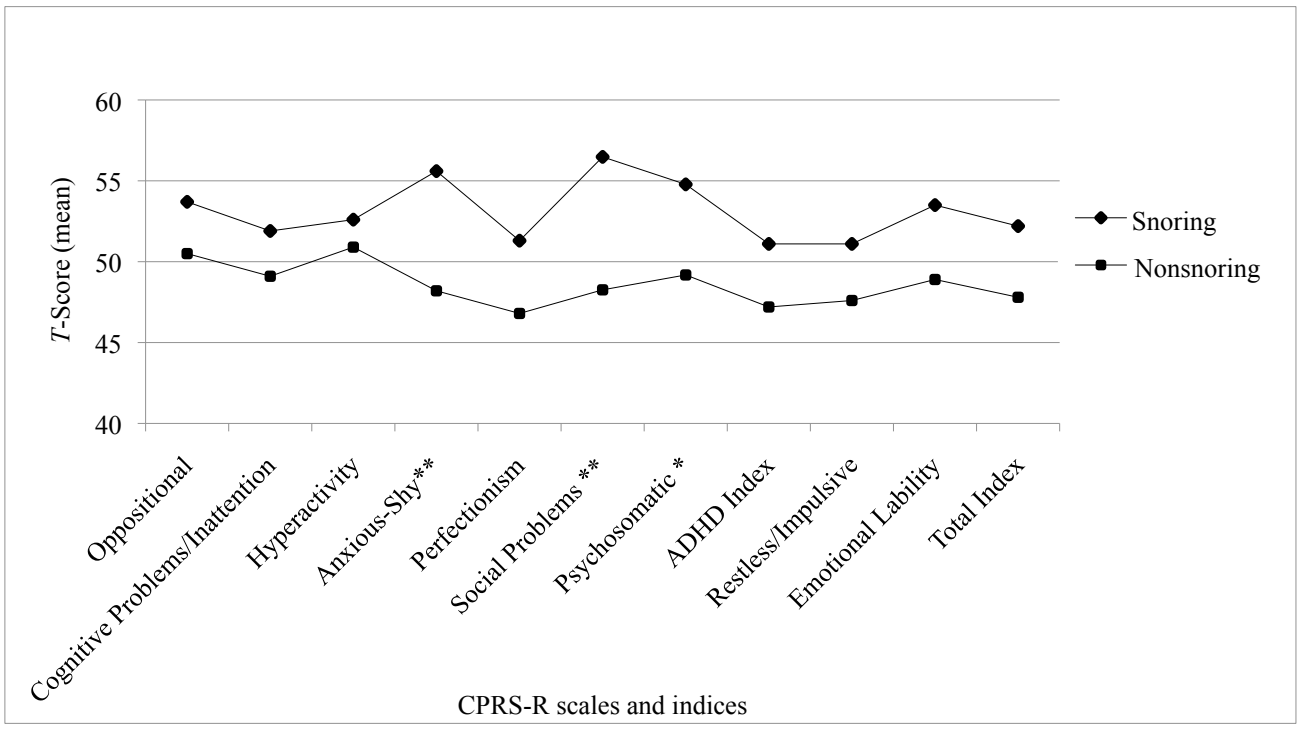

Figure 2. Scores on the Conners' Parent Rating Scale-Revised for snoring and nonsnoring children. **p* < .05. ***p* < .01.

The teachers did not report many significant behavioral problems in the TRF or the CTRS-R in snoring children (see Appendix 1). Besides this, the teachers rated snoring children with lower scores in all scales and indices than the parents did. This tendency was not as evident with nonsnoring children.

In the TRF scales, the scores ranged between 50-78 (mean was 51) in snoring children and between 50-74 (mean was 52) in nonsnoring children. On the TRF Internalizing scale, two children (9%) of the snoring group and two children (6%) in the nonsnoring group scored on the clinical range. In the CTRS-R scales, the scores ranged between 40-88 (mean was 48) in snoring children and between 40-90 (mean was 49) in nonsnoring peers. In the CTRS-R, the teachers estimated that nonsnoring children had more problems in borderline or clinical range than snoring children. Also in the CTRS-R, the teachers estimated nonsnoring children to be significantly more impulsive and hyperactive than snoring children ($U = 228.50$, $p = .033$). Although there was a lot of variability in how long the teacher had taught the child (from one month to 36 months), no statistically significant differences were found between snoring and nonsnoring groups in these times.

Neurocognitive functions

Table 3 summarizes the results of the intellectual functions. On average, intellectual functioning was within normal range for both groups. Although snoring children had lower scores on each WISC-III subtests and in Verbal, Performance and Full Scale IQ scores, these differences were not statistically significant.

Table 3 Intellectual functioning in snoring and nonsnoring children measured using the WISC-III

WISC-III	Snoring children (N = 27) Mean ± SD (Range)	Nonsnoring children (N = 35) Mean ± SD (Range)	*P*-value Mann-Whitney *U*-test
Subtests			
Picture Completion	10.7 ± 2.9 (6-18)	11.2 ± 3.3 (5-18)	.480
Information	10.0 ± 1.8 (7-14)	10.7 ± 2.6 (7-18)	.369
Similarities	10.8 ± 4.7 (1-18)	11.3 ± 3.2 (4-18)	.859
Arithmetic	10.0 ± 2.3 (7-16)	11.4 ± 3.2 (7-19)	.068
Block Design	9.6 ± 3.0 (4-15)	10.7 ± 2.8 (5-16)	.168
Object Assembly	9.4 ± 3.0 (1-15)	10.7 ± 3.3 (4-17)	.155
Intelligence			
Verbal	101.6 ± 16.0 (73-131)	107.3 ± 16.9 (73-156)	.221
Performance	99.4 ± 17.4 (64-136)	106.3 ± 18.6 (71-132)	.123
Full Scale	100.2 ± 14.8 (75-124)	105.9 ± 16.4 (76-141)	.164

Similarly, the performance for both groups in the NEPSY subtests was within normal range. There were no significant differences between the groups in any of the fourteen subtests or in the five neurocognitive domains (see Table 4).

Table 4 Mean standard scores of the NEPSY domains for snoring and nonsnoring children

NEPSY	Snoring children (N = 27) Mean ± SD (Range)	Nonsnoring children (N = 35) Mean ± SD (Range)	*P*-value Mann-Whitney *U*-test
Domains			
Attention and Executive Function	11.4 ± 2.0 (8-16)	11.4 ± 2.0 (7-15)	.870
Language Function	10.5 ± 2.0 (6-15)	10.5 ± 2.5 (6-14)	.943
Sensomotor Function	10.4 ± 1.9 (5-14)	10.4 ± 1.6 (7-13)	.609
Visuospatial Function	10.2 ± 2.4 (5-14)	10.8 ± 2.3 (5-15)	.354
Memory and Learning Function	9.9 ± 2.6 (3-14)	9.9 ± 2.1 (6-13)	.837

Sleep-related problems associated with behavioral and neurocognitive outcomes

Sleep-related problems were associated with behavioral and neurocognitive problems. Often (3 to 5 nights a week) or always (every night) snoring children had significantly elevated scores on the CBCL scales Anxious/Depressed (U = 143.00, p = .024), Withdrawn/Depressed (U = 135.50, p = .017), Somatic Complaints (U = 150.00, p = .042), Thought Problems (U = 133.50, p = .014), Internalizing Problems (U = 126.00, p = .010), and Total Problems (U = 141.50, p = .027), and in the CPRS-R scales Anxious-Shy (U = 141.00, p = .026), Social Problems (U = 125.00, p = .007), and Psychosomatic (U = 118.00, p = .005) compared with children who snored occasionally or sometimes. Children who snored occasionally (1 to 2 nights a month) or sometimes (1 to 2 nights a week) had significantly lower scores on memory and learning function compared with children who

never snored ($U = 79.50$, $p = .008$).

The correlations between the SDSC factors and behavioral and neurocognitive parameters for the combined participant sample are presented in Table 5. Behavioral problems were most consistently associated with factors Initiating and Maintaining Sleep, Disorders of Arousal and Sleep Breathing Disorders. SDSC Total Problem score was linked to almost all CBCL scales and Internal, External and Total Problems and CPRS-R Anxious-Shy, Social Problems, and Psychosomatic. Elevated scores in Sleep Breathing Disorders were associated with lower intellectual functioning.

Table 5 Correlation coefficients for the Sleep Disturbance Scale for Children factors and behavioral and neurocognitive parameters

	Initiating and Maintaining Sleep	Sleep Breathing Disorders	Disorders of Arousal	Disorders of Sleep-Wake Transition	Disorders of Excessive Somnolence	Sleep Hyper-hydrosis	Total Score
CBCL							
Internalizing	.268*	.236	.305*	.373**	.312*	.180	.416**
Externalizing	.359**	.157	.218	.152	.180	.237	.304*
Total	.379**	.320*	.305*	.263*	.275*	.227	.437**
CPRS-R							
Anxious-Shy	.509**	.330**	.350**	.422**	.201	.281*	.501**
Social Problems	.235	.379**	.202	.234	.348**	.186	.414**
Psychosomatic	.352**	.124	.312*	.333**	.442**	.270*	.479**
WISC-III							
Verbal IQ	.211	-.280*	-.084	-.037	.134	.060	.019
Performance IQ	.155	-.354**	-.126	-.252*	.064	-.009	-.092
Full Scale IQ	.200	-.326**	-.130	-.142	.102	.045	-.024
NEPSY Domains							
Attention and Executive	.242	-.113	.050	.159	.023	.125	.122
Language	.128	-.165	.061	.136	.027	.099	.116
Sensomotor	.037	-.040	-.006	.136	.057	.064	.149
Visuospatial	.181	-.227	.059	.130	.241	.263*	.143
Memory and Learning	.083	-.040	.057	.091	.118	.000	.104

*$p < .05$. **$p < .01$.

DISCUSSION

The aim of this study was to describe snoring and other sleep-related problems, behavioral problems, and neurocognitive functioning in snoring and nonsnoring school-aged children. Previously, only a few studies have widely investigated both behavioral problems and neurocognitive functions in snoring children. None of these studies have concentrated solely on school-aged children and used age-matched controls.

Sleep-related symptoms, behavior, and neurocognitive functioning

Firstly, in this study snoring children had significantly more parent-reported sleep breathing disorders, more problems in sleep-wake transition, higher incidence of sweating at night, and more daytime sleepiness than nonsnoring children. This finding was consistent with hypothesis. These results with sleep related problems were expected and are in accordance with earlier studies reporting many types of sleep problems in children with snoring (Blunden et al., 2000; Eitner et al., 2007; Ferreira et al., 2000).

Secondly, as expected, the findings indicate that snoring children have significantly more parent-reported internalizing behavioral problems (including anxious, depressed, withdrawn, and psychosomatic symptoms), thought problems, social problems, and total problems than their nonsnoring peers. Moreover, snoring children not only had higher incidence of these problems, the problems also were more severe, showing that almost half of the children had clinically significant symptoms. These findings are consistent with existing SDB studies showing that children with SDB have more behavioral problems than their nonsnoring peers, particularly symptoms of withdrawn, depressed and anxious mood, somatic complaints, social problems, and thought problems (Bourke et al., 2011; O'Brien et al., 2004). Similar findings have been reported in younger children; Aronen et al. (2009) found in a Finnish preschool group (aged 3-6 years) that snoring children had significantly more internalizing symptoms, especially anxious and depressed mood and emotional reactivity than nonsnoring peers. Despite these parent-reported behavior problems and contrary to initial hypothesis, teachers in this study did not report snoring children to have more behavioral problems than nonsnoring peers. Teachers rated children with lower scores than parents (a phenomenon that has been noted before by Ali et al., 1993 and Arman et al., 2005).

Hypothesis concerning elevated externalizing behavioral problems was not confirmed; in contrast to previous studies (e.g. Rosen et al., 2004), current results do not support the association between snoring and externalizing behavioral problems, especially hyperactivity, oppositional and aggressive behavior in snoring children. In this study, externalizing symptoms were no more frequent in snorers than nonsnorers. However, completely contrary to the initial hypothesis, the

teachers reported nonsnorers to be more impulsive and hyperactive than snoring children.

Thirdly, on the basis of previous studies (Archbold et al., 2004; Blunden et al., 2000; Gottlieb et al., 2004; Kennedy et al., 2004), it was hypothesized that diffuse neurocognitive impairments would be present in children with snoring. Although analyses showed that snorers had lower scores in the intellectual functions, these differences were not statistically significant. In addition, snorers' intelligence quotients were within the normal range. This means that contrary to initial hypothesis, in neurocognitive measurements there were no significant differences between the two groups. All studied children attended mainstream schools and received only part-time special education or remedial teaching, which may partially explain these results. There were no children with observed learning disabilities among participants.

Finally, as expected, associations between sleep quality, behavior and neurocognitive functions were found. Unlike in Blunden et al. (2000) study, most associations were found between sleep quality and behavior, and the association with neurocognitive functioning was weak. Behavioral problems were mostly associated with problems in initiating and maintaining sleep, disorders of arousal, sleep breathing disorders, and total sleep problems. Children who snored at least three nights a week had significantly more behavioral problems than less snoring children. In neurocognitive functioning, the only firm association was found between sleep breathing disorders and lower IQ. Children who snored a maximum of two nights a week had lower performance in memory and learning function compared with never snoring children.

In this study it was considered important to obtain teachers' observations on children's behavior in the school settings, because objective measures in naturalistic settings other than parents have been sparse and results have been controversial. The inconsistency between parent and teacher reports of behavior was evident in this study. This is consistent with previous reports showing that parents and teachers perceive the same children quite differently (Conners, 1997). This inconsistency has also been found in other studies examining snoring and behavior (Arman et al., 2005; O'Brien et al., 2011). The difference in parent and teacher reports in this study brings two possible explanations into mind. First, there was some variation in how long the teacher had known the child. Teachers with the lowest knowing time might have been cautious in reporting internalizing behavioral problems. Second, in the classroom children with internalizing problems are less visible than children with impulsive-hyperactive problems or aggressiveness. Therefore, teachers may have had difficulties in recognizing anxious, depressed, and shy children or children with psychosomatic symptoms in the class.

Strenghts and limitations of this study

There are several strengths in the present study. This study has the advantage of using simultaneously parent- and teacher-reported data, age-appropriate control group and standardized tests of neurocognitive functions and widely used and well-validated rating scales. Participants in this study were recruited from the local mainstream schools and were not being evaluated for sleep disturbances, behavioral problems or neurocognitive problems. The questionnaires were handed to all children, so the original sample of 1538 children was representative. It can be thought that the participants in this study represent Finnish pupils attending mainstream schools. The data consisted only school children aged 6-10, so the age range is very limited compared to many other SDB studies.

The current study has also limitations. First, the data on both snoring and behavioral problems relied on parental reports. Reliance on parental perceptions may introduce potential measurement error. It has been suggested (on a observational study by Montgomery-Downs, O'Brien, Holbrook, & Gozal, 2004) that parental-report questionnaires of children's snoring can be used as substitute predictors of snoring. In studies by O'Brien et al. (2004) and Blunden et al. (2000), parent-reported snoring was confirmed by polysomnography. Taken together, parents seem to be an applicable source of information regarding their children's snoring. It is possible that results in this study are biased by a tendency for some parents to be overcritical of their child, thus producing higher scores on questionnaires. Some parents may also have been aware of the association between snoring and behavioral problems and this might have influenced their evaluations. Because the categorization of the children into snoring and nonsnoring groups in this study was based on parental reported snoring, it was not possible to examine association between SDB severity and behavioral or neurocognitive impairments.

Second limitation concerns the use of the rating scales. Although Finnish versions of these scales were used, there are no Finnish normative data of these measures. This limitation is mainly diminished by the use of age-matched control group.

Third, initially less than one third of the questionnaires were returned, and we were able to recruit four percent from the initial target population to the final stage of this study. This low participation percent is probably due to inconvenience of the study protocol. During the PSG studies, the children (and most parents) slept two successive nights at the sleep laboratory and at the day of the psychological assessment children were absent from school. For some families this may have been too demanding of a procedure and therefore they chose not to participate in the clinical part of the study.

Clinical implications and future research aims

The cause of observed behavior problems cannot be answered by this study. The beginning or duration of snoring or other SDB symptoms was not examined. Only a few studies have investigated pediatric snoring longitudinally and more studies are needed to clarify this issue. Eitner et al. (2007) found that long-term habitual snorers were at significantly increased risk for sleep-wake transition disorders, sleep hyperhydrosis, disorders of arousal, and excessive somnolence. Children who had spontaneously ceased to snore showed fewer sleep problems. Bonuck, Freeman, Chervin, & Xu (2012) found in a population-based, longitudinal study that early-life SDB symptoms predicted hyperactivity, conduct, and peer problems as well as emotional difficulties at ages 4 and 7.

In this study excessive daytime sleepiness was found to be more prominent in snoring children, but only a few relationships were observed between daytime sleepiness and behavioral outcomes. The many associations found between sleep problems and behavioral outcomes suggest that behavioral problems in snoring children may be explained by comorbid sleep problems. Problems found in memory and learning function indicates that even mild snoring frequency may have an impact on neurocognitive functions. Potential mechanisms of these problems in snoring are unknown and need further investigation (Liukkonen, 2011).

In conclusion, the results of this study indicate that compared with nonsnoring peers, school-aged snoring children are at risk for internalizing problems, thought problems, and social problems. As pointed out earlier, snoring is common in children and without adverse sleep-related or daytime consequences needs no treatment (McColley, 2005). Children who have sleep-related symptoms should be referred to diagnostic testing and possibly treatment. Also children with daytime somnolence, problems with behavior, or school performance, should have their sleep evaluated. Although there were no neurocognitive problems to be shown between the two groups in this study, internalizing problems, if not treated, may cause severe consequences in the long run, leading to social isolation, severe psychological difficulties, learning problems, and poor school performance.

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Appendix 1

Scores on the Teacher Report Form and the Conners' Teacher Rating Scale-Revised in snoring and nonsnoring children

	Snoring children Mean ± SD (Range)	Nonsnoring children Mean ± SD (Range)	*P*-value Mann-Whitney *U*-test
TRF			
Scales	n = 23	n = 32	
Anxious/Depressed	52.4 ± 4.4 (50-64)	52.7 ± 4.7 (50-69)	.451
Withdrawn/Depressed	53.8 ± 6.8 (50-78)	53.5 ± 5.9 (50-74)	.708
Somatic Complaints	51.3 ± 3.6 (50-65)	53.3 ± 4.8 (50-62)	.071
Social Problems	53.6 ± 5.9 (50-76)	52.8 ± 4.9 (50-69)	.358
Thought Problems	51.7 ± 4.1 (50-63)	52.0 ± 3.7 (50-60)	.586
Attention Problems	52.0 ± 3.4 (50-63)	52.3 ± 4.2 (50-65)	.603
Rule-Breaking-Behavior	52.0 ± 3.8 (50-63)	52.6 ± 4.9 (50-70)	.867
Aggressive Behavior	53.6 ± 4.9 (50-65)	54.1 ± 5.1 (50-66)	.669
Indices			
Internalizing Problems	46.7 ± 9.2 (37-68)	47.8 ± 9.4 (37-68)	.712
Externalizing Problems	49.2 ± 7.9 (41-63)	50.2 ± 8.1 (41-68)	.748
Total Problems	47.5 ± 8.3 (32-63)	47.7 ± 8.9 (32-65)	.898
CTRS-R			
Scales	n = 23	n = 30	
Oppositional	49.5 ± 7.0 (45-69)	52.3 ± 11.3 (45-90)	.286
Cognitive Problems/Inattention	46.0 ± 5.3 (41-62)	47.3 ± 7.8 (41-77)	.792
Hyperactivity	48.4 ± 7.3 (43-70)	50.5 ± 7.5 (43-78)	.073
Anxious-Shy	50.1 ± 8.0 (42-74)	51.6 ± 9.9 (42-77)	.758
Perfectionism	49.5 ± 11.0 (42-81)	49.7 ± 7.9 (42-76)	.232
Social Problems	48.1 ± 8.9 (45-88)	49.4 ± 9.6 (45-84)	.947
Indices			
ADHD	45.9 ± 5.9 (41-68)	48.0 ± 7.0 (41-66)	.342
Restless/Impulsive	46.7 ± 7.2 (41-71)	49.1 ± 7.9 (41-71)	.178
Emotional Lability	49.0 ± 9.2 (44-77)	49.0 ± 8.0 (44-75)	.754
Total Index	46.9 ± 7.1 (41-66)	48.8 ± 8.0 (41-71)	.329
DSM-IV Inattentive	46.9 ± 6.2 (40-63)	48.1 ± 7.4 (40-72)	.581
DSM-IV Hyperactive/Impulsive	46.8 ± 5.9 (42-63)	49.2 ± 6.3 (42-69)	.033*
DSM-IV Total	46.6 ± 5.7 (41-65)	48.5 ± 6.5 (41-64)	.300

*$p < .05$.