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CLINICAL REVIEW

The conundrum of primary snoring in children: What are we missing in regards to cognitive and behavioural morbidity?

Sarah N. Biggs [a, b, *], Gillian M. Nixon [a, b, c], Rosemary S.C. Horne [a, b]

[a] The Ritchie Centre, Monash Institute of Medical Research – Prince Henry's Institute, Monash University, Melbourne, Australia
[b] Department of Paediatrics, Monash University, Melbourne, Australia
[c] Melbourne Children's Sleep Centre, Monash Children's Hospital, Monash Medical Centre, Melbourne, Australia

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SUMMARY

Sleep disordered breathing (SDB) is common in children and describes a continuum of nocturnal respiratory disturbance from primary snoring (PS) to obstructive sleep apnoea (OSA). Historically, PS has been considered benign, however there is growing evidence that children with PS exhibit cognitive and behavioural deficits equivalent to children with OSA. There are two popular mechanistic theories linking SDB with daytime morbidity: hypoxic insult to the developing brain; and sleep disruption due to repeated arousals. These theories apply well to OSA, but children with PS experience neither hypoxia nor increased arousals when compared to non snoring controls. So what are we missing? This review summarises the literature examining daytime morbidity in children with PS and discusses the current debates surrounding this relationship. Specifically, questions exist as to the sensitivity of our standard assessment techniques to measure subtle hypoxia and arousal. There is also a suggestion that the association between PS and daytime morbidity may not be mediated by nocturnal respiratory disturbance at all, but by a number of other comorbid, but perhaps unrelated factors. As approximately 70% of children with SDB are diagnosed with PS, but are rarely treated, a paradigm shift in the investigation of PS may be required.

Introduction

Obstructive sleep disordered breathing (SDB) in children describes a continuum of nocturnal respiratory disturbance characterised by increasing upper airway obstruction and degrees of gas exchange abnormalities [1,2]. The cardinal symptom of SDB is habitual snoring. At the most severe end of the spectrum is obstructive sleep apnoea (OSA), which is characterised by repetitive episodes of full or partial obstruction of the airway resulting in oxygen desaturation and/or an arousal from sleep, if not a full awakening. At the mild end of the SDB spectrum is primary snoring (PS). PS is also characterised by habitual snoring, but with few respiratory events (<1 event/h), oxygen desaturation or formally defined respiratory arousals [1]. A continuous scale of respiratory effort, desaturation and arousal from sleep lie in between these two extremes, with the quantifying cut-off between one severity group and the next being relatively arbitrary. Classification of SDB severity has usually been defined by the frequency of obstructive events during sleep – variously termed the apnoea hypopnea index (AHI), or respiratory disturbance index (RDI). Throughout this review, the term SDB will be used as an encompassing term, referring to the full continuum of the disease, whereas PS and OSA will refer to those specific categories within the continuum.

In adults, the phenotype of OSA is most often described as overweight males with sedentary lifestyles, although genetic predisposition, craniofacial anatomy and abnormal regulation of upper airway musculature are also risk factors [3]. In children, who are otherwise healthy, the traditional phenotype of OSA is not related to adipose tissue, but to adenotonsillar hypertrophy that occludes a relatively small pharyngeal space [4]. Prevalence of OSA in children is reported to be 1–5% of the population [2]. The prevalence of habitual snoring reported in the literature varies widely, with population studies reporting ranges from less than 3% [5] to approximately 35% [6], with the discrepancy arising predominantly from the authors' definition of habitual snoring. Most commonly, habitual snoring is defined as snoring often or more than three times per week, for which prevalence rates are reported to be

* Corresponding author. The Ritchie Centre, MIMR-PHI Institute, Monash University, Level 5, Monash Medical Centre, 27-31 Wright St, Clayton, Victoria 3168, Australia. Tel.: +61 3 9594 4759; fax: +61 9594 6811.
E-mail address: sarah.biggs@monash.edu (S.N. Biggs).

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Abbreviations

ABAS	adaptive behavior assessment system
ACPT	auditory continuous performance test
ADHD	attention deficit hyperactivity disorder
AHI	apnoea/hypopnoea index
ArI	arousal index
BASC	behavioral assessment scale for children
BRIEF	behavior rating inventory of executive function
CAP	cyclic alternating pattern
CBCL	child behavior checklist
CMS	children's memory scale
COWAT	controlled oral word association test
CVLT-C	California verbal learning test for children
DAS	differential abilities scale
EEG	electroencephalogram
EVT	expressive vocabulary test
GDS	Gordon diagnostic system
IQ	intelligence quotient
MSOSA	moderate–severe OSA
NEPSY	neuropsychological assessment
NREM	non-rapid eye movement
OAI	obstructive apnoea index
OAHI	obstructive apnoea/hypopnoea index
OSA	obstructive sleep apnoea
pCO_2	partial pressure of blood carbon dioxide
PPVT	Peabody picture vocabulary test
PSG	polysomnography
PS	primary snoring
RAVLT	Rey auditory verbal learning test
RBMT	Rivermead behavioural memory test for children
RCFT	Rey complex figure test
RDI	respiratory disturbance index
REM	rapid eye movement
SDB	sleep disordered breathing
SE	sleep efficiency
SOL	sleep onset latency
SpO^2	blood oxygen saturation
SWA	slow wave activity
TST	total sleep time
UARS	upper airway resistance syndrome
WASI	Wechsler abbreviated scale of intelligence
WCST	Wisconsin card sorting test
WISC	Wechsler intelligence scale
WPPSI-R	Wechsler pre-school and primary scale of intelligence (revised)
WRAML	wide range assessment of memory and learning
WRAT	wide range achievement test

between 10% and 15% [7]. While adenotonsillar hypertrophy is the most common aetiology of SDB in children, with rising obesity rates in children, there is an increasing incidence of the more classical adult profile of OSA, where body weight plays a major role. Indeed, there has been some suggestion that in children there are now two distinct disease profiles of OSA with different sequelae [8]. Syndromes and conditions involving craniofacial malformation and neuromuscular factors that affect the patency of the airway can also result in OSA [9–11]. However, these conditions are beyond the scope of the current review. For the purposes of this review, we will only be discussing SDB and the associated neurocognitive and behavioural consequences in children without craniofacial or neuromuscular comorbid conditions.

Reports of cognitive and behavioural deficits in children with OSA date back to the late 1880's [12], however formal investigation of the daytime consequences of SDB has only been conducted in the last four decades. Since the first seminal studies by Guilleminault and colleagues [13,14], the literature regarding the effects of SDB on cognition, behaviour and school performance in children has increased exponentially, with more than 80 studies published in this area in the last 12 years. Although causality is difficult to establish, due to the complexities of known confounders (e.g., environment, socio-economic factors, race) and the limitations of study designs (e.g., majority are cross-sectional), it is now widely accepted that OSA is associated with cognitive and behavioural dysfunction.

There are two popular, interconnected, theories describing the mechanisms linking OSA to daytime deficits. The first proposes that the repetitive hypoxic insults to the brain interrupt normal synaptic functioning which results in neuronal injury and cognitive impairments. The second proposes that the increased sleep disruption from repetitive arousals at respiratory event termination leads to sleep deprivation and excessive daytime sleepiness, which in turn affects cognitive and behavioural functioning [15–17]. Historically, it was assumed that the level of daytime deficits would be linearly related to the severity of SDB, and until relatively recently, PS was considered benign [18]. Unexpected evidence of cognitive and behavioural deficits in children with PS, confirmed by polysomnography (PSG), was first presented by Blunden and colleagues [19]. The aim of that study was to examine cognitive and behavioural deficits in children with OSA, however few of their cohort met the criteria for OSA, instead receiving a diagnosis of PS (AHI < 1 event/h). Despite this, the results showed a significant difference in cognitive functioning between the snoring children and the control group. That study sparked much intrigue surrounding the morbidity of PS. Subsequently, a number of studies have specifically examined children with PS and compared sleep and respiratory indices, neurocognitive and behavioural outcomes to children with OSA, as well as healthy, non snoring controls with surprising results [20–31]. Specifically, behavioural, most often measured via parent-report questionnaire, and to some extent, cognitive deficits in children with PS are similar to children with OSA, when compared to non snoring controls. As by definition, children with PS do not experience gas exchange abnormalities or increased arousals compared to normative values, this begs the question: what are we missing in the relationship between PS and daytime sequelae? Furthermore, as the majority of children with PS do not get treated for their condition, are we placing them at risk of life-long deleterious consequences?

This review will summarise the current literature regarding cognitive and behavioural performance in children with PS, discuss the relevance of current mechanistic theories as applied to this group, and propose some alternate explanations for the association between PS and daytime deficits in children. There are a number of comprehensive reviews outlining the neurocognitive and behavioural consequences of parent-reported habitual snoring and SDB in more general terms, without discretely separating PS from OSA [15–17,32–38]. As such, we have chosen to present and discuss only those studies which employed PSG to confirm the severity of SDB, categorised PS as a separate group, and assessed cognition and/or behaviour as a study outcome against children with more severe SDB and/or non snoring healthy controls. Articles were