Natural history of snoring in children: Do neurocognitive deficits improve if snoring resolves?

by

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A thesis submitted for the degree of

Doctor of Philosophy in Psychology

School of Psychology, Social Work and Social Policy

Division of Education, Arts and Social Science



University of South Australia

April, 2014

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Glossary

3% ODI	Number of dips in oxygen saturation ≥3%
A&T	adenoidectomy and tonsillectomy
ADHD	attention deficit hyperactive disorder
AHI	apnoea-hypopnoea index
AI	arousal index
ANOVA	analysis of variance
ASEBA	Achenbach System of Empirically Based Assessment
BMI	body mass index
CAHI	central apnoea-hypopnoea index
CAP	cyclic alternating pattern
CBCL	Child Behavior Checklist
CBCL/6-18	Child Behavior Checklist for 6-18 years
CHC	Cattell-Horn-Carroll theory
CI	Confidence Interval
$Clinical_{PS}$	clinical primary snorer
$Community_{NS}$	community non-snorer
$Community_{PS}$	community primary snorer
CYWHS	Children, Youth & Women's Health Service
DAS-II	Differential Ability Scales, Second Edition
DSM	Diagnostic and Statistical Manual of Mental Disorders
ECG	electrocardiogram
EDS	excessive daytime sleepiness
EEG	electroencephalogram, electromyography
EMG	Electromyogram,
ENT	ear, nose and throat
EOG	electrooculogram, electrooculography
Ga	Auditory Processing
Gc	Crystallized Intelligence/Knowledge
GCA	General Conceptual Ability
Gf	Fluid Intelligence
Glr	Long-Term Memory

Gs	Processing Speed
Gsm	Short-Term Memory
Gv	Visual Processing
ICSD-2	International Classification of Sleep Disorders
lab-PSG	laboratory-based polysomnography
NEPSY	Developmental Neuropsychological Assessment
NREM	Non Rapid Eye Movement Sleep
NV	Non-verbal Ability
NVR	Non-verbal Reasoning Ability
OAHI	obstructive apnoea-hypopnoea index
OR	odds ratio
OSAS	obstructive sleep apnoea syndrome
PLM	periodic limb movement
PS	primary snoring
PSG	polysomnography, polysomnographic, polysomnogram
RAI	Respiratory Arousal Index
RDI	Respiratory Disturbance Index
REM	rapid eye movement
RIP	respiratory inductive plethysmography
S	Spatial Ability
SAI	Spontaneous Arousal Index
SAPSS	South Australian Paediatric Sleep Survey Database
SAPSS-Q	South Australian Paediatric Sleep Survey Database Questionnaire
SCN	suprachiasmatic nuclei
SD	standard deviation
SDB	sleep-disordered breathing
SDSC	Sleep Disturbance Scale for Children
SDQ	Strengths and Difficulties Questionnaire
SEIFA	Socio-economic Indexes for Areas
SES	socioeconomic status
SOL	sleep onset latency
SWS	slow wave sleep
TIB	time in bed

TRF	teacher’s report form
TST	Total Sleep Time
UARS	Upper Airway Resistance Syndrome
U.S.	United States
V	Verbal Ability
WASO	wakefulness after sleep onset
YSR	Youth Self-Report

Summary

It is commonly accepted that daytime functioning is reduced in children with mild upper airway obstruction such as primary snoring. However, much of this evidence is based on studies of children from clinical settings; the evidence is less clear in studies of children from community settings. To address the limited data and better explore the association between primary snoring and daytime functioning, this study presents the results of a 24-month follow-up study examining sleep, neurocognition and behavioural performance of snoring versus non-snoring school-age children recruited from the community.

Twenty-four children with primary snoring from the community (age = 7.7 ± 1.7 years) and 92 non-snorers (8.2 ± 1.6 years) were recruited from a pre-existing survey database, and the following measures were collected at baseline and 24-month follow-up: polysomnography; questionnaire; seven-day diary; executive functioning, using Developmental Neuropsychological Assessment; intelligence, using Differential Ability Scales; and behaviour, using the Child Behavior Checklist. Additional assessment of sleep and behaviour was conducted at 12 months. To permit an examination of potential differences between children who snore from community versus clinical settings, the study also compared the community sample of children with a previously examined cohort of 15 children on a clinical waiting list for adenotonsillectomy.

The study found a very limited number of significant differences between primary snorers and non-snorers on any of the sleep, neurocognitive and behavioural measures at both the initial assessment and 24-month follow-up. This finding was regardless of whether the children were classified according to parental ratings of snoring frequency into low or high obstructive apnoea-hypopnea index groups, or according to parental concern about snoring (not concerned vs. concerned). Compared to primary snorers from the clinical setting, primary snoring children from the community had a slightly lower frequency of neurocognitive and behavioural problems, less family history of smoking and higher birth weights.

Examination of the natural history of parental-reported snoring revealed that if a child did not snore at their initial assessment then they were unlikely to snore at either the 12 or 24-month follow-up. By contrast, snoring status showed more variability in children who snored at initial assessment—they had an equal likelihood that they would have stopped snoring at the 24-month follow-up. Although the sample size was small, little evidence was

found to support the hypothesis that a change in snoring status would be associated with a corresponding change in daytime functioning.

Taken together, the present findings suggest that primary snoring may not be associated with daytime deficits in otherwise healthy children in the general community. In this research, little evidence was found that primary snoring (regardless of its definition) was associated with meaningful neurocognitive or behavioural deficits. Further, a change in snoring status was not associated with any change in neurocognitive or behavioural status. These findings raise uncertainty as to the assumption of an association in children between mild upper airway obstruction and daytime deficits and suggest that the daytime deficits in children recruited from clinical settings may be better explained by other factors, such as a referral bias; however, this remains to be explored.

Summary (Spanish version)

Actualmente es ampliamente aceptado el hecho de que el funcionamiento cognitivo diurno se deteriora en niños con obstrucción leve de las vías respiratorias superiores que genera el ronquido primario. Esta evidencia proviene de estudios realizados en niños con patologías relacionadas con obstrucción de vías respiratorias, mientras que la evidencia de estudios realizados con niños sin patologías asociadas con ronquido primario, no es concluyente. Con el fin de analizar la asociación entre ronquido primario y funcionamiento cognitivo diurno, se presentan los resultados de la investigación realizada durante un periodo de 24 meses de seguimiento, en los que se examinó sueño, funcionamiento neurocognitivo y comportamiento en niños y niñas de edad escolar con y sin ronquido primario, provenientes de la comunidad en general.

La información inicial, se obtuvo de un estudio epidemiológico realizado con veinticuatro niños con ronquido primario (edades = 7.7 ± 1.7 años) y 92 no roncadores (8.2 ± 1.6 años). Las variables estudiadas corresponden a los siguientes estudios: polisomnografía, patrones de sueño y vigilia, características sociodemográficas, diarios de sueño durante siete días de duración, funcionamiento ejecutivo (NEPSY), inteligencia en general (DAS) y comportamiento (Child Behavior Checklist). Se realizó una evaluación inicial, después a los 12 meses y posteriormente a los 24 meses. Los resultados obtenidos, fueron comparados con los resultados obtenidos de una muestra de 15 niños provenientes de una lista de espera para adenoamigdalectomía. Esta comparación tuvo como fin examinar las posibles diferencias en déficits neurocognitivos y del comportamiento entre niños con historia clínica de ronquido primario con quienes no lo padecían. .

Se encontraron mínimas diferencias estadísticamente significativas en la valoración inicial y en el posterior seguimiento a los 24 meses entre ronquido primario y no roncadores en mediciones de sueño, funcionamiento neurocognitivo y comportamiento. Independientemente de si el niño era catalogado como roncador por los padres, las diferencias fueron encontradas cuando estos niños se clasificaron de acuerdo a bajo o alto índice de apneas-hipopneas obstructivas, o de acuerdo a si los padres consideraban el ronquido como un problema (no preocupado versus preocupado). Adicionalmente, comparando los niños con ronquido primario con aquellos con antecedentes clínicos de obstrucción leve de las vías respiratorias superiores que genera ronquido primario, se observó que estos últimos tenían leves alteraciones del funcionamiento neurocognitivo y

problemas de comportamiento, así como un menor nivel de consumo de tabaco en la familia y un mayor peso al nacer.

En el análisis de la historia natural del ronquido reportado por los padres, se observó que si un niño no roncaba durante la valoración inicial era poco probable que roncara a los 12 o 24 meses posteriores. Aunque el tamaño de la muestra era pequeño, se encontró poca evidencia que soportara la hipótesis de que un cambio en el estado del ronquido estuviera asociado con un correspondiente cambio en el funcionamiento cognitivo diurno.

En conclusión, los resultados encontrados sugieren que el ronquido primario podría no estar asociado con déficits cognitivo diurno en niños de la comunidad que no presentan ningún otro trastorno. En esta investigación se encontró poca evidencia de que el ronquido primario (independientemente de cómo sea definido) estuviera asociado con déficits neurocognitivos o comportamentales. Estos resultados aumentan la incertidumbre en la presunta asociación entre la obstrucción de las vías aéreas superiores y déficits en el desempeño diurno en niños, y también sugiere que déficits en niños provenientes de un contexto clínico podrían ser explicados por otros factores tales como un sesgo de referencia, sin embargo, esto sigue siendo un tema para ser investigado.

Declaration

I declare that this thesis presents work carried out by myself and does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university. To the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text; and all substantive contributions by others to the work presented, including jointly authored publications, is clearly acknowledged.

Signature: Date:

Acknowledgments

First and foremost, I want to thank my supervisors for all their help and support during these years. To my principal supervisor Professor Kurt Lushington, I am profoundly thankful for his guidance and patience. The good advice, valuable feedback and ideas of my co-supervisor, Dr Mark Kohler, has given me confidence as a researcher.

This project would not have been possible without the initial role of Dr Sarah Biggs, who is a research model for so many of us. I also thank A/Professor Declan Kennedy, Dr James Martin and Dr Yvonne Pamula, for their important advice and support throughout this project. Dr Cameron van den Heuvel, without your initial response I would not have been here. I would like to acknowledge other staff from the Sleep Disorders Unit who participated in this study, especially Scott Coussens, who patiently taught me the art of scoring sleep. Thanks to Melissa Coussens and Alicia Hoberg for training me and for our conversations during exhausting overnights. Additionally, I would like to thank Mr Thomas Sullivan for your statistical support, Ms Rosemary Purcell for copyediting this document and Mrs Margaret Heddle for her support with the recruitment process.

I would like to thank the University of South Australia; from which I received a Postgraduate Scholarship. Also to the Learning and Teaching Unit staff, especially to Dr Monica Behrend who has given me the best example and support throughout my process as a PhD student. Thanks to the Writer's Circle and research workshops where I found not only knowledge, but also invaluable friendships: thanks to Nur and Jenny who have been in every step giving me words of wisdom and enthusiasm.

The members of the 'Tangle' and also staff from the Centre for Sleep Research: Millie, Gabby, Cassie, Stephanie, Georgina, Alex, Gemma and Rachael. I am blessed with their friendship, support and help. I am most grateful to Melaura Bradford, Sr Elena Marie (Alicia) and the Piteo's family for their support and encouragement during the most difficult times.

Finally I would like to thank my family and close friends here and in Colombia, who regardless of the distance have celebrated all my triumphs and have encouraged me when times have been difficult. A special thanks to my parents and my brother, to whom I dedicate this work; I would not be who I am without you.

Acknowledgments (Spanish version)

En primer lugar, quiero dar las gracias a mis supervisores por toda su ayuda y apoyo durante estos años. A mi supervisor, profesor Kurt Lushington, estoy profundamente agradecida por su guía y paciencia. El buen consejo, valiosa información e ideas de mi co-supervisor, el Dr. Mark Kohler, su apoyo me ha dado la confianza como investigadora.

Este proyecto no habría sido posible sin el papel inicial de la Dra. Sarah Biggs, que es un modelo de investigación para muchos de nosotros. También quiero agradecer al Profesor Asociado Declan Kennedy, el Dr. James Martin y la Dra. Yvonne Pamula, por su asesoramiento y apoyo importante a través de este proyecto. Dr. Cameron van den Heuvel, sin su respuesta inicial que no habría estado aquí. Me gustaría reconocer otros miembros del personal de la Unidad de Trastornos del sueño que participaron en este estudio, sobre todo, Scott Coussens que pacientemente me enseñó el arte de analizar el sueño. Gracias a Melissa Coussens y Alicia Hoberg por nuestras conversaciones durante noches agotadoras. Además, me gustaría dar las gracias al señor Thomas Sullivan por su apoyo estadístico, la señora Rosemary Purcell por editar este documento y la señora Margaret Heddle por su ayuda con el proceso de reclutamiento de los participantes.

Me gustaría dar las gracias a the University of South Australia, de la cual he recibido una beca de postgrado. También para Learning and Teaching Unit, en especial a la Dra. Mónica Behrend que me ha dado el mejor ejemplo y apoyo durante mi proceso como estudiante de doctorado. Gracias al Círculo de Escritores y talleres de investigación en el que pude encontrar no sólo el conocimiento, sino también amistades valiosas: gracias a Nur y Jenny que han estado en cada paso dándome palabras de sabiduría y entusiasmo.

Los miembros del 'Tangle' y también al personal del Centro de Investigación del Sueño: Millie, Gabby, Cassie, Stephanie, Georgina, Alex, Gemma y Rachael. He sido bendecida con su amistad, apoyo y ayuda. Estoy muy agradecida con Melaura Bradford, la hermana Elena Marie (Alicia) y la familia Piteo por su apoyo y aliento en los momentos más difíciles.

Por último, quisiera dar las gracias a mi familia y amigos aquí y en Colombia, que sin importar la distancia han celebrado todos mis triunfos y me han animado cuando los tiempos han sido difíciles. Un agradecimiento especial a mis padres y mi hermano a quienes dedico este trabajo, yo no sería quien soy sin ustedes.

Preface

> *'… Sleep is not simply a period of reduced activity or alertness …'* p.1264 (Siegel, 2005)

From the prosaic to the divine function, sleep is much studied (Barbera, 2008), and the change in sleep that accompanies development and its impact on daytime functioning has been subject to intense investigation. The studies have not been without their methodological challenges. Unlike adults, the experimental manipulation of sleep is not feasible in children for practical and ethical reasons. Therefore, research in children has relied on naturalistic studies, especially those that investigate the impact of the pathologies that mostly affect sleep. A particularly well studied key disorder that helps us understand the role that sleep plays in developmental daytime functioning is sleep-disordered breathing. This disorder falls along a continuum of upper airway resistance ranging from mild obstruction to severe obstruction. The characteristics and consequences of severe forms, including obstructive sleep apnoea syndrome, have been extensively studied in adult and paediatric populations. By contrast, a common, but less well-explored sleep-disordered breathing is primary snoring. Although primary snoring is associated with reduced daytime functioning, the literature is largely based on data collected from children in clinical settings with all its accompanying biases raising questions about the veracity of the findings. To address this shortcoming, this thesis recruited children from the community to explore the effect of snoring on daytime functioning in otherwise healthy children who snore compared to non-snorers.

The children examined in this study were recruited from a previous epidemiological project that examined sleep/wake patterns and sleep problems in school-age children from South Australia (Biggs, 2009). The children reported to snore in this initial survey were invited to participate in further studies; it is from this pool that participants were recruited. This study comprises second (baseline), third (12-month follow-up) and fourth (24-month follow-up) phases investigating neurocognitive functioning and behavioural performance of children aged between five and 12 years from a community setting with and without primary snoring; as well as the natural history of parental-reported snoring. Demographics, snoring status, and sleep and neuropsychological functioning were assessed using validated parental-report questionnaires, subjective (e.g. sleep diaries) and objective (i.e.

polysomnography) sleep measures, standardised neuropsychological tests and behavioural checklists.

The first part of this thesis (Chapter 1) provides a general review of the existing literature regarding the function of sleep; the role of sleep-disordered breathing and, in particular, primary snoring in children. It examines in detail the epidemiology of primary snoring, including its associated risk factors, followed by a review of the consequences, and a review of the natural history of snoring in children.

Chapter 2 documents the methodology used for the entire project, discussing sampling, procedure, materials and ethical considerations.

Due to the nature of this project, this thesis is divided into seven studies (i.e. experimental chapters) where a brief background and methodology followed by results and discussion are given for each chapter. Chapter 3 presents the first study, detailing the results of the second phase of data collection (baseline) involving comparisons between children with and without reports of snoring on neurocognitive, behavioural and polysomnographic outcomes. In that chapter, the impact of different classifications, including snoring frequency and level of obstruction measured by the obstructive apnoea-hypopnoea index on outcome measures, are explored. Chapter 4 examines the factors that are associated with snoring including demographic and health characteristics parentally-reported. Chapter 5 explores the correspondence between subjective and objective measures.

Chapter 6 explores parental concern about snoring and compares sleep, neurocognition and behaviour in children whose parents were or were not concerned about snoring.

Chapter 7 investigates sleep and wake patterns using sleep diary and questionnaire measures in children with and without snoring, low versus high obstructive apnoea-hypopnoea index and parental concern versus non-concern about snoring.

Chapter 8 investigates the natural history of parental-reported snoring over a period of two years; as well as the associated performance (i.e. neurocognition and behaviour) at follow-up and whether changes in snoring status are related to changes to daytime functioning.

The final experimental chapter (Chapter 9) explores differences between children with similar conditions but who are drawn from distinctive populations. Demographic, neurocognitive, behavioural and sleep characteristics of snoring and non-snoring children drawn from community and clinical settings are compared.

Finally, Chapter 10 discusses the main findings from all studies and provides final considerations for future research.

Hypotheses

Three main hypotheses were followed for this project:

1. Primary snoring children from a community setting would display impaired neurocognitive and behavioural performance compared to non-snoring children.

2. Primary snoring would resolve in some snoring children, but not in others, and its associated deficits would improve among those whose primary snoring resolved.

3. Children with primary snoring recruited from community settings and those recruited from clinical settings would differ.

Chapter 1 General overview

1.1. Normal sleep

A good night's sleep is vital for optimal functioning, and it is generally recognised that this is especially true for children. In recent decades the impact of disturbed sleep on child wellbeing has received increasing interest, and a particular focus of recent research has been the impact of sleep-disordered breathing (SDB) on daytime functioning. Much of this latter literature, however, concentrates on children with severe SDB, such as obstructive sleep apnoea syndrome (OSAS). By contrast, whether the same deficits are present in children at the mild end of the SDB spectrum has received less attention, especially those whose symptoms may not have led to the child coming to the attention of their general practitioner—such as otherwise healthy children who are habitual snorers in the general community. This review examines the impact of mild SDB, that is, primary snoring (PS) on child sleep and its contribution to impaired daytime functioning. The following section is divided into two parts: an overview of sleep followed by a review of snoring and its consequences.

1.1.1. History, measurement and analysis of sleep

The modern study of sleep has its origins with the application by Loomis et al. (1937) of electrophysiological methodologies to the measurement of brain activity—that is electroencephalography (EEG) (Loomis, Harvey, & Hobart, 1937). In his seminal work, Loomis revealed that the electrical activity during sleep differed to that when awake and moreover, that different patterns of electrophysiological activity could be observed during sleep itself. In the early 1950s Aserinsky and Kleitman (1953) observed periods of rapid eye movement (REM) sleep; which were associated with an increased heart rate and variable respiration. In later studies, Aserinsky and Kleitman (1955), used continuous night sleep recordings to confirm the cyclical pattern of non-rapid eye movement (NREM) sleep followed by REM sleep. These variations in cerebral activity during sleep coupled with monitoring of eye movement (electrooculography; EOG), and muscle activity (electromyography; EMG) were subsequently used by Rechtschaffen and Kales in the late 1960s to classify sleep. This sleep classification system, which with some minor modifications remains in use to this day, is commonly known as the R&K rules (Rechtschaffen & Kales, 1968). Notably, Rechtschaffen and Kales set the rules for scoring NREM stages including NREM sleep stages: Stage 1, Stage 2, Stage 3, Stage 4, as well as

REM sleep and wake. Developed as a clinical tool, an updated version of these rules was published in 2007 (Iber & American Academy of Sleep Medicine, 2007). The collective study of sleep using EEG, EMG and EOG is known as polysomnography (PSG).

1.1.2. Sleep stages

Three main physiological states can be distinguished on PSG, these include wake, NREM sleep and REM sleep. Each state is characterised by specific cortical electrical and peripheral physiological activities, which appear throughout a 24-hour cycle. Through a normal night sleep period, NREM and REM sleep alternate in a cyclical manner with an initial period extending from 70–90 minutes to 90–120 minutes later (Carskadon & Dement, 2011). A brief description of the essential features in each stage is presented below.

Wake

Wakefulness constitutes the predominant brain state for humans. During the wake period, waves in the alpha (8–13 Hz) and beta (>13 Hz) range predominate. Increased alpha waves are generally present when a person is relaxed with eyes closed, while beta waves are usually seen for active thinking. During relaxed wakefulness alpha activity is most prominent over occipital areas in the brain, which attenuate when eye opening (Sheldon, 2005). Figure 1.1 shows a portion of EEG from one participant in the current study.

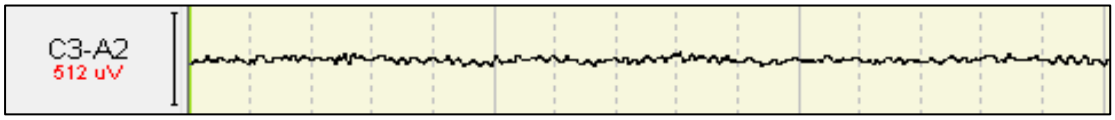


Figure 1.1 Portion of electroencephalogram depicted from an 11-year-old participant during relaxed-wake period

Stage 1 non-rapid eye movement sleep

Generally with a lower frequency than the EEG frequency seen during wake, Stage 1 (Figure 1.2) is characterised by low-voltage mixed-frequency EEG waveform with predominant theta activity (4–7 Hz). During the onset of Stage 1 from wake, rolling eye movements and later vertex sharp waves are seen and are evident from the first six months of age. These sharp waves continue to develop throughout childhood, and they become prominent between three and ten-years-old (Grigg-Damberger et al., 2007). In children, Stage 1 occupies about 4% of their total sleep time (Novelli, Ferri, & Bruni, 2010).

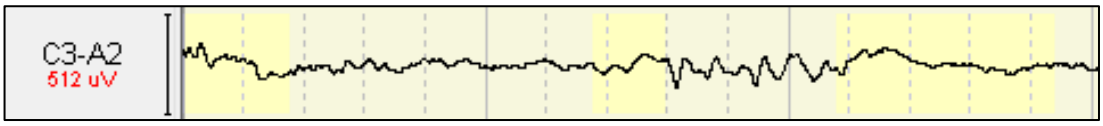


Figure 1.2 Portion of electroencephalogram depicted from an 11-year-old participant during Stage 1 non-rapid eye movement sleep

Stage 2 non-rapid eye movement sleep

During Stage 2 (Figure 1.3), eyes movements are generally absent and it is characterised by distinctive EEG markers: 'sleep spindles' and 'K-complexes'. While spindles are clusters of high frequency activity normally with a waxing and waning form, K-complexes are transient biphasic EEG waveforms involving an initial large sharp negative wave followed immediately by a slower positive component (Rechtschaffen & Kales, 1968). K-complexes reach their maximum amplitude at about three-years-old, and decrease after 12 years, acquiring adult form during this period (Kahn, Dan, Groswasser, Franco, & Sottiaux, 1996). By eight to twelve weeks after birth sleep spindles are noticed, but it is not until around three months that spindles reach the maximum duration and density. Moreover, during the first 12 months of life, spindles show major changes regarding their morphology, amplitude and frequency (Dan & Boyd, 2006; Grigg-Damberger et al., 2007). Spindles have been observed to have different frequencies (slow and fast), which may relate to different phenomena. For example, fast frequency spindles (13–15.9 Hz) have been associated with narrative memory and sensorimotor ability (Chatburn et al., 2013).

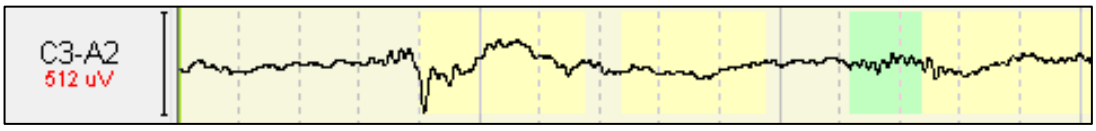


Figure 1.3 Portion of electroencephalogram depicted from an 11-year-old participant during Stage 2 non-rapid eye movement sleep; green shade indicates spindle activity

Stage 3 and 4

Also known as slow wave sleep (SWS), Stages 3 and 4 (Figure 1.4) are characterised by predominance of wave activity with low frequency, with most of the waves found to be in the delta range (0.5–2 Hz). Similar to Stage 2, eye movements are absent and muscle tone is lower than during the waking period. NREM Stage 3 and 4 combined occupy 23% of the total sleep time (Novelli et al., 2010). SWS is predominant throughout the first part of the night; which decreases at the last part of the sleep period, and it is replaced by an increased REM sleep proportion (Jenni & Carskadon, 2007).

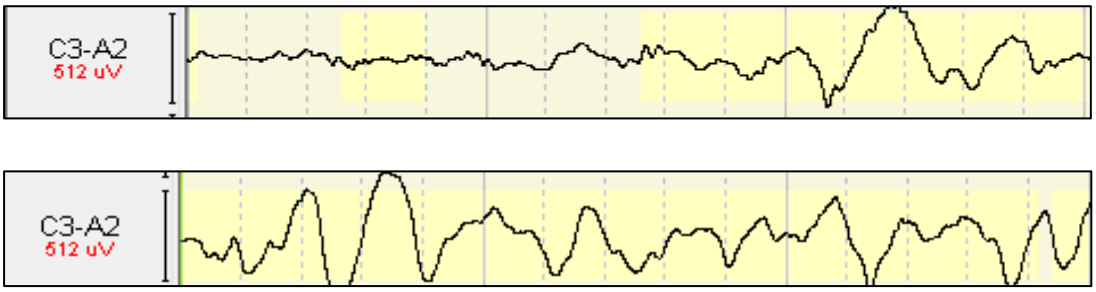


Figure 1.4 Portion of electroencephalogram depicted from an 11-year-old participant during Stage 3 non-rapid eye movement sleep (top) and Stage 4 non-rapid eye movement sleep (bottom)

Rapid eye movement sleep

Similar to wake brain activity, during REM sleep (Figure 1.5) a low-voltage mixed-frequency activity is seen. Alpha activity (8–13 Hz) is prominent during this stage, but has a lower frequency compared to wakefulness. Sequences of 'saw-tooth' waves are sometimes characteristic of this stage (Rechtschaffen & Kales, 1968). This stage occupies about 23% of the total sleep time in children and involves two phases (Novelli et al., 2010). On one hand, the 'phasic' phase of REM is characterised by bursts of rapid, conjugate eye movements, heart and breathing irregularities. On the other hand, the 'tonic' phase is characterised by the absence of eye movements and muscle tone (i.e. muscle atonia).

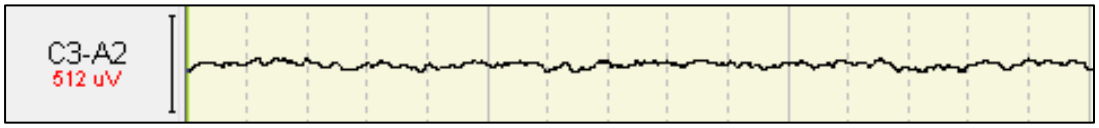


Figure 1.5 Portion of electroencephalogram depicted from an 11-year-old participant during rapid eye movement sleep

The sleep scoring process involves the manual scoring of the sleep stage during an epoch (typically 30-second length) based predominantly on the characteristics described above. Once each epoch is scored a summary of the distribution and length of the sleep stages across the night can be visually obtained—known as 'hypnogram' (Figure 1.6). Normally, sleep cycles begin with NREM sleep and later REM sleep appears. These two periods alternate throughout the night, but the amount of NREM sleep (Stages 3 and 4 specifically) tends to decrease with the progression of the night, while REM sleep increases. The cycling pattern and the electrophysiological features of each stage constitute the 'macrostructure of sleep'.

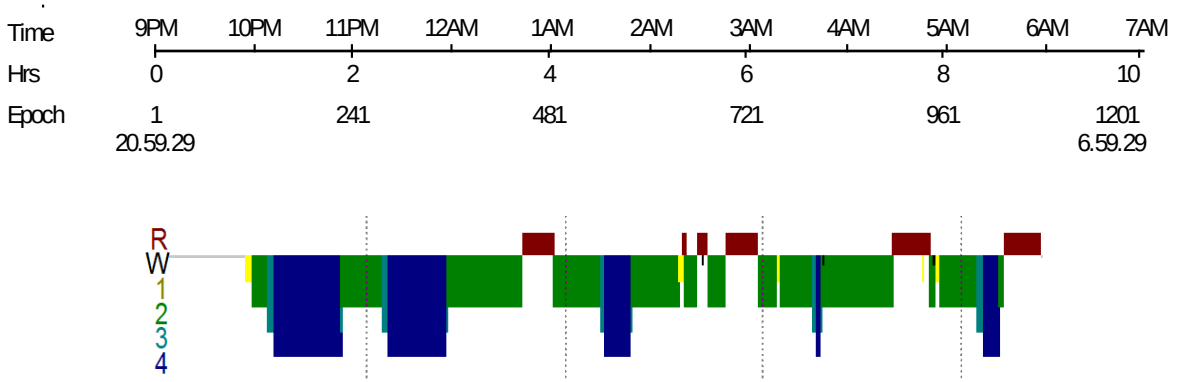


Figure 1.6 Progression of sleep stages across single night in a normal 12-year-old child, using Rechtschaffen and Kales scoring system

Note. Grey line represents wake period, yellow and green symbolises Stages 1 and 2, and light/dark blue Stages 3 and 4 respectively. REM sleep is represented by red. Analysis was conducted in 30-second epochs

Updated scoring and recording rules for polysomnography

In 2007, the American Academy of Sleep Medicine introduced an updated version of the PSG scoring and recording rules (American Academy of Sleep Medicine, 2007). The modifications involve on one hand changes to the existing terminology, as well as to the recording methodology. On the other hand, specifications of arousal, movement and respiratory rules have also been updated. Despite the benefit of those specifications especially when assessing sleep-related events, changes in terminology have generated controversy (Carskadon & Dement, 2011).

Changes in terminology were applied for the different sleep stages. The term W was introduced for wake stage, N for NREM sleep stages, including N1 and N2 instead of Stage 1 and Stage 2; N3 involving the sum of Stage 3 and Stage 4; and R for REM sleep stage. Another change included was to the terms for the recording placements; for example, M1 and M2 instead of A1 and A2. Additional changes involved recommendations for inclusion of frontal EEG electrodes (F3/F4), to be used rather than central locations (C3/C4) for visual sleep scoring; especially of delta waves and K-complexes. The updated scoring rules are indicated for adults and children two months post-term or older (American Academy of Sleep Medicine, 2007).

Changes presented by the academy have not been completely adopted worldwide and concerns have been raised in regard to the consequences that these changes might lead to. Research investigating the differences between the R&K and AASM rules has been conducted in adult and children populations (Novelli et al., 2010). Turning to the impact of the changes in scoring on child sleep parameters the following are to be noted. Novelli, et al. (2010) in a study comparing the impact of R&K versus AASM rules on sleep staging,

revealed that the updated guidelines generally result in an increase in the amount of Stage 1 (N1), a decrease in Stage 2 (N2) and REM (R) and shorter sleep onset latency estimates. They also report that the increased N1 can be explained by the change in scoring of arousals during N2 rules, which result in a lighter stage being scored in the subsequent epoch (i.e. following an arousal during N2 the epoch is marked as N1). In a review of the latest American Academy of Sleep Medicine rules experts from the two main Australian sleep bodies (Australasian Sleep Association and the Australasian Sleep Technologist Association) have advised that Australia would adopt the majority of the new scoring rules, but not all (i.e. technical specifications, visual and arousal rules and respiratory rules) (Pamula et al., 2011). How sleep is measured, and as discussed later, arousals, do impact on the interpretation of findings and complicate the comparisons between studies.

1.1.3. Arousals

An important aspect of assessing sleep quality is the assessment of arousals (Pace-Schott, 2009). Specific criteria have been developed in order to identify and quantify these phenomena on the EEG, including the differences between subcortical activation (i.e. no evident changes on the EEG) and cortical arousals (i.e. evidence of EEG changes) (Grigg-Damberger et al., 2007). It has been noted that the majority of arousals that occur in NREM sleep are preceded by characteristic EEG features such as K-complexes or delta bursts, and these observations have led to alternative methods for analysing arousals, such as cyclic alternating pattern (CAP) analysis, (Terzano, Parrino, Rosa, Palomba, & Smerieri, 2002). Arousals can be secondary to a number of factors, including neurological, respiratory, and environmental. Arousals in children with SDB are secondary to respiratory events which are either cortical in origin (typical of central apnoea syndrome) or as a consequence of upper airway obstruction (typical of OSAS). These abnormalities require the assessment of both EEG and respiratory functioning with PSG.

1.1.4. Polysomnography

PSG is the measurement of sleep, and in addition to EEG, EMG and EOG can also include cardiac electrical activity (electrocardiogram; ECG) and measures of respiration including chest wall movement, oxygen saturation in the blood, nasal airflow and carbon dioxide levels, (Pace-Schott, 2009). An example of an epoch from a PSG recording showing the different variable recorded is given in Figure 1.7. Incorporation of the different respiratory variables during sleep recording facilitated the process of scoring breathing-related sleep problems. In particular, paradoxical breathing and obstruction, changes in the oxygen levels, as well as additional alterations which are used in the diagnosis of SDB.

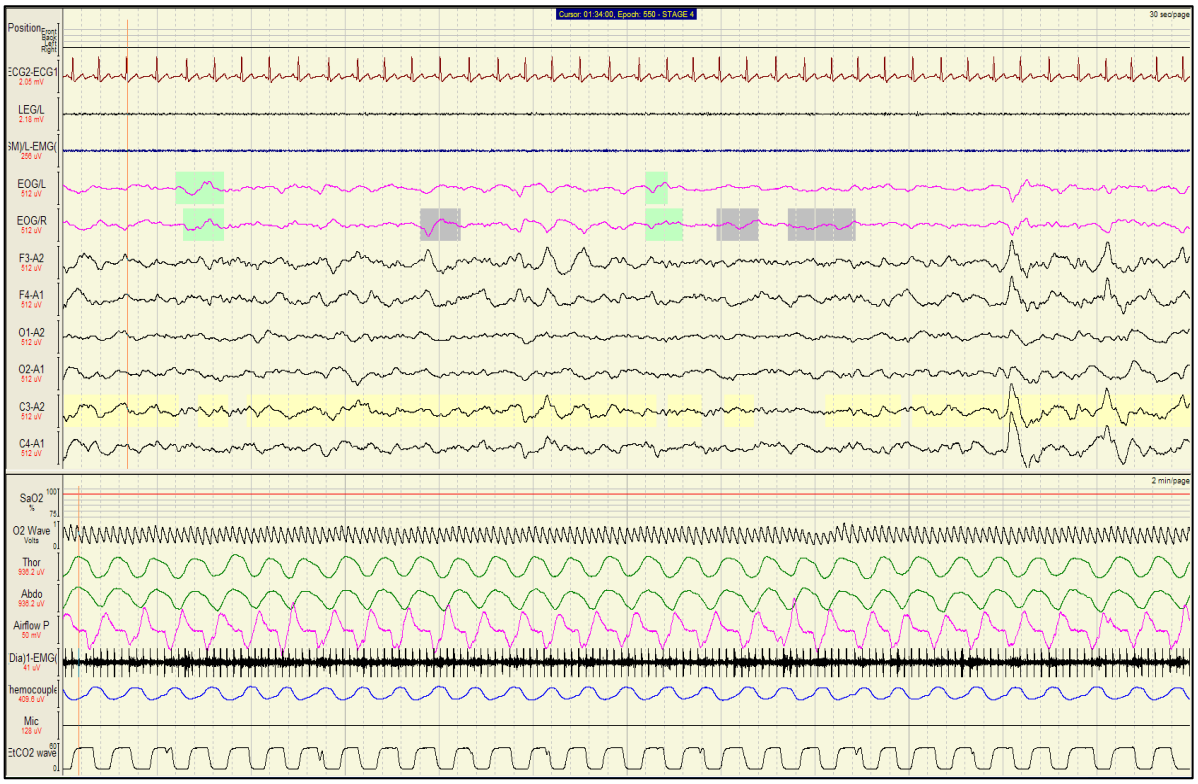


Figure 1.7 Example of a 30-second epoch polysomnography from an 11-year-old participant

Note. Top frame includes: position, ECG, EMG (tibial), EMG (sub-mental), EOG and EEG (e.g. F3−A2, C4−A1). Bottom frame includes: oxygen saturation (SpO_2), respiratory variables (airflow, wall chest movements), microphone and transcutaneous CO_2 level ($EtCO_2$)

Despite the wide application of PSG in adult populations, there is still limited normative data for PSG in children (Scholle et al., 2011). Part of the reason for limited evidence may be explained by the practical difficulty in conducting a child PSG in a laboratory environment. Special considerations have been suggested when assessing sleep in children through PSG, including the use of a child-friendly environment and how technicians approach children; use of such strategies is likely to increase the feasibility of PSG recording of child sleep (Beck & Marcus, 2009).

1.1.5. Alternative measures of sleep and analysis of the electrooculogram

Despite PSG being claimed as the 'gold standard' measure for sleep (Chiner et al., 1999), the expensive cost and time involved have encouraged researchers to find alternative methods for both clinical and research purposes. Moreover, the need for more sensitive ways to explore the phenomena of sleep has led to a growing acceptance of non-traditional methods. From portable devices to mathematical methods of wave analysis, a number of techniques are now available.

Unattended polysomnography

In the same manner that a laboratory PSG records physiological signals while sleeping, portable devices are used to assess sleep architecture including respiratory, cardiac and movement sensors like the traditional PSG. The need for simple but accurate techniques resulted in the development of devices capable of recording signals normally recorded in a normal PSG. Thus, unattended home PSG has gained increased acceptance among researchers and clinicians for more than a decade (Campbell & Neill, 2011).

Home PSG has been widely validated for assessment of SDB, specifically OSAS (Mykytyn, Sajkov, Neill, & McEvoy, 1999). Among adults this method has shown high validity when compared directly to laboratory PSG, and is proposed as an alternative method with similar standards as a normal PSG conducted generally in a laboratory setting (Mykytyn et al., 1999; Zou, Grote, Peker, Lindblad, & Hedner, 2006). Nevertheless, risks of losing signals during the night resulting in poor recordings have been reported, but due to the advance in technologies many of the problems previously seen have been considerably solved (Campbell & Neill, 2011).

Unattended PSG has also been proven to be a successful method when assessing sleep in school-age children (Goodwin et al., 2001). Comparisons between home and laboratory PSG showed that sleep architecture was equivalent between the two methods. Therefore, this method could be beneficial for projects where participants live in remote areas or have limited access to the laboratory facilities; and in other cases this method might allow scientists to have a picture closer to the reality of the participant.

Actigraphy

Less expensive than PSG, actigraphy monitors are small wristwatch-like motion sensors developed to record movement for extended periods, in order to estimate sleep patterns over a period of time (usually one week). The data recorded is transferred to a computer where a predetermined algorithm is used for identification of sleep-wake periods. Actigraphy monitors are usually attached to the non-dominant hand and they had been validated for a wide age range, as well as for participants with and without sleep disorders (Sadeh & Acebo, 2002).

Compared to PSG, actigraphy is suggested to be reliable when determining sleep-wake periods. However, the main concern about this instrument is the low sensitivity to detect wakefulness within sleep periods. Additionally, come concerns are raised regarding the validity of actigraphy in special populations (e.g. people with significant health issues,

elderly, or people with quality-related sleep problems) (Sadeh, 2011). . However, inconsistencies are suggested among sleep-wake transitions; and it is not recommended when precise sleep variables are investigated (e.g. duration of sleep onset). Although actigraphy is recommended for long assessment periods of sleep, it is described as not accurate when the purpose is to diagnose a sleep disorder (e.g. SDB). In those cases, a complete PSG assessment is highly advised because it includes respiratory measures (Middelkoop, Knuistingh Neven, van Hilten, Ruwhof, & Kamphuisen, 1995).

Sleep diaries and questionnaires

A commonly employed method to assess child sleep is parental self-report either using questionnaire or sleep diary. Due to the low cost and high accessibility, these subjective methods provide information about sleep schedules during specific periods of time. Sleep diaries generally provide information on habitual sleep schedules. They contain information from seven consecutive days where detailed times regarding bedtimes, wake times and number of awakenings during the night are reported. In contrast, through questionnaires parents are asked to estimate habitual sleep schedules (Iwasaki et al., 2010). Both questionnaires and sleep diaries have been widely used in different investigations examining normal sleep patterns across different age ranges (Galland, Taylor, Elder, & Herbison, 2012). These methods, however, rely on parental observation, which might constitute a limitation in some cases, especially when precise information is required regarding the child's normal sleep patterns. Limitations on these methods have been previously reported by Iwasaki et al. (2010). They found that compared to actigraphy, parents reported earlier sleep onset times, in sleep diaries, as well as later sleep and end times hence prolonged sleep periods. Therefore, such subjective methods (sleep diaries and questionnaires) can be used however, the aim and the number of participants in a study, the accuracy required need to be considered.

Spectral analysis of the electroencephalogram

Objective analysis of the EEG has been widely used, but minimal changes reported on the EEG macrostructure among patients with breathing-related sleep problems raises the need for alternative methods (Bandla & Gozal, 2000; Chervin et al., 2004). The aim of such techniques has been to find what was not visually seen on the EEG through more sensitive approaches such as spectral analysis of EEG signals. This method has also proven to be useful when demonstrating developmental changes on NREM sleep EEG power among adolescents (Jenni & Carskadon, 2004). Spectral analysis refers to the process where an electrical signal is displayed without processing the signal information and from which can

be extracted power and frequency. Traditional EEG signals are analysed under the function of time (their variation over time); by contrast, spectral analysis measures 'complex signals' as a function of frequency-domains (Brown, 1997).

Cyclic alternating pattern analysis

Evidence showing that there is a slow rhythmic oscillation of the electrical activity in the human brain, especially within the transition from light to deep sleep (i.e. NREM sleep), has led to the emergence of another alternative method to analyse the EEG (Terzano et al., 1985). This oscillation has been termed CAP; which is thought to reflect the 'main expression of sleep microstructure' (Parrino, Ferri, Bruni, & Terzano, 2012). CAP has been identified, therefore, as an alternative method to quantify sleep disruption, generally difficult to be shown by conventional EEG analysis.

In order to identify CAP in the EEG, it is necessary to have sleep stages previously scored (with the normal EEG scoring rules). Additionally, that slow wave activity and sleep spindles must exist to score CAP accurately (Miano, Peraita-Adrados, et al., 2011). CAP is described as a cycle comprising two patterns or phases: an initial Phase A followed by a Phase B (background frequency). While Phase B constitutes the normal slow wave activity characteristic of NREM sleep, Phase A comprises a transient and visible activation (i.e. change in the frequency of the waves) of the EEG. This phase is subdivided in three types: Phase A1, a prominent slow high-voltage frequency (occupying >50%); Phase A2, a mixed slow and rapid frequency(occupying 20%); and Phase A3, a prominent rapid low-voltage frequency (occupying >50%) (Parrino et al., 2012).

Because of the fast low-voltage rhythm, EEG arousals have been associated with the activity seen on the A2 and A3 CAP phases. The high voltage slow wave activation (commonly sequences of K-complexes or delta bursts) that precedes the faster activity is usually not included in the arousal event under the traditional scoring. However, under CAP analysis this slow activity is the initiating part, and it has been suggested as increased readiness of the brain to cortical activation (i.e. the arousal). The relationship between Phases A2/A3 and cortical arousals have raised the hypothesis that these two phases are the expression of disruption during NREM sleep, while A1 would act as a protective mechanism maintaining sleep through the slow activity. Thus, CAP is presented as a periodic phenomenon in NREM sleep that serves as a measurement of sleep stability or instability depending on how it is presented—i.e. whether A1, or A2/A3 are increased (Terzano & Parrino, 2000).

At birth, CAP is described to be almost inexistent, but it increases with age; which is explained by the development seen in voltage, specifically for NREM sleep. Essentially, before 46 weeks of conceptional age CAP activity is not scored and the EEG is characterised by *tracé alternant* combined with high-voltage slow activity. CAP emerges when *tracé alternant* disappears, and usually involves 13% of the total NREM sleep. Additionally, no differences between Phase A subtypes have been observed in infants between one and four-months-old (Miano et al., 2009).

The first year of life is marked by changes in slow-wave activity; thereby changes in CAP are also expected. At this stage, CAP comprises 24% of the total NREM sleep which, as stated before, it is associated with increased slow-wave activity seen during the first years of life. A1 occupies 78% of the total CAP, while A2 and A3 increase from 10% and 4% at 55 weeks of conceptional age, to 14% and 8% respectively (Miano, Peraita-Adrados, et al., 2011).

At pre-school ages, CAP reaches 26% of the total NREM sleep and A1 phases constitute 63% of CAP, followed by 22% A2, and 15% A3. Moreover, A1 phases are periodically distributed in a 20 to 40 second interval (Bruni et al., 2005). In contrast, CAP among school-age children involves 33% of the total NREM sleep with 84% of this as A1, 6% as A2 and 9% A3. This ascending pattern seen in A1 among school-age children is described as the protective mechanism that maintains sleep as opposed to arousals. Thus, sleep across this age group is seen as restorative sleep and perhaps the best sleep throughout the lifespan (Bruni et al., 2002).

With the development of new technologies and the digitisation of signals, more advanced forms of EEG recording have been developed. For example, multiple scalp sites have been used to give a more complete picture of the brain activity during sleep (Dement, 2011). However, these fall outside of the scope of this review and are not discussed.

1.1.6. Sleep development

Substantial change in the timing, organisation and architecture of sleep occur in the first few years of life. A summary of sleep-related milestones at different ages are given below in Table 1.1. Cyclic periods of activity and inactivity are observable in the developing foetus and many of the electroencephalographic features of sleep are recognisable during the periods of inactivity (Kahn et al., 1996; Peirano, Algarín, & Uauy, 2003). Shortly after birth, three distinct sleep stages, labelled active, quiet and indeterminate sleep, can be distinguished with active and quiet sleep stages demonstrating many of the characteristics

of REM and NREM sleep, respectively (Louis, Cannard, Bastuji, & Challamel, 1997). In infants, the cycles between active and quiet sleep occur in periods of between 50 and 60 minutes; which compared to older children are shorter and more frequent (Davis, Parker, & Montgomery-Downs, 2004; McLaughlin-Crabtree, Varni, & Gozal, 2009).

Sleep onset in newborns occurs with active sleep, during this age 50% of the total sleep time is characterised by active sleep, while around 14% is quiet sleep. By three-months-old, approximately 34% to 55% of the total sleep period is characterised by active sleep and 25% to 49% of sleep time in quiet sleep (Davis et al., 2004). By six-months-old, the four NREM sleep stages can be differentiated on EEG, NREM-REM sleep cycling is clearly present and the distribution of sleep stages at night is characterised by greater NREM sleep in the first half and REM sleep in the second half of the night (Coons & Guilleminault, 1982; De Weerd & van den Bossche, 2003; Jenni & Carskadon, 2007). The timing of sleep also changes over infancy with sleep-wake changing from a polyphasic pattern of approximately four hours in duration in early infancy to a triphasic pattern of morning and afternoon naps followed by a major nocturnal sleep period and biphasic sleep pattern in most children of afternoon naps and a major nocturnal sleep period by six-months-old (McLaughlin-Crabtree et al., 2009).

Changes in sleep EEG are especially evident during the first months of life. EEG features unique to sleep such as alpha activity, vertex waves, K-complexes and sleep spindles emerge very early in life (De Weerd & van den Bossche, 2003). Alpha activity typically evident during relaxed wakefulness appears between two and four-months-old with a frequency between 3.5 and 4.5 Hz which increases with age reaching 8–12 Hz after 12 years of age. (Grigg-Damberger et al., 2007). Well-formed sleep spindles are seen by eight to 12 weeks after birth, reaching maximal density and duration around three-months-old (Grigg-Damberger et al., 2007; Jenni & Carskadon, 2004).

Sleep architecture and the timing of sleep continue to change after infancy. Between three and five-years-old most children cease having naps and as consequence the total sleep duration per 24-hour period decreases to about an average of 12 hours (Galland et al., 2012; Jenni & Carskadon, 2007). By six to nine-years-old the NREM-REM cycle length has shortened to the 90–110-minute length seen in adults (Jenni & Carskadon, 2007). Sleep duration continues to gradually decrease over later childhood, especially at the commencement of schooling (Touchette, Mongrain, Petit, Tremblay, & Montplaisir, 2008). Further changes in sleep architecture are evident during adolescence with an increase in

Stage 2 sleep and a decline in SWS (up to 60%), a reduction in the latency to REM onset (approximately 100 minutes) and marked reduction in the EEG voltage (Jenni & Carskadon, 2007; Tarokh & Carskadon, 2009). Changes in the timing of sleep are also evident in adolescence, with teenagers tending to go to bed later and waking later especially on non-school days (Dan & Boyd, 2006; Jenni & Carskadon, 2007).

Table 1.1 Age-related sleep changes in day-sleep and night-sleep

Age	Sleep Duration	Milestone
1–3 months	14/15 hours	Sleep occupies greater part of time, first spindles appear
6–9 months	14 hours	Sleep mostly at night; NREM stages differentiated
12 months	13 hours	Melatonin production increases
3 years	12 hours	Night sleep fully established
5 years	11 hours	Naps disappeared, reduction of REM sleep
10 years	9/10 hours	Circadian cycle well established
>12 years	≤9 hours	Sleep phase delayed

Note. Source of data: previous published literature (Coons & Guilleminault, 1982; Dan & Boyd, 2006; Galland et al., 2012; Iglowstein, Jenni, Molinari, & Largo, 2003; Jenni & Carskadon, 2007)

Despite all the evidence that indicates that sleep is mainly regulated by neurophysiological mechanisms (i.e. maturational processes), caution should be exercised when attempting to give indications to what is considered normal regarding sleep patterns because of the psychosocial context behind sleep in children (Jenni & Carskadon, 2007). Differences in culture might play an important role in the amount and quality of sleep. Therefore when sleep is evaluated, social characteristics need to be taken into account when sleep patterns are investigated.

1.1.7. Regulation of sleep

The rhythmic expression of sleep/wake activity is thought to be regulated by two processes: Process S (homeostatic system) and Process C (circadian system) which has been termed as the 'two-process model of sleep (Borbély, 1982). He proposed in his model that these two independent regulatory processes interact and regulate the initiation, maintenance and strength of the sleep period. Process S refers to the homeostatic process that maintains a balance between wakefulness and sleep, which involves an increased pressure for sleep (i.e. the need for sleep), which depends on the length of previous wakefulness; and its decay during the sleep opportunity. Slow wave activity is believed to be indicative of the level of intensity when sleeping, and this EEG activity has been found to be affected by the degree of preceding wakefulness (i.e. the more wakefulness, the higher slow wave activity seen). The development of the homeostatic process in early life is not fully understood. Nevertheless, there are some indications that slow wave activity

responds to sleep loss at 10-years-old in a similar way that it is seen in adults. In contrast, during infancy the homeostatic sleep process is suggested to run faster compared to older children and, especially, to adults, with shorter periods of wakefulness resulting in higher levels of Process S (Jenni & Carskadon, 2007).

The other process that regulates sleep/wake activity is Process C (circadian rhythm). This rhythm it is synchronised with the natural light-dark cycle oscillating in about a 24-hour period. In mammals, this circadian rhythm is generated by the suprachiasmatic nuclei (SCN) in the hypothalamus, which have intrinsic rhythmicity regulated by light exposure transduced through retino-hypothalamic pathways from specialised retinal cells to the SCN. The SCN is described as a 'pacemaker' for other internal systems and processes including sleep (Achermann & Borbély, 2011). The circadian system is not fully developed until about six months of age (Kahn et al., 1996). Further developmental changes in Process C are not well explored but anecdotal evidence and the variability reported in sleep timing would suggest that the timing of sleep and wake are more rigid in younger compared to older children.

1.2. Pathological sleep

A good night's sleep can be essential for adequate psychological and physiological functioning during the day. However, external and internal factors can affect the normal sleep patterns at different ages, and the morbidity associated with disrupted sleep has been widely documented in the literature. The following sections examine the literature concerning sleep disorders in children, and specifically respiratory-related sleep disorders (i.e. SDB). The first section presents a brief description of the different sleep disorders in children, followed by the general characteristics of SDB. Subsequent discussion concentrates on snoring in children, which is the primary focus of this thesis. This latter section reviews the different methods used to assess snoring with emphasis on parental self-report questionnaires. Later, the epidemiology of snoring is discussed (prevalence and associated factors), and also the morbidity associated with snoring in childhood. The chapter concludes with a review of the literature that has evaluated the natural history of snoring in children.

1.2.1. Sleep disorders in children

Diagnostic criteria for the different disorders that compromise sleep are defined in the second version of the International Classification of Sleep Disorders (ICSD-2) (American Academy of Sleep Medicine, 2005). These criteria involve more than 80 sleep disorders,

which are grouped under eight major categories (Figure 1.8). A comprehensive review of adult sleep disorders has been presented by Kryger, Roth, and Dement (2011), and review of the paediatric sleep disorders by Sheldon, Ferber, and Kryger (2005).

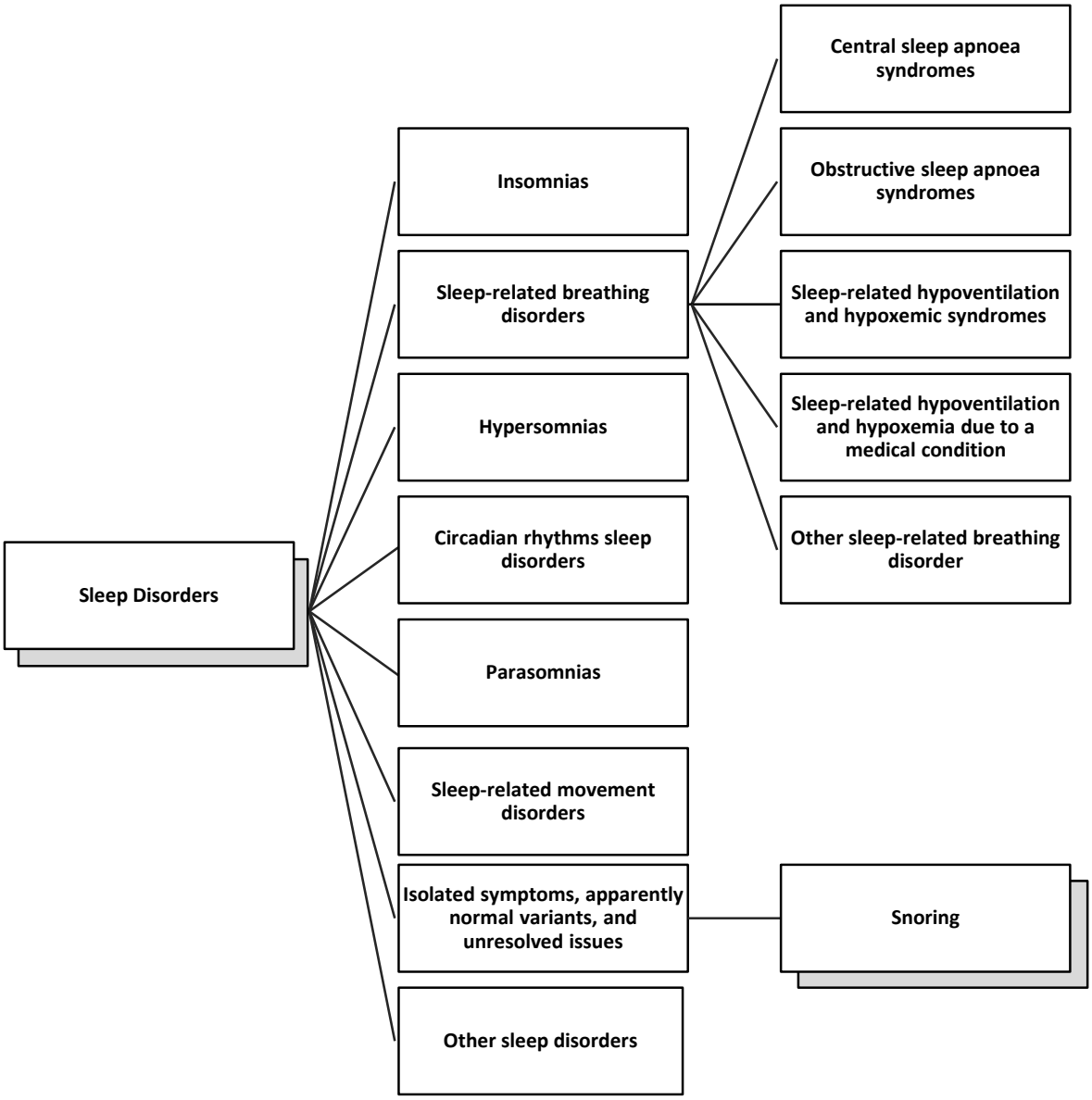


Figure 1.8 Major International Classification of Sleep Disorders categories of sleep disorders

Note. For purposes of the current study, main emphasis has been given to sleep-related breathing disorders and snoring

Although the ICSD-2 covers an extensive number of sleep problems, criteria for these are not always met among children (Meltzer & Mindell, 2008). A number of approaches have been used to define abnormal sleep in children (Owens, 2008). These include: (1) whether the sleep meets developmental norms; (2) or cultural norms; (3) whether parents perceive that their child's sleep is abnormal (i.e. is it considered a problem or not); (4) the daytime consequences; and (5) if the sleep patterns are considered abnormal by the child and other observers other than parents. A limitation of many studies is that the exact nature of the

sleep abnormality is poorly defined. For example, the terms ‘bad’ and ‘poor’ sleepers are repeatedly used in the literature to cover a range of sleep abnormalities such as the inability to fall asleep, frequent awakening after sleep onset, increased arousal durations and shortened sleep (Fichten, Creti, Amsel, Bailes, & Libman, 2005; Fichten et al., 1995; Libman, Creti, Amsel, Brender, & Fichten, 1997; Morgan, Healey, & Healey, 1989; Sadeh, Raviv, & Gruber, 2000; Shackell, Jones, Harding, Pearse, & Campbell, 2007).

While adults may seek professional help if they have problems with their sleep, children on the other hand cannot always report or even recognise their sleep problems and the onus falls on parents to recognise that their child’s sleep pattern is a problem. For this reason clinical and research evaluation of sleep problems in children typically rely on parental report as the main source of information. Thus, the definition of sleep problems is not only subjective but diverse (Owens, 2008).

1.2.2. Prevalence of sleep problems in children

Although a detailed analysis of the different sleep problems across childhood is beyond the scope of the current thesis, a brief overview in the prevalence of different sleep problems in the general community suggests that sleep complaints may be common in children. For example, a community-based study by Laberge, Tremblay, Vitaro, and Montplaisir (2000) conducted in Canada indicated that from a sample of 1353 children 78% had experienced at least one childhood parasomnia. In a different study by Liu et al. (2005) 21.2% of 5979 Chinese children (two to 12 years) were reported to have any symptom related to sleep disorders. The most common sleep disorders included bruxism (6.5% of the total sample), frequent snoring (5.6%), restless sleep (5.0%) and sleep talking (4.9%). In Israel, 17.9% of school-age children were reported to be ‘poor sleepers’. This group included children who either spent more than 10% of the night after sleep onset awake, or waking ≥3 times per night on average for at least five minutes each time (Sadeh et al., 2000).

Canadian data for children between 2.5 and six-years-old (Petit, Tremblay, Boivin, & Montplaisir, 2007) showed that 84% of children included in the analysis (n/N = 879/1041) were reported to sleep talk by their parents, 61% (n/N = 599/988) to have frequent night wakings, 46% (n/N = 484/1062) bruxism, 40% (n/N = 415/1043) sleep terrors, 33% (n/N = 345/1045) sleep-onset difficulties, 25% (n/N = 284/1137) enuresis, 14% (n/N = 150/1035) somnambulism and 9% (n/N = 971058) rhythmic movements (e.g. body-rocking and head-banging). Also in Canada, Laberge et al. (2000) found that in children three to10-years-old, the most common sleep disorder was sleep talking (56%, n/N = 437/787), followed by

restless legs (32%, n/N = 307/967), sleep bruxism (28%, n/N = 200/712), and the least reported was sleepwalking (14%, n/N = 116/840).

On the other hand, data from clinically-referred participants (Blunden et al., 2004) suggested that in a group of 361 Australian children attending their general practitioner, 23.6% were reported to have a sleep problem which reached clinical significance in a standardised clinical sleep disturbance scale. Sleep problems were distributed as follows: 24.1% had sleep initiation and maintenance problems, 19.7% sleep-wake transition difficulties, 14.5% arousal disorders, 14.1% sleep breathing problems, 13.3% excessive sleepiness and 8% to sleep hyperhidrosis. Although a high proportion of children had sleep problems, only 4.1% of cases were discussed during consultation. Swedish data suggest that 6.7% of parents of school-age children consulted healthcare services because of their children's sleep problem. Difficulties included falling asleep, reported in 5.6% of the children; snoring in 7.7%; night arousals in 15.5%; bedwetting in 5.3%; and nightmares in 3.1% (Smedje, Broman, & Hetta, 1999). Moreover, data from a more recent study by Meltzer, Johnson, Crosette, Ramos, and Mindell (2010) retrospectively examined medical records of 154,957 patients between 0 and 18 years attending pediatric centres in the United States U.S. Results revealed that 3.7% of children had a formal diagnosis for a sleep disorder—based on criteria by the International Classification of Diseases, ninth revision. Despite that sleep complaints appear to be a common issue for children in the community, their existence may be underdiagnosed during medical consultation, as well as underreported by parents. This pattern is seen for specific sleep problems such as SDB (Blunden et al., 2003), which raises questions as to why some children who experience sleep difficulties are referred to clinics while others not.

In the last two decades the importance of respiratory-related sleep problems (e.g. SDB), has been recognised not only because of its high childhood prevalence but also because of the increasing understanding of its morbidity, which affects daytime functioning (Beebe, 2006) cardiovascular health (Gozal, McLaughlin, Sans-Capdevila, Witcher, & Kheirandish-Gozal, 2007; Horne et al., 2011) and quality of life (Mitchell & Kelly, 2006). However, the effect of non-respiratory sleep problems as a cause for impaired daily performance is also recognised, because they can disrupt sleep in children and may be concurrent to respiratory disturbance (Blunden & Beebe, 2006). Shakespeare (1564–1616) recognised that when 'sorrows come they do so not as single spies but in battalions' and so it may be with children's sleep problems. Community-based data (Petit et al., 2007) suggested that concurrent sleep disorders were commonly seen in children (2.5 to six

years), with 56.3% of children reported to have night terrors reporting frequent night wakings. Laberge et al. (2000) in their study, also indicated association between different sleep problems including sleepwalking and sleep talking, sleep talking and bruxism, and sleep walking and night terrors.

1.2.3. Respiratory-related sleep disorders

The upper airway undergoes structural and functional changes during childhood. While the lymphoid tissue rapidly increases, the upper airway structure gradually grows; hence adenoids and tonsils are larger relative to the airway space, particularly in children between two and eight years (Marcus, 2001).Evidence shows that children have a higher ventilatory drive compared to adults. However, during sleep, and mainly REM sleep, their respiratory rate normally decreases; while the upper airway resistance increases. Given the reduced ventilator drive central apnoeas are considered common in infants and children, while obstructive apnoeas are considered a much less common clinical problem, but one that is increasingly recognised in young children (Marcus, 2001). Thus, the different breathing patterns that can be recognised include normal breathing and apnoea of either central or obstructive component (Figure 1.9). These alterations seem to be a threat to the body's vitality, and its response is to arouse in order to restore the muscle tone triggering normal breathing.

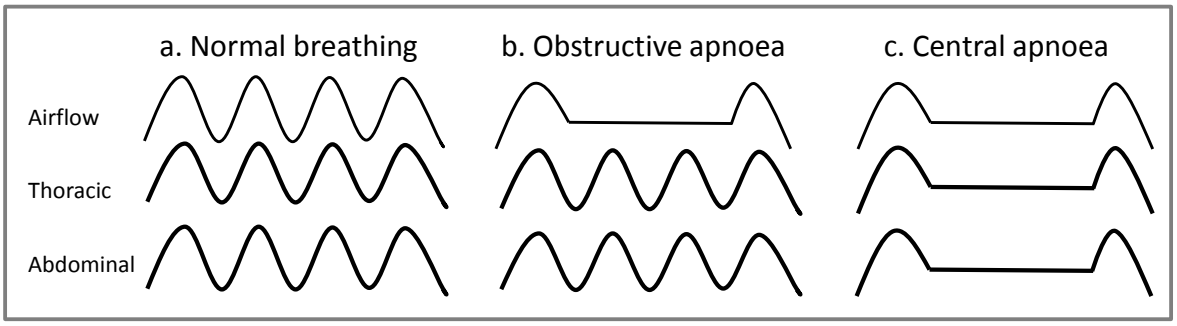


Figure 1.9 a. Normal breathing; b. Obstructive apnoea syndrome: no airflow accompanied by continuous effort and c. Central apnoea: no airflow in absence of respiratory effort

Despite limited normative data regarding respiratory patterns among normal children, respiratory patterns during PSG consistently indicate that central apnoea normally occurs in children (Traeger et al., 2005; Uliel, Tauman, Greenfeld, & Sivan, 2004; Verhulst et al., 2007), particularly in young children (Montgomery-Downs, O'Brien, Gulliver, & Gozal, 2006). The presence of central apnoeas in infants have been described as a risk factor for Sudden Infant Death Syndrome (Task Force on Sudden Infant Death Syndrome, 2011). However, a combination of obstructive and mixed apnoeas have also been reported to be

more likely to explain deaths related to this syndrome in infants (Kato et al., 2001). Contrary to central apnoea seen among young children, both obstructive apnoea and hypopnoea events are found to be unusual among normal children and adolescents (Traeger et al., 2005; Uliel et al., 2004; Verhulst et al., 2007).

1.2.4. Sleep-disordered breathing in children

SDB involves a continuum of upper airway resistance from PS (i.e. without disruption of sleep architecture with arousals or hypoxia), to upper airway resistance (where arousals from sleep secondary to obstruction disrupt the normal sleep pattern), to OSAS (Figure 1.10). The prevalence of moderate SDB objectively assessed has been reported to be 1.2%, 25.0% for mild SDB, and 15.5% for primary snoring (Bixler et al., 2009). In children, SDB is generally thought to be caused by hypertrophy of the adenoids and tonsils in children (Chervin et al., 2006; Guilleminault, Li, Khramtsov, Palombini, & Pelayo, 2004; Hodges, Bloomfield, Coulas, & Giordani, 2008), but factors including neuromuscular control and craniofacial characteristics have also been recognised as important for the development of this condition (Gozal, 2008; Urschitz, Brockmann, Schlaud, & Poets, 2010). For purposes of this thesis, a main emphasis will be given to PS and only a brief description is presented for more severe forms of SDB.

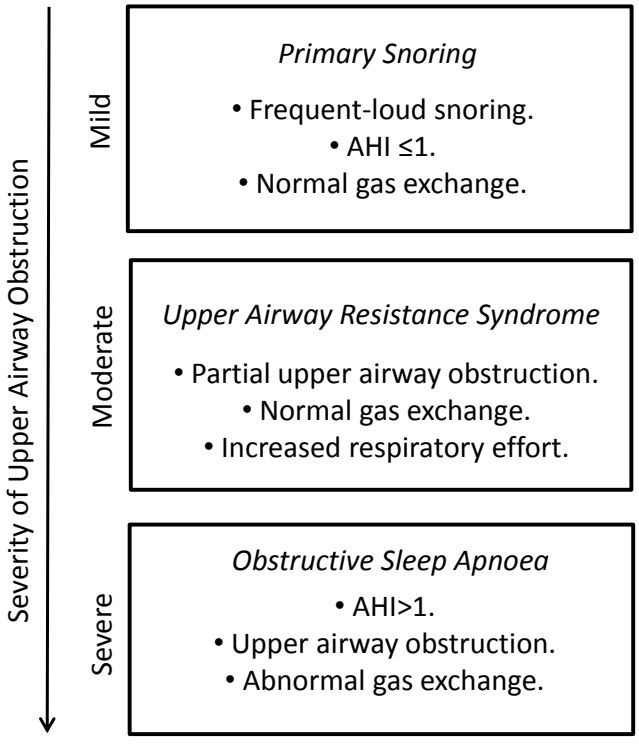


Figure 1.10 Sleep-disordered breathing spectrum: increasing in upper airway obstruction (general characteristics). Adapted from information reported on Katz (2005)

At the severe end of SDB spectrum, OSAS is characterised by periods of partial or complete airway obstruction, continued abnormal breathing effort, gas exchange abnormalities, hypoxia, hypercapnia, and sleep fragmentation (Brooks, 2005; Guilleminault et al., 2004; Katz & Marcus, 2005b; Leong & Davis, 2007; Stradling & Davies, 2004). Based on the apnoea-hypopnoea index (AHI) children are typically subdivided into mild OSAS (AHI 1–4), moderate OSAS (AHI 5–10) and severe OSAS (AHI >10) (Brooks, 2005; Katz & Marcus, 2005b; Leong & Davis, 2007). OSAS in children has been associated with hyperactivity; inattention; neurocognitive deficits, such as verbal working memory and verbal fluency problems, as well as decreased general intelligence, and some evidence of neuronal damage in the frontal cortex and hippocampus; and cardiovascular alterations (Gozal, 2008; Gozal, Kheirandish-Gozal, Bhattacharjee, & Spruyt, 2010; Halbower et al., 2006).

In the continuum of upper airway resistance, an intermediate condition is Upper Airway Resistance Syndrome (UARS). UARS is characterised by partial airway obstruction, without gas exchange abnormalities, occurrence of increased respiratory effort (i.e. intrathoracic pressure alterations) and sleep fragmentation (Brooks, 2005; Leong & Davis, 2007; McColley, 2005). The gold standard for diagnosing UARS is esophageal pressure measurement. However, because of its invasive nature it is not easily tolerated, especially by children, and as a consequence the disorder is not well described (Bao & Guilleminault, 2004).

Primary snoring

At the mild end of the SDB spectrum is PS, which was initially believed to be a relatively harmless condition in children. However, studies have shown that this condition may not be as harmless as previously thought with there now being accumulating evidence that daytime functioning is impaired in children with PS, mainly in studies which have examined children recruited from clinical settings (Beebe, 2006). Although most studies indicate some level of neurocognitive deficits, their results are inconsistent. Mixed findings have been found across investigations, with some studies reporting similar neurocognitive performance in children with SDB compared to controls (Cai et al., 2013; Calhoun et al., 2009). Several terms are used to denote the sound that is produced in the upper airway during inspiratory expiratory and/or inspiratory breathing while sleeping including ‘snoring’, ‘habitual snoring’, ‘frequent snoring’ and ‘simple snoring’ (Li & Hoffstein, 2011). By definition PS does not alter the macrostructure of sleep, but there is a paucity of quantitative EEG studies in children with PS and more subtle EEG changes may be evident

(Chervin, Fetterolf, Ruzicka, Thelen, & Burns, 2009). PS is characterised by mild levels of upper airway obstruction and is defined by frequent (nightly) loud snoring with normal gas exchange; and the absence of hypoventilation, dips in oxygen blood levels (hypoxemia), or sleep fragmentation (Brooks, 2005; Leong & Davis, 2007; McColley, 2005). A general profile of a child with PS on PSG will by definition have an AHI < 1 per hour, arterial oxygen saturation (SpO_2 Nadir) >92%, oxygen desaturation less than 3%, and end-tidal arterial carbon dioxide partial pressure ($P_{ET}CO_2$) ≤ 53% (Brooks, 2005; Guilleminault et al., 2004; Katz & Marcus, 2005b; Marcus, Hamer, & Loughlin, 1998; Uliel et al., 2004). Generally, an increased risk for habitual snoring is explained by differences in gender, weight status and factors regarding environmental and health characteristics (Lumeng & Chervin, 2008). Additional information regarding factors associated with snoring are provided later in this chapter.

1.2.5. Assessment of snoring in children

At present, standardised and universal criteria have not been established to quantify snoring. In addition to snoring, standardised and universal criteria based on clinical outcomes have also not been well established for SDB and based on inconsistent results. Therefore, classification criteria vary widely. Typically, a combination of objective sound recording measures and subjective report are mostly used when assessing snoring (Lumeng & Chervin, 2008; Montgomery-Downs, O'Brien, Holbrook, & Gozal, 2004). For adults, a bed partner is the one who usually provides information about the frequency and quality of snoring. This is typically confirmed with PSG in both clinical and research studies. However, in the case of children, parents are the informants about their child's snoring and, while PSG is used in clinical studies, by contrast a wide variety of techniques have been used in research studies in addition to PSG including parental self-report on questionnaire, sound analysis and video recording.

Sound recording

The majority of portable and in-laboratory sleep systems include the use of a microphone in order to record sound frequency during the night, and specifically the presence of snoring. A baseline sound trace is established which then shows in decibels (dB) any variations in the baseline trace is generated by the change in pitch of snoring and these are displayed in graph form. Additionally, the changes in the trace can also be manually identified by listening to the sound directly in order to confirm that the sound is a snoring sound and no other noises are present in the background (Gill, Schaughency, Gray, & Galland, 2012). Generally with sound recording no further analysis is conducted, other

than quantifying the amount (i.e. length of snoring periods) of snoring during the night. Furthermore, there is no established range for sound baseline trace and due to differences across laboratories this can vary from one place to another. For example, some researchers estimated that the ambient sound baseline at their laboratory was 40.8 dBA and sounds exceeding this had to be inspected in order to define snoring (Furukawa et al., 2010). In contrast, other group of researchers did not defined a baseline level, but indicated that sounds exceeding 60 dB were snoring-related sounds (Cathcart, Hamilton, Gibson, & Wilson, 2010).

Acoustic analysis

Acoustic analysis techniques have been developed in order to define more accurately the acoustic properties of the sound which might be related to a specific area of obstruction; hence facilitate the identification of SDB (Beck, Odeh, Oliven, & Gavriely, 1995). This method involves analysis of the acoustic properties in the time and frequency domains, and mathematical models of the snoring waveform are developed to aid analysis of the traces. Fiz et al. (1996) compared individuals with OSAS with those who did not have the condition, but only snored. A spectral analysis of the snoring sound was conducted for all participants and findings revealed the existence of two patterns that differed between groups (OSAS vs. primary snorers) by a determined frequency and the presence/absence of harmonies. In a more recent study by Hara, Murakami, Miyauchi, and Yamashita (2006) a comparison between similar types of groups was conducted using a multidimensional voice program to analyse snoring sound. Specific sound characteristics involving frequency, harmony, phonation and power of the sound spectrum were measured. Similarly to (Fiz et al., 1996), differential patterns were found between the groups, particularly higher amplitudes for a number of the characteristics measured (e.g. higher peak frequencies). Given that acoustic analysis of the snoring sound provides a more accurate description of this phenomenon, there is a call for more reliable methods that could aid the SDB diagnosis (Pillar, Etzioni, & Katz, 2012). It has yet to be established in children.

Report by sleep technician

Similar to parental observation, the presence of snoring can be reported by technicians during overnight PSG. Although there are no objective criteria and guidelines, this method is widely used when assessing SDB in children (Calhoun et al., 2009; Smedje, Broman, & Hetta, 2001). Due to direct observation throughout the night, sleep technicians are in a position to report snoring. However, this method lacks standardisation and may not represent the pattern of snoring in the home. In the latter case, although not well studied,

preliminary evidence suggests that the agreement between technician-report and parental self-report is not high with parental rather than technician-report being more predictive of obstruction (Montgomery-Downs et al. (2004). Because children spend the majority of 'sleep time' at home, parents or carers are likely to have a more realistic appreciation of the prevalence and severity of any snoring. Factors such as the presence of a first-night effect and night-to-night variability that may impact on the reliability of a single night of technician-reported snoring have yet to be systematically quantified (Gill, Schaughency, Gray, et al., 2012; Scholle et al., 2003). A consensus remains to be established as to whether the snoring sounds heard overnight are representative of frequent snoring and how best snoring may be quantified (e.g. a determined proportion of snoring episodes relative to the total sleep time during PSG).

Self-report questionnaires and the prevalence of snoring

The majority of research investigating habitual snoring has relied on parents or carers' ability to assess frequency and loudness. This information is usually acquired through self-report questionnaire and less often interview (Castronovo et al., 2003; Owens, Spirito, & McGuinn, 2000). Although PSG is the standard tool for objectively diagnosing SDB (McLaughlin-Crabtree et al., 2009), a variety of questionnaires have been designed and standardised to assess snoring (and other related symptoms of SDB) (Lumeng & Chervin, 2008). Questionnaires have proven reliable for identifying severe SDB, but are less sensitive at the mild end of the spectrum (Chervin, Hedger, Dillon, & Pituch, 2000). The difficulty of clinically distinguishing between mild and more severe degrees of SDB on history has been previously highlighted by Carroll, McColley, Marcus, Curtis, and Loughlin (1995). In order to address these types of limitations, Montgomery-Downs et al. (2004) evaluated whether the addition of a history of sleep-wake behaviours improved the sensitivity of the questionnaire. These additional behaviours were found to be useful when predicting SDB, especially in older children. Due to the amount of time that parents or carers spend with children it is important to include their observations when examining snoring in children. However, it is fundamental to corroborate the accuracy of these observations not only with objective measures like PSG, but also to help develop a unitary the definition of habitual snoring which is highly variable across studies. A comprehensive SDB review by Lumeng and Chervin (2008) indicated that one of the main difficulties when comparing studies that have relied on parental self-report questionnaires is the variability of the questions used to assess snoring.

The findings from studies with prevalence of snoring obtained through parental self-report questionnaire are detailed in Table 1.2. The majority of these studies were cross-sectional, and only four were longitudinal in design (Anuntaseree, Kuasirikul, & Suntornlohanakul, 2005; Bonuck et al., 2011; Löfstrand-Tideström & Hultcrantz, 2007; Urschitz et al., 2004). In addition, the majority of the studies recruited participants from community settings, and only three studies recruited participants from clinical settings (Archbold, Pituch, Panahi, & Chervin, 2002; Kulnis, Nelson, Strohl, & Hans, 2000; Montgomery-Downs et al., 2010).

The nature of the questionnaires varied across studies. Most of the studies (n = 13) used purposed-design questionnaires (Alexopoulos et al., 2006; Bonuck et al., 2011; Chng, Goh, Wang, Tan, & Ong, 2004; Ferreira et al., 2000; Kalra et al., 2006; Kara, Ergin, Koçak, Kiliç, & Yurdakul, 2002; Kargoshaie, Najafi, Akhlaghi, Khazraie, & Hekmatdoost, 2009; Kuehni, Strippoli, Chauliac, & Silverman, 2008; Löfstrand-Tideström & Hultcrantz, 2007; Montgomery-Downs & Gozal, 2006; Smedje et al., 1999; Umana et al., 2007); five used validated questionnaires (Archbold et al., 2002; Li, Au, So, et al., 2010; Li, Jin, et al., 2010; Montgomery-Downs et al., 2010; Urschitz et al., 2004); seven modified or reduced validated questionnaires (Corbo et al., 2001; Corbo, Fuciarelli, Foresi, & De Benedetto, 1989; Gill, Schaughency, & Galland, 2012; Liu et al., 2005; Liukkonen, Virkkula, Aronen, Kirjavainen, & Pitkäranta, 2008; Rosen et al., 2004; Zhang, Spickett, Rumchev, Lee, & Stick, 2004); seven used questionnaires developed from clinical guidelines by Carroll et al. (1995) and Brouillette, Fernbach, and Hunt (1982), Brouilette et al. (1984); five used questionnaires adapted from a previous questionnaire (Stradling, Thomas, Warley, Williams, & Freeland, 1990); three used questionnaire previously developed by Gozal (1998); three used The Tucson Children's Assessment of Sleep Apnea (TuCASA) questionnaire (Goodwin et al., 2003), but one translated it to Cantonese (Ng et al., 2005), and another to Portuguese (Petry, Pereira, Pitrez, Jones, & Stein, 2008); and four studies used a single question to assess snoring (Kelmanson, 2000; Piteo, Lushington, Roberts, van den Heuvel, et al., 2011; Tafur et al., 2009; Teculescu, Caillier, Perrin, Rebstock, & Rauch, 1992).

Table 1.2 highlights the variability in the definition of habitual snoring across studies. Some studies for example, refer to habitual snoring as 'snoring most nights' (Anuntaseree, et al., 2005; Anuntaseree, et al., 2001) while other studies referred to habitual snoring as 'snoring often or always' (Alabi et al., 2012; Arman et al., 2005; Corbo et al., 2001; Ersu et al., 2004; Kuehni et al., 2008; Tafur et al., 2009), others use 'snoring frequently'(Li, Au, So, et al., 2010; Liu et al., 2005), others use 'always' (Bonuck et al., 2011), and others are

more specific '≥ 3 nights per week'(Kalra et al., 2006; Kargoshaie et al., 2009; Liukkonen et al., 2008; Montgomery-Downs & Gozal, 2006; Montgomery-Downs, Jones, Molfese, & Gozal, 2003; Montgomery-Downs et al., 2010; Piteo, Lushington, Roberts, van den Heuvel, et al., 2011; Sogut et al., 2005; Sogut, Yilmaz, Dinc, & Yuksel, 2009). Difference in the response keys may have an impact in the prevalence estimates.

Along with the variability in the definition, there is also great variation in the way in which the question about snoring has been asked. For example, in some studies the authors have asked parents to report the frequency of snoring in the past week (Ng et al., 2005), while other studies have asked the parents to report snoring in the past month (Rosen et al., 2003), in the past six months (Kaditis et al., 2004), or in the past 12 months (Liu et al., 2005). Additionally, the majority of studies in Table 1.2 examined snoring using a Likert Scale; however, there a several inconsistencies in the way in which snoring frequency has been defined. Some studies have defined 'rarely' snoring as 'once a week' (Montgomery-Downs & Gozal, 2006), while in another study (Li, Au, Ng, et al., 2010) 'rarely' was considered '0–1 nights per month'. Other studies have not used quantified Likert Scale responses (Lumeng & Chervin, 2008), for example, habitual snoring has been defined as 'on most nights' (Ali, Pitson, & Stradling, 1993).

From the 46 studies included in the table, 15 studies were conducted in European countries; 13 in Asia; 10 in North America, particularly the U.S.; three in Oceania (two from Australia and one from New Zealand) and three in South America. When examining the studies based on their location, studies that were conducted in South America reported high snoring prevalence (15.1%, 18% and 27.6%), while those from Asian countries reported the lowest prevalence levels (e.g. 2.4%–4% with a highest prevalence reported of 12%). Studies from European countries also reported low snoring prevalence, but not as low as Asian studies (3.6% lowest to 12.1% as highest). The two African studies had contrasting prevalence rates (7.5% vs. 19.1%). Similarly, four of the studies conducted in the U.S. reported prevalence rates from 5.3% to 11% and the other six reported prevalence from 15% to 22%. Finally, the three studies conducted in Oceania reported close prevalence rates (12%, 11.3% and 15.2%).

When the nature of the questionnaire was examined according to the location where the research was conducted, five Asian studies used questionnaires developed from similar clinical guidelines. Purposed-designed questionnaires were more common among European studies (n = 7), while variability of questionnaires were used in studies from the

U.S. (e.g. validated questionnaire, purposed design and modified version of validated questionnaire). A limited number of studies from Africa, Oceania and South America were included in the table; hence comparisons are restricted.

Table 1.2 Details of large studies examining snoring in children assessed by parental self-report questionnaire organised by location

First author (Year)	Country	Sample size	Design	Nature of question/questionnaire	Question used to define habitual snoring (possible responses)	Prevalence (%)
Umana (2007)	Nigeria	469	CS	Purposed-design, pre-tested semi-structured questionnaire.	Question not specified. (Never; some nights, <3 nights/week; most nights, >3 nights/week; and every night)	7.5
Alabi (2012)	Nigeria	909	CS	Purposed-design questionnaire following previous guidelines by Brouillette et al. (1982, 1984), and Carroll et al. (1995).	Question not specified (Never, occasional, often, always).	19.1
Kara (2002)	Turkey	1211	CS	Purposed-design questionnaire regarding oropharyngeal symptoms.	Question not specified. (Never, occasionally, often and every night)	2.4
Sogut (2005)	Turkey	1198	CS	Purposed-design questionnaire following previous guidelines by Brouillette et al. (1982, 1984), and Carroll et al. (1995).	'Does your child snore during sleep?' (Never; seldom, ≤ 1/week; sometimes, twice/week; and always, ≥ 3 times/week)	3.3
Sahin (2009)	Turkey	1164	CS	Questionnaire previously used by Ersu et al. (2004), who had used guidelines by Brouillette et al. (1982, 1984), and Carroll et al. (1995).	Question not specified. (Never, seldom, occasionally, frequently and almost every day)	3.5
Sogut (2009)	Turkey	1030	CS	Purposed-design questionnaire following previous guidelines by Brouillette et al. (1982, 1984), and Carroll et al. (1995).	'Does your child ever snore? (Never, occasionally, often, always)'	4.0
Liu (2005)	China	6600	CS	Epidemiologic survey questionnaire from an Australian paediatric sleep centre translated into Chinese.	Question not specified: presence of frequent snoring. (yes/no)	5.6
Chng (2004)	Singapore	11114	CS	Purposed-design questionnaire administered in 4 different languages, based on parents' preference.	'Does your child snore during sleep? (Yes/no); How often does the snoring occur? (Never, occasionally, frequently, constantly)?'	6.1
Arman (2005)	Turkey	286	CS	Purposed-design questionnaire following previous guidelines by Brouillette et al. (1982, 1984), and Carroll et al. (1995).	Question not specified (Occasionally, often, and always).	7.0
Ersu (2004)	Turkey	2147	CS	Purposed-design questionnaire following previous guidelines by Brouillette et al. (1982, 1984), and Carroll et al. (1995).	Question not specified (Never, occasionally, often, always).	7.0
Li, A (2010)	China	6349	CS	Validated questionnaire (HK-CSQ).	Question not specified. (Never; rarely, 0-1 night/month; sometimes, 1-2 nights/month; often, 1-2 nights/week; and frequenty, ≥ 3 nights/week)	7.2
Anuntaseree (2005)	Thailand	755	L	Purposed-design questionnaire.	'Does your child snore at night? (Never, only with colds, occasionally, most nights)'	8.5

First author (Year)	Country	Sample size	Design	Nature of question/questionnaire	Question used to define habitual snoring (possible responses)	Prevalence (%)
Anuntaseree (2001)	Thailand	1008	CS	Reduced version of a previous questionnaire used by Ali et al. (1993); translated into Thai.	'Does your child snore at night?' (Never, only with colds, occasionally and most nights)	8.5
Ng (2005) [b]	Hong Kong	3047	CS	Purposed-design questionnaire (TuCASA) translated to Cantonese.	'In the preceding week, how often has your child snored (snoring is audible)? (no, 1-2 nights, 3-5 nights and 6-7 nights)'	10.9
Li, S (2010)	China	20152	CS	Validated questionnaire (CSHQ).	'How often does your child snore loudly during a typical recent week? (Almost always (5-7 nights/week); frequently (2-4 nights/week; and occasionally/never (0-1 nights/week)'	12.0
Bonuck (2011)	UK	12447	L	Purposed-design questionnaire (pre-existing) developed by ALSPAC.	'Does she snore for more than a few minutes at a time? Responses varied over time: (most nights, quite often, rarely) at 6 months, (most nights, quite often, sometimes, rarely/never) at 1.5 years, (yes/often, yes/sometimes, no) at 2.5 years, (most nights, quite often, rarely) at 3.5 years, and (most nights, quite often, sometimes, only rarely, never) from 4.5 years onward'	3.6
Kaditis (2004)	Greece	3680	CS	Purposed-design questionnaire following previous guidelines by Brouillette et al. (1984), and Carroll et al. (1995).	'Does your child snore during night sleep? (Never/only with colds/less frequently than once a week/at least once a week but not every night/every night/do not know)'	4.2
Löfstrand-Tideström (2007)	Sweden	509	L	Purposed-design questionnaire.	Question not specified. (Not snoring, snoring sometimes and snoring every night)	4.5
Kelmanson (2000)	Russia	200	CS	Single question.	'Snoring or noisy breathing in sleep? (Yes/no)'	5.0
Corbo (2001) [a]	Italy	2209	CS	Questionnaire adapted from the American Thoracic Society Questionnaire on Children.	'Does your child ever snored? (Never, only with colds, occasionally without a cold, often)'	5.6
Kargoshaie (2009)	Italy	320	CS	Purposed-design questionnaire to assess sleep patterns and sleep problems.	'Does your child snore? (Never, occasionally, frequently, always?'	6.0
Liukkonen (2008)	Finland	1471	CS	Modified version of validated questionnaire SDSC (Finish/Swedish version).	'How often does your child snore?' Symptoms during the previous 6 months were described	6.3

First author (Year)	Country	Sample size	Design	Nature of question/questionnaire	Question used to define habitual snoring (possible responses)	Prevalence (%)
Corbo (1989)	Italy	1615	CS	Questionnaire adapted from the American Thoracic Society Questionnaire on Children.	'Does your child ever snore? (Never, only with colds, occasionally without a cold, often)'	7.3
Alexopoulos (2006)	Greece	1821	CS	Purposed-design questionnaire based on previous tools used by authors. Questions regarding symptoms of SDB present for at least 6 months were included.	Question not specified. (>3 nights/week within previous 6 months)	7.4
Smedje (1999)	Sweden	1844	CS	Purposed-design questionnaire.	Question not specified.(Never, occasionally, 1-2/week, 3 or 4 days/week and at least 5 days/week)	7.5
Kuehni (2008)	U.K.	6742	CS	Purposed-design questionnaire.	'Over the past 12 months, has your child snored at night? If yes, how often, only with a cold/sometimes even without a cold/almost always?'	7.9
Ferreira (2000)	Portugal	976	CS	Purposed-design questionnaire.	'During the night, how often does your child: snore loudly during sleep? (Never, occasionally, frequently, always)'.	8.6
Teculescu (1992)	France	190	CS	Single question.	'Does this child snore? (Never, only during colds, sometimes apart from colds, and often)	10.0
Urschitz (2004)	Germany	1144	L	Validated questionnaire (SDBQ).	'Does your child snore?' (Never, occasionally, frequently and always)	10.1
Ali (1993)	UK	782	CS	Reduced version of a previous questionnaire used by Stradling et al. (1990)	'Does he/she snore at night? (Never, rarely, sometimes, often)'	12.1
Montgomery-Downs (2006)	U.S.	944	CS	Purposed-design questionnaire.	'How often does your child snore? How loud is the snore? (Mildly quiet, medium loud, loud, very loud, extremely loud)'	5.3
Montgomery-Downs (2010)	U.S	173	CS	Validated questionnaire by Montgomery-Downs et al. (2004).	'How often does your child snore? How loud is the snore? (Mildly quiet, medium loud, loud, very loud, extremely loud)'	8.1
Gozal (2001)	U.S.	1588	CS	Questionnaire previously used by Gozal (1998).	'Does your child snore now?', if a positive answer: (Occasionally, 1-2 nights/week; frequently, 3-4 times/week; very frequently, 5-6 times/week; and always, every night)	9.0
Goodwin (2003)	U.S.	1214	CS	Purposed-design questionnaire (TuCASA) English/Spanish version.	'How often does your child snore loudly?' (Never, rarely, occasionally, frequently, almost always and don't know)	10.5

First author (Year)	Country	Sample size	Design	Nature of question/questionnaire	Question used to define habitual snoring (possible responses)	Prevalence (%)
Kalra (2006)	U.S.	700	CS	Purposed-design questionnaire.	Question not specified. (Never; rarely, <1/week; sometimes, 1-2/week; frequently, 3-4 times/week; and almost always, 5-7 times/week)	15.0
Rosen (2004)	U.S.	850	CS	Paediatric modification of a validated questionnaire (CSQ).	Loud snoring in the past month at least 1-2 times/week. (yes/no)	15.0
Kulnis (2000)	U.S.	228	CS	Questionnaire adapted from questionnaire used by Ali et al. (1993)	'Does he/she snore at night? (Never, rarely, sometimes, often)'	16.0
Archbold (2002)	U.S.	1038	CS	Validated questionnaire (PSQ).	'While sleeping, does your child snore more than half of the time?' (Yes/no, don't know)	17.0
Nelson (2001)	U.S.	405	CS	Questionnaire adapted from a previous questionnaire used by Ali et al. (1993)	Question not specified. (Never, rarely, sometimes and often)	17.0
Montgomery-Downs (2003)	U.S.	1010	CS	Questionnaire previously used by Gozal (1998).	'How often does your child snore? How loud is the snore? (mildly quiet, medium loud, loud, very loud, extremely loud)'	22.0
Piteo (2011)	Australia	457	CS	Single question.	'How often in the past week did your child snore?' (Never in the absence of a cold, 1–2 nights/week, 3–5 nights/week or ≥6 nights/week)	12.0
Gill (2012)	New Zealand	823	CS	Reduced version of the SDB Scale.	'How often does your child snore while he/she is asleep?' (only reported: often and almost always)	11.3
Zhang (2004)	Australia	996	CS	Modified questions from a previous questionnaire on respiratory health and indoor air quality.	Question not specified. (<4 times/week or >4 times/week)	15.2
Tafur (2009)	Ecuador	806	CS	Single question.	'Does your child snore?' (Never, occasionally, often and always)	15.1
Brockman (2012)	Chile	523	CS	Questionnaire adapted and translated into Spanish from questionnaire used by Gozal (1998).	'Does your child snore? (5-point scale: never to always)'	18.0
Petry (2008) [a]	Brazil	998	CS	Purposed-design questionnaire (TuCASA) translated to Portuguese.	'How often does your child snore loudly?' (Don't know, never, rarely, frequently and always)	27.6

Note. SDBQ = Sleep-Disordered Breathing Questionnaire; PSQ = Pediatric Sleep Questionnaire; HK-CSQ = Hong Kong Children Sleep Questionnaire; SDSC = Sleep Disturbance Scale for Children; TuCASA = Tucson Children's Assessment of Sleep Apnea Study; ALSPAC = The Avon Longitudinal Study of Parents and Children; CSQ = Child Sleep Questionnaire; SDB Scale = Sleep Disrupted Breathing Scale by Goldstein

[a] Face to face interview using a parental report questionnaire; [b] Telephone interview using a parental report questionnaire; [c] Prevalence calculated from paper

Snoring prevalence measured through parental self-report questionnaire cannot only be influenced by the instrument itself, but also cultural practices (Castronovo et al., 2003; Ferreira et al., 2000). Castronovo et al. (2003) reported that a higher prevalence of snoring may be more common in places where co-sleeping is a regular practice. More recent research (Ramos, Youngclarke, & Anderson, 2007) directly investigated co-sleeping and how this practice influenced perception of different sleep problems. Their conclusion was that frequency of different sleep behaviours was higher among those who co-sleep compared to those who did not. Additionally, the authors raised the issue that parental judgment of the different sleep behaviours (i.e. whether parents considered a problematic behaviour) also influenced parental-reports, which could be determined by cultural expectations. Cultural beliefs and parental expectations play an important role not only in the development of sleep patterns of their children, but also in how they might perceive sleep-related behaviours (Jenni & O'Connor, 2005). For example, in Chinese culture snoring has been reported to be a sign of a healthy child (Biggs et al., 2010). A different understanding of what could be considered a problematic sign would markedly impact not only the assessment, but further treatment if required. Thus, an approach that includes parental knowledge and also beliefs it might be critical when assessing sleep behaviours such as snoring (Owens, 2005).

The prevalence of habitual snoring by parental self-report in a recent extensive review about SDB symptoms by Lumeng and Chervin (2008), was determined to range between 5% and 12%. A higher prevalence (15.5%) has been reported in a population study where snoring was objectively measured in children between five and 12 years of age (Bixler et al., 2009). One of Lumeng and Chervin's main conclusions was the high variability in the definition of snoring. This variability was also observed among the studies included in the current section; along with the used of different assessment tools to evaluate habitual snoring. In addition, differences may be influenced by location of the research. Higher prevalence rates were has been reported among studies from the Americas, particularly in South America; while the lowest prevalence rates have been reported among Asian studies. These differences raise questions whether ethnic characteristics or cultural patterns may explain the variability in snoring prevalence. However, other characteristics (e.g. physiological and socioeconomic) inherent to the studies samples need to be considered.

1.2.6. Factors associated with habitual snoring in children

'*All snoring is not adenoids…*' p.79 (Liukkonen et al., 2008)

A number of factors are reported to be associated with an increased risk of habitual snoring, but their identification remains incomplete and their relative contribution is not fully understood. The aim of the present section is to examine a number of factors commonly associated with habitual snoring in children. An overview of the literature is presented in this section, which was conducted using the following keywords 'snoring', 'risk factor'' and 'children' in the PUBMED database. The search was restricted to children aged 0 to 18 years. Initially, 222 articles were identified, but 178 of them were excluded for the following reasons: 80 did not investigate snoring directly or indirectly, or investigated sleep disorders without differentiating snoring; 25 investigated non-sleep related topics; 10 were written in languages other than English or Spanish; 28 were review papers; and 35 included adult populations in their sample. Included in this review were eight studies which examined snoring among special populations (e.g. children with cystic fibrosis, autism, epilepsy or Down syndrome) in order to highlight how specific conditions can increase the risk of snoring. In total, 44 articles were included in the review of habitual snoring and associated factors in children.

The factors associated with habitual snoring can be broadly divided into two categories: medical and demographic. Risk factors were examined under these broad headings, and whether they were associated with habitual snoring are summarised for each study in Table 1.3. Study details and demographic information are presented in Table 1.4.

Methodological variation in the snoring literature

A major feature of the studies examined in this review is the multiple definitions used for habitual snoring, which has been highlighted in previous sections and also in the literature (Lumeng & Chervin, 2008). The majority of studies assessed snoring using parental-report questionnaires (n = 31) with a subset using parental interviews (n = 2), overnight sleep technician report (n = 1) or parental-report together with child-report (n = 1). Although the items used to assess snoring frequency in the questionnaires' studies were similarly worded, a broad range of criteria were used to classify habitual snoring thus making comparisons difficult (e.g. snoring ≥1 night per week, >2 nights per week, ≥3 nights per week, or any incidence of snoring). The variability in definitions has previously been

highlighted, and it raises the need for a unified criteria when assessing habitual snoring (Lumeng & Chervin, 2008). A second feature of the studies in the review is that despite the majority of studies being community surveys with large sample sizes, subgroups were assessed in some studies including overweight children (Verhulst et al., 2008), children with a parental history of atopic conditions (Kalra et al., 2006; Marshall et al., 2007) and children from asthma and allergies databases (Petry et al., 2008). A third feature of the studies in the review is that the majority examined broad age ranges (e.g. 1.5–13 years, etc.). Given the possible impact of age on snoring, this limits the understanding of the relative contributions of other potential risk factors. A final feature of the studies in this review is that most studies that examined medical factors have been typically restricted to either an investigation of atopic conditions (20 examining asthma, 20 rhinitis and eight eczema) or weight status (15 studies) with only a limited number of studies examining physiological factors known to be important in the pathogenesis of upper airway obstruction and snoring such as craniofacial and upper airway structure (n = 2). Among the different demographic factors, the most commonly examined is gender (23 studies), followed by passive smoking (20 studies).

Table 1.3 Summary of factors associated with habitual snoring in children across different studies

First Author	Medical risk factors							Demographic risk factors					
	Asthma	**Rhinitis**	**Eczema**	**Adenotonsillar hypertrophy**	**UAN**	**URI**	**Weight status**	**Ethnicity**	**Male gender**	**Age (Young)**	**Parental snoring**	**Passive smoking**	**SES**
Bonuck	+							+	+				+
Li, A	+	+	–			+	+		+		+	–	
Li , S	+	+		+			+				+	+	+
Bixler[a]							+	+		+			
Kargoshaie				+					–	–			
Sahin	–	+					–		+	+		+	–
Sogut (2009)	–	+		+			+		–	+		+	
Tafur		+							+	–			
Kuehni	+	+	+			+	–					+	+
Liukkonen		+		+			+		–	–	+	+	
Petry	–	+							–			+	
Verhulst[a]					+								
Marshall	+		+				–		–			+	
Umana						+			–	–			–
Bidad	+		–	+			+		+				
Kalra		+						+			+	–	
Zhifei[a,b]													
Ng	–	–							+		+		
Sogut (2005)	–	+										–	
Chng	–	+	+				+					+	
Ersu	+	+										+	
Kaditis	–	+	–						+		+	+	
Urschitz	–	–	–			+	+		–	–		+	

First Author	Medical risk factors							Demographic risk factors					
	Asthma	**Rhinitis**	**Eczema**	**Adenotonsillar hypertrophy**	**UAN**	**URI**	**Weight status**	**Ethnicity**	**Male gender**	**Age (young)**	**Parental snoring**	**Parental smoking**	**SES**
Valery	+						–		+				
Zhang	+	+							–	+		+	
Goodwin								+	–	–			
Mitchell						+			+			+	
Montgomery-Downs								+	+				
Anuntaseree		+		+			–		–			+	
Kara				+									
Corbo (2001)	+	+		+			+		+	–		+	–
Kulnis					+		–						
Smedje						+			–				
Teculescu	+	+	–	+					–			–	
Corbo (1989)	–	+										+	
TOTAL	20	20	8	9	2	6	15	5	23	11	6	20	6
+ Association	11	18	3	9	2	6	9	5	11	4	6	16	3

Note. Positive signs represent association reported between habitual snoring and each factor, negative signs represent no association and blank cells represent that the factor was either not investigated or not reported

UR = upper respiratory infections; UAN = upper airway narrowing; SES = socioeconomic status

[a] examining both PS and SDB; only data regarding PS are reported here

Table 1.4 Studies examining habitual snoring and associated factors in children (demographic information)

First Author (Year)	Location	Sample size	Age (years)[a]	Definition of snoring	Demographic characteristics				
					Gender (male, %) [c]	Weight status	Socioeconomic status	Household Smoking	Ethnicity
Bonuck (2011)	England	12447	T_1 = 1.5 T_2 = 4.75 T_3 = 6.75	'Always' (PR).	Male vs. female, OR (CI) T_1 = 1.46 (CI, 1.10–1.93) T_2 = 1 (CI, 0.82–1.22) T_3 = 0.89 (CI, 0.71–1.13)	NR	Maternal education (lower vs. higher; OR (CI)) T_1 = 1.82 (CI, 1.30–2.55) T_2 = 1.18 (CI,0.94–1.48) T_3 = 1.08 (CI,0.84–1.40)	Maternal smoking, ever, OR (CI) T_1 = 0.90 (CI, 0.68–1.19) T_2 = 1.11 (CI, 0.91–1.35) T_3 = 1.11 (CI, 0.88–1.40)	Other vs. White OR (CI) T_1 = 2.80 (CI, 1.38–5.70) T_2 = 1.24 (CI, 0.57–2.71) T_3 = White 100%
Li, A (2010)	China	6349	5 − 14	'Frequently' (PR).	NS = 43.8% OS = 55.6% HS = 65.9%	Z–score, Kg/cm^2, mean (SD) NS = 0.06 ± 1.12 OS = 0.28 ± 1.16 HS = 0.52 ± 1.18	NS = 37.3% OS = 24.9% HS = 22.2%	NS = 33.3% OS = 32.3% HS = 31.6%	Chinese
Li, S (2010)	China	20152	9.0 (1.6) (HS) 8.8 (1.6) (NS)	≥2 nights/week (PR).	NS = 47.9% HS = 59.9%	Kg/m^2, mean (SD) NS = 17.85 (4.40) HS = 17.26 (4.02)	Family income <800 NS = 23.9% vs. HS = 28.2% Family income 800–2500 NS = 56.8% vs. HS = 55% Family income ≥2500 NS = 19.3% vs. HS = 16.8%	NS = 24.5 HS = 27.8	Chinese
Bixler[b] (2009)	U.S.	700	5–12	Technician-report at PSG and AHI < 1.	NS = 49% HS = 48%	Percentile, mean (SD) NS = 58.5 (1.4) HS = 63.9 (2.9)	NR	NR	Caucasian 76%
Kargoshaie (2009)	Iran	320	10.5 ± 0.5	'Occasionally', 'frequently' or 'always' (PR).	NR	Kg/m^2, mean (SD): 16.8 (2.7)	NR	NR	NR
Sahin (2009)	Turkey	1164	9.73 ± 1.5	'Frequently' or 'almost every day' (PR).	NS = 54.2% OS = 41.6% HS = 4.2%	Percentile NS = 60.6% (75th–90th); 51.8% (>90th) OS = 34.1% (75th–90th); 42.7% (>90th) HS = 5.3% (75th–90th); 5.5% (>90th)	Education ≤8 y NS = 62.9% (mother); 61.6%(father) OS = 33.5% (mother); 34.6%(father) HS = 3.6% (mother); 3.8%(father)	NS = 55.5% (+); 67.3% (–) OS = 40.3% (+); 30% (–) HS = 4.3% (+); 2.7% (–)	Turkish

First Author (Year)	Location	Sample size	Age (years)[a]	Definition of snoring	Demographic characteristics				
					Gender (male, %) [c]	Weight status	Socioeconomic status	Household Smoking	Ethnicity
Sogut (2009)	Turkey	1030	12 − 19	≥3 nights/week (PR).	NS = 62.6% OS = 32.8% HS = 4.6%	HS vs. NS, OR (CI) Percentile 76th–90th = 1.76 (CI, 0.76–4.06) Percentile 91th–95th= 3.09 (CI, 1.09–8.78) Percentile >95th = 1.81 (CI, 0.39–8.30)	NR	HS vs. NS, OR (CI) Father = 1.5 (CI, 0.8–2.9) Mother = OR 2.3 (CI, 1.1–4.4)	Turkish
Tafur (2009)	Ecuador	806	8.9 ± 1.6	'Often' or 'always' (PR).	NS = 36.7% HS = 42.6%	NR	NR	NR	Hispanic
Kuehni (2008)	U.K.	6742	2.5 − 13	'Almost always' (PR).	NS = 3.7% OC = 27.4% SwC = 26.4% HS = 8.4%	NR	NS = 41.4% OC = 29% SwC = 23.2% HS = 6.4%	Both parents smoking NS = 32.5% OC = 27.4 % SwC = 27.7% HS = 12.5%	Caucasian: NS = 39% OC = 28% SwC = 25% HS = 9%
Liukkonen (2008)	Finland	1471	4.0 (HS) 3.8 (NS)	>1/week (PR).	NS = 48% HS = 51%	NR	NR	NS = 10% HS = 20%	Swedish and Finish
Petry (2008)	Brazil	998	11.2	Child snores (PR).	51% (combined)	NR	Predominant from low SES	Maternal, OR (CI) 1.8 (CI, 1.3–2.5)	Hispanic
Verhulst[b] (2008)	Belgium	48	11.2 (2.5) (NS) 11.1 (1.8) (HS)	'often' or 'always' (PR) and OAH < 1.	NS = 38% HS = 43%	Z-score, Kg/cm^2, mean (SD) NS = –0.6 (0.8) HS = 2.3 (0.5)	NR	NR	NR
Marshall (2007)	Australia	219	5.0	≥3 nights/week (I).	HS = 18%	NR	NR	Any exposure 3.2%	NR
Umana (2007)	Nigeria	469	7.2 (NS) 7.1 (HS)	>3 nights/week (PR).	HS = 48.8%	NR	HS = 54.1%	NR	African
Bidad (2006)	Iran	2900	11.2	≥ 3 nights/week in absence of colds (SR).	HS = 12.4%	Overweight = 12.4% (HS) Obese = 13.9% (HS)	NR	NR	Iranian
Kalra (2006)	U.S.	700	13.7 (2.6) months	≥ 3 nights/week (PR).	NS = 45% HS = 50%	NR	NR	NS = 27% HS = 33%	African–American NS = 15% HS = 37%
Zhifei[b] (2006)	China	19	4 − 18	Suspected OSA (I) and AHI ≤ 5	M/F ratio 3.8:1 (Combined)	BMI Kg/m^2 Kg/cm^2, mean (SD): 20.4 (6.9)	NR	NR	Chinese
Ng (2005)	China	3047	8.9 (1.7)	6–7 nights/week (PR).	M/F ratio 2.4:1 (HS)	NA	NA	NA	Chinese

First Author (Year)	Location	Sample size	Age (years)[a]	Definition of snoring	Demographic characteristics				
					Gender (male, %) [c]	Weight status	Socioeconomic status	Household Smoking	Ethnicity
Sogut (2005)	Turkey	1198	8.1 (1.9)	≥ 3 night/week (PR).	48.6% (Combined)	NA	NR	NS = 54.1% HS = 66.7%	Turkish
Chng (2004)	Singapore	10279	5.8 (1.3)	Snoring > 3 nights/week (PR).	OS = 31% HS = 7%	Obese, OR (CI) OS = not significant HS = OR 3.75 (CI, 1.67–8.42)	NR	Maternal, OR (CI) OS = OR 2.36 (CI, 1.6–3.3) HS = OR 2.22 (CI, 1.09–4.53)	OS = 30% (Chinese); 25% (Malay); 19% (Indi) HS = 6% (Chinese); 6% (Malay); 4% (Indi)
Ersu (2004)	Turkey	2147	8.5 (1.3)	'Often' or 'always'" (PR).	HS = 9%	NR	NR	Maternal, OR (CI) 2.3 (CI, 1.6–3.3) Paternal, OR (CI) 1.6 (CI, 1.1–2.3)	Turkish
Kaditis (2004)	Greece	3680	9.8 (median)	'Every night' (PR).	NS = 46% HS = 58%	NA	NR	NS = 53%; HS = 69% OR 1.4 (1.1–1.8)	Greek
Urschitz (2004)	Germany	1144	9.6 (0.7)	'Frequent' or 'always' (PR).	NS = 91% HS = 9%	Percentile, OR (CI) for HS 75–89 = 2 (CI, 1.1–3.5) ≥90 = 3.8 (CI, 2.2–6.6)	12.4% (combined)	HS 1–10 cig = 7.7% >10 cig = 14.4	German
Valery (2004)	Australia	1650	0−17	≥ 2 nights/week (PR: 0–13-years-old; SR: 14–17-years-old).	HS = 17%	HS = 13.3% (Over weight); 33.3% (Obese)	Mostly Unemployed , OR (CI) HS = 14.2 (CI, 10.9–17.4) No completed high school, OR (CI) HS = 12.1 (CI, 8.9–15.3)	NR	HS = 13% (InA); 15% (C/SP)
Zhang (2004)	Australia	996	4−12	>4 nights/week (PR).	IS = 26% HS = 16%	NR	NR	Household smoking: HS= OR 1.77 (CI, 1.20–2.61)	NR
Goodwin (2003)	U.S.	1494	4−11	Loud snoring 'frequently' or 'almost always' (PR)	HS = 12%	NR	NR	NR	HS = 11% (H)
Mitchell (2003)	New Zealand	1585	1–6 months	In the previous 2 weeks or first 4 weeks of life (PR).	NS = 71% HS = 29%	NR	NR	Maternal smoking NS = 68.3% HS = 31.7%	NR

First Author (Year)	Location	Sample size	Age (years)[a]	Definition of snoring	Demographic characteristics				
					Gender (male, %) [c]	Weight status	Socioeconomic status	Household Smoking	Ethnicity
Montgomery-Downs (2003)	U.S.	1010	4.2 (0.5)	≥ 3 nights/week (PR)	S = 26%	NR	Mostly from low SES	NR	HS = 28% (AA); 18% (C)
Anuntaseree (2001)	Thailand	1142	7.3 (0.6)	'Most nights' (PR).	S = 57% NS = 45%	Weight for height > 120kg S = 17.6% NS = 9.4%	NR	S = 58% NS = 44.1%	Asian
Kara (2002)	Turkey	1211	9.3 (2)	'Every day' (PR).	53% (combined)	Weight 25 percentile NS = 72.5% HS = 22.5%	NR	NS = 46.7% HS = 53.3%	Thai
Corbo (2001)	Italy	2209	10 −15	'Often' (PR).	NS = 63% OC = 19% OS = 12% HS = 7%	Percentile 76–90 OR(CI) OC =1.31 (1.00–1.7) OS = 1.08 (0.7–1.5) HS = 0.97 (0.6–1.6) Percentile 91–95 OR(CI) OC = 1.76 (1.3–2.6) OS = 2.10 (1.4–3.2) HS = 1.99 (1.1–3.5) Percentile >95 OR (CI) OC = 2.05 (1.3–3.1) OS = 2.17 (1.3–3.7) HS = 2.66 (1.4–4.9)	Father's education <6 years NS = 65.9 OC = 16.8 OS = 9.2% HS = 8% Father's education 6–8 years NS = 65.5% OC = 18.5% OS = 11.2% HS = 4.9%	Low SES, OR (CI) OC = 1.12 (CI, 0.9–1.4) OS = 1.20 (CI, 0.9–1.6) HS = 1.58 (CI, 1.03–2.4)	Italian
Kulnis (2000)	U.S.	56	10.0 (2.0)	'Often' with a volume moderate-very loud (PR).	36% (combined)	Kg/cm^2, mean (SD) NS = 20.4 (4.6) HS = 17.9 (3.4)	NR	NR	Caucasian 82%
Smedje (1999)	Sweden	2215	5.8 (0.4)	≥3 nights/week (PR).	52% (combined)	NR	9.3% (mother) and 6.1% (father) unemployed (combined)	NR	Swedish
Teculescu (1992)	France	190	5.8 (0.3)	'Often' (PR).	51% (combined)	Kg/cm^2, mean (SD) NS = 15.5 (1.3) SeS = 15.8 (1.5) OS = 15.4 (0.9) HS = 15.4 (1.3)	Areas with majority of poor populations excluded	NR	Areas with majority non-Caucasian populations excluded
Corbo (1989)	Italy	1615	6–13	'Often' (PR).	NS = 49% HS = 7%	NR	NR	NS = 55.2% HS = 69.5%	Italian

Note. NS = non-snorer; HS = habitual snorer; OS = occasional snorer; OC = snoring only with colds; SeS = Seldom snorer; PR = parental report; SR = self-report; I = interview; NR = not reported; T_1 = assessment time 1; T_2 = assessment time 2; T_3 = assessment time 3; M/F = Male/Female; OR = odds ratio

[a] Mean age in years, otherwise age range; [b] Study examining both snoring and SDB/OSA; only data regarding to snoring are reported here; [c] Percentages within each condition, this do not sum up to 100%.

1.2.6.1. Medical factors associated with habitual snoring

Adenotonsillar hypertrophy

Hypertrophy of the tonsils or adenoids is the most commonly identified risk factor for snoring (Ungkanont & Areyasathidmon, 2006) and adenotonsillectomy a preferred treatment option for SDB (Mitchell & Kelly, 2004; Parker & Walner, 2011). Despite relieving symptoms, residual snoring is reported following adenotonsillectomy suggesting that adenotonsillar hypertrophy alone is unlikely to explain snoring (Mitchell & Kelly, 2004). Consistent with that study, Liukkonen et al. (2008) compared non-snoring with snoring children through a parental self-report questionnaire regarding a number of demographic and health characteristics. They also found that although a high proportion of snoring children had a history of either adenoidectomy or tonsillectomy, frequent snoring was still reported in this group. The authors also found that the majority of adenoidectomies were performed as a result of ear infections rather than snoring, raising questions about whether all cases of snoring are related to adenotonsillar hypertrophy.

Among the studies included in Table 1.3, eight assessed either tonsil, adenoid or adenotonsillar hypertrophy and all of them reported that hypertrophy of either tonsils or adenoids was associated with snoring. The majority of the studies (n = 6) used direct clinical examination to assess the size of the tonsils either by an otolaryngologist (Anuntaseree et al., 2001; Kargoshaie et al., 2009) or physician (Bidad et al., 2006; Corbo et al., 2001; Kara et al., 2002; Sogut et al., 2009); and another study asked parents to report any previous adenotonsillar or tonsil hypertrophy diagnosis (Li, Jin, et al., 2010; Teculescu et al., 1992).

Results for studies that used direct clinical examination revealed that moderate enlargement of the tonsils (beyond the pillars but not meeting uvula or ‘kissing’) was associated with habitual snoring, Odds Ratio (OR) 2.60 (Anuntaseree et al., 2001) and OR 1.29 (Corbo et al., 2001). To a greater extent, a marked enlargement of the tonsils (meeting the uvula or kissing) were also associated with habitual snoring—OR 6.33 meeting the uvula and OR 10.18 when tonsils were ‘kissing’ (Anuntaseree et al., 2001); and OR 5.07 (meeting the uvula/kissing) in another study (Corbo et al., 2001). Sogut et al. (2009) classified tonsillar enlargement relative to airway diameter: tonsil enlargement Stage 2 (occupying half of the transverse diameter of the oropharynx) and Stage 3 (occupying more than half of the transverse diameter of the oropharynx). Sogut’s group report that the OR of habitual snoring at Stage 2 was 6.64 and Stage 3 was 19.17. These findings point to perhaps the obvious conclusion that the greater the tonsil size relative to the airway the

greater the risk of snoring. Contrary to previous findings, Bixler et al. (2009) upon clinical examination in a community-based sample of young children suggested that tonsil size did not predict snoring.

Results from the two studies that asked for previous diagnosis indicated that the odds of having habitual snoring were 2.17 (Li, Jin, et al., 2010) to 2.2 (Teculescu et al., 1992) times higher than when a previous diagnosis of tonsil hypertrophy existed. A higher percentage of children with enlarged tonsils are reported to snore (5.3%) compared to those with non-obstructive tonsils (2.1%) (Kara et al., 2002). Two further studies report that hypertrophy of the tonsils was more common among snorers, but do not provide either OR or frequency of children (Bidad et al., 2006; Kargoshaie et al., 2009).

Upper airway narrowing

An obvious anatomical risk factor for snoring is a narrow airway, which regardless of adenotonsillar hypertrophy may place children at higher risk for snoring and SDB (Casselbrant, 1999). Only two studies included in the review have directly assessed upper airway characteristics as a potential risk factor for snoring. Kulnis et al. (2000) found that the anterior-posterior dimension of the pharynx among snoring children was narrower compared to controls. In contrast, Verhulst et al. (2008), who examined snoring in overweight children, revealed that inflammation of the upper airway, rather than anatomical narrowing, was a feature in children who snored, supported by increased levels of exhaled nitric oxide. Thus these two studies indicate that at least two mechanisms could narrow the upper airways: morphology and inflammatory changes. Of note is that Verhulst et al. (2008) included in their study children who not only snored, but who were also overweight. Both inflammation of the upper airway and being overweight may increase the risk for snoring. In a study by Corbo et al. (2001) the distribution of risk factors was explored and results indicated that pharynx problems and obesity together were more prevalent among habitual snorers compared to non-snorers (11.3% vs. 4%), than each single factor. Although Verhulst et al. (2008) did not find an association between being overweight and upper airway inflammation, it may be possible that co-morbidity rather than association explains increased risk for snoring.

Upper airway respiratory infections

The role of upper respiratory infections is thought to involve an increased lymphatic response, resulting in inflammatory responses in the upper airway, which becomes narrower, increasing the risk for obstruction and snoring (Eccles, 2005). Six studies in

Table 1.3 examined upper respiratory infection (Kuehni et al., 2008; Li, Au, So, et al., 2010; Mitchell & Thompson, 2003; Smedje et al., 1999; Umana et al., 2007; Urschitz et al., 2004), and all report that upper airway infection was more prevalent among snoring children. The contribution of a range of upper airway infections to snoring has been investigated. Two studies have examined the contribution of tonsillitis: Li, Au, So, et al. (2010) report an OR of 3.08 times higher in snorers while Umana et al. (2007) report a higher prevalence of tonsillitis in snorers (36.6%) versus non-snorers (15.3%). Otitis was reported to be 1.94 and 5.8 higher in snorers (Kuehni et al., 2008; Urschitz et al., 2004); frequency of colds, 1.94 times higher in snorers (Kuehni et al., 2008); ear, nose and throat (ENT) infections in general were 1.89 times higher among snorers (Smedje et al., 1999); and the number of respiratory symptoms was 1.50 higher among snorers (Mitchell & Thompson, 2003).

Atopy

Various atopic conditions have been associated with increased risk for snoring including asthma, rhinitis and eczema.

Asthma

This is a common allergic condition among pre-school and school-age children, it is suggested that its prevalence worldwide ranges from 4.1% to 32.1%. Asthma affects pharyngeal size due to an increased pharyngeal dilatation, resulting in upper airway obstruction thereby increasing the risk for snoring (Asher et al., 1998; Tai, Volkmer, & Burton, 2009; Taylor et al., 2008). Compared to other factors in this review, asthma was one of the most investigated (20 studies). However, the conflicting findings as to the association between asthma and snoring raise questions whether they are causally linked. It is important therefore, to analyse the studies to identify characteristics that could explain why some of the studies found a positive relationship between asthma and snoring while others did not.

Most of the studies relied on parental-report questionnaires to assess presence of asthma (Bonuck et al., 2011; Corbo et al., 2001; Ersu et al., 2004; Kuehni et al., 2008; Li, Au, So, et al., 2010; Li, Jin, et al., 2010; Zhang et al., 2004). Only two of the studies directly interviewed parents or children (Bidad et al., 2006; Valery et al., 2004); while two combined subjective reports (parental questionnaire or interview) with medical assessment of asthma severity (Marshall et al., 2007; Teculescu et al., 1992).

In total, 11 studies found a positive relationship between asthma and snoring. Among them, one recruited participants from a clinical setting (Marshall et al., 2007) and the remainder from community settings. Participants recruited from community settings were typically recruited from primary school cohorts (Bidad et al., 2006; Corbo et al., 2001; Ersu et al., 2004; Li, Au, So, et al., 2010; Li, Jin, et al., 2010; Teculescu et al., 1992; Zhang et al., 2004). Additionally, two studies targeted specific ethnic groups, including South Asian children in one study and indigenous Australians in another (Kuehni et al., 2008; Valery et al., 2004); and one examined children with a history of asthma among their immediate family (Marshall et al., 2007).

Classification of asthma status also varied across studies that found the positive association. Definition of asthma included first, whether the child had been diagnosed as asthmatic in the past by a physician (Corbo et al., 2001; Li, Jin, et al., 2010; Marshall et al., 2007); second, a history of asthma with the time frame unspecified (Ersu et al., 2004; Valery et al., 2004; Zhang et al., 2004); third, whether wheezing was present in the last 12 months (Li, Au, So, et al., 2010); fourth, reports of wheezing (Bonuck et al., 2011); fifth, frequency of wheezing >10 during the last 12 months (Kuehni et al., 2008); and sixth, exercise-induced asthma as a surrogate definition of asthma diagnosis (Bidad et al., 2006; Teculescu et al., 1992).

In the studies that asked if asthma had been diagnosed by physician, the odds of having asthma were reported to be 1.43 to 3.36 times higher among snoring children (Corbo et al., 2001; Li, Jin, et al., 2010; Marshall et al., 2007). Among those that asked about a history of asthma, Zhang et al. (2004) report that the frequency of asthma was higher in snorers than non-snorers (37.1% vs. 23.9%), while Ersu et al. (2004) and Valery et al. (2004) report that the odds of having asthma were 2.0 to 3.2 times higher among snorers, respectively. Li, Au, So, et al. (2010) in the single study that asked about wheezing in the past 12 months, report that the odds of wheezing were 2.44 times higher in snorers; Bonuck et al. (2011) in the single study that asked about wheezing without a specifying a time frame report that wheezing was associated with a higher risk of snoring in children at 1.5 years (OR 1.06), at 4.7 years (OR 1.05) and also at 6.7 years (OR 1.06); while Kuehni et al. (2008) report that >10 ‘wheezing attacks’ were associated with a greater risk of habitual snoring (OR 2.61). Finally, Teculescu et al. (1992) report that exercise-induced asthma was more common for habitual snoring (OR 8.7), and Bidad et al. (2006) for snorers (OR 1.69).

Among the nine studies that did not find a positive relationship, all of them included samples drawn from the general community (Chng et al., 2004; Corbo et al., 1989; Kaditis et al., 2004; Montgomery-Downs et al., 2003; Ng et al., 2005; Petry et al., 2008; Sahin et al., 2009; Sogut et al., 2005; Sogut et al., 2009; Urschitz et al., 2004). The majority of participants were recruited from school settings (Chng et al., 2004; Corbo et al., 1989; Kaditis et al., 2004; Ng et al., 2005; Sahin et al., 2009; Sogut et al., 2005; Sogut et al., 2009; Urschitz et al., 2004), one from programs developed for disadvantaged families (Montgomery-Downs et al., 2003), and another from an asthma/allergies database (Petry et al., 2008). Additionally, all of the studies reporting a negative association used parental-report questionnaires to assess presence of asthma. Four studies asked whether the child had asthma diagnosed by a doctor (Chng et al., 2004; Corbo et al., 1989; Ng et al., 2005; Sahin et al., 2009; Sogut et al., 2005; Sogut et al., 2009), one if there was any history of asthma (Montgomery-Downs et al., 2003); one if there were reports of wheezing during the last 12 months combined with asthma at least once during the child's lifetime (Petry et al., 2008); one if there were any reports of ever wheezing, having bronchitis or bronchial asthma diagnosed plus whether specified asthma medications had been used (Kaditis et al., 2004); and one whether there was presence of any chronic lung disease (Urschitz et al., 2004).

Rhinitis

Worldwide reports indicate that the average overall prevalence of rhinoconjunctivitis for school-age children is 8.5%, while for 13 to 14-year-old children it ranges from 1% to 45% (Aït-Khaled et al., 2009). Australian data indicate that its prevalence among pre-school age children is 20.7% (Tai et al., 2009). The association between rhinitis and snoring was investigated in 20 studies, and all studies recruited children from the general community. The majority of studies recruited children from pre-school or primary school settings (Anuntaseree et al., 2001; Chng et al., 2004; Corbo et al., 2001; Corbo et al., 1989; Ersu et al., 2004; Kaditis et al., 2004; Kuehni et al., 2008; Li, Au, So, et al., 2010; Li, Jin, et al., 2010; Liukkonen et al., 2008; Ng et al., 2005; Petry et al., 2008; Sahin et al., 2009; Sogut et al., 2005; Sogut et al., 2009; Tafur et al., 2009; Teculescu et al., 1992; Urschitz et al., 2004; Zhang et al., 2004), two from asthma and allergies databases (Kalra et al., 2006; Petry et al., 2008), one from a population register (Sahin et al., 2009), and one from a census database which targeted specific ethnic groups (Kuehni et al., 2008).

All the studies used parental-report questionnaires to assess the presence of rhinitis, but the criteria used to define rhinitis varied across studies. However, rhinitis was consistently

found to be a common condition associated with habitual snoring (n = 18). The criteria used to classify a child as having rhinitis included reports of rhinitis diagnosed by physician, which were higher among snoring children and the odds of having that diagnosis ranged from 1.41 to 2.90 (Chng et al., 2004; Kaditis et al., 2004; Li, Jin, et al., 2010; Sahin et al., 2009; Tafur et al., 2009); diagnosis of rhinitis by a physician, plus a history of rhinitis symptoms including sneezing and nasal itching which were 4.23–5.27 times higher in snorers (Anuntaseree et al., 2001; Sogut et al., 2005); presence of symptoms such as stuffy, runny nose, itchy eyes and sneezing, OR between 2.0 and 3.7 (Corbo et al., 2001; Corbo et al., 1989; Kalra et al., 2006; Sogut et al., 2009); history of allergic rhinitis or hay fever, OR between 2.1 and 2.83 or a higher prevalence of 61.7% for snorers compared to 37.6% for non-snorers (Ersu et al., 2004; Teculescu et al., 1992; Zhang et al., 2004); symptoms of rhinitis during the last 12 months, which was 2.9 times higher among habitual snorers (Li, Au, So, et al., 2010), rhinitis at least once during the child's lifetime, 1.9 time higher for snorers (Petry et al., 2008); and reports of chronic rhinitis, which were reported to be 1.73 times higher by one study (Kuehni et al., 2008; Liukkonen et al., 2008), and in another study these were reported in 24% of habitual snorers compared to 14% in non-snorers.

Only two studies reported that rhinitis was not associated with snoring (Ng et al., 2005; Urschitz et al., 2004). Notably, both studies had a large sample sizes (n = 3047 and n = 1144 respectively). Of note is that the definition that Urschitz et al. (2004) used included an open question regarding previous diagnosis of allergies or chronic rhinitis, which was then examined by the authors in order to classify the response into non-respiratory and respiratory allergies, or absence of any condition. However, it is possible that this indirect approach may explain the lack of association between rhinitis and habitual snoring.

Eczema

Worldwide, the prevalence of eczema among six–seven-year-old children is reported to range from 0.9 to 22.5% and for 13–14-year-old children 0.2% to 24.6% (Williams et al., 1999). Children with eczema tend to report reduced sleep quality—occasionally prolonged nocturnal wakefulness secondary to itchiness and scratching that results in awakening during sleep (Camfferman, Kennedy, Gold, Martin, & Lushington, 2010). Furthermore, children with eczema have an increased frequency of asthma and rhinitis, as well as a higher frequency of sleep disorders, including SDB (Camfferman et al., 2010).

Eight studies in this review assessed the relationship between snoring and eczema. Three report a positive relationship and four no relationship. Among the studies that found a positive association, only one study by Marshall et al. (2007) assessed eczema using validated objective diagnostic criteria and reported that eczema was more common in snorers (OR 1.28). Chng et al. (2004) and Kuehni et al. (2008) used parental-report to assess eczema (either atopic dermatitis confirmed by a doctor or frequency and severity of eczema) and report that eczema was more common in children who snored (OR 1.80 and 1.25, respectively).

The studies which did not report an association between eczema and snoring used a variety of criteria to classify whether a child had eczema. Urschitz et al. (2004) asked parents whether their children had a diagnosis of allergy in general, and responses were classified as having a respiratory or a non-respiratory allergy. The problem with this classification is that the authors did not discriminate within the non-respiratory allergies group. It might be possible that the lack of association between snoring and eczema was due to the inclusion of other allergies different from atopic dermatitis, such as specific allergens (e.g. grass, fur) or food allergies. Bidad et al. (2006) interviewed children directly and asked them about any allergic symptoms. Although the age range in this study allowed the use of self-report to obtain information, the questionnaire has not been well validated in children; hence the validity of responses might be compromised. Teculescu et al. (1992) asked parents whether children had any eczema under two-years-old, while Kaditis et al. (2004) asked parents whether children had ever been diagnosed with eczema or atopic dermatitis by a pediatrician. Finally, Li, Au, So, et al. (2010) asked parents whether their children ever had eczema. In general, a few studies found a positive association between eczema and snoring; however this relationship is not fully understood. Questions remain whether both conditions are co-morbid or not.

Weight

The percentage of overweight children is reported to be on the increase. Worldwide reports suggest that the prevalence of overweight in children aged 5 to 17 years is about 10%, and the prevalence of obesity up to 3% (Lobstein, Baur, Uauy, & TaskForce, 2004). There is strong evidence that obese children are more likely to develop SDB (Goodwin, Vasquez, Silva, & Quan, 2010; Meltzer et al., 2010; Udomittipong et al., 2011). This predisposition is thought to be secondary to the increase of adipose tissue in the upper airway causing a reduction in pharyngeal size and thereby increasing the risk for upper airway obstruction and snoring (Kargoshaie et al., 2009). Of note is that rates of obesity vary among

subgroups within a population and a possible interaction between ethnicity and obesity, and its association with SDB has been previously highlighted (Kohler & van den Heuvel, 2008).

In total, 15 studies in this review examined the association between weight and snoring. Most of the studies used body mass index (BMI) such as raw, percentile or z-score (Bidad et al., 2006; Chng et al., 2004; Corbo et al., 2001; Kuehni et al., 2008; Kulnis et al., 2000; Li, Au, So, et al., 2010; Li, Jin, et al., 2010; Marshall et al., 2007; Sahin et al., 2009; Sogut et al., 2009; Urschitz et al., 2004; Valery et al., 2004), two used mean weight and height (Liukkonen et al., 2008), and a single study used percentage of ideal weight by height (Anuntaseree et al., 2001).

Nine studies report that increased weight status was associated with snoring. Five of these studies report that a higher BMI percentile increased the risk for snoring. The OR for snoring for children in the 75th to 80th BMI percentile was 2.0 (Urschitz et al., 2004), ≥85th percentile ranged from 1.35 to 2.0 (Bidad et al., 2006; Li, Au, So, et al., 2010), ≥90th percentile was 3.8 (Urschitz et al., 2004), between the 91st to the 95th percentile were between 1.99 and 3.09 (Corbo et al., 2001; Sogut et al., 2009), and >95th percentile ranged between 1.50 and 2.66 (Bidad et al., 2006; Corbo et al., 2001; Li, Au, So, et al., 2010; Li, Jin, et al., 2010; Sogut et al., 2009). Two of the studies used raw BMI (Chng et al., 2004) and mean weight as indicator for obesity (Liukkonen et al., 2008). The first study reported that the OR of being obese 3.75 higher among snorers, and the second study that weight was higher in children who snored (mean (standard deviation, SD) = 1.4 (4.9) kg vs. non-snorers (16.6 (4.7) kg). Finally, Bixler et al. (2009) reported that waist circumference and BMI were associated with snoring, particularly increased waist.

Other factors in conjunction with snoring may be present, for example, systemic inflammation has been noted in some children with mild SDB (Gozal, McLaughlin, et al., 2007; Lui et al., 2009). This suggests that children with primary snoring may not be a homogenous population and there may be two or more types of snoring disorders. Gozal, Sans-Capdevila, Kheirandish-Gozal, and McLaughlin-Crabtree (2007) have suggested how in children with OSAS particular genetic determinants (APOE ε4) are associated with both OSAS and neurocognitive dysfunction. Evidence showing an association between genetic markers and SDB suggests the existence of other pathways in addition to adipose tissue in throat.

1.2.6.2. Demographic factors associated with habitual snoring

Gender differences

Of the risk factors for snoring, gender has been the most frequently studied. Previous data suggest that males are more likely not only to have SDB, but to be more frequently diagnosed with other sleep disorders (Lumeng & Chervin, 2008; Meltzer et al., 2010). Some suggestions as to why males are more likely to snore and have SDB is that sleeping disorders are linked to the production of sex hormones such as testosterone, particularly among adolescent males (Fuentes-Pradera et al., 2004). Nevertheless, and despite the association between testosterone and upper airway narrowing, Lumeng and Chervin (2008) conclude in their review that hormonal changes may not be the only explanation for gender differences in snoring.

In total, 23 studies included in the review examined the association between gender and snoring. Of these studies, 11 report that male gender was associated with habitual snoring. Montgomery-Downs et al. (2003) report that the prevalence of being at risk for SDB was 26% in boys compared to 19.2% in girls, while (Valery et al., 2004) found a prevalence of snoring of 17.1% in boys versus 10.8% in girls. The OR for habitually snoring in males is reported to range from 1.3 to 2.47 (Kaditis et al., 2004; Ng et al., 2005; Tafur et al., 2009), (Bidad et al., 2006; Li, Au, So, et al., 2010; Sahin et al., 2009).

Of note is that the frequency of snoring amongst males varied with age. Four studies reported a higher prevalence of snoring among males during pre-school years (Bonuck et al., 2011; Mitchell & Thompson, 2003; Montgomery-Downs et al., 2003; Valery et al., 2004). Bonuck et al. (2011) found that the relationship between male gender and snoring was significant in 1.5-year-old children (OR 1.46). By contrast, Li, Au, So, et al. (2010) reported that the prevalence of snoring was higher among boys between the ages of seven and 11 years than other age groups; while Corbo et al. (2001) reported it was highest in 15-year-olds (OR 4.23). The remaining studies did not examine the impact of age on the relationship between male gender and snoring but reported a positive association in school-age children between six and 13 years (Ng et al., 2005; Sahin et al., 2009; Tafur et al., 2009), 11 and 17 years (Bidad et al., 2006) and one and 18 years (Kaditis et al., 2004).

Twelve of the studies did not find any relationship between snoring and gender (Anuntaseree et al., 2001; Goodwin et al., 2003; Kargoshaie et al., 2009; Liukkonen et al., 2008; Marshall et al., 2007; Petry et al., 2008; Smedje et al., 2001; Sogut et al., 2009; Teculescu et al., 1992; Umana et al., 2007; Urschitz et al., 2004; Zhang et al., 2004).

Indeed, three of the studies reported a higher frequency of snoring in females (Marshall et al., 2007; Smedje et al., 1999; Urschitz et al., 2004). Marshall et al. (2007) reported a higher frequency of snoring in girls if they had rhinitis, Urschitz et al. (2004) in girls older than 10-years-old, and Smedje et al. (1999) found that the higher frequency of snoring in girls was associated with a higher frequency of sleep problems, and in particular nightmares.

Age

A review that examined the prevalence of snoring and OSAS (Lumeng & Chervin, 2008) suggested that it was not possible to identify age-related changes in the prevalence of snoring. However, this assumption is challenged by more recent research. Bonuck et al. (2011) in their longitudinal study following children for a period of six years, report that the prevalence of snoring increased markedly between 18 months and 3.5 years (3.6% to 7.7%), but then slightly decreases over time after four years of age. Developmental changes in the ratio of size of tonsils relative to upper airway size may explain in part the high prevalence of snoring in young compared to older infants (Casselbrant, 1999).

From the 12 studies that examined the association between age and snoring, five studies reported that age was associated with snoring; additionally all were cross-sectional in design. The studies that reported an association between younger ages and snoring investigated the relationship either examining the contribution to snoring status (through regression models) or by comparing snoring rates according to age group. Bixler et al. (2009) examined five–12-year-old children with PS (objectively measured with PSG) and found that this condition was associated with younger ages (logistic regression: $\beta = -0.017$, OR 0.98; 95% Confidence Interval (CI) 0.97–0.99). Zhang et al. (2004) found that habitual snoring significantly decreased with age: 20.1% among <seven-year-old children, 15.3% between seven and nine years and 12.2% in >9-year-old children. Sahin et al. (2009) found a higher prevalence of snoring among seven to eight-year-old children compared to older ages (OR 1.85; 95% CI 0.81–4.22). Somewhat paradoxically Sogut et al. (2009) reported that 12–13-year-old children were at greater risk for snoring compared to 17-year-olds (OR 5.89; 95% CI 1.32–26.23 vs. 4.71 95% CI 1.03–21.44). Conversely, Corbo et al. (2001) reported that snoring was more common among older children, particularly among males aged over 15 years (OR 4.23; 95% CI 1.6–11.2). This raises a further issue of a possible interaction between age and gender and the combined impact on snoring. However, this possibility has not been well explored.

Eight studies failed to find an association between age and snoring. For example, Liukkonen et al. (2008) divided participants according to three age groups (one–two years, three–four years and five–six years). Their results indicated that the prevalence of snoring did not differ statistically between the age groups (4%, 8% and 7% respectively). Goodwin et al. (2003) found that prevalence of snoring was similar between two age groups: four–seven years and eight–11 (10.7% and 10.4% snoring prevalence). Tafur et al. (2009) did not find any association between snoring and age, which was explained by the authors as a result fewer children in the pubertal period. Kaditis et al. (2004) included children between one and 18 years, but did not find any differences in snoring prevalence across ages. Kargoshaie et al. (2009) also reported lack of association between age and snoring. Their results however may be explained by the narrow age band of the children in the study (i.e. fourth grade children with a mean (SD) age of 10.5 (0.5)). Two studies found a non-significant trend for a higher prevalence of snoring in older rather than younger ages. Urschitz et al. (2004) found that although not significant, when children were classified according to age groups snoring was higher in older children: 9% in <nine-year-olds, 10.1% at nine-years-old and 11% in >9-year-olds. Similarly, Umana et al. (2007) found while not significant, snoring prevalence (snoring <three nights/week to every night) was slightly higher among older age groups: two–four years (12.9%), five–seven years (25.2%), eight–10 (35.9%) and 10–13 (25.9%).This is consistent with the trend for a higher prevalence of snoring in older children reported by Corbo et al. (2001).

Family history of snoring

It is suggested that genetic factors may play an important role in SDB. There is some evidence that conditions such as OSAS run are more likely to occur within some families than others (El Bayadi et al., 1990; Redline et al., 1995). As well, and independent of common risk factors (e.g. obesity, etc.), there is evidence that specific candidate genes may be involved in both habitual snoring and OSAS (Jennum, Hein, Suadicani, Sørensen, & Gyntelberg, 1995; Larkin et al., 2010). Only six of the studies in the review examined family history of snoring. Two of these studies examined general history of snoring in the family. Li, Jin, et al. (2010) reported that the OR of having family history of snoring were 1.72 times higher (95% CI 1.57–1.87) among children with habitual snoring, while Ng et al. (2005) indicated that the odds of have other family members who snored were 4.23 times higher (95% CI 2.44–7.32) among snoring children. A more detailed examination of the contribution of parental, paternal, maternal and sibling snoring was also investigated. A parental history of snoring was explored by Kalra et al. (2006), who indicated that the odds

of having parents who snored were 2.9 times higher (95% CI 1.6–5.0) among snorers compared to non-snorers. Similarly, Ng et al. (2005) report an OR of 2.54 (95% CI 1.76–3.66) of having parents who snored. Whether paternal or maternal snoring was a stronger predictor of child snoring was investigated in four of the studies. Li, Au, So, et al. (2010) report that children with PS were more likely to have snoring mothers (OR 3.4; 95% CI 2.0–5.7); Kaditis et al. (2004) indicated that habitual snoring was associated with having a snoring mother (OR 1.5; 95% CI 1.1–2.0); and (Liukkonen et al., 2008) reported that a higher percentage of children who snored (37%) compared to non-snoring children (20%) had mothers who snored (either 'sometimes', 'often' or 'always'). Paternal snoring was also predictive of SDB. (Li, Au, So, et al., 2010) report that the OR of having a father who snored were 3.8 times higher (95% CI 2.7–5.5) in children who snored compared to non-snorers. Ng et al. (2005) report that the OR of having a snoring father were 2.05 times higher (95% CI 1.60–2.62); while Kaditis et al. (2004) report an OR of 1.5 (95% CI 1.2–1.9). Liukkonen et al. (2008) reported that the number of fathers who snored was higher among snorers than non-snorers (73% vs. 59%). A history of snoring in siblings was specifically investigated in two studies. Kaditis et al. (2004) report that having a sibling who snored was associated with an increased risk for habitual snoring (OR 1.7; 95% CI 1.2–2.4) while (Ng et al., 2005) found that having both a father and a sibling who snored was associated with an increased risk for habitual snoring (OR 2.08 95% CI 1.34–3.23). A comparison of maternal, paternal and sibling snoring as risk factors for child snoring found they were broadly equivalent.

Passive smoking

The association between passive smoking and respiratory health is well-known. Children living in a heavy smoking household are more likely to develop respiratory symptoms including chronic cough and phlegm, asthma and breathlessness all of which may predispose a child to upper airway irritation, inflammation and obstruction and hence snoring (Cook & Strachan, 1997).

Passive smoking was the second most frequently examined demographic factor (n = 20). All studies relied on parental self-report; and one study (Corbo et al., 2001) also included child-reports of smoking. Of note is that different definitions were used to classify passive smoking, complicating the comparisons between studies. Five studies asked whether any member living at the household smoked (Kaditis et al., 2004; Li, Au, So, et al., 2010; Li, Jin, et al., 2010; Liukkonen et al., 2008; Zhang et al., 2004); eight examined either parental, maternal or paternal smoking (Anuntaseree et al., 2001; Corbo et al., 1989; Ersu

et al., 2004; Kalra et al., 2006; Mitchell & Thompson, 2003; Petry et al., 2008; Sahin et al., 2009; Sogut et al., 2009; Teculescu et al., 1992); one specifically asked the number of cigarettes smoked at home (Urschitz et al., 2004); four studies examined multiple variables associated with smoking including prenatal smoking and maternal smoking during the first years of child's life (Chng et al., 2004; Kuehni et al., 2008; Marshall et al., 2007; Sogut et al., 2005); and one study examined both parental and child smoking (Corbo et al., 2001).

Corbo et al. (1989) examined parental smoking without discriminating between maternal or paternal smoking and the number of cigarettes smoked. The authors reported that all parents had smoked before their child's birth. They found that the prevalence of snoring was higher in children from moderate (<20 cigarettes/day; $\chi^2 = 13.4$) and heavy smoking households (>20 cigarettes/day; $\chi^2 = 14.8$). Kuehni et al. (2008) reported that the risk for habitual snoring in children was higher when both parents smoked compared to none (OR 2.06). In the studies that did discriminate between the relative contributions of paternal and maternal smoking, in general they were equally predictive of child snoring. Three studies found that both paternal and maternal smoking were associated with snoring. Sogut et al. (2009) reported that the OR of habitual snoring were 1.5 higher for children whose fathers smoked and 2.3 times higher in those whose mothers smoked. Sahin et al. (2009) reported an OR of 1.69 for maternal smoking and 1.65 for paternal smoking. Finally, Ersu et al. (2004) reported an OR of 3.3 for maternal smoking and 3.4 for paternal smoking. By contrast, Chng et al. (2004) found that paternal smoking was not associated (OR not reported) while maternal smoking was associated (OR 2.22) with an increased risk of snoring. Anuntaseree et al. (2001) reported that household smoking from at least one member (without discriminating) was associated with an increased risk of snoring in children with an OR of 1.75. However, and while household smoking was associated with habitual snoring in children, Anuntaseree's group did not find an association between paternal smoking and snoring and that within the whole sample a significantly low number of mothers were reported to smoke (n = 8). Finally, Marshall et al. (2007) found that maternal smoking during the first year of life was associated with an increased risk for habitual snoring with an OR of 2.08 as did Petry et al. (2008) who only studied maternal smoking, and report an increased risk for child snoring with an OR of 1.8.

Of the 20 studies that examined smoking, four did not report a significant association between smoking (regardless of source) and snoring (Kalra et al., 2006; Li, Au, So, et al., 2010; Sogut et al., 2005; Teculescu et al., 1992). Kalra et al. (2006) examined household smoking and found no relationship with snoring frequency. They attributed the failure to

find an association due to either the low rate of tobacco use in their sample of parents or because they studied very young infants (average age 13.7 months) and the length of exposure may not have been sufficient to have affected children. The latter, however, is contradicted by findings from several groups that tobacco exposure in the first years of age (e.g. one to five-years-old) is associated not only with snoring (Chng et al., 2004; Kuehni et al., 2008; Marshall et al., 2007), but also with respiratory problems (Xepapadaki et al., 2009), as a result of spending prolonged time with parents, increasing exposure to tobacco (Irvine et al., 1997). Sogut, et al. (2005) examined 1198 children in their survey of OSAS prevalence and they identified 39 children who were habitual snorers (≥ 3 nights/week). Despite a trend towards a higher frequency of parental smoking and smoking during pregnancy in habitual snorers, this did not reach significance. Li, Au, So, et al. (2010) also failed to find an association between passive smoking and child snoring and suggest that the lack of association may be due parents under-reporting household smoking for reasons of social desirability, thus raising concerns regarding parental self-report on tobacco use. Finally, Teculescu et al. (1992) specifically examined maternal smoking during pregnancy. There was a trend towards a higher frequency of maternal smoking during pregnancy in children who were habitual snorers compared to seldom snorers and non-snorers this did not reach significance (relative risk 1.1).

Smoking is not the only environmental pollutant that has an effect on health. Children from urban areas are especially exposed to pollutants and may be at greater risk for developing SDB. For example, Kuehni et al. (2008) found that 33.4% of habitual snoring was explained by air pollutants distributed as following, 20% parental smoking, 15% road traffic exposure and 3% lack of central heating. Air pollution may be particularly important as it is associated with respiratory disorders, such as asthma, which in itself may predispose a child to an increased risk of snoring (Shima, Nitta, Ando, & Adachi, 2002). In the review of studies, only two studies examined the association between pollutants with snoring (Kuehni et al., 2008; Zhang et al., 2004). Zhan's group investigated pollutants which can be normally found in the environment, but which can have an adverse effect on health. They examined a subgroup of children randomly selected from the total sample (n = 88), who were visited at their homes to measure the levels of formaldehyde and nitrogen dioxide. Results revealed that medium and high exposure to nitrogen dioxide increased the risk for snoring (OR 2.5 and OR 4.5 respectively). In summary, passive smoking was frequently reported to be associated with snoring in children. Of particular note is that

passive smoking seems to contribute not only to SDB development, but also to respiratory-related symptoms (e.g. asthma, rhinitis) which have also been related to snoring.

Socioeconomic status

Socioeconomic status (SES) and snoring was examined in six of the studies in this review. Measures of SES included duration of parental education (Corbo et al., 2001; Sahin et al., 2009); household income (Li, Jin, et al., 2010); number of people per room, parental education, single parenthood and level of SES deprivation based on the geographical area (Kuehni et al., 2008); ratings of social class (e.g. low, middle to upper class on a scale from 1 to 5) (Umana et al., 2007); paternal employment (manual vs. professional); and inadequate housing and maternal education (Bonuck et al., 2011). Only three of the five studies reported that low SES was associated with an increased risk of snoring (Bonuck et al., 2011; Kuehni et al., 2008; Li, Jin, et al., 2010). In the study conducted by Kuehni et al. (2008) only two SES factors remained associated with habitual snoring after adjusting for other demographic and health characteristics: single parenthood (OR 1.49) and high deprivation based on geographical area of housing, but only in Caucasian children (OR 1.69). Li, Jin, et al. (2010) reported that low income was more common among habitual snorers compared to non-snorers (OR, 1.36) while Bonuck et al. (2011) who followed-up children at different periods of time (at 1.5 years, 4.75 years and 6.75 years), report that lower maternal education was associated with reports of snoring 'always' (OR 1.82) at 1.5 years, while both inadequate housing (OR 1.44) and manual paternal employment (OR 1.28) were associated with reports of snoring at 6.7 years.

In general, most of the studies in this review support an association between SES and snoring in children. However, despite the general finding that low SES is common in children who receive a sleep disorder diagnosis (Meltzer et al., 2010), it may not be straightforward. This is because additional factors that may accompany SES (e.g. ethnicity, access to health care, education levels) may also contribute to a higher risk of snoring. Boss, Smith, and Ishman (2011) in their review examining ethnic and socioeconomic inequality among children with SDB identify that minority groups across different countries are not only at a higher risk for SDB, but they also have more limited access to treatment options.

Ethnic differences

From the studies included in this review, only five explored ethnicity as a contributing factor and all reported that ethnicity was associated with snoring. The ethnic groups

identified at risk for snoring included African-American (Bixler et al., 2009; Kalra et al., 2006; Montgomery-Downs et al., 2003), African/Caribbean/Indian (Bonuck et al., 2011) and Hispanic children (Bixler et al., 2009; Goodwin et al., 2003).

Bixler et al. (2009) reported that the OR of being a snorer from a minority group (13.8% from African-American ethnicity and 6.3% Hispanic) were 1.8 times higher compared to children with white ethnicity. Kalra et al. (2006) found that being African-American was significantly associated with an increased risk of habitual snoring (OR 3.3). Similarly, Montgomery-Downs et al. (2003) found that increased risk for SDB was more common among African-American (27.6%) than Caucasian children (17.8%). Goodwin et al. (2003) reported that snoring was more prevalent in Hispanic (11.4%) than Caucasian children (7.4%). Finally, (Bonuck et al., 2011) indicated that other ethnicity than Caucasian was associated with snoring, but this relationship was found only in 1.5-year-old children (OR 2.80 CI 95% 1.38–5.70).

The difference in snoring rates among ethnic groups might be explained by ethnic-related variations in upper airway structure and morphology. For example craniofacial characteristics and possible genetic predisposition have been suggested as placing African-American children at greater risk for SDB (Randerath, Sanner, & Somers, 2006). However, and as discussed earlier, because ethnicity is associated with low SES, both factors could contribute to the increased risk for snoring. Although not specifically examined, three of the studies in the review that report an association between ethnicity and snoring did include indirect measures of SES. Montgomery-Downs et al. (2003) reported that the children in their study were recruited from 'Jump Start programs', which was directed to families from low SES. Kalra et al. (2006) indicated that 35% of children in the total sample were from low income families, whilst Goodwin et al. (2003) highlighted that minority groups in their study (Hispanic) were located in low income census areas.

The contribution of both ethnicity and low SES to increased risk of snoring is not completely clear. However, recent data (Calhoun et al., 2010) investigating families who had children with SDB (AHI $\geq$ 5) suggests that the association between SES/ethnicity and snoring might be explained by the increased prevalence of prenatal and perinatal complications among minority groups who usually live in deprived conditions. Thus, SES and ethnicity play a mediating role.

1.2.6.3. Other risk factors (special conditions)

Several medical conditions, and particularly those which impact craniofacial and upper airway structure, are associated with an increased risk for snoring and SDB. The largest affected group is children with Down syndrome. The high prevalence of SDB among this population is explained by the abnormal craniofacial structure characterised by upper airway narrowing due to adenotonsillar hypertrophy, abnormal back placement of the tongue (i.e. glossoptosis) and other mandibular characteristics (Breslin, Edgin, Bootzin, Goodwin, & Nadel, 2011; Dahlqvist, Rask, Rosenqvist, Sahlin, & Franklin, 2003). Children with Down syndrome are also reported to have an increased range of sleep complaints, including the initiation and maintenance of sleep, resistance to bed at night, restless sleep and excessive daytime sleepiness (EDS) (Levanon, Tarasiuk, & Tal, 1999). Similarly, congenital conditions that affect the normal craniofacial structure (e.g. asymmetric abnormal development of different facial structures) are also associated with an increased risk for snoring and SDB (Cloonan et al., 2009; Sze, Paladin, Lee, & Cunningham, 2002). Although rare, benign tumors (lipoma) can compromise the pharyngeal space. Gong, et al. (2006) documented a case of a 11-year-old girl who had a five year history lipoma compromising her nasopharyngeal space. This girl was diagnosed with OSAS, which was reversed following tumor removal.

Other conditions such as cerebral palsy and bronchiectasis have also been identified as risk factors for a wide range of sleep problems. Due to the abnormalities in muscle tone, hence poor respiratory control, children with cerebral palsy have breathing difficulties that affect normal daytime and nighttime functioning. Sandella, O'Brien, Shank, and Warschausky (2011) examined 41 number of children with cerebral palsy, reporting that these children were at an increased risk for SDB. Nevertheless, it is to be noted that apart from cerebral palsy, a high number of children in Sandella's study were pre-term and had low birth weight; factors that have previously been indicated to predict SDB in otherwise healthy children (Emancipator et al., 2006; Montgomery-Downs et al., 2010).

Bronchiectasis in turn, is a chronic respiratory condition characterised by recurrent respiratory infections, obstructive lung disease and other symptoms affecting the respiratory system. Erdem et al. (2011) compared 54 children with bronchiectasis and 54 healthy controls and collected frequency measures of snoring using the Pediatric Sleep Questionnaire. Children with bronchiectasis had higher snoring scores (mean (SD) =1.7 (1.1)) than controls (1.3 (1.3)). In addition, a high percentage of children in Erdem's study

also had a concomitant diagnosis of asthma and higher snoring scores were observed in wheezing (2.0 (1.2)) than non-wheezing patients (1.3 (0.8)).

In conclusion, when comparing the OR of the different medical factors associated with snoring the strongest predictors in order were: tonsil hypertrophy (OR ranging from 2.6 to 19.2), followed by upper airway respiratory infections (OR ranging from 1.9 to 5.8), to a lesser extent asthma, rhinitis, weight, waist circumference and the weakest was eczema (OR from 1.28 to 2.0). On the other hand, when comparing the different demographic factors air pollutants such as nitrogen dioxide was more common among habitual snorers (OR 2.5 and 4.5); however, this was only reported by one study and it would be necessary to confirm with further reports. To a lesser extent, other demographic factors associated with snoring were snoring history in both parents (OR 2.6 and 2.9) and family history of snoring without discriminating between members (OR 1.72 to 4.23). The associations that were less strongly associated included low SES (OR 1.49 to 1.82) and young age (OR 0.89 to 2.5). Interestingly, when the age factor was examined it was found that two studies reported that pubertal age was more strongly associated with snoring (OR 4.23 and 4.71). From some of the literature examining habitual snoring and associated factors, it is apparent that medical factors, particularly those that directly compromise the upper airways, may be a key indicator for habitual snoring in children. However, the factors associated with snoring may be additive and the interaction between risk factors remains unexplored.

1.2.7. Consequences of habitual snoring in children

The impact of severe childhood SDB, for example, OSAS, on daytime functioning is more commonly associated with deficits. There have been extensive reviews conducted over the last seven years examining neurocognitive and behavioural performance in children with SDB. One of the most recent reviews (Kohler, Lushington, & Kennedy, 2010) concluded that children with any degree of SDB are more likely to have deficits in neurocognitive functioning such as impaired executive function, attention, general intellectual ability, and to a lesser extent language development. Children with SDB are also more likely to display a higher frequency of problematic behaviours, especially externalising problems such as hyperactivity and aggression (Beebe, 2006). However, Kohler et al. (2010) in their review indicated that the more rigorous research shows that inattentiveness and hyperactivity are

as prevalent as other disruptive behaviours including depression, somatic complaints, and social problems.

However, much of the evidence that daytime functioning is impaired in children with SDB has come from studies which have examined children with OSAS. What is less appreciated is that similar deficits are also evident in children with mild SDB such as PS (Brockmann, Urschitz, Schlaud, & Poets, 2012; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004). Studies that have examined neurocognitive and behavioural performance in children who snore habitually or with PS (n = 26) are summarised in Table 1.5. Despite PSG being considered the 'gold standard' measure when assessing SDB, not all studies have used this tool to confirm PS status; those which have utilised parental self-report measures suggestive of PS (snoring on a frequently basis) were included. Of these studies, 17 recruited children from community settings. These included epidemiologic databases (Barnes et al., 2009; Beebe, Rausch, Byars, Lanphear, & Yolton, 2012; Bonuck, Freeman, Chervin, & Xu, 2012b; Emancipator et al., 2006; Rosen et al., 2004), primary schools (Arman et al., 2005; Brockmann, Bertrand, et al., 2012; Calhoun et al., 2009; Ferreira et al., 2000; Honaker, Gozal, Bennett, Sans-Capdevila, & Spruyt, 2009; Kaemingk et al., 2003; Key, Molfese, O'Brien, & Gozal, 2009; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004; Urschitz et al., 2003; Witcher et al., 2012), first medical check-ups after birth (Piteo, Lushington, Roberts, Martin, et al., 2011) and centralised visitor health centres (Ali et al., 1993). Of these 17 studies, five assessed only neurocognitive functioning, eight assessed only behaviour and four assessed both neurocognitive and behaviour. In addition, six studies examined sleep using PSG (Barnes, Calhoun, Honaker, Key, Obrien, Kaemingk), three used purposed-design questionnaires (Arman et al., 2005; Ferreira et al., 2000; Piteo, Lushington, Roberts, Martin, et al., 2011), one used a validated parental self-report questionnaire (Witcher et al., 2012), and another used both a purposed-design questionnaire and home video recording of sleep with oximetry (Ali et al., 1993). Finally, only three studies examined daytime sleepiness (Ali et al., 1993; Arman et al., 2005; Brockmann, Urschitz, et al., 2012).

Nine of the studies summarised in Table 1.5 examined children with PS recruited from clinical settings. These included sleep centres (Beebe et al., 2004; Bourke et al., 2011; Jackman et al., 2012; Melendres, Lutz, Rubin, & Marcus, 2004; Miano, Paolino, et al., 2011), ENT specialist (Blunden, Lushington, Kennedy, Martin, & Dawson, 2000; Kennedy et al., 2004) and general practice for children who were sick (Blunden, Lushington, Lorenzen, Martin, & Kennedy, 2005). Of these eight studies, two examined only

neurocognitive functioning (Cai et al., 2013; Kennedy et al., 2004), two examined only behaviour (Bourke et al., 2011; Melendres et al., 2004) and five examined both neurocognitive functioning and behaviour (Beebe et al., 2004; Blunden et al., 2000; Blunden et al., 2005; Jackman et al., 2012; Miano, Paolino, et al., 2011). Additionally, all studies but one (Blunden et al., 2005) used PSG to assess sleep; however, two examined only index children (Beebe et al., 2004; Melendres et al., 2004), two included additional measures such as sleep diaries (Blunden et al., 2000; Jackman et al., 2012) and one study included alternative scoring (i.e. CAP) criteria to assess sleep (Miano, Paolino, et al., 2011). Finally, only two studies examined daytime sleepiness (Blunden et al., 2000; Melendres et al., 2004).

Neurocogntive functioning

Of nine studies that reported neurocognitive findings in children recruited from community settings, six of those described neurocognitive deficits in childhood PS (Barnes et al., 2009; Emancipator et al., 2006; Honaker et al., 2009; Kaemingk et al., 2003; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004; Piteo, Lushington, Roberts, Martin, et al., 2011) compared to three reporting no deficits (Beebe et al., 2012; Calhoun et al., 2009; Key et al., 2009). However, of the studies reporting neurocognitive deficits, one study reported deficits only for pre-term children and not for full-term children with SDB (Emancipator et al., 2006). Although another study reported worse performance in general cognitive scales (Piteo, Lushington, Roberts, Martin, et al., 2011), the authors did not find any association with other scales regarding language, motor and social development. Finally, in the study conducted by Kaemingk et al. (2003) children with AHI > 5 were included; hence children with OSAS were also included in that study. In general, verbal ability seemed to be the functioning most affected by snoring. On the other hand, general intelligence and verbal ability were the most common deficits reported among studies that recruited children from clinical settings and which found neurocognitive deficits (Blunden et al., 2000; Blunden et al., 2005; Kennedy et al., 2004; Miano, Paolino, et al., 2011).

Although research indicates that decreased cognitive functioning is associated with several forms of SDB including primary snoring, it remains unclear whether this condition directly contributes to neurocognitive deficits and the mechanisms behind this relationship (Calhoun et al., 2009). Indeed, research has not been able to identify a clear association between physiological variables recorded using PSG and neurocognitive variables (Beebe et al., 2004; Calhoun et al., 2009; Chervin et al., 2006; Kaemingk et al., 2003). The lack of association between PSG variables and neurocognitive performance has raised the need for

alternative indexes or approaches that could provide a more realistic explanation of how sleep and cognition is linked. In the search for alternative methods, CAP was developed as a method to describe sleep instability/stability. Some aspects of CAP have been shown to correlate with cognitive performance. For example, subtypes of CAP (A1) are modified by learning tasks These subtypes are noted to be affected in conditions such as SDB; suggesting that the microstructure of sleep is important, particularly the stability during SWS where A1 subtypes are normally seen (Bruni et al., 2010).

Table 1.5 Findings and methodology of studies examining neurocognitive and behavioural functioning in snoring children*

First Author (Year)	Main Findings	Components of assessment	Definition of index group	Participants	Recruitment
Community samples					
Beebe (2012)	**Neurocognitive**: No association with early motor development problems. **Behaviour**: Persistent snorers had higher behaviour problem scores at age 3 compared to transient snorers and controls.	**Neurocognitive:** BSID-II. **Behaviour:** BASC-pre-school form.	"Persistent snorers (PS)": loud snoring ≥ 2 times/week at both age 2 and 3	170 non-snorers; 57 transient-snorers; 22 PS	Mother/child pairs participating from a birth cohort at a metropolitan area.
Bonuck (2012a)	**Behaviour:** SDB associated with robust and persistent effect on following behaviour in children. SDB associated with 40% behavioural difficulties at 4 years and with 60% at 7 years.	**Behaviour:** SDQ.	"Always" to question: Does he or she snore for more than a few minutes at a time?	13467 infants to derive SDB clusters and behavioural outcomes.	Geographically based cohort that initially enrolled pregnant women.
Brockmann (2012)	**Sleep:** Authors unable to identify wake/sleep periods due to EEG, EOG, EMG was not included in assessment. **Behaviour:** PS had increased risk for hyperactive and inattentive behaviour **School performance:** snorers had poor school performance **Daytime sleepiness**: snorers had increased daytime sleepiness	**Sleep:** Limited-channel cardiorespiratory recordings (home) for PS, UARS/OSA. **Behaviour:** Purposed-designed questions for hyperactive-inattentive behaviour. **School performance:** Academic grades transformed into class and school subject stratified performance percentiles. **Daytime sleepiness**: Purposed-designed questions for daytime sleepiness.	Loud snoring "frequently" or "always" and AHI < 1, RDI < 1 and O_2 desat Index < 4/h	410 non-snorers; 69 PS; 23 UARS/OSA.	Third-grade children from 27 public schools randomly selected in Hanover, Germany
Witcher (2012)	**Sleep:** Poorer sleep hygiene with behaviour problems in PS. **Behaviour:** PS had higher scores on all scales than non-snorers (e.g. oppositional, hyperactivity and social problems).	**Sleep:** CSHS. **Behaviour:** CPRS-R:L.	Snoring "frequently" to "almost always"	71 non-snorers; 100 PS	Children reported to snore 'frequently' or 'always' and 'never' in a validated questionnaire sent to three public school districts
Piteo (2011)	**Sleep:** Frequent snorers had more restless sleep, and shorter total sleep duration and nocturnal sleep **Neurocognitive:** Frequent snorers had lower cognitive scores compared to controls. However, snoring frequency was not associated with language, motor or social development.	**Sleep:** Parental estimation in regard to previous week (different sleep variables) **Neurocognitive:** BSITD-III.	Snoring "frequently" in the absence of colds shortly after birth, and continued snoring "frequently" when assessments at 6 and 12 months.	31 controls; 10 snorers.	First medical check-up appointments in South Australia

First Author (Year)	Main Findings	Components of assessment	Definition of index group	Participants	Recruitment
Barnes (2009)	**Sleep:** Decreased Stage 2 and increased Stage 4 in occasional snorers compared to non-snorers. **Neurocognitive**: Altered neural processing for attention processes in occasional snoring children. However, no differences on PPVT-III or NEPSY. **Behaviour:** Increased scores for restlessness/impulsivity, cognitive problems/inattention, and ADHD subscale among rarely snorers compared to controls.	**Sleep:** PSG. **Neurocognitive**: Event-related potentials; PPVT-III; Visual attention (NEPSY). **Behaviour:** CPRS:R; Childhood Symptom Inventory-4.	Snoring "rarely" or "occasionally".	22 controls; 22 non-habitual snorers.	Children from an ongoing study examining sleep characteristic in healthy children.
Calhoun (2009)	**Sleep:** No relationship between breathing-related arousals and neuropsychological measures. **Neurocognitive**: No relationship between mild SDB and measures of neuropsychological functioning, except non-verbal reasoning; which was significant lower in mild SDB snoring children, but with a small effect size.	**Sleep:** PSG. **Neurocognitive**: WASI; GDS; VMI; ANT; CVLT; Stroop; WCST-64; Digit Span and Coding from WISC-III.	AHI < 1 and snoring related arousals counted by technician.	413 AHI < 1; 152 ≥ 1 AHI < 5; 6 AHI ≥ 5 Reclassified 329 non-snorers (AHI < 1); 84 PS; 96 non-snorers (AHI ≥ 1) and 62 snorers (AHI ≥ 1)	Using stratification of age, grade, sex and risk for having SDB (parental self-report questionnaire) children were randomly selected from elementary schools.
Honaker (2009)	**Sleep:** No differences between the groups in any of the sleep-related PSG variables (e.g. total sleep time, spontaneous arousal, % of sleep stages). **Neurocognitive**: Although within the normal range, habitual snorers had decreased verbal ability (DAS) compared to controls (school-children).	**Sleep:** PSG. **Neurocognitive**: DAS; NEPSY; PPVT-III; Expressive vocabulary test.	Snoring "frequently" (3-4 times/week) or "almost always" (> 4 times/week); and composite score ≤ 3 based on RDI, RAI, SaO_2 nadir.	76 controls; 76 PS; 76 OSA.	Children from 1st to 3rd grades in public school systems whose parents completed a validated questionnaire.
Key (2009)	**Sleep:** No differences reported. **Neurocognitive**: No relationship between NEPSY (attention and memory) and AHI. No associations between ERP measures and oxygen desaturation index or arousal index in children with very mild SDB.	**Sleep:** PSG. **Neurocognitive**: ERP to speech sounds; NEPSY.	Habitual snoring reported by parents	3 SDB; 32 SDB sub-clinical levels (AHI = 0.12–3.37/hr).	Children from 1st grade in public schools from whose parents completed a validated questionnaire.
Emancipator (2006)	**Sleep:** Authors unable to identify wake/sleep periods due to EEG, EOG, EMG was not included in assessment. **Neurocognitive**: Association between SDB and cognitive ability in **preterm** children. SDB had lower scores on global scales, arithmetic, faces and places, reading (decoding and understanding), riddles and triangles. Equivalent neurocognition in **full-term** children with and without SDB (data not shown). Snoring duration strongly associated with lower neurocognitive performance.	**Sleep:** Limited-channel cardiorespiratory recordings (home). **Neurocognitive**: PPVT; K-ABC; CPT.	Either loud snoring 1-2/week of greater during last month (habitual snoring); or OSAS: OAHI ≥ 5 and OAI ≥ 1.	671 non-SDB; 164 SDB Reclassified as 568 non-snorers; 267 snorers.	'Cleveland Children's Sleep and Health Study'. Stratified random sample of full-term and preterm children born in in an urban community.

First Author (Year)	Main Findings	Components of assessment	Definition of index group	Participants	Recruitment
Arman (2005)	**Sleep:** PS had more reports for restless sleep, nocturnal enuresis, increased parental anxiety during child's sleep, **Behaviour**: Elevated inattentive, conduct, oppositional defiant, ADHD index; total problem scores. **Daytime sleepiness:** Daytime hyperactivity and sleepiness while watching TV	**Sleep:** Purposed-design questionnaire for sleep habits and night-time symptoms. **Behaviour**: CPRS-R:L; HIS. **Daytime sleepiness:** Purposed-design questionnaire for daytime symptoms.	Snoring "always" or "often".	190 controls; 96 PS.	72 schools from nine districts in Istanbul randomly selected via multistage sampling.
O'Brien (2004)	**Sleep:** Reduced REM %/TST and increased respiratory arousal index in PS. **Neurocognitive**: PS had worse verbal non-verbal and general ability, naming, verbal comprehension, pattern construction, language, visuospatial, visual attention, phonological processing and arrows scores. **Behaviour**: PS had elevated withdrawn, anxious/depressed, social, attention, internalizing problems; hyperactivity, social, hyperactive-impulse and total problems.	**Sleep:** PSG. **Neurocognitive**: DAS; NEPSY. **Behaviour**: CPRS-R:L; CBCL/6-18.	Snoring ≥ 2 nights/week; OAI < 1/hr of TST, and AHI < 5/hr TST, normal gas exchange.	31 controls; 87 PS.	Children from 1st grade public schools from Jefferson County whose parents completed a validated questionnaire.
Rosen (2004)	**Sleep:** Authors unable to identify wake/sleep periods due to EEG, EOG, EMG was not included in assessment. **Behaviour**: SDB group had higher chances of having borderline or clinically abnormal internalizing and externalizing problems, hyperactivity, global total index, oppositional behaviours.	**Sleep:** Limited-channel cardiorespiratory recordings (home). **Behaviour**: CBCL; CPRS-R:L.	Children without OSA and snoring "loudly" 1 2/week in the last month.	667 non-SDB; 162 SDB.	'Cleveland Children's Sleep and Health Study'. Stratified random sample of full-term and preterm children born in in an urban community.
Kaemingk (2003)	**Sleep:** Increased Stage 1 in AHI ≥ 5 than AHI < 5. **Neurocognitive:** No differences among any cognitive scale (full-scale IQ, verbal IQ and performance IQ). Decreased verbal learning and memory (delayed recall) for AHI > 5. **Behaviour**: No differences in any behavioural measure. **School performance**: No differences for academic performance.	**Sleep:** Home-PSG. **Neurocognitive:** WASI; CAVLT-2. **Behaviour**: CPRS. **School performance**: Woodcock Johnson Psycho-Educational Battery-Revised Tests of Achievement.	Respiratory disturbance during sleep AHI ≥ 5.	72 AHI < 5; 77AHI ≥ 5	'TuCASA study': children recruited during 1999–2000 and 2000–2001 school years from the Tucson Unified School District.
Urschitz (2003)	**Sleep:** Authors unable to identify wake/sleep periods due to EEG, EOG, EMG was not included in assessment. **School performance**: Habitual snoring related to poor school performance, partially explained by intermittent hypoxia.	**Sleep:** Nocturnal home pulse oximetry. **School performance**: Previous term's report, poor academic performance defined as grade 4 or worse (from 1 "outstanding" to 6 "failed"), or special assistance required for science, mathematics, reading and handwriting.	Snoring "frequent" or "always".	410 never snoring; 605 occasionally snoring; 89 frequently snoring; 25 always snoring.	27 of 59 public primary schools within urban limits in Hannover (Germany) randomly selected within strata of SES.

First Author (Year)	Main Findings	Components of assessment	Definition of index group	Participants	Recruitment
Ferreira (2000)	**Sleep:** Snorers had more bedtime struggles, comforting habits to sleep, night light to fall asleep, afraid of sleeping alone, teeth grinding, sleep talking, and night terrors. **Behaviour:** Medical and behavioural problems (parental and teacher reported scores). **Daytime sleepiness:** Sleepy and irritable during day	**Sleep:** Purposed-design questionnaire regarding sleep/wake behavioural patterns. **Behaviour**: behavioural disturbances using the Children's Behavior; Questionnaire for Teachers.	Loud snoring "frequent" or "always".	876 non-snorers; 84 loud snorers.	Children from10 primary schools from a city parish in Coimbra (Portugal) during 1994–1995 school year.
Ali (1993)	**Sleep:** Increased restless sleep among children who snored most nights compared to never snorers. **Behaviour:** High risk SDB more hyperactive and inattentive (parent/teacher), more aggressive (parents). **Daytime sleepiness:** Daytime sleepiness more common among children who snored most nights compared to never snorers.	**Sleep:** Questionnaire survey: snoring and sleep problems; home recording: video camera, microphone and oximetry. **Behaviour:** three scales from CPRS (aggression, inattention and hyperactivity) **Daytime Sleepiness:** Purposed-design questionnaire.	Overall score of the 66 highest rankings; Four snoring categories (never, rarely, sometimes and most nights).	58 controls; 52 high risk of SDB children.	Children consecutively born between 8 January and 22 September who lived in Oxford (UK) from a centralised health visitor register
Clinically-referred samples					
Cai (2013)	**Sleep:** No differences between PS and OSAS in TST, sleep efficiency stage 2. **Neurocognitive:** No group differences between controls and PS for any cognitive variable.	**Sleep:** PSG only for PS and OSAS group. **Neurocognitive:** WISC-R; CPT.	Snoring, AHI ≤ 5 or OAI ≤ 1	60 controls; 63 PS; 89 OSAS.	Children with snoring recruited from a paediatric clinic.
Jackman (2012)	**Sleep:** PS had increased respiratory arousal index, Stage 3/4 per TST, NREM/REM per TST and shorter average sleep duration (sleep diary). **Neurocognitive:** No group differences for any cognitive variable. **Behaviour:** PS and mild OSAS had increased scores compared to controls on behavioural measures: executive and problematic behaviours in general.	**Sleep:** PSG; sleep diary **Neurocognitive:** IQ-ABIQ; NEPSY (Attention, Language, Visuospatial, and Sensorimotor Skills domains); 1 verbal and non-verbal subtest from RBMT; DA; SR. **Behaviour:** BRIEF-P; CBCL/1.5-5; C-TRF/1.5-5; ABAS-II.	OAHI ≤ 1/event per hour.	37 controls; 60 PS; 32 mild OSAS; 24 moderate/severe OSAS.	Children referred to sleep centre for SDB assessment. Controls recruited from community via posters and email advertisements.
Miano (2011)	**Sleep:** PS decreased verbal, performance and global IQ than controls. Positive correlations between global intelligence and percentage of wakefulness, NREM Stage 1, CAP-A2, arousal and A2 index. **Neurocognitive:** PS and OSAS children had reduced total, verbal and performance IQ scores. **Behaviour:** PS and OSAS children had increased ADHD scores.	**Sleep:** PSG for PS and OSAS (Traditional scoring and CAP Analyses). **Neurocognitive:** WISC-III R. **Behaviour:** ADHD Rating Scale.	AHI < 1, and microphone-detected snoring.	60 controls; 13 PS; 31 OSAS.	Children referred to a sleep centre for habitual snoring, apnoea or restless sleep. Controls recruited from two schools (same urban area).
Bourke (2011)	**Sleep:** No differences in any sleep-related variable on PSG between PS and controls. **Behaviour:** PS had increased behavioural regulation problems, impaired working memory, planning/organization and monitoring function. Increased internalising and externalising, withdrawn/depressed, attention and thought problems.	**Sleep:** PSG. **Behaviour:** BRIEF; CBCL/6-18.	OAHI ≤ 1 event/hour with a history of snoring.	59 PS; 24 mild OSAS; 18 Moderate/Severe OSAS.	Children referred to sleep centre for SDB assessment. Controls recruited from community via posters and email advertisements.

First Author (Year)	Main Findings	Components of assessment	Definition of index group	Participants	Recruitment
Blunden (2005)	**Neurocognitive:** Snorers and snorers+BSP performed worse on all IQ and attention tests, compared to BSP and controls. **Behaviour:** Snorers and controls had similar competent behaviour scores and external behaviour scores. Total problematic behaviour higher than controls, but comparable to BSP and snorers+BSP.	**Neurocognitive:** WISC-III; CMS; ACPT. **Behaviour:** CBCL.	Snoring ≥3–5 times/week; same frequency + a reported Behavioural Sleep Problem (BSP)T-score <60	31 controls; 11 snorers; 13 BSP; 9 snorers+BSP.	Children who were sick and waiting for consultation in five general practices from South Australia.
Beebe (2004)	**Sleep:** OSAS had increased Stage 1 % compared to PS. **Neurocognitive:** Only OSAS associated with worse processing speed (word reading speed), visual attention, verbal fluency. In contrast, verbal memory and global intelligence not affected for any group. **Behaviour:** PS had higher scores for behavioural problems compared controls, also slightly higher than OSAS.	**Sleep:** PSG only for PS and OSAS groups. **Neurocognitive:** vocabulary, block design and digit span of WISC-III; verbal learning of WRAML; Stroop; GDS. **Behaviour:** BASC (Hyperactivity, Conduct Problems, Aggression, Attention, Depression and Anxiety scales) and BRIEF	Chronic loud snoring and AHI < 1	17 controls; 17 PS; 7 mild OSAS; 6 moderate/severe OSAS.	Consecutive referrals to a sleep centre for OSAS symptoms. Controls recruited via door-to-door solicitation in the neighbourhoods of index children.
Kennedy (2004)	**Sleep:** No group differences in any sleep-related PSG variable. **Neurocognitive:** Snorers performed worse on verbal IQ, global IQ, memory index, selective attention and sustained attention.	**Sleep:** PSG. **Neurocognitive:** WPPSI-R (< 6 years); WISC-III (> 6 years); WRAML; ACPT.	Snoring referral and RDI < 1.	13 controls; 13 snorers.	Children referred to ENT specialist for evaluation of snoring and the need of adenotonsillectomy.
Melendres (2004)	**Sleep:** Authors unable to compares PSG parameters due to controls were not assessed. **Behaviour:** SDB children had increased scores for hyperactivity compared to controls. **Daytime sleepiness:** Sleepiness scores higher than controls (scores below adult cut-off). No differences in sleepiness scores between PS and OSAS.	**Sleep:** PSG only for SDB group **Behaviour:** The Conners Abbreviated Symptom Questionnaire for Hyperactivity **Daytime sleepiness:** Modified-ESS	SDB referral and snoring without episodes of apnoea, desaturation, hypoventilation, or excessive arousals (PSG).	72 controls; 108 SDB.	Children referred to a sleep centre for suspected SDB secondary to adenotonsillar hypertrophy.
Blunden (2000)	**Sleep:** No group differences in any sleep-related PSG variable. However, on SDSC PS had more problems with initiating and maintaining sleep, and making the transition from wake to sleep. **Neurocognitive:** PS had reduced attention, lower memory and intelligence compared to controls. **Behaviour:** PS reported reduced social competency and increased problematic behaviours, but these were not statistically different from controls. **Daytime sleepiness:** Increased daytime sleepiness	**Sleep:** PSG and sleep log; SDSC. **Neurocognitive:** WPPSI-R; WISC-III; memory screening index scale of WRAML; ACPT. **Behaviour:** CBCL/4-18. **Daytime sleepiness:** SDSC	Snoring referral and RDI < 1.	16 controls; 16 PS.	Children referred to ENT specialist for evaluation of snoring and the need of adenotonsillectomy.

Note. * **Test abbreviations:** CSHQ = Child Sleep Habits Questionnaire; BSITD-II orBSITD-III = Bayley Scales of Infant and Toddler Development (2nd or3rd Edition); BASC-pre-school form = Behavior Assessment System for Children (pre-school form); SDQ = The Strengths and Difficulties Questionnaire; CPRS-R:L = Conners' Parent Rating Scale-Revised Long Form; PPVT-III = Peabody Picture Vocabulary Test-III; WASI = Wechsler Abbreviated Scales of Intelligence; GDS = Gordon Diagnostic; VMI = System; Developmental Test of Visual-Motor Integration; ANT = Animal Naming Test; CVLT = California Verbal Learning Test; Stroop = Stroop Color and Word Test Children's Version; WCST-64 = Wisconsin Card Sorting Test-64 Card Version; WISC-III = Wechsler Intelligence Scale for Children (III); ERP = Event related potentials; K-ABC=Kaufman Assessment Battery for Children; HIS = Teacher Scales; Inattention Hyperactivity Scale; DAS = Differential Ability Scales; NEPSY = Developmental Neuropsychological Assessment; The CBCL/6-18 = Child Behavior Checklist Ages 6-18; CAVLT-2 = Children's Auditory Verbal Learning Test-2; IQ-ABIQ = The Abbreviated Battery; RBMT = Rivermead Behavioural Memory Test for Children; DA = The Shape School, Delayed Alternation; SR = Spatial Reversal Tasks; BRIEF-P = The Behavior Rating Inventory of Executive Function-Preschool version); CBCL/1.5-5 = The Child Behavior Checklist Ages 1.5.-5; C-TRF/1.5-5 = The Caregiver-Teacher Report Form Ages 1.5-5; ABAS-II = The Adaptive Behavior Assessment System®-Second Edition; ESS = Epworth Sleepiness Scale; SDSC = Sleep Disturbance Scale for Children WPPSI-R = Scale of Intelligence-Revised; WRAML = Wide Range Assessment of Memory and Learning: picture, design and story memory, and verbal learning; ACPT = Auditory Continuous Performance Test; CMS = Children's Memory Scale

Behavioural performance

Behavioural deficits are reported in 12 studies that included children recruited from community, while eight studies examined behaviour in children with PS recruited from a clinical setting. Among those that recruited children from community settings, 11 studies reported that children with either habitual snoring or PS had increased behavioural problems. The most common problem reported are hyperactivity and inattentive behaviour (Ali et al., 1993; Arman et al., 2005; Barnes et al., 2009; Beebe et al., 2012; Bonuck et al., 2012a; Brockmann, Urschitz, et al., 2012; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004; Rosen et al., 2004; Witcher et al., 2012). Externalising behavioural problems like hyperactivity have been reported consistently in the literature of childhood SDB (Beebe, 2006; O'Brien & Chervin, 2008)

In contrast, of the eight studies that examined children from clinical settings six reported behavioural problems among this group of children. However, there were slightly more deficits reported in this group. Three studies reported increased hyperactivity-related problems (Beebe et al., 2004; Melendres et al., 2004; Miano, Paolino, et al., 2011), other two reported behavioural problems associated with executive functioning (e.g. inhibition, working memory and planning) (Beebe et al., 2004; Bourke et al., 2011; Jackman et al., 2012). Therefore, hyperactivity is the problematic behaviour more frequently reported among studies examining children with this condition. There is a strong belief that externilising behaviour problems are more common in children who snore. However, in a previous review by (Kohler et al., 2010) which examined studies investigating both neurocognitive and behavioural performance, it was found that externalising behaviours were not privileged over internalising behaviours, but maybe under assessed resulting in fewer reports. Sleep findings

Aside from the apnoea and hypoxia typically associated with more severe SDB, children with PS also tended to have a range of other sleep problems. All the studies that have recruited children from clinical setting have used PSG to assess PS. In the studies that have recruited children from community studies, two did not have any measures of sleep, four used subjective measures (parental-report questionnaires validated and purposed-designed); two a combination of objective (PSG and home recording of a number of variables) and subjective measures (validated questionnaires); and although 10 used objective measures, one study collected PSG only in snorers and two collected limited variables such as nocturnal home oxymetry and home cardiorespiratory information only.

From this brief review, it is noted that negative neurocognitive findings are found in a more consistent way in studies that have used samples drawn from clinical settings; while community populations seem to be more mixed. The mixed findings could be explained in part by methodological limitations including: small sample sizes, varying criteria used to define PS, reliance on subjective assessment of SDB, and no inclusion of control children.

Several studies have relied on small sizes (Barnes et al., 2009; Kennedy et al., 2004; Key et al., 2009; Piteo, Lushington, Roberts, Martin, et al., 2011) and not inclusion of control groups or comparison of results only with population norms (Archbold, Giordani, Ruzicka, & Chervin, 2004; Bourke et al., 2011; Kaemingk et al., 2003; Key et al., 2009).

A further limitation of the studies examining neurocognitive functioning on snoring children is that, even though results showed a lower performance in this group (i.e. lower scores compared to control groups), their performance was within the normal expected range. This raises questions about the selection of controls.

Daytime sleepiness

Excessive daytime sleepiness is commonly reported in adults with SDB and especially OSAS (Fichten et al., 1995). This has been attributed to the sleep fragmentation resulting from upper airway obstruction and the subsequent non-restorative sleep. In contrast to adults, the association between SDB and daytime sleepiness is less clear in children. A particular topic of debate in the literature has been the difficulty of evaluating sleepiness in children. This can be partly attributed to the lack of tools to assess sleepiness in children (Brockmann, Urschitz, et al., 2012; Melendres et al., 2004). A further problem is that children may react differently to sleep fragmentation compared to adults. Children do not typically demonstrate 'sleepiness' but rather irritability and hyperactivity when challenged by sleep fragmentation and deprivation (Djonlagic, Saboisky, Carusona, Stickgold, & Malhotra, 2012). As noted by several authors the symptoms are similar to that observed in children with attention deficit hyperactivity disorder (ADHD) (Gruber et al., 2011). Incidentally, as well as children with different degrees of SDB demonstrating ADHD symptoms the reverse has also been reported with children with ADHD demonstrating a high frequency of SDB (O'Brien et al., 2003). The presence of increased disruptive behaviour raises the question as to whether neurodevelopmental factors might underlie the difference between children and adults in their response to sleep fragmentation. For example, the less well developed prefrontal areas in the cortex and predisposition to impulsive behaviour may make children less likely to demonstrate sleepiness, but rather

hyperactivity, in response to sleep fragmentation (Anderson, 2002; Lenroot & Giedd, 2006). From the studies included in Table 1.5, six studies assessed daytime sleepiness and four of these studies recruited children from community settings (Ali et al., 1993; Arman et al., 2005; Brockmann, Urschitz, et al., 2012; Ferreira et al., 2000). The studies that examined the association between SDB and sleepiness found that the latter was higher among PS groups. Explanations as to why SDB leads to increased sleepiness are not completely understood, particularly among children with mild forms of SDB. There is limited research regarding the risk factors and prevalence of sleepiness in children from community settings. A recent study (Calhoun et al., 2011) suggested that obesity, asthma and anxiety/depression reported by parents, are more likely to explain daytime sleepiness than SDB. These findings suggest that the relationship between SDB and daytime sleepiness may not be as direct as it is thought. However, further research is needed to clarify the relationship.

Conclusions from studies regarding the effects of snoring on neurocognitive and behavioural functioning need to take into account the different populations studied (community and clinical). Typically, studies including children from clinical settings recruit their participants from ENT specialist lists or from children who snore on waiting lists for adenotonsillectomy. The problem with these population groups is twofold. First, the snoring may be secondary to some other health issues or predisposition (e.g. tonsillitis, pre-term children), and second, there may be a referral bias making it more likely for children who snore and are struggling at school to be referred for treatment than a child who simply snores, but is performing well at school and at home.

1.2.8. Natural history of snoring: Does snoring resolve over time?

As outlined earlier in this literature overview, an association has been documented in children, at least from clinical samples, that PS is associated with neurocognitive deficits. However it is not entirely clear in the literature that change in child snoring status also changes the status of their daytime functioning. The most common treatment for sleep-related upper airway obstruction is adenoidectomy and tonsillectomy (A&T); which is reported to improve upper airway obstruction in the majority of cases (Kohler, Lushington, et al., 2009; Nieminen, Tolomen, & Löppönen, 2000; Wei, Mayo, Smith, Reese, & Weatherly, 2007), but it is not without risk, including mortality (Leong & Davis, 2007). The indication for A&T is strong in children with more severe SDB such as OSAS, but the value of surgery is less clear in children with milder SDB such as PS. It has been suggested that although PS rarely progresses to OSAS it is recommended to monitor children over

time (McColley, 2005). A better understanding of the natural history of snoring in children with PS is therefore important for informing practice.

Longitudinal research examining the natural history of primary snoring in children

To locate studies that have examined the natural history of snoring in children with PS, the following key words were entered into Google Scholar database: 'longitudinal', 'natural history', 'snoring', 'children', habitual snoring', and 'primary snoring'. Studies which have exclusively examined natural history of children with a diagnosis of OSAS or those that examined the effect of treatment in OSAS have not been included here. Because most studies have not used PSG to confirm a diagnosis of PS, those which utilised parental self-report measures suggestive of PS were included. Although it is likely that those studies included children with PS and possibly OSAS, at this stage of development in the field there is only limited longitudinal information available and the broader range of children were therefore included. In total, nine studies that have examined either PS (objectively verified by PSG) or habitual snoring (based on parental self-report) are presented in Table 1.6. A summary of each study is given in the table including definition of habitual snoring or PS, initial age at recruitment, assessment tools used, follow-up length, sample size and the progression of condition at follow-up.

The earliest study was conducted by Ali, Pitson, and Stradling (1994), and asked parents how often their child snored at night. The overall snoring prevalence did not change from baseline to follow up; however, more than 50% of snorers improved. In addition, reports of sleepiness decreased over time, but these were in general greater among the snoring group.

Later, Marcus et al. (1998) recruited children from a clinical setting who had PSG assessment and were diagnosed with PS. Snoring frequency was assessed through technician report using a 4-point scale to obtain a snoring index. They also asked parents questions regarding change in symptoms (only at follow up). Based on parental self-report 70% remained as PS, 20% snored more and 10% snored less. Similarly, Topol and Brooks (2001) recruited children from a clinical setting and asked parents whether symptoms had changed since initial assessment. From a sample of 13 children only nine underwent PSG and additional nine control children were examined. Based on parental self-report 38% of snorers had improved at follow up, 31% remained the same and 31% had worsened. PSG results suggested that 11% (one case) had developed OSAS. Although children were classified as PS, inspection of the paper revealed that the mean (SD) AHI in the snoring group was 1.4 (1.22) at baseline and 3.54 (4.94) at follow-up.

In 2004 Urschitz et al. assessed 80 children reported to snore habitually after a year of initial evaluation. They asked parents whether their children snored and results showed that 49% of habitual snorers continued snoring while the other children improved. Additionally, the authors found that ENT surgery was more common among those children who stopped snoring over time (51%). In contrast, louder snoring, lower maternal education and smoking environments were more common in children who continued snoring (49%).

Anuntaseree et al. (2005) examined a group of 55 children reported to snore habitually and 409 non-snorers. Authors asked parents whether their children snored most of the nights. Although it was reported that 9% of snoring children developed OSAS, only a reduced number of snorers underwent PSG and none of the non-snorers were objectively examined. One year later, Löfstrand-Tideström and Hultcrantz (2007) published a study examining 509 six year-old children who were initially examined at four years. Based on frequency estimates, children were classified into three groups ('never snoring', 'snoring sometimes' and 'snoring every night'). Of the non-snoring group, only two cases (2%) snored every night at follow-up, while 11 cases (5%) from the 'sometimes snoring' group. In contrast, 61% improved over time (three no longer snored and eight snored sometimes).

Piteo, Lushington, Roberts, Martin, et al. (2011) examined the effects of persistent snoring (from birth to six months and to 12 months) on neurocognitive functioning during the first year of life in 78 controls and 13 persistent snorers. From an initial group of 88 controls (soon after birth), 7% (six cases) started to snore occasionally between six and 12 months. Of a group including 16 children initially reported to snore ≥ 3 nights/week, 6% (one case) stopped snoring at 12 months and 12% decreased the frequency of snoring. Only children who were persistent non-snorers and persistent snorers were included in the analysis. In the same year Bonuck et al. (2011) published a six-year longitudinal study examining SDB symptoms including snoring (frequency = 'always') in a large group (initial sample of 14049 children) from the general community. Using parental self-report the authors examined whether children snored for more than a few minutes at night. Overall, persistence of snoring was less common than resolution of development of new cases.

The most recent study examining the natural history of snoring and particularly PS objectively assessed (i.e. PSG) was conducted by Li et al. (2013). In that study, 70 children with parental self-report of snoring underwent PSG to confirm PS status (obstructive apnoea-hypopnoea index, OAHI < 1) and they were then re-assessed after four years of

initial assessment. At follow-up, 37.1% of these children developed OSAS, 26% resolved snoring. The authors found that persistent overweight/obesity was more common among children who developed OSAS (OR 7.95). In general, the majority of studies (n = 7) recruited children from community settings, but two (Marcus et al., 1998; Topol & Brooks, 2001) included children recruited from clinical contexts. Although there have only been nine studies there are some conclusions that can be drawn; however, the small numbers in some studies and differences in methodologies such as variable definitions complicate direct comparisons. Because of this variability, participants in the studies listed in the table were reclassified into 'habitual snorers' and 'non-snorers'. Analysis of the natural history of snoring was conducted separately for non-snorers and snorers (Table 1.6). If available, information was extracted from each study in order to obtain the percentage of those that had not changed the initial status (no change), those that became more severe (more severe), those that stopped snoring or decreased in frequency (resolved), and cases that developed di novo (developed).

Table 1.6 Studies examining the natural history of either primary snoring or habitual snoring in children: clinically and community-based research

First author (Year)	How authors defined habitual snoring/PS	Age at enrolment mean (SD)	Assessment devices	Follow-up (years)	Participants	Progression of condition at follow-up			
						No change	More severe	Resolved	Developed
Marcus (1998)	OAI ≤ 1; S_pO_2 nadir > 90%; peak $P_{ET}CO_2 \leq 53$ mmHg; hypoventilation < 10%/TST.	6 (4)	Lab-PSG and TechR	1–3	HS = 20	80%	20%[b]		
Topol (2001)	Normal PSG findings, but OSAS symptoms.	5.5 (3.1)	PSG[c] and PQ	3	NS = 9 HS = 9	 89%	 11%		
Ali (1994)	'Most nights'	4.5 to 5	PQ	2	NS = 447 HS = 59	93% 49%		 51%	7%
Urschitz (2004)	Snoring 'frequently' or 'always'.	9.6 (0.7)	PQ	1	HS = 80	49%		51%	
Anuntaseree (2005)	'Most nights' or ≥ 1 sleep-related symptom (PQ). AHI < 1/hr.	10.2 (0.5)	PQ and limited PSG [d]	3	NS = 409 HS = 55	97% 18%	 9%[e]	 73%	3%
Löfstrand-Tideström (2007)	'Every night'.	4	PQ and limited PSG [f]	2	NS = 235 [SS = 214[g] HS = 18	99% 59% 39%		 36% 61%	1% 5%]
Piteo (2011)	≥3 nights/week	6 months	PQ	0.5	NS = 88 HS = 16	93% 82%		 18%	7%

First author (Year)	How authors defined habitual snoring/PS	Age at enrolment mean (SD)	Assessment devices	Follow-up (years)	Participants	Progression of condition at follow-up			
						No change	More severe	Resolved	Developed
Bonuck (2011)	'Always' and 'habitually'	At birth	PQ	0.5–1.5[h]	NS = 83%[i]				
					$HS_{(1)}$ = 14%			9.1%	5.6%[j]
					$HS_{(2)}$ = 3%	1%		2.5%	2.7%[k]
				3.5–4.7[h]	NS = 71%[i]				
								10.9%	5.3%[j]
					$HS_{(1)}$ = 21%	3.4%		4.1%	4.4%[k]
					$HS_{(2)}$ = 8%				
				5.7–6.7[h]	NS = 77%[i]				
					$HS_{(1)}$ = 16%			7.3%	4.9%[j]
					$HS_{(2)}$ = 7%	3.4%		3.7%	2.4%[k]
Li (2013)	1–2 nights/month, 1–2 nights/week or ≥3 nights/week; OAHI ≤ 1.	10.2 (1.7)	PQ and PSG	4.6	PS = 70[l]	31%	37%	26%	

NS = Non-snorers, HS = Habitual snorers; PQ = Parental report questionnaire; TechR = Snoring reported by technicians on during PSG; $HS_{(1)}$ = 'habitual snoring'; $HS_{(2)}$ = 'always snoring'. [a] Frequency not specified; PQ regarding change in symptoms administered only at follow-up; [b] Developed to OSAS (two children AHI = 1.4–1.8 and two AHI = 3); [c] Either laboratory or home PSG was performed only for 9 snorers and controls; [d] Apnoea -Hypopnoea examined only with thermistor, PSG only for five snorers; [e] Only six children with HS underwent PSG; [f] Modified PSG protocol including oxymetry, position sensor, thermistors for nose and mouth and an electrostatic mattress; [g] Authors also assessed children who snore sometimes (SS) at follow-up; [h] Only total N reported, n for NS and AS unreported; sum < 100% due to second snoring group ('snoring habitually') not included; [i]; Transition from one year to another; [j] % of cases that developed HS di novo; [k] cases that developed 'always snoring'; [l] 6% of the total sample were unclassified at follow-up, hence sum of categories is 94%.

Parental self-report and the natural history of snoring

As outlined in previous sections, parental self-report is commonly used when assessing snoring frequency, particularly in studies that recruit children from community settings. Nevertheless, the limitation of this methodology is the variability in definitions (Lumeng & Chervin, 2008). Of the seven community-based studies, four developed their own instrument (Ali et al., 1994; Anuntaseree et al., 2005; Löfstrand-Tideström & Hultcrantz, 2007), while two (Li et al., 2013; Urschitz et al., 2004) used a validated instrument, one (Piteo, Lushington, Roberts, Martin, et al., 2011) used a single question to assess snoring frequency, and Bonuck et al. (2011) used a pre-existing questionnaire developed for a larger study. Definition of snoring varied between studies, especially because of the different scales that used to assess frequency (Table 1.7).

Table 1.7 Questions and answer scales used by studies with children recruited from community settings

First author	Question	Possible responses
Ali	'Does he/she snore at night (even without a cold)?'	'Never', 'rarely', 'sometimes' and 'most nights'.
Urschitz	'Does your child snore?'	'Never', 'occasionally', 'frequently' and 'always'.
Anuntaseree	'Does your child snore at night?'	'Never', 'only with colds', 'occasionally' and 'most nights'.
Löfstrand-Tideström	Question regarding snoring frequency not reported	'Never', 'sometimes' and 'every night'
Piteo	'How often in the past week did your child snore?'	'Never in the absence of a cold', '1–2 nights/week' and '≥3 nights/week'.
Bonuck	'Does she snore for more than few minutes at a time?'	Options varied across assessment points: - At 6 months: 'most nights', 'quite often', and 'rarely'. - At 1.5 years: 'most nights', 'quite often', 'sometimes' and 'rarely/never'. - At 2.5 years: 'yes/often', 'yes/sometimes' and 'no'. - At 3.5 years: 'most nights, quite often' and 'rarely'. - At 4.7 years onwards: 'most nights, quite often, sometimes, only rarely, never'.
Li	Question regarding snoring frequency not reported	'1–2 nights/month', '1–2 nights/week' and '≥3 nights/week'.

The greatest variability was observed in the study conducted by Bonuck et al. (2011), which used different scales to assess frequency of snoring over the years. In order to address that

limitation, the authors reclassified answers in a dichotomous variable (symptom absent/present). For presence of symptom the left-most extreme ('always') and the second left-most extreme answer ('habitual') were included in the analyses. Parental self-report can provide valuable information regarding snoring history in children, but reports vary from study to study and sometimes within studies. That variability, and in some cases the limited use of validated questions/questionnaires raise concerns regarding the accuracy of the observations to diagnose SDB conditions including PS (Spruyt & Gozal, 2011).

Recruitment population, methods and the natural history of snoring

Among the studies that recruited children from clinical settings, one recruited children who had been referred to the otolaryngologist for suspected OSAS (Topol & Brooks, 2001), and another recruited patients initially presented to a sleep clinic for evaluation of snoring and difficulty breathing during sleep (Marcus et al., 1998). In contrast, studies using community-based samples included children from previous epidemiological databases (Bonuck et al., 2011; Li et al., 2013), from initial medical controls after birth (Piteo, Lushington, Roberts, Martin, et al., 2011). Two studies recruited children from primary schools either from first grade (Anuntaseree et al., 2005) or third grade (Urschitz et al., 2004), from dental-care appointments offered normally in the public health system (Löfstrand-Tideström & Hultcrantz, 2007), or from a centralised health visitor register (Ali et al., 1994).

Although PSG is known as the 'gold standard' measure to assess SDB, not all studies performed it. Both clinical studies used PSG with full assessment protocol, but only one of these included a control group (Topol & Brooks, 2001). Additionally, PSG was performed in only nine of 19 eligible snorers at follow-up. In contrast, Marcus et al. (1998) examined all 20 children with PS included in their study. In summary, the understanding of the natural history of snoring in children with PS recruited from clinical settings and who were diagnosed with PSG is limited to a total of 29 children.

On the other hand, of the seven studies that recruited children from the community three used PSG, but two of these were limited PSG. In brief, Anuntaseree et al. (2005) only collected PSG in five habitual snorers who were suspected to have OSAS. Löfstrand-Tideström and Hultcrantz (2007) used a modified PSG protocol consisting of oxymetry, position sensor, thermistors for nose and mouth and an electrostatic mattress, thereby affecting the confidence of the diagnosis. Only Li et al. (2013) used a full-montage PSG for all children. Thus, data in

regard to the natural history of PS objectively assessed in children recruited from community settings are available for 70 children. Given the limited data using objective measures to evaluate sleep, PSG is needed when examining PS in children.

Age and the natural history of snoring

It is not known whether the natural history of snoring in children varies with age. That is, for example, whether the probability that a child who snores at age two years and continues to snore at age five years would be the same as the probability for a child who snores at age seven years and continues to snore at age 10 years. Two studies recruited infants at initial assessment (Bonuck et al., 2011; Piteo, Lushington, Roberts, Martin, et al., 2011), while three recruited pre-school children (Ali et al., 1994; Löfstrand-Tideström & Hultcrantz, 2007; Topol & Brooks, 2001) and four school-age children (Anuntaseree et al., 2005; Li et al., 2013; Marcus et al., 1998; Urschitz et al., 2004).

The proportion of snoring children who were reported to continue snoring among studies that initially recruited infants ranged from 1% to 82% of reported change. Although both studies were conducted in children from the community, one of the studies (Bonuck et al., 2011) had a considerably bigger sample compared to the other one (Piteo, Lushington, Roberts, Martin, et al., 2011), and the definition of snoring differed between the two.

Across studies that recruited pre-school children (i.e. more than four-years-old, but less than six). In general, half of the pre-school children who had an initial history of snoring continued snoring at follow-up, while the other half were reported to resolve. Two studies included school-age children at recruitment (six years and older), and findings across these studies were markedly different. For example, Marcus et al. (1998) reported that 90% of children with an initial diagnosis of PS continued snoring at subsequent assessment, while Urschitz et al. (2004) reported that 45% of children who initially had been reported to snore habitually continued to snore, Anuntaseree et al. (2005) reported that only 18% of snorers continued snoring; and Li et al. (2013) indicated that 31% of children with PS remained with the same condition four years after first evaluation. The difference across these three studies highlights, as previously discussed, differences between children recruited from clinical or community settings, as well as the use of objective measures instead of parental observations.

Based on the age at recruitment, a slight difference was seen for the emergence of new cases. The problem with studies that recruited school-age children is that they did not obtain precise information about when children started to snore. Previous research suggests that early age is associated with an increased risk for snoring (Bixler et al., 2009; Sahin et al., 2009; Zhang et al., 2004), and information regarding past snoring history may provide information as to whether age of snoring-onset predicts a persistent snoring status. Only Bonuck, et al. (2011) investigated the natural history of snoring from infancy to the school-age years. Their results showed that new cases were more common in pre-school ages. The proportion of new cases was comparable with Ali's study, which recruited pre-school children. Finally, regardless of the age group, a great proportion (>70%) of children who initially did not have a history of snoring continued to be reported as non-snorers at follow-up assessments.

Snoring stability and the natural history of snoring

The longitudinal studies have examined the stability of snoring status over varying lengths of time. The majority of studies had only one follow-up assessment point (range 0.5–four years) and only Bonuck et al. (2011) assessed children multiple times over a considerable period of time. Despite the latter study being conducted during a six-year period, the authors calculated snoring transitions on a yearly basis using complete data for two consecutive points (e.g. between 0.5 and 1.5-years-old). Based on raw data presented in that study, there is no evidence of how many children who were reported to snore always remained snoring at follow-up. Similarly, no evidence for transitions from the different categories across time were provided (i.e. whether children changed across categories: 'non-snoring' to 'habitual snoring' and 'always snoring').

Based on the time between initial evaluation and follow-up assessments, it was observed that the proportion of children who were initially classified as non-snorers consistently remained as non-snorers across studies. In contrast, a variable pattern was reported among children who were initially reported to snore (e.g. 1%–80% remained with the same status while 2.5%–73% resolved).

Characteristics of children who continue to snore and the natural history of snoring

Yet to be fully answered is the question regarding the factors that predispose a child to continue to snore. Piteo, Lushington, Roberts, Martin, et al. (2011) identified 13 children who were reported to snore in the first month of life and continued to snore at six months and then

at 12 months. Compared to non-snorers, snoring children were predominantly males, had lower SES, had more frequent episodes of wheezing, and fewer days of breast feeding. Moreover, Marcus et al. (1998) reported that recurrent snoring was associated with an increased BMI, while (Urschitz et al., 2004) indicated that maternal education, louder snoring, household smoking and ENT surgery after first assessment were factors associated with recurrent snoring. By contrast, Li et al. (2013) did not find any differences that could explain why some continued with PS compared to those that resolved from the condition.

Resolution of snoring and the natural history of snoring

Restricted explanations as to why some snorers improved over time were found across the studies that reported a snoring resolution. Anuntaseree et al. (2005) indicated that improvement might be a result of increased pharyngeal size and regression of lymphoid tissue because of normal development. However, this hypothesis was not confirmed in that study because the authors did not assess either pharyngeal or tonsillar size. Urschitz et al. (2004) suggested that factors such as level of maternal education, higher SES, less household smoking, quieter snoring, and less surgical intervention were associated with resolution of snoring. Unfortunately, the other community-based studies did not include children who recovered and, likewise, developed snoring.

Only two studies did not find cases that resolved over time. The first study was conducted by Marcus et al. (1998) who included snoring reports by technicians during PSG, which revealed that all children continued snoring at follow-up, but based on parental self-report 10% of children were reported to snore less frequently. However, the authors indicated that this type of assessment was only conducted at follow-up. The problem is that in Marcus' study the follow-up assessment was conducted in a period of one–three years; retrieving information regarding frequency of snoring may not be accurate in all cases. The second study by Topol and Brooks (2001) did not report cases that resolved at follow-up. Of special note is that mean AHI was ≥ 1 event/hour at baseline and SpO_2 nadir < 90, indicating that some children had mild OSAS. Therefore, natural history among this group may not be a true representation of children with PS.

Worsening conditions and the natural history of snoring

A variable pattern was seen when comparing the four studies that objectively found that children with PS developed OSAS (9% to 37%). However, as described earlier Anuntaseree et

al. (2005) only examined a reduced number of children, hence results may not be generalised. Moreover, Topol and Brooks (2001) included children with an initial AHI ≥ 1. Methodological problems among these two studies leave only two studies where information can be extracted (Li et al., 2013; Marcus et al., 1998). Despite that these two studies examined children with PS, one recruited children from a clinical setting (Marcus et al., 1998) and the other from community settings (Li et al., 2013). Furthermore, scoring criteria to analyse PSG is not comparable becasue the second study used recent academy rules (American Academy of Sleep Medicine, 2007), while the first study used previous criteria (Marcus et al., 1992). Explanations as to why some children with PS developed OSAS was presented only by Li et al. (2013), who reported that persistent overweight/obesity was associated with development of OSAS.

In addition to the studies included, two studies examined the natural history of mild OSAS when left untreated in children. Li, Au, Ng, et al. (2010) found that two years after the initial diagnosis, 29% of children with mild OSAS (OAHI = one–five events/hr) had worsened. In that group children were more likely to be boys, had an increased waist circumference, larger tonsils and a higher prevalence of habitual snoring at both baseline and follow-up assessments. These findings highlight the importance of physiological characteristics in the progression of SDB conditions; especially those directly related to the upper airway as highlighted in previous sections. On the other hand, Goodwin et al. (2010) found that 70% of children with OSAS (RDI ≥ 1 event/hr) remained with OSAS after five years from the initial diagnosis, and 10% of children without OSAS had developed the condition at follow-up. In that study, male sex and obesity were found to be key factors associated with developing the condition.

Development of snoring and the natural history of snoring

The development of new snoring cases from children initially classified as non-snorers was reported to be ≤5%. For example, Ali, et al. (1994) suggested that 2% of children who at baseline were reported to never snore started to snore ‘most of nights’ at follow-up. Similarly, Anuntaseree et al. (2005) found that 3% of non-snorers started to snore three years after first assessment. Löfstrand-Tideström and Hultcrantz (2007) reported that 1% of children who were classified as non-snorers at four-years-old started to snore ‘every night’ at six-years-old and 5% snored ‘sometimes’. Bonuck, et al. (2011) reported that new cases (‘always snoring’) were 2.7% at 0.5–1.5-years-old, 4.4% at 3.5–4.7-years-old and 23.4% at 5.7–6.7-years-old.

Based on these few reports, it seems that a small proportion of children who are initially reported to be non-snorers develop snoring later on. Nevertheless, none of the studies included PSG to confirm PS status and among those that used this technique, controls groups were not evaluated.

Development of snoring among treatment studies and the natural history of snoring

There is a reasonably sized literature set that has examined the efficacy of adenotonsillectomy in children who snore. Studies typically include a control group, but not all report the change in snoring status in controls. Inclusion of controls may expand the understanding of the rate of development of snoring. For example, from a sample of 48 controls 8.3% of those children who never snored at baseline, started to snore ≥ 3 nights/week and developed OSAS after six months from initial assessment (Kohler, Lushington, et al., 2009). Similarly, Chervin et al. (2006) found that from a control group of 27 non-snorers 4% of these children developed OSAS (AHI ≥ 1) after one year of the initial assessment. The incidence of new snoring and SDB cases among children who were found not to snore at initial assessments encourage inclusion of these type of groups, as well as a more detailed analysis of personal characteristics, which could be associated with snoring incidence.

Daytime performance and the natural history of snoring

The natural history of snoring is not fully understood; neither are the long-term implications for daytime performance in children who snore habitually. Scarce evidence regarding changes in performance along with snoring progression has been provided. Such evidence includes reports in infants by Piteo, Lushington, Roberts, Martin, et al. (2011), which suggest a decreased cognitive development in children snoring more than three nights per week from the first month of life; and who continue snoring at six and then at 12 months. Furthermore, Ali et al. (1994) found decreased sleepiness associated with improvement of snoring. It is readily apparent that this limited research increases the difficulty of determining whether or not neurocognitive deficits and behavioural problems improve if snoring resolves.

1.3. Summary

In summary, the literature suggests that snoring is common in children. However, methodological issues such as assessment of frequency and severity of this condition have raised questions whether variability in the methodologies to evaluate snoring may have an impact in results across studies. Despite the majority of these methodologies rely on parental observation, it is not clear whether parents consider snoring problematic or not.

While substantial literature shows that OSAS can have a significant effect on a child's development and learning, evidence shows that relatively mild upper airway obstruction can also have an impact on a child's daytime functioning, particularly on behaviour. Although studies have revealed that snoring children can have deficits in IQ, executive functioning, memory, learning and school performance, and daytime sleepiness; studies that include children recruited from community settings tend to report mixed findings. Thus, the direction of the relationship between mild SDB forms (i.e. PS) and neuropsychological deficits is not clear. While treatment of upper airway obstruction with surgery has shown reduced breathing problems post-surgery, for example some studies have shown that post-surgery children with SDB improve in learning and behaviour compared to before the surgery (Archbold et al., 2004), but others not (Kohler, Lushington, et al., 2009). Even less clear are the long-term consequences of upper airway obstruction when untreated, particularly in mild forms such as PS. A recent study examining the effectiveness of adenotonsillectomy in children with mild OSAS (OAI $\geq$ 1 or AHI $\geq$ 2) showed that 46% of children who were left untreated improved over a period of seven months. Improvement over time was more common in children who were not obese and who were from non-black ethnic groups (Marcus et al., 2013). Furthermore, the longitudinal data examining the natural history of snoring seem to indicate that if a child has a history of 'never snoring' they would be unlikely to start snoring. By contrast, if a child has a history of even some snoring, then the chances are that the status may be highly variable even during a short period of time. Based on the limited data, children who continue to snore seem to be males, from low SES contexts, live in smoking households and with increased BMI. However, the literature in regard to the natural history of snoring needs to be expanded; in particular there is a need to examine its associated performance using psychometric tests and to include children who do not snore for comparison. Because only a reduced number of studies have used objective sleep measures, PSG should be included when assessing PS children over time.

Chapter 2 General methodology

This chapter contains a detailed description of the methods and procedures utilised in this study and a general explanation about the variables and data collected.

2.1. Overview and study design

This thesis is part of a larger study, which consisted of four phases and examined the relationship between snoring and daytime behaviour in children from the general community. This thesis examines Phases 2–4. Figure 2.1 outlines the design of the study.

Phase 1 of the omnibus study involved a questionnaire survey of school-age children from a community setting in Australia. This phase examined sleep/wake patterns, sleep problems and behavioural correlates in children recruited from the general community. In brief, a sleep, health and behaviour questionnaire was developed—the South Australian Paediatric Sleep Survey Database Questionnaire (SAPSS-Q)—and was given to 1904 Australian children (mean age 7.7 ± 1.7 years). The research from Phase 1 of this study formed the basis of a previous PhD thesis (Biggs, 2009).

The current thesis presents the results from the second, third and fourth phases of the project, which longitudinally followed a cohort of children from Phase 1 of the study. Phase 2 (baseline) was a cross-sectional study which invited children who had reported any snoring (or the absence of snoring) in Phase 1 of the study to participate in a further study to examine the natural history of snoring, sleep and neurocognitive performance. Children with and without reports of snoring underwent neurocognitive testing and PSG, or sleep study, at a tertiary paediatric hospital in South Australia. During the night of the sleep study, parents were given questionnaires to complete about their child's sleep and behaviour. Parents also completed sleep diaries for seven nights, collected during the neurocognitive testing session. Parents and children were contacted again to participate in Phase 3 of the study (12-month follow-up). A letter, sleep questionnaire, the behaviour checklist and reply-paid envelope were sent to each participant for completion. Finally, at Phase 4 (24-month follow-up) participants were invited to undertake a second neurocognitive assessment and PSG at the same venue as the initial testing.

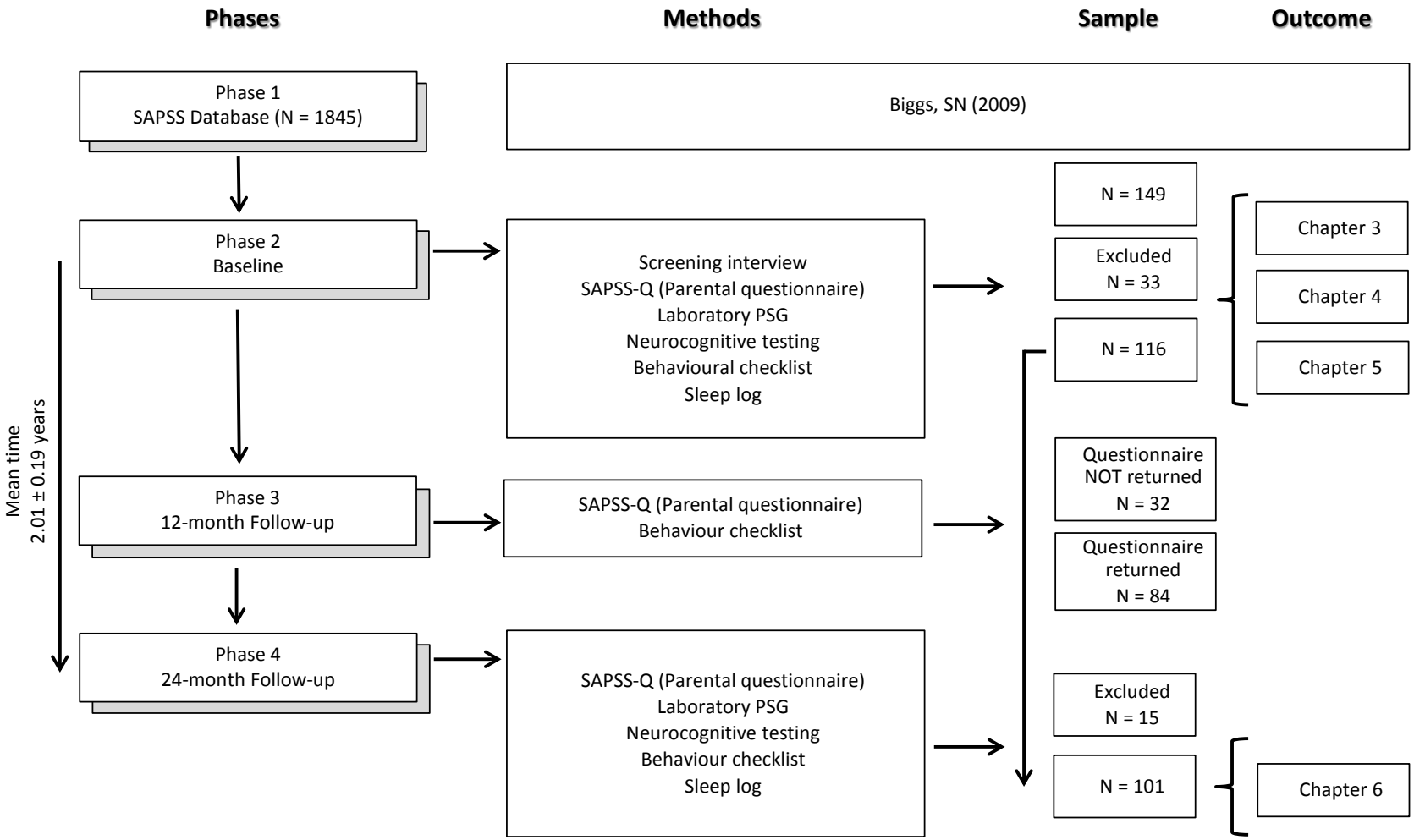


Figure 2.1 Overview of the current study design including general methods used and sample sizes in each phase of the study

Chapter 3 reports data for Phase 2 of the study and Chapters 4 and 5 present additional analyses using these data. Chapter 6 discusses analyses comprising data from Phases 2–4. Finally, Chapter 7 presents a comparison between snoring children identified from the current study and snorers from an existing clinical database. The mean time between the second and fourth phase of the study was 2.01 ± 0.19 years. At Phase 2 the mean time between PSG and neurocognitive testing was 1.59 days. At Phase 4, the mean time between PSG and neurocognitive testing was 1.87 days. Finally, PSG assessments were conducted evenly across different seasons throughout the year, thereby avoiding any seasonal biases (Figure 2.2).

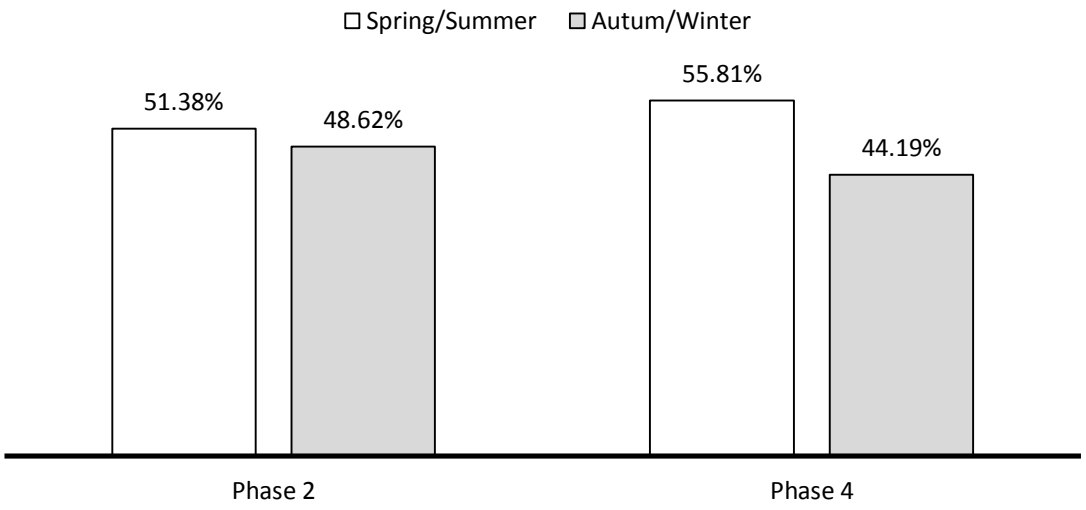


Figure 2.2 Percentage of polysomnography conducted on Phases 2 and 4 across seasons

2.2. Procedure and general overview of participants

Children in this study were drawn from a sample of 1845 children from the South Australian Paediatric Sleep Survey Database (SAPSS)—an epidemiological study conducted in 2007, which examined the prevalence of sleep complaints and sleep/wake behaviours in children from South Australia (Biggs, 2009). In Phase 1 of this study, children had been given the SAPSS-Q (Pediatric Sleep Problems Survey Instrument, see Appendix A), and those who agreed to participate were then contacted for Phase 2 of the study and a screening telephone interview was conducted. Children were excluded from any further involvement in the study if, i) participant contact details were unavailable ii) parents reported children to have psychological (e.g. Attention Deficit Hyperactivity Disorder, Autism Spectrum Disorder) or medical conditions which affect nocturnal ventilation or sleep iii) children took medications

known to affect neuropsychiatric measures iv) children spoke English as their second language (in order to not affect neurocognitive language testing). These criteria were applied at all phases of the study—baseline, 12-month follow-up and 24-month follow-up. A detailed description of the study participants and the testing procedures utilised at each study phase is given below.

After the screening interview eligible children were scheduled to undergo a one-night laboratory-based PSG (lab-PSG) assessment at the Sleep Unit at the Adelaide Women's and Children's Hospital followed by neurocognitive and behavioural assessment using a validated battery of test instruments. Participants were free to withdraw from the study at any time. Both lab-PSG and neurocognitive testing were conducted on the same day if the neurocognitive testing session was scheduled first. Otherwise, if PSG was scheduled first, neurocognitive testing was conducted within the following two weeks of the sleep study. On the night of the PSG, height and weight were measured in order to calculate BMI and BMI z scores and percentiles. Parents were also given a sleep questionnaire, which was used to assess the presence of co-morbid sleep problems, including snoring and other sleep/wake patterns, and a behavioural checklist (Child Behavior Checklist; CBCL) to complete. Details of the sleep questionnaire, behavioural checklist and neurocognitive testing are provided later in this chapter.

After the children had completed the neurocognitive assessments, parents were provided with a report of their child's performance. A trained clinical psychologist prepared the report, which contained a detailed explanation of the different tests (Appendix J). Children with severe neurocognitive deficits were referred to the Psychology Unit at the hospital for further evaluation. If indications of obstructive sleep apnoea (AHI $\geq$ 5 events per hour) were found after PSG, children were referred to an ENT specialist in the same hospital for further evaluation.

Twelve months after the baseline sleep and neurocognitive assessment, participants were sent the same sleep questionnaire as used at baseline to complete with an explanatory letter and a reply-paid envelope requesting that parents return the questionnaire upon completion. If after two weeks from sending the questionnaire it had not been returned, a reminder letter with another copy of the questionnaire and the reply-paid envelope were posted. If after this

reminder no response was obtained, parents were contacted via telephone to confirm the address in order to again send the questionnaire.

Finally, 24 months from baseline assessment, participants were contacted again in order to arrange a second set of sleep studies and neurocognitive testing. The same procedure and methods used at baseline were conducted at this 24-month follow-up. Details about participants and the number of participants are provided in each experimental chapter (Chapters 3 to 7).

2.3. Data collection and variables measured

In this section all devices used for data collection at Phases 2, 3 and 4 are described. Phases 2 and 4 included a parental sleep questionnaire, neurobehavioural and PSG assessment, and sleep diaries. Phase 3 of the study included both the parental sleep questionnaire and the behaviour checklist.

2.3.1. Sleep questionnaire

A booklet was given to parents which included the SAPSS-Q, a statistically reliable measure of sleep problems (Biggs, Kennedy, Martin, van den Heuvel, & Lushington, 2012). In brief, the instrument contains 30 items and generates six scales: Sleep Routine; Bedtime Anxiety; Restless Sleep; Night Arousals; Sleep-Disordered Breathing and Morning Tiredness (Appendix A). All items are rated on a 4-point scale of 'Never', 'Rarely' (once per week), 'Sometimes' (2–4 times per week), and 'Usually' (5–7 times per week). Additionally, a general question was included for each item asking parents if they considered each sleep behaviour a problem. Responses could be rated on a 4-point scale of 'N/A', 'No', 'Somewhat', or 'Yes'.

The booklet included a series of demographic questions (including child's date of birth, birth weight, gender and gestational age). In addition, other information was gathered regarding current weight and height, as well as the relationship of the respondent to the child, number of children in the family, birth order of the child, postcode and ethnicity. The booklet had an activity section which gathered information about physical activity, time spent on homework and screen time (e.g. TV, computer or video games) during the week. Items related to screen time and homework queried the amount of television viewing and homework. Items relating to physical activity included organised and unorganised sports that the child engaged in weekly.

The last section gathered information regarding general medical history. It included physical or psychological complaints that could affect the child's sleep and/or behaviour. This section was only given during the initial assessment (see later in this chapter for more detailed information about demographic and health information recorded in the study).

2.3.2. Neurobehavioural assessment

Two standardised tests assessed neurocognitive functioning for each participant. A trained psychologist blinded to the group status of the children administered these psychometric tests, the order of which was counterbalanced. Sessions of one–two hours were conducted mainly during the mornings in a separate room. Parents were asked to wait outside the room while the child was tested. In the middle of the session, each child was given the opportunity to have a short break and snacks were provided in order to decrease fatigue. The PhD candidate scored all tests and sent a brief summary of each child's performance to parents. A detailed description of the psychometric tests and the behaviour checklist used are presented below.

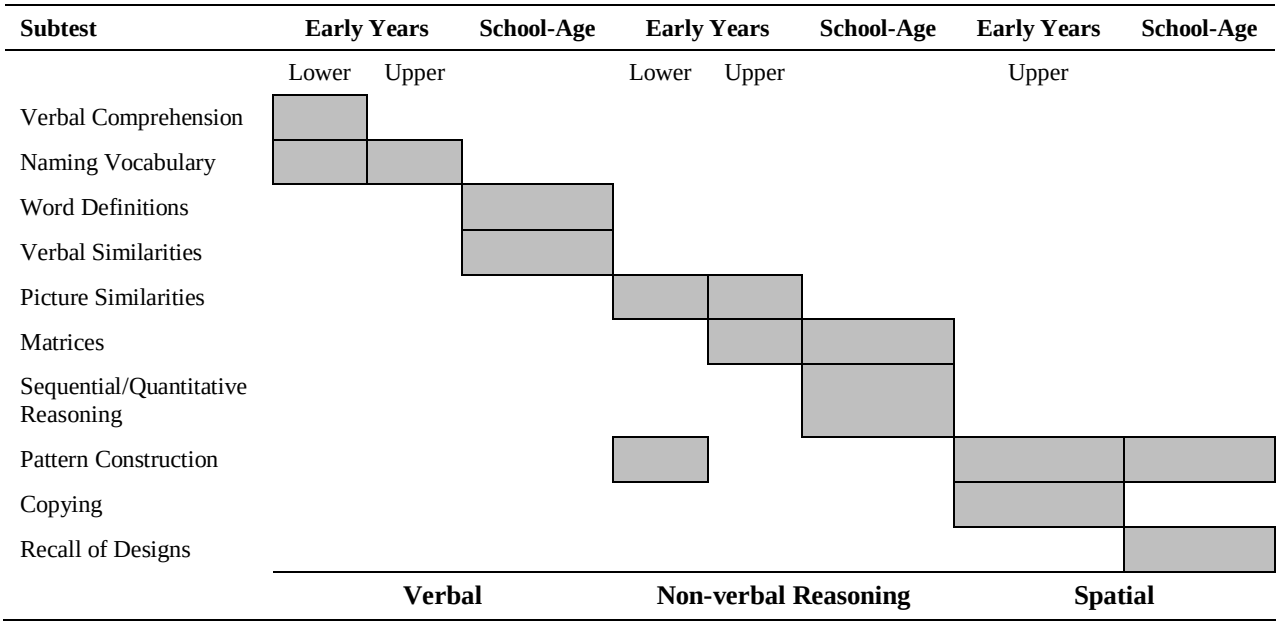
The Differential Abilities Scale-Second Edition

While there is a variety of tests and batteries used to assess cognitive ability, the Differential Abilities Scale, Second Edition (DAS-II) was selected as a measure of cognitive abilities and general intelligence (Elliott, 2007). Its predecessor (Elliott, 1990) was described as a good measure not only of intelligence, but also of verbal ability and non-verbal reasoning skills (Keith, 1990). In the past, the first version was broadly used to assess neurocognitive functioning in children with SDB from community and clinical settings (Gozal et al., 2009; Honaker et al., 2009; Montgomery-Downs, McLaughlin-Crabtree, & Gozal, 2005; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004). The use of this instrument across different studies allows comparison of the data in this study with other results.

The DAS-II is a revised and updated version, which keeps the main organisational structure of the first version. Main changes to the content were introduced in order have a design consistent with the Cattell-Horn-Carroll theory (CHC) (Keith, Low, Reynolds, Patel, & Ridley, 2010). The core and diagnostic subtests were designed to reflect seven abilities including Crystallized Intelligence/Knowledge (Gc), Fluid Intelligence (Gf), Visual Processing (Gv), Short-Term Memory (Gsm), Long-Term Memory (Glr), Processing Speed (Gs), and Auditory Processing (Ga). The DAS-II contains 20 subtests distributed in two batteries (Early Years and School-Age batteries). The Early Years battery is further divided

into two forms (lower and upper levels). The lower level was designed for children between two years and six months to three years and five months years, and the upper level for children between three years and six months to six years and 11 months. The School-Age battery was designed for children between seven years and 17 years to 11 months. These two batteries are organised in subtests that generate a global composite score or General Conceptual Ability (GCA) score. Apart from the GCA, subtests generate cluster scores. Cluster scores for children from two years and six months to three years and five months include Verbal Ability (V) and Non-verbal Ability (NV) measurements. On the other hand, subtests for children from three years and six months to 17 years and 11 months generate cluster scores for V, Non-verbal Reasoning Ability (NVR), and Spatial Ability (S). Subtest scores are normalised and converted to *T* scores; they have a mean of 50 and a standard deviation of 10. The sum of these *T* subtest scores form cluster scores (V, NVR and S) are used to generate the GCA. Cluster and composite scores have a mean of 100 and an SD of 15. For purposes of this research, we used 10 subtests, which allowed us to obtain measures for the three cluster scores and GCA (Table 2.1).

Table 2.1 DAS-II subtests in the Early Years and School-Age batteries administered in the study



Note. Shaded cells represent subtests which generate cluster scores (Verbal, Non-verbal Reasoning and Spatial)

Validity and reliability

After the DAS-II was developed, a study on 2952 children (aged four to 17 years) was conducted in order to determine the constructs assessed by the test, and to determine whether

it measures the same constructs across ages (Keith et al., 2010). This study aimed to overcome some limitations found in previous studies included in the DAS-II manual as evidence for validity. Analyses were conducted using variations of confirmatory factor analysis, and an initial model was developed. This model was consistent with the structure of the DAS-II, and included all 20 subtests loaded onto six factors from the CHC theory. The standardisation stage included all 20 subtests, which were administered to children aged five to eight years, and a further model was developed from this. Then, models drawn from subtests administered to children aged (four, nine to 12, and 13 to 17 years) were compared against models from children aged five to eight years. From this comparison authors could test the consistency of constructs measured by the DAS-II across ages.

Although the authors found that in general the structure of the DAS-II measures the constructs the test was designated to measure, they recommend being cautious with four subtests. These subtests include the Pattern Construction subtest, the Verbal Comprehension subtest, the Early Number Concepts subtest and the Copying and Recall of Designs subtests. In detail, the findings from the study show that:

1. An untimed version of Pattern Construction should be given, in order to have a more accurate measure of Gv.
2. The Verbal Comprehension subtest was found to measure Gf secondary to Gc.
3. The Early Number Concepts subtest should be interpreted as a measure of Gf.
4. The Copying and Recall of Designs subtests were found to measure more than only Gv.

On the other hand, when invariance across ages was tested, the authors found that in general the DAS-II measures the same constructs in children aged four to 17 years. Although subtest residual variances diverged for subtests including Pattern Construction and Matrices (ages nine to 12 years), and Recall of Objects-Delayed (ages 13 to 17 years), this finding did not risk the overall fit of the model, hence the level of invariance of the DAS-II is acceptable.

It is important to note that conclusions drawn from the DAS-II factor structure are applicable only for children aged four years or older. This applies to the age range of children included in the current thesis. Moreover, the DAS-II is described as a reliable and valid instrument

measuring a wide range of cognitive abilities and general intelligence (Baron & Leonberger, 2012).

The Developmental Neuropsychological Assessment

The Developmental Neuropsychological Assessment (NEPSY) (Korkman, Kirk, & Kemp, 1998) is a comprehensive, validated and standardised instrument. It is a unique test developed to assess cognitive functional domains which can have an effect on learning in children—it was designed for single or long-term follow-up use. Based on the approach used by Luria to assess cognitive functions, a Finnish version of the NEPSY was first created in 1980. Seven years later, and over 10 years, the NEPSY (version used in this thesis) was developed in three phases—a pilot phase, a trial phase, and a standardisation and validation phase.

The NEPSY was chosen for this project because it includes Australian norms, making it suitable for measuring neuropsychological functioning among our target population. The NEPSY was also chosen because it is an instrument that was developed to be used for long-term follow-up assessments, which are in line with the study design. Along with the DAS-II, the NEPSY has been previously used to assess children with SBD (Gottlieb et al., 2004; Honaker et al., 2009; Kohler, Lushington, et al., 2009).

The NEPSY is composed of a number of subtests distributed into five domains (three were administered in this study). The domains include Attention/Executive Functions, Language, Sensorimotor Functions, Visuospatial Processing, and Memory and Learning. Each domain is composed of Core and Expanded subtests. Selected subtests allowed us to conduct a 'core assessment' in order to have a general profile of each child's neuropsychological status.

All subtest raw scores are transformed to scale scores or percentile ranks—summarised in a performance profile. This profile shows the strengths and difficulties in performance across the functional domains. Scale scores derived from raw scores were calculated if criteria was reached (raw scores for the subtest were normally distributed and not floor or ceiling effects resulting in attenuation of the raw scores). Scale scores for each subtest have a mean of 10 and standard deviation of 3. Then, five Core Domain scores are derived from the sum of scaled scores for each subtest within each domain. Core Domain scale scores (mean of 100 and SD of 15) were calculated based on two age bands (three to four years and five to 12 years).

For the purpose of this thesis, three Core Domains were assessed involving nine subtests. Subtests administered include: Tower, Auditory Attention Response Set, Visual Attention, Phonological Processing, Speeded Naming, Comprehension of Instructions, Memory for Faces (immediate and delayed recall), Memory for Names (immediate and delayed recall), and Narrative Memory (Table 2.2).

Table 2.2 Developmental Neuropsychological Assessment core subtests across functional domains of attention, language and memory

Domains	Attention/Executive Functions	Language	Memory & Learning
Subtest			
Design copying			
Phonological processing		■	
Memory for faces			■
Tower	■		
Auditory attention/response set	■		
Speeded naming		■	
Arrows			
Memory for names			■
Fingertip tapping			
Visual attention	■		
Comprehension of instructions		■	
Imitating hand positions			
Visuomotor precision			
Narrative memory			■

Note. Shaded cells represent subtests administered in the study. Subtests generate functional domains

Reliability and validity

Internal Consistency Reliability Coefficients have been derived for the NEPSY subtest and Core Domain Scores (Korkman et al., 1998). The authors divided each subtest into two similar halves (i.e. similar length and qualities). Most of the subtests showed a moderate to high internal consistency or stability. On the other hand, the Core Domain Scores showed moderately high reliability scores ranging from 0.88 to 0.91 in three to four-year-old children (with the exception of Attention/Executive Functions Domain), and 0.79 to 0.87 in five to 12-year-old children (Korkman et al., 1998). The authors assessed the stability of performance on the subtests and assessed the Core Domain Scores by administering the NEPSY twice (intervals of two to 10 weeks between administration sessions) to 168 children (49% males, 74% Caucasian). Pearson Correlation Coefficients were calculated to obtain stability scores between scores from the first administration session and the second session. Although Core

Domain Scores (i.e. mean scores) had a trend showing a higher performance during the second administration session compared to the first time, increments were uneven (e.g. larger increases were found in the Memory and Learning domain). A group of experts in paediatric neuropsychology and school psychology in the U.S. twice assessed the structure and content of the NEPSY. Data from pilot studies and revisions by experts allowed authors to modify the subtests. In addition, construct validity analysis showed that subtests within domains were correlated higher compared to subtests across the domain, with language subtests demonstrating the highest correlations across domains—highlighting the relevance of language as mediator for other cognitive abilities in children.

A number of studies examining children with characteristics known to affect neurocognitive performance show the validity of the NEPSY (Schmitt & Wodrich, 2004). Mikkola et al. (2005) examined five-year-old children with a history of extremely low birth weight (i.e. <1000g) and who were born at < 27 weeks of gestational age. Results showed that this group had significantly lower scores for Attention, Language, Sensorimotor, Visuospatial, and Verbal Memory. Similarly, Taylor et al. (2006) investigated the consequences and risks for eight-year-old children with a history of extremely low birth weight compared to full-term normal weight children. These authors found that children with a birth weight <750g had decreased Executive Function and Memory scores among the NEPSY than the control group.

The NEPSY has been also found to be useful for assessing neuropsychological functioning in children with epilepsy (Bender, Marks, Brown, Zach, & Zaroff, 2007). Findings from this study revealed scores >1.5 SDs below the normative mean for attention/executive function, language, and sensorimotor domains in children (aged three to 12 years) with a diagnosis of epilepsy. Additionally, the NEPSY has been used to assess executive functioning and selective attention in young children with subcortical lesions in the brain resulting from severe traumatic brain injury (Bonnier, Marique, Van Hout, & Potelle, 2007). Children with subcortical lesions were found to perform worse in subtests used to evaluate flexibility, working memory, visual attention and auditory attention. Moreover, investigations on children with prenatal alcohol exposure leading to diffusion abnormalities in the brain (Lebel et al., 2008) have demonstrated that these children perform significantly worse in subtests related to cognitive functions such as memory for names, judgment of line orientation, fine motor skills and selective auditory attention.

Child Behavior Checklist for Ages 6-18

The CBL for 6 to 18 years (CBCL/6-18) (Achenbach & Rescorla, 2001) is one of three forms of the Achenbach System of Empirically Based Assessment (ASEBA)—a comprehensive set of forms developed to assess competent and problematic behaviour, as well as adaptive/maladaptive functioning in children aged one to 18 years. The CBCL/6-18 is a well validated, reliable and empirically-based assessment completed in pen and paper format mostly by parents or immediate care providers (on special occasions it can be administered by an interviewer).

Initial versions of the ASEBA instruments (the CBCL, the Teacher's Report Form; TRF, and the Youth Self Report; YSR) were developed to extend the diagnostic syndromes defined in the first and second versions of the American Psychiatric Association's Diagnostic and Statistical Manual (DSM-I and DSM-II). Initially, items in the ASEBA were used to explore whether reports from multiples informants (e.g. child, parents and teachers) could give empirical information of different syndromes. These items were then revised by reviewing psychiatric case records and feedback from informants (Achenbach et al., 2008).

In 2001, the CBCL was slightly revised and labelled as CBCL/6-18. This version is scored based on eight syndromes: Anxious/Depressed; Withdrawn/Depressed; Somatic Complaints; Thought Problems; Attention Problems; Rule/Breaking Behaviour; and Aggressive Behaviour—these syndrome scales resulted from confirmatory factor analysis and samples of non-referred and clinically-referred children. Furthermore, based on second-order factor analysis syndromes were collapsed into two groups of syndrome scales (i.e. internalising and externalising problems). In addition to the eight syndromes, the CBCL/6-18 included scales used to assess psychopathology obtained from 16 cultures where experts identified behaviours consistent with DSM-IV diagnostic criteria—DSM-oriented scales including Affective, Anxiety, Somatic, Attention Deficit/Hyperactive, Oppositional Defiant and Conduct Problems (Achenbach & Rescorla, 2001). Finally, competent behaviour is measured in the CBCL/6-18 through the competence scales (social, school and activity scales). From all scales, scaled scores (T-scores) are obtained; for the syndrome and DSM-oriented scales the mean used is 50 with a standard deviation of 10.

Reliability and validity

Item scores on the CBCL/6-18A have a high test-retest reliability (Achenbach & Rescorla, 2001). In that study, the test was administered to mothers of 72 non-referred children with the internal consistency represented by Cronbach's alphas showing that the competent scales had a high level of internal consistency. In addition, the correlation between problems scales were high (range 0.78 to 0.97) on the CBCL; and the DSM-oriented scales also showed a high level of internal consistency—alpha ranging from 0.72 to 0.91.

The CBCL/6-18 has been validated among different samples (e.g. referred and non-referred, and from diverse cultural backgrounds). Research using the CBCL/6-18 on extremely premature children (i.e. <26 weeks of gestational age) suggests that they are at higher risk for depressive symptoms. Consistent with parental reports, teacher reports (on the TRF) show that premature children had increased ratings for behavioural problems (Farooqi, Hägglöf, Sedin, Gothefors, & Serenius, 2007). In addition, data from Russian children adopted from psychosocially depriving institutions compared to never-institutionalised children showed increased behavioural problems in the institutionalised children. Furthermore, an age effect on the problem was reported—behavioural problems augmented with age at adoption (Merz & McCall, 2010). Data from Singaporean referred and non-referred children (Ang et al., 2012) demonstrated that both the CBCL/6-18 and the TRF problem scales had an adequate internal consistency—most of the scales differentiate between the two samples (i.e. referred children had higher scores for the majority of problem items). The CBCL/6-18 has also been used to assess children with previous traumatic brain injury (Chapman et al., 2010). The checklist showed sensitivity in demonstrating that children with traumatic brain injury had elevated externalising behavioural problems which persisted at follow-up assessments.

Validity analyses of the different scales in the CBCL/6-18 have also been conducted. One example is the individual variability in the CBCL/6-18 DSM-oriented scales; which was examined on the basis of genetic and environmental influence among Italian twins aged eight to 17 years (Spatola et al., 2007). Results provide evidence that the DSM-oriented scales adequately capture psychopathological signs and symptoms (i.e. these scales showed a higher heritability than the eight-syndrome scales).

2.3.3. Polysomnographic assessment

The PhD candidate and other trained paediatric sleep technicians conducted overnight lab-PSG at the Children's Sleep Disorders Unit at the Adelaide Women's and Children's Hospital. This is a tertiary referral centre and the only specialist paediatric hospital for South Australia. It specialises in women's and children's health, and serves a population of 1.2 million.

Recommended conditions for performing PSG were followed for all studies (Wiater & Niewerth, 2000). In brief, PSG was performed without sedatives or sleep deprivation, and began at each child's usual bedtime. A parent accompanied each child throughout the procedure. Each participant and one parent stayed in a dark, soundproof room. A trained paediatric sleep technician explained all procedures to parents and children and monitored children overnight. Sleep technicians documented observations every 15 minutes regarding any sleep behaviours (e.g. snoring).

The following standard parameters were measured and recorded continuously using the Compumedics E-Series Sleep System (Melbourne, Australia): electroencephalogram (EEG)— C3-A2, C4-A1, F3-A2, F4-A1, O1-A2 and O2-A1; left and right EOG; sub-mental and diaphragmatic EMG. Heart rate was assessed by ECG modified lead II, leg movements by piezoelectric motion detection, oro-nasal airflow by thermistor and nasal pressure, respiratory movements of the chest and abdominal wall using uncalibrated respiratory inductive plethysmography (RIP), arterial oxygen saturation by pulse oximetry SpO_2 (Nellcor N595; two to three-second averaging time), and snoring via microphone. All data were digitised and stored for subsequent analysis. Each child was monitored continuously overnight via infrared camera by a paediatric sleep technician, who also documented observations of sleep behaviour including the presence or absence of snoring.

Polysomnogram scoring

The PhD candidate, who was blinded to the snoring status of the children, scored all data on Profusion PSG 2 (Compumedics, Melbourne). The candidate was previously trained to score PSG by an experienced sleep technician based at the Women's and Children's Hospital with several years' experience in scoring paediatric sleep studies. Concordance analyses between the author and the trainer was 95% for Stages 2, 3, 4 combined, and 97% for awake, NREM and REM.

Sleep stages

Sleep stages were scored in 30-second epochs according to the standardised criteria of Reschtscaffen and Kales (1968). For reporting purposes, Stages 3 and 4 NREM sleep were combined as SWS. Epochs were scored as movement if the EEG and EOG signals were obscured for >50% of the epoch by muscle tension or artefact associated with movement of the subject. Movement time was scored as a separate category and was not included in either sleep or wake time. Wake time was referred to as time spent awake during the recording period after initial sleep onset.

Arousals

Cortical arousals were scored using slightly modified criteria (Women's and Children's Sleep Disorders Unit PSG Scoring Manual, unpublished) of the American Sleep Disorders Association (Bonnet et al., 1992) and were expressed as the total number of arousals per hour of sleep (arousal index; AI). In brief, arousals were defined as a transient change in the EEG frequency of at least 1 Hz and/or change in the EEG amplitude with respect to the background EEG activity, for at least three-seconds duration and a maximum duration of 15 seconds per epoch. A simultaneous increase in sub-mental EMG for one second was necessary to score arousals in REM sleep. Additionally, a simultaneous increase in ≥1 independent PSG channels (e.g. ECG, EMG) was required to be present to score arousals dominated by theta (3–8Hz) or high frequency (>30Hz) EEG frequencies (Women's and Children's Sleep Disorders Unit PSG Scoring Manual, unpublished). Cortical arousals were categorised using the following criteria:

- Respiratory arousal: occurring during or within two breaths of respiratory event termination.
- External arousal: occurring in response to an external stimulus (e.g. due to the technician or parent entering/leaving room; machine alarms).
- PLM arousal: occurring concurrently or 0.5 seconds pre- or post-limb movement.
- Spontaneous arousal: a cortical arousal not associated with respiratory, external or PLM events / stimuli.

- Subcortical arousal: no evidence of changes on any of the EEG traces, but changes on at least two independent PSG traces such as ECG (i.e. increased heart rate), EMG for at least three-seconds duration. Sub-cortical arousals scored in REM sleep needed to be accompanied by at least one second of sub-mental EMG activation.

Respiratory events

Respiratory variables were scored according to standard guidelines recommended for paediatric sleep studies (American Thoracic Society, 1996). Obstructive apnoeas were defined as a >90% reduction in airflow associated with continued chest and abdominal wall movement for a minimum duration of two missed breaths. Obstructive hypopnoeas were defined as a >50% reduction in airflow signal associated with continued chest and abdominal wall movement for a minimum duration of two missed breaths and associated with either a >3% oxygen desaturation and/or arousal.

Central apnoeas were defined as a >90% reduction in airflow in conjunction with absent chest and abdominal wall movement for a minimum duration of two missed breaths and associated with either a >3% oxygen desaturation and/or arousal or were of >20 seconds in duration. Central hypopnoeas were defined as a >50% reduction in the airflow signal associated with in phase chest/abdominal wall movement for a minimum duration of two missed breaths and associated with either a >3% oxygen desaturation and/or arousal. The presence of any other supportive data such as increased intercostal or sub-mental EMG activity was also used to distinguish between obstructive and central hypopnoeas. The AHI was calculated as the number of obstructive and non-obstructive events per hour of sleep. The OAHI was also calculated—as the number of obstructive events per hour of sleep. PLM were scored according to the criteria of the International Restless Leg Syndrome Study Group (Zucconi et al., 2006)

2.3.4. Sleep diaries

Sleep-wake diaries were given to parents a week prior the neurocognitive testing. Parents were asked to record bed and wake times, number of awakenings and time spent awake, as well as whether the child shared bed or room, and if someone woke the child in the morning. The sleep diary included information about the previous normal school week, or the last normal school week if the child was on holidays. An example of a sleep diary is presented below (Figure 2.3); a copy of the complete sleep diary can be seen in Appendix I.

CHILD SLEEP DIARY

Child's Full Name:

Office use only
Study ID: XX1 (B)

Date	Day	Number of daytime naps	Total time of all daytime naps (mins)	Time went to bed in evening	Time went to sleep	Time woke up next morning	Time got out of bed	Number of awakenings during night	Total time awake during night (minutes)	Total hours of sleep	Child woken by self, parent, sibling, alarm or other?(specify)	Did your child share a bedroom with anyone? (Y/N)	Did your child share a bed with anyone? (Y/N)	Mood scale (refer to instructions)
2/7/03	*Wed*	*1*	*30 min*	*8:15pm*	*8:45pm*	*7:15am*	*7:30am*	*2*	*20 minutes*		*self*	*Yes - brother*	*No*	*4*
29/6/11	Wed	0	—	7:30	8:00	5:10	5:10	1	5 mins	9hr 10m	self	No	No	2
30/6/11	Thu	0	—	7:30	9:00	5.30	5:30	1	5 mins	8hr 30m	"	"	"	2
1/7/11	Fri	0	—	8:30	9:00	6:20	6:20	1	5 mins	9hr 20m	"	"	"	1
2/7/11	Sat	0	—	7:00	8:00	5:00	5:00	1	5 mins	9hr	"	"	"	4
3/7/11	Sun	0	—	7:00	8:00	5:00	5:00	1	5 mins	9hr	"	"	"	3
4/7/11	Mon	0	—	7:00	8:30	5:00	5:30	1	5 mins	8hr 30m	"	"	"	3
5/7/11	Tue	0	—	7:30	8:30	6:00	6:00	0	0	9hr 30m	"	"	"	3

Figure 2.3 Example of a sleep diary from one participant in the current study

2.3.5. Demographic and health information

Habitual snoring is the suggested result of combined environmental, health and heredity factors. Therefore, we gathered information related to the child (e.g. age, gender, BMI, birth weight) and also to the parents (e.g. level of education, smoking, snoring). This information was recorded through the SAPSS-Q, at the screening interview, and during interview on PSG night.

Child characteristics

Body mass index

Evidence shows that increased BMI is associated with a greater risk for snoring and SDB in children (Kohler et al., 2008). Therefore, height (cm) and weight (kg) were recorded and used to calculate BMI and BMI z score. Both indices were estimated using the Centers for Disease Control and Prevention 2000 growth charts (Ogden et al., 2002). During the initial PSG assessment, a technician measured child's weight and height using appropriate paediatric scales available at the sleep unit; waist and hip size were also measured.

Age

There are indications that age is associated with SDB (Bonuck et al., 2011). We determined the age at PSG assessment; derived by subtracting the child's birth date from the date when the sleep study was performed. Similarly, age at neurocognitive test was obtained by subtracting the date of birth from the neurocognitive testing date. Date of birth was reported by parents on the sleep questionnaire and the behaviour checklist, and was also confirmed during the interview by the sleep technician.

Gender

We included gender because of the gender differences for SDB that have been previously reported (Kaditis et al., 2004; Ng et al., 2005) Parents were asked to indicate the child's gender on the SAPSS-Q and the behaviour checklist. Also, the sleep technician and the psychologist included this information in the respective sessions.

Socioeconomic status

Snoring and SDB in children has been often associated with low SES (Chervin et al., 2003; Montgomery-Downs et al., 2003) The postcode gathered in the SAPSS-Q was used to calculate the SES of the family, which was determined through the Australian Bureau of Statistics Index of Relative Socio-economic Advantage/Disadvantage from 2006 National Census Data (Australian Bureau of Statistics, 2006). This index is one of four Socio-

economic Indexes for Areas (SEIFA score). The indexes summarise measures of different variables that represent relative access to materials and social resources, and the ability to participate in social activities, in a certain geographic sector. The four indexes are the Index of Relative Socio-economic Disadvantage, the Index of Relative Socio-economic Advantage and Disadvantage, the Index of Economic Resources, and the Index of Education and Occupation. Each index is given a score, a rank and a decile. The SEIFA score is developed from a number of variables such as household income, education, occupation and ethnicity, which are obtained through the census and is standardised with a national mean of 1000 and SD of 100. The score is an average of people and households in the area and reflects the relative disadvantage of all living in that area; thus, the lower the score the greater the disadvantage for the area. For the purposes of this thesis, the Index of Relative Socio-Economic Disadvantage was used as the measure of SES.

Ethnicity

Racial background has been found to be an indicator of snoring and SDB in children (Chervin et al., 2003; Montgomery-Downs et al., 2003; Rosen et al., 2003). Ethnicity for this study was recorded through the sleep questionnaire at initial assessment. Seven options were given including, Caucasian, Indigenous, African, Asian, Polynesian, Caribbean and other ethnicity not listed. Additionally, ethnicity was recorded through the CBCL.

Gestational age and birth weight

Previous literature has proposed a relationship between snoring/SDB and prematurity (Emancipator et al., 2006; Rosen et al., 2003). Length of pregnancy (weeks) was gathered on the sleep questionnaire and during interview at PSG assessment. Weight at child's birth (kg or lbs, oz) was determined at the initial assessment sleep questionnaire.

Snoring onset

Under the section of general medical history in the SAPSS-Q, parents were questioned about whether their child had ever snored. If so, it was further asked at what age the snoring was first noticed. This information was gathered in order to see whether snoring onset is associated with remission of snoring.

Health information

In order to screen for conditions which could affect either sleep or neurobehavioural performance, parents were asked to report on specific medical conditions. All health information was recorded through the SAPSS-Q at initial assessment. The information

included the presence of asthma, rhinitis, eczema, hay fever, neuromuscular or neurological disorders, developmental delay, and craniofacial abnormalities; as well as any surgical procedures that the child had undergone (e.g. adenoid or tonsillectomy). Additionally, during the PSG assessment parent(s)/caregiver(s) in the study were asked for details of any medical conditions, allergies or current medications. This information was recorded by the sleep technician on each child's sleep study sheet. All sheets were scanned and stored for later consultation by the researcher. We gathered information related to the child's health based on previous reports, which have shown that snoring is associated to allergic conditions, such as asthma, rhinitis and eczema (Bidad et al., 2006; Chng et al., 2004; Ersu et al., 2004; Marshall et al., 2007).

Parent characteristics

Mother and father education

Apart from the interview and the sleep questionnaire given to parents during PSG assessment, an additional form was provided where they were asked for the highest completed education level by each parent. Six options were included, and parents could choose only one of those for each person—primary school, high school year, completed high school, trade or apprenticeship, university, or other.

Household smoking

Smoking in the household (i.e. passive smoking) has been found to be an indicator of increased snoring (Corbo et al., 1989; Li, Jin, et al., 2010). Information about smoking at home was gathered through the SAPSS-Q with the question: "How many cigarettes are smoked per week (in total) by members of the immediate household (anyone currently living in the house)? Please answer even if smoking occurs outside the house". To facilitate analyses, responses were condensed into two categories: presence of smoking at household (i.e. reports of any amount of cigarettes smoked during the week) and no smoking at household (i.e. reports of no cigarettes smoked during the week).

Family history of snoring

SDB at all severities is described as having hereditary characteristics; reports suggest that family history of habitual snoring is strongly associated with habitual snoring in children (Li, Jin, et al., 2010). Through the SAPSS-Q parents were asked whether any family members (mother, father, sibling and grandparents) snored.

2.4. Ethical considerations

Ethics approval for this study was granted first by the Children, Youth & Women's Health Service (CYWHS) Human Research Ethics Committee (Number REC1802/06/11). Then, an Ethics protocol was submitted for consideration to the University of South Australia Human Research Ethics Committee and further approved. Copies of the different information and consent forms can be seen in appendices C, D, E, F and G.

A brief report of the general neurocognitive performance was sent to parents after assessments in both Phase 2 and Phase 4 (Appendix J). That report was not intended to be a diagnostic report, but to give a general overview of the child's performance during assessment. In addition, children identified with obstructive sleep apnoea during PSG were referred to an ENT specialist in the same hospital. PSG and neurocognitive testing completion parents were reimbursed for out-of-pocket expenses.

Chapter 3 Neurobehavioural differences between children who snore and non-snorers from a community-based sample

3.1. Introduction

PS is characterised by snoring in the absence of hypoxemia, hypercapnia and sleep fragmentation, or associated apnoea or hypopnoea with an AHI < 1 events per hour (Katz & Marcus, 2005b; McColley, 2005). It affects up to 10% of all children and is associated with reduced neurocognitive performance and increased problematic behaviour (Beebe, 2006; Bourke et al., 2011). Some of the reported neurocognitive deficits include memory problems, immediate recall, visual-spatial abilities, mental flexibility, sustained and selective attention, and vigilance (Mitchell & Kelly, 2006). Behavioural deficits include inattention, hyperactivity, impulsivity, aggression and bullying, conduct, social problems, anxiety, depression and lower academic performance. (Blunden et al., 2000; O'Brien et al., 2011; Owens, 2009). Of note is that the evidence (see consequences of snoring outlined in Chapter 1) for neurobehavioural deficits in children with PS is mainly based on data collected from hospital/clinical samples (Blunden et al., 2005; Melendres et al., 2004; Miano, Paolino, et al., 2011). In contrast to the findings reported for clinical samples, evidence of deficits are less clear in other population groups such as children who snore recruited from community samples (Beebe et al., 2012; Calhoun et al., 2009). This inconsistency raises concerns as to our understanding of the impact of snoring on neurocognitive performance in children who snore.

To date, 18 studies have investigated PS and psychological functioning using community-based samples , five of which have specifically examined neurocognitive functioning, five neurocognitive functioning and behaviour (one also examined academic performance) and eight have only assessed behaviour (including academic performance). The general consensus is that behavioural functioning is impaired, whereas the findings for neurocognitive functioning are mixed. Nine studies revealed that increased problematic behaviours were common for children who snore, as was poor school performance among the same group, while one study reported no behavioural deficits (Barnes et al., 2009) or reduced school performance (Kaemingk et al., 2003). In contrast, the neurocognitive findings are mixed. Seven studies found that snorers had reduced neurocognitive performance compared to control groups (Barnes et al., 2009; Emancipator et al., 2006; Honaker et al., 2009; Kaemingk et al., 2003; O'Brien, Mervis, Holbrook, Bruner, Klaus, et

al., 2004; O'Brien, Mervis, Holbrook, Bruner, Smith, et al., 2004; Piteo, Lushington, Roberts, Martin, et al., 2011). However, one group reported no verbal deficits (Kaemingk et al., 2003), and further, no language or motor development deficits (Piteo, Lushington, Roberts, Martin, et al., 2011), and a third study reported neurocognitive deficits in pre-term but not full-term children with SDB (Emancipator et al., 2006).

The inconsistency in the findings in the studies that examined children from community samples, together with the discrepancy between the findings for community and hospital/clinical studies, raises concerns as to the understanding of the relationship between habitual snoring and neurocognitive deficits. A possible explanation is the methodological differences between the studies. Not all studies restricted their sample to just children with PS: of the studies included in Table 3.1, 10 specifically investigated children who snored, while eight combined children with different levels of SDB in the index group. A further limitation is that of those that evaluated children who snored, only three used PSG to examine sleep and confirm SDB status. Of these, O'Brien, Mervis, Holbrook, Bruner, Klaus, et al. , (2004) examined both neurocognitive functioning and behavioural performance, while Honaker et al. (2009) examined only behavioural performance, and Brockmann, Urschitz, et al. (2012) assessed school performance. Among the studies that combined children with different severity levels of SDB, six used PSG to examine sleep, but only Calhoun et al. (2009) reported outcomes for children with PS (i.e. AHI < 1 plus snoring at PSG).

In summary, the literature on children who snore needs to be expanded. The methodological limitations in the current literature include the use of mixed groups, lack of objective sleep measures and assessment of limited domains. Therefore, it would be instructive to undertake further research in children who snore who have been recruited from the community, whose symptoms have been validated using objective measures such as PSG, and whose neurocognitive deficits have been assessed using validated measures.

Table 3.1 Findings and methodology of studies examining neuropsychological functioning in children with primary snoring from the community*

First Author (Year)	Participants	Components of assessment	Main findings for index group
Beebe (2012)	170 non-snorers; 57 transient-snorers; 22 primary snorers	**Sleep:** CSHQ. **Neurocognitive:** BSID-II. **Behaviour:** BASC-pre-school form.	No association with early motor development problems. Persistent snorers has higher behaviour problem scores at age 3 compared to transient snorers and controls.
Bonuck (2012a)	13467 infants classified into SDB/behavioural outcomes.	**Sleep:** N/A. **Behaviour:** SDQ.	SDB associated with 40% behavioural difficulties at 4 years and with 60% at 7 years.
Brockmann (2012)	410 non-snorers; 69 primary snorers; 23 UARS/OSA.	**Sleep:** Home-PSG for snorers. **School performance:** Academic grades. **Daytime symptoms**: purposed-design questions.	Snorers had increased risk for hyperactive and inattentive behaviour, daytime sleepiness; poor school performance.
Witcher (2012)	71 non-snorers; 100 primary snorers	**Sleep:** CSHS. **Behaviour:** CPRS-R:L	Poorer sleep hygiene + behaviour problems, higher scores on all scales than non-snorers (e.g. oppositional, hyperactivity and social problems).
Piteo (2011)	31 controls; 10 snorers.	**Sleep:** Parental estimation in regard to previous week (different sleep variables) **Neurocognitive:** BSITD-III.	Lower cognitive scores compared to controls. However, snoring frequency was not associated with language, motor or social development.
Barnes (2009)	22 controls; 22 non-habitual snorers.	**Sleep:** PSG; Sleep Behaviour Questionnaire **Neurocognitive**: Event-related potentials; PPVT-III; Visual attention (NEPSY). **Behaviour:** CPRS:R; Childhood Symptom Inventory-4.	Altered neural processing in occasional snoring children. Increased scores for restlessness/impulsivity, cognitive problems/inattention, and ADHD subscale among rarely snorers compared to controls.
Calhoun (2009)	413 AHI < 1; 152 ≥ 1 AHI < 5; 6 AHI ≥ 5.	**Sleep:** PSG. **Neurocognitive**: WASI; GDS; VMI; ANT; CVLT; Stroop; WCST-64; Digit Span and Coding from WISC-III.	No relationship between mild SDB and measures of neuropsychological functioning, except non-verbal reasoning; which was significant lower in mild SDB snoring children, but with a small effect size.
Honaker (2009)	76 controls; 76 habitual snorers; 76 OSAS.	**Sleep:** PSG. **Neurocognitive**: DAS; NEPSY; PPVT-III; Expressive vocabulary test.	Habitual snorers had decreased verbal ability (DAS) compared to controls (values within normal range).
Key (2009)	3 SDB; 32 SDB sub-clinical levels (AHI = 0.12–3.37/hr).	**Sleep:** PSG. **Neurocognitive**: Event-related potentials; NEPSY.	No relationship between NEPSY (attention and memory) and sub-clinical levels of SDB.
Emancipator (2006)	671 non-SDB; 164 SDB	**Sleep:** Home-PSG. **Neurocognitive**: PPVT; K-ABC; CPT.	Association between SDB with worse cognitive ability in **preterm** children. Equivalent neurocognition in **full-term** children with and without SDB.
Arman (2005)	190 controls; 96 primary snorers.	**Sleep:** N/A **Behaviour**: CPRS-R:L; HIS.	Snorers had more restless sleep, nocturnal enuresis, increased parental anxiety during child's sleep, sleepiness while watching TV, daytime hyperactivity; elevated inattentive conduct, oppositional defiant, ADHD index; total problem scores.

First Author (Year)	Participants	Components of assessment	Main findings for index group
O'Brien (2004)	31 controls; 87 primary snorers.	**Sleep:** PSG. **Neurocognitive**: DAS; NEPSY. **Behaviour**: CPRS-R:L; CBCL/6-18.	Snorers had worse performance in verbal non-verbal and general ability, naming, verbal comprehension, pattern construction, language, visuospatial, visual attention, phonological processing and arrows scores. Elevated withdrawn, anxious/depressed, social, attention, internalising problems; hyperactivity, social, hyperactive-impulse and total problems.
O'Brien (2004)	35 controls; 35 SDB.	**Sleep:** PSG. **Neurocognitive:** DAS; NEPSY. **Behaviour**: CBCL; CPRS-R:L.	SDB had worse performance for: non-verbal, cognitive ability, attention/executive functioning, executive functioning (planning, monitoring and self-regulation), visual attention, phonological reasoning.
Rosen (2004)	667 non-SDB; 162 SDB.	**Sleep:** Limited-channel cardiorespiratory recordings (home). **Behaviour**: CBCL; CPRS-R:L.	SDB group had higher chances of having borderline or clinically abnormal internalising and externalising problems, hyperactivity, global total index; oppositional behaviours.
Kaemingk (2003)	72 AHI < 5; 77AHI ≥ 5	**Sleep:** PSG. **Neurocognitive:** WASI; CAVLT-2. **Behaviour/School performance**: CPRS; Woodcock Johnson Psycho-Educational Battery-Revised Tests of Achievement.	Groups differed for: verbal learning trials and delayed recall. No differences for: academic performance, verbal IQ, recall when 1 item presented.
Urschitz (2003)	410 never snoring; 605 occasionally snoring; 89 frequently snoring; 25 always snoring.	**Sleep:** Nocturnal home pulse oximetry. **School performance**: Previous term's report (academic grades)	Habitual snoring related to poor school performance, partially explained by intermittent hypoxia.
Ferreira (2000)	876 non-snorers; 84 loud snorers.	**Sleep:** Purposed-designed questionnaire (sleep and wake behavioural patterns) **Behaviour**: behavioural disturbances using the Children's Behavior; Questionnaire for Teachers.	Snorers had more bedtime struggles, comforting habits to sleep, night light to fall asleep, afraid of sleeping alone, teeth grinding, sleep talking, night terrors, sleepy and irritable during day, medical and behavioural problems (parental/teacher reported scores).
Ali (1993)	58 controls; 52 high risk of SDB children.	**Sleep:** Questionnaire survey about snoring and sleep problems. Home recording: video, microphone, and oximetry. **Behaviour:** CPRS	Parents and teachers reported that children with high risk of SDB were more hyperactive and inattentive. Only parents thought they were more aggressive.

Note. * *Test abbreviations: CSHQ* = Child Sleep Habits Questionnaire; *BSITD-II orBSITD-III* = Bayley Scales of Infant and Toddler Development (2nd or3rd Edition); *BASC-pre-school form* = Behavior Assessment System for Children (pre-school form); *SDQ* = The Strengths and Difficulties Questionnaire; *CPRS-R:L* = Conners' Parent Rating Scale-Revised Long Form; *PPVT-III* = Peabody Picture Vocabulary Test-III; *WASI* = Wechsler Abbreviated Scales of Intelligence; *GDS* = Gordon Diagnostic; *VMI* = System; Developmental Test of Visual-Motor Integration; *ANT* = Animal Naming Test; *CVLT* = California Verbal Learning Test; *Stroop* = Stroop Color and Word Test Children's Version; *WCST*-64 = Wisconsin Card Sorting Test-64 Card Version; *WISC-III* = Wechsler Intelligence Scale for Children (III); *K-ABC* = Kaufman Assessment Battery for Children; *HIS* = Teacher Scales; Inattention Hyperactivity Scale; *DAS* = Differential Ability Scales; *NEPSY* = Developmental Neuropsychological Assessment; The *CBCL/6-18* = Child Behavior Checklist Ages 6-18; *CAVLT-2* = Children's Auditory Verbal Learning Test-2; *IQ-ABIQ* = The Abbreviated Battery; *BRIEF-P* = The Behavior Rating Inventory of Executive Function-Preschool version); *CBCL/1.5-5* = The Child Behavior Checklist Ages 1.5.-5; *C-TRF/1.5-5* = The Caregiver-Teacher Report Form Ages 1.5-5; *WPPSI-R* = Scale of Intelligence-Revised. SBD = sleep-disordered breathing; PSG = polysomnography; ADHA = attention deficit hyperactivity disorder; AHI = apnoea/hypopnoea index; OSAS = Obstructive Sleep Apnoea Syndrome; UARS = Upper Airway Resistance Syndrome

3.2. Methodology

Participants

One hundred and sixteen children were included in this study. Participants were selected from the SAPSS—an epidemiological study conducted in 2007 which examined the prevalence of sleep complaints and sleep/wake behaviours in children from South Australia (Biggs, Lushington, van den Heuvel, Martin, & Kennedy, 2011). In brief, a population-based, cross-sectional design targeted public and private primary schools (Year 1 to Year 5) in the Adelaide metropolitan area. Schools were given questionnaires to distribute to children by teachers, and parents were asked to return the surveys by post. The questionnaire also included an invitation to participate in a further study examining the natural history of snoring, requiring children to undergo neurocognitive and PSG testing on two occasions separated by 24 months. One hundred and forty-nine families who indicated a willingness to participate in future research were contacted and then screened at interview. Children were excluded if they spoke English as a second language (because of language measures), had a medical or psychological condition (e.g. Attention Deficit Hyperactivity Disorder, Autism Spectrum Disorder, neurological disorder, auditory processing disorder) associated with cognitive deficits and/or behavioural problems, and if they were currently taking medications known to affect sleep, respiratory function or neuropsychological measures (e.g. stimulants). Of the 136 children who were finally contacted, five children were excluded for medical conditions. In total, 131 children underwent PSG, but eight were excluded because they refused to complete all assessments, and another seven were further excluded for an abnormal PSG (i.e. OAH ≥ 1). A final sample of 65 non-snoring children and 24 snoring children were included in this study see Figure 3.1.

Participating children underwent detailed neurocognitive, behaviour and PSG examination. Demographic data including parental education, SES, ethnicity, a detailed medical history and growth parameters were obtained. SES was determined using the Index of Relative Socio-economic Disadvantage from the SEIFA collected by the Australian Bureau of Statistics' 2006 national census data (Australian Bureau of Statistics, 2006). BMI was determined by established growth charts, corrected for age and gender (Bellizi & Dietz, 1999); using height and weight measured on the PSG night. More detailed information can be found in Chapter 2.

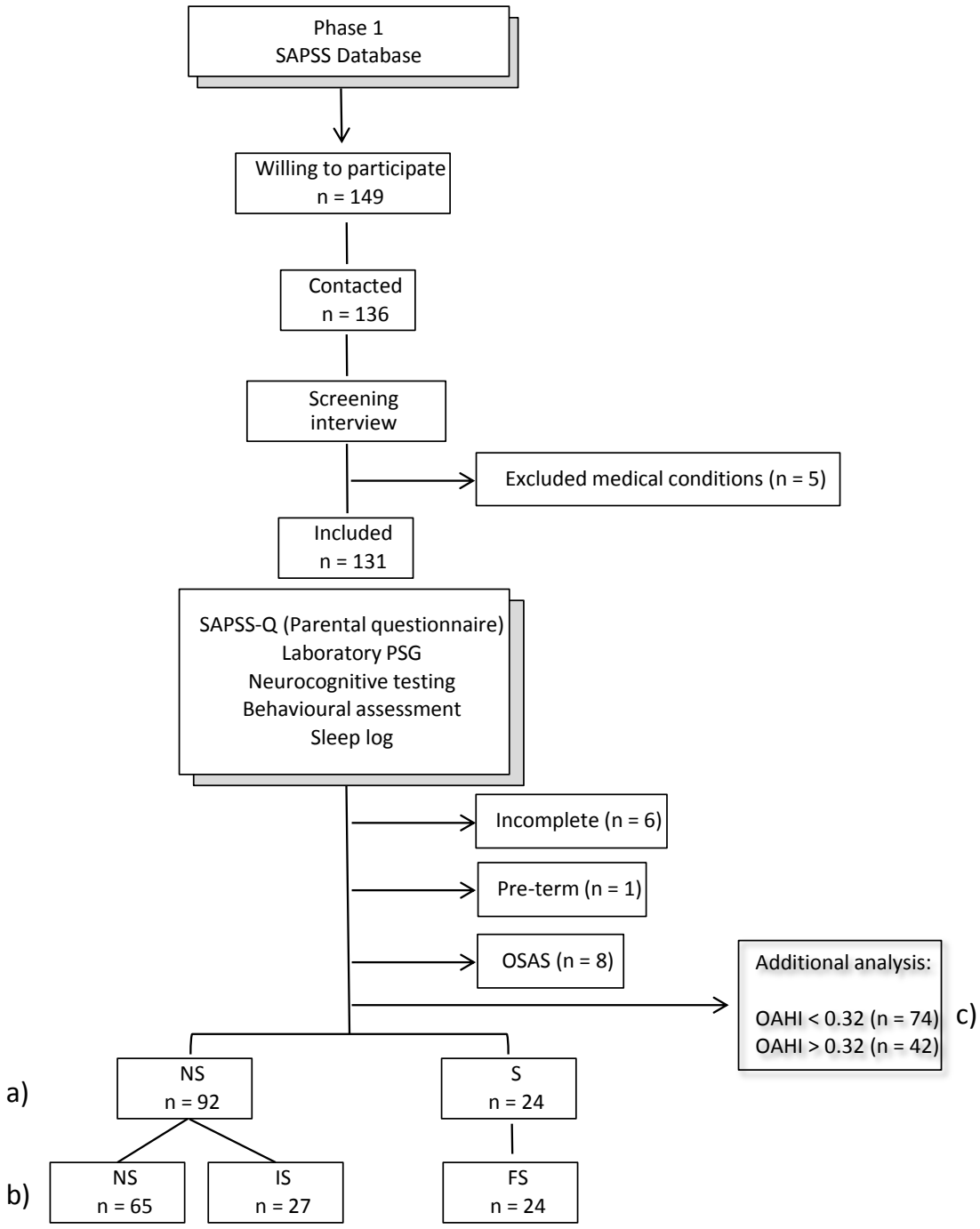


Figure 3.1 Sampling and protocol at baseline

Note. a) Analysis 1 using NS = non-snorers and S = snorers; b) Analysis 2 using NS = non-snorers, IS = infrequent snorers and FS = frequent snorers; c) Analysis 3 using OAHI <0.32 and OAHI >0.32
SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire; OSAS = obstructive sleep apnoea syndrome; PSG = polysomnography; OAHI = Obstructive Apnoea-Hypopnoea Index

Protocol

Subjects participated in a two-hour neurocognitive testing session where children were assessed by a psychologist blinded to the group status of the participants. Within two weeks of assessment children underwent a full-night lab-PSG undertaken at the Sleep Disorders Unit at the Women's and Children's Hospital; a tertiary education centre for South Australia serving a population of 1.2 million.

Based on snoring history collected at the first testing session, 24 children were reported to snore 'sometimes' or 'usually' (i.e. ≥2 nights/week), while 27 snored 'rarely' (i.e. ≥1 night/week); and 65 children were reported to never snore during the previous week. These children then underwent PSG, and if abnormal PSG was found they were excluded prior to the start of the study because of OSAS and referred to an ENT specialist. The data reported in this study constitute the first wave of a larger study examining the natural history of snoring involving a complete assessment (sleep, neurocognition and behaviour) of children on two occasions at 24 months apart.

The study was approved by the Human Research Ethics Committees of the University of South Australia and the CYWHS Number REC1802/06/11.

Materials

Sleep questionnaire

Sleep was assessed using a purposed-designed questionnaire—the SAPSS-Q (Appendix A); which contains questions examining sleep problems using items from well-known and validated instruments (Bruni et al., 1996; Owens et al., 2000). The SAPSS-Q has six major robust scales used to assess co-morbid sleep problems such as sleep routine, bedtime anxiety, restless sleep, night arousals, SDB and morning tiredness. One item from the SDB scale was used to classify children into the different groups ('your child currently snores loudly'). Additionally, for each scale parents were asked to rate whether they considered the sleep behaviour a problem. A particular note was taken for those items where parents considered it a problem if their child breathed heavily during the night, snored frequently, snored loudly, and if they watched their child while sleeping at night because they were afraid that their child would stop breathing.

Demographic and health information

Demographic and health information was recorded through questions in the SAPSS-Q and during a face-to-face interview at the PSG assessment. Analyses for these variables are presented in the following chapter (Chapter 4).

Polysomnographic assessment

Overnight PSG was conducted without sedation or sleep deprivation and began at each child's usual bedtime. A parent accompanied each child throughout the procedure. The following standard parameters were measured and recorded continuously using the Compumedics E-Series Sleep System (Melbourne, Australia): EEG; C3-A2, C4-A1, F3-A2, F4-A1, O1-A2 and O2-A1, left and right EOG, sub-mental and diaphragmatic EMG.

Heart rate was assessed by ECG, leg movements by piezoelectric motion detection, oro-nasal airflow by thermistor and nasal pressure, respiratory movements of the chest and abdominal wall using uncalibrated respiratory inductive RIP, arterial oxygen saturation (SpO_2) by pulse oximetry (Nellcor N595; two to three-second averaging time) and snoring via microphone. All data were digitised and stored for subsequent analysis. Each child was monitored continuously overnight via infrared camera by a paediatric sleep technician, who also documented observations of sleep behaviour including the presence or absence of snoring (i.e. technician reporting of snoring).

Sleep stages were scored in 30-second epochs according to the standardised criteria (Rechtschaffen & Kales, 1968). For reporting purposes Stages 3 and 4 NREM sleep were combined as SWS. Epochs were scored as movement if the EEG and EOG signals were obscured for >50% of the epoch by muscle tension or artefact associated with movement of the subject. Movement time was scored as a separate category and was not included in either sleep or wake time. Wake time refers to time spent awake during the recording period after initial sleep onset. Respiratory variables were scored according to standard guidelines recommended for paediatric sleep studies (Loughlin et al., 1996). The AHI was calculated as the number of obstructive and non-obstructive events per hour of sleep. Spontaneous and respiratory arousals were scored according to the criteria of the American Sleep Disorders Association (Bonnet et al., 1992) and are expressed as the total number of arousals per hour of sleep (AI).

Neurocognitive and behavioural assessment

Cognitive ability was assessed using DAS (Elliott, 2007), which contains six subtests that generate three scale scores—verbal (word definitions and verbal similarities), non-verbal reasoning (matrices, sequential and quantitative reasoning) and spatial ability (recall of designs and pattern construction)—and a composite general ability score. Scale scores have a mean of 100 and an SD of 15. The DAS is a well-recognised and validated instrument used for assessing children with SBDs (Gozal, McLaughlin, et al., 2007; Gozal et al., 2009; Kheirandish & Gozal, 2006).

Executive functioning was assessed through the NEPSY (Korkman et al., 1998), which contains 12 subtests. Nine were administered (we excluded the visual spatial subtest because it was assessed through the DAS) to generate three domain scores—Attention/Executive Function (Tower, Auditory Attention and Response Set, and Visual Attention), Language (Phonological Processing, Speeded Naming and Comprehension of

Instructions) and Memory and Learning (immediate and delayed Memory for Faces and for Names, and Narrative Memory). Domain scores have a mean of 100 and an SD of 15.

Problematic behaviour was assessed using the CBCL/6-18 (Achenbach & Rescorla, 2001). This checklist is a well-validated, reliable and empirically-based assessment completed by parents which evaluates adaptive and maladaptive functioning in children. The CBCL/6-18 contains three competency scales (social, school and activity scales), eight problematic behaviour scales (Anxious/Depressed, Withdrawn/Depressed, Somatic, Thought and Attention Problems, and Rule-Breaking and Aggressive Behaviour) which constitute internalising and externalising problems. It also contains scales used to assess psychopathology consistent with DSM diagnostic criteria (scales include Affective, Anxiety, Somatic, ADHD, Oppositional Defiant and Conduct Problems). All *t*-scores have a mean of 50 and an SD of 10.

Data analysis

Children were classified according to three criteria. First, to allow comparisons between the current and previous research findings by O'Brien, Mervis, Holbrook, Bruner, Klaus, et al. (2004) the children were classified into two groups: non-snorers (never snoring or snoring once a week and OAHI < 1/hr.) and snorers (snoring ≥2 nights/week and OAHI < 1/hr). Second, because of previous research by Barnes et al. (2009) suggesting that non-habitual snorers (e.g. snoring once a week) have neurocognitive-related deficits, the children were divided into three groups: non-snorers (never snoring), infrequent snorers (snoring once a week) and frequent snorers (snoring ≥ 2 nights/week), with all groups OAHI < 1/hr. Third, in order to explore the impact of objective criteria for snoring severity on neurocognitive and behavioural performance the children were classified according to the OAHI. That is, regardless of the patient-reported snoring status, according to the mean OAHI (0.32) children were classified into OAHI < 0.32 and OAHI > 0.32.

Statistical analysis

Independent *t*-tests were used to test group differences (continuous variables) for dichotomous independent variables (non-snorers vs. snorers and OAHI < 0.32 vs. OAHI > 0.32); with *p* values adjusted for unequal variances when appropriate (Levene's test for equality of variances). Kruskal-Wallis, Mann-Whitney tests or analysis of variance (ANOVA) were conducted to test group differences for continuous variables for snoring groups including non-snorers, infrequent snorers and frequent snorers. Mann-Whitney tests were used to follow up significant results on Kruskall-Wallis tests, and a Bonferroni

correction was applied to follow-up significant ANOVA results. The effect size estimate (r) for t-tests and partial eta squared (η^2_ρ) for ANOVA was calculated in order to test the magnitude of the effect on the dependent variable. Data are presented as mean (SD) unless otherwise stated. Spearman's correlation coefficients were performed to test associations between behavioural outcomes and respiratory variables on the PSG for the entire sample. A similar analysis was conducted, this time for SDB-related items from the SAPSS-Q and respiratory variables on the PSG. All analyses were conducted using the statistical package SPSS for windows version 21.

3.3. Results

Sample characteristics

A total sample of 116 children was included in this analysis. Of these children, 93% were of Caucasian ethnicity, with 2% Asian, and 5% 'other' ethnicity. Of the children included in this sample, 40% were males, with a mean (SD) age of 8.1 (1.6), BMI percentile 63.6 (25.2), gestational age 39.2 (1.7), and SES defined as the SEIFA index of 991.5 (72.8). None of the children had tonsils or adenoids removed, and within the sample there were no children with facial abnormalities, cleft palate, neurological disorders or muscular disorders.

Non-snorers versus snorers: Neurocognitive functioning and behavioural performance

Neurocognitive performance

Table 3.2 presents data related to neurocognitive performance using the DAS and NEPSY tests. In general, groups performed similarly on all neurocognitive measures.

Table 3.2 Mean (SD) DAS and NEPSY domain scores for non-snorers and snorers together with *t*-test and effect size values

Neurocognitive Domain	Non-snorer (n = 87)		Snorer (n = 24)		*t-test*	Effect size (*r*)
	Mean	(SD)	Mean	(SD)		
DAS						
Verbal Ability	102.2	(11.8)	101.1	(10.0)	0.43	.04
Non-verbal Reasoning Ability	98.2	(10.1)	97.8	(10.7)	0.15	.01
Spatial Ability	106.8	(10.5)	107.8	(10.3)	–0.39	.04
General Cognitive Ability	102.3	(9.7)	102.2	(9.1)	0.03	.00
NEPSY						
Attention Executive Functioning	101.2	(10.4)	103.9	(11.7)	–1.23	.12
Language	103.9	(11.7)	103.8	(15.4)	0.05	.00
Memory	106.6	(15.7)	105.5	(19.9)	0.28	.03
Memory for faces	11.8	(2.8)	11.5	(3.3)	0.39	.04
Immediate recall	11.8	(3.0)	11.2	(3.1)	0.80	.08
Delayed recall	11.5	(2.5)	11.5	(2.9)	0.11	.01
Memory for names	10.6	(3.2)	9.7	(3.1)	1.21	.12
Immediate recall	10.7	(2.9)	10.1	(2.7)	0.94	.09
Delayed recall	10.7	(3.2)	9.5	(3.4)	1.48	.15
Narrative Memory	10.2	(2.8)	10.7	(3.4)	–0.74	.07

Note. DAS = Differential Ability Scales; NEPSY = Developmental Neuropsychological Assessment

Behavioural performance

Table 3.3 presents data related to behavioural performance on the CBCL/6-18 for snorers and non-snorers. Groups were matched for the competence scales in Analysis 1 (non-snorers vs. snorers). Similarly, the two groups had similar scores for most of the problematic scales, except that children who snored had higher scores for Somatic Complaints (syndrome scales); Thought Problems (syndrome scales); and for Affective Problems. Although only three scales differed between groups, there was a trend towards problematic behaviour in children who snored. These findings may be significant if a larger sample is used.

Table 3.3 Mean (SD) Child Behavior Checklist scale scores across two snoring groups

CBCL Scale	Non-snorer (n = 83)		Snorer (n = 22)		*t-value*	Effect size (*r*)
	Mean	(SD)	Mean	(SD)		
Competence Scale						
Activity	47.2	(10.8)	46.6	(11.6)	0.21	.02
Social	48.7	(7.3)	45.1	(10.7)	1.49	.29
School	48.1	(6.2)	45.6	(7.1)	1.56	.16
Total Competence	48.5	(8.5)	44.4	(10.3)	1.79	.18
Syndrome Scales						
Internal Problems	50.8	(10.5)	54.8	(12.1)	–1.52	.15
External Problems	50.6	(8.7)	53.7	(10.9)	–1.38	.14
Total Problems	50.9	(9.2)	55.2	(11.7)	–1.57	.28
Anxious/Depressed	54.3	(6.3)	56.4	(7.4)	–1.32	.13
Withdrawn/Depressed	54.5	(5.7)	55.5	(6.2)	–0.74	.07
Somatic complaints	55.7	(6.7)	59.9	(8.8)	**–2.06***	.36
Social Problems	54.4	(4.6)	56.0	(6.8)	–1.28	.13
Thought Problems	55.4	(6.1)	60.1	(9.8)	**–2.09***	.38
Attention Problems	54.6	(5.3)	56.7	(7.8)	–1.20	.23
Rule–breaking Behaviour	54.4	(4.8)	54.9	(7.6)	–0.36	.04
Aggressive Behaviour	54.1	(5.1)	57.2	(8.1)	–1.72	.32
DSM–oriented Scales						
Affective Problems	55.2	(6.1)	58.5	(7.6)	**–2.11***	.20
Anxiety Problems	54.5	(6.6)	57.1	(8.9)	–1.26	.23
Somatic Problems	55.6	(7.4)	59.9	(10.9)	–1.61	.30
ADHD	53.8	(4.7)	56.5	(8.3)	–1.47	.29
Oppositional Defiant	54.4	(5.3)	56.1	(6.8)	–1.18	.12
Conduct Problems	54.4	(5.7)	55.2	(8.8)	–0.39	.08

Note. Maladaptive behaviour is indicated by lower scores on the *competence scale* and higher scores on the *syndrome* and *DSM-oriented* scales
ADHD = attention deficit hyperactive disorder
*denotes $p < 0.05$

Polysomnographic results

Table 3.4 presents the results for PSG data. Groups were matched for variables including total sleep time, REM%, SWS%, respiratory arousal, spontaneous AI, central apnoea-hypopnoea and for AHI. In contrast, snorers had lower sleep efficiency than non-snorers. This difference was significant, but small in magnitude. Similarly, snorers had increased wakefulness after sleep onset (WASO), but it too was small in magnitude. Although within the expected range, snorers had a higher OAHI compared to non-snorers, again small in magnitude.

Table 3.4 Mean (SD) polysomnographic values for non-snorers versus snorers together with *t*-test and effect size values

Domain	Non-snorer (n = 91)		Snorer (n = 23)		*t-test*	Effect size (*r*)
	Mean	**(SD)**	**Mean**	**(SD)**		
TST (mins)	424.1	(45.7)	405.2	(52.3)	1.72	.16
Sleep efficiency (%)	80.4	(8.3)	75.6	(10.3)	**2.34***	.22
REM (%)	19.9	(4.0)	20.3	(4.3)	–0.39	.04
SWS (%)	27.5	(5.1)	28.8	(6.0)	1.04	.10
WASO (min)	50.0	(36.4)	72.9	(41.9)	**–2.61***	.24
RAI (events/hr)	0.6	(0.5)	0.5	(0.3)	0.26.0	.03
SAI (events/hr)	7.6	(2.4)	7.0	(2.3)	1.04	.10
3% ODI (events/hr)	0.8	(0.6)	0.9	(0.8)	–0.27	.03
OAHI (events/hr)	0.2	(0.2)	0.4	(0.2)	**–2.25***	.21
CAHI (events/hr)	0.5	(0.4)	0.5	(0.5)	–0.60	.06
AHI (events/hr)	0.8	(0.4)	1.0	(0.7)	–1.56	.23

Note. TST = total sleep time; REM = rapid eye movement sleep; SWS = slow wave sleep; WASO = wakefulness after sleep onset; RAI = respiratory arousal index; SAI = spontaneous arousal index; 3% ODI = the number of dips in oxygen saturation ≥ 3%; OAHI = obstructive apnoea-hypopnoea index; CAHI = central apnoea-hypopnoea index; AHI = apnoea-hypopnoea index
*denotes $p < 0.05$

Co-morbid sleep problems

Analyses revealed that snorers had increased scores for co-morbid sleep problems compared to non-snorers, including night arousals, $t(113) = –2.96$, $p < 0.05$, $r = .26$; SDB, $t(26.24) = –9.85$, $p < 0.05$, $r = .88$; and restless sleep, $t(27.39) = –3.82$, $p < 0.05$, $r = .58$ (Figure 3.2).

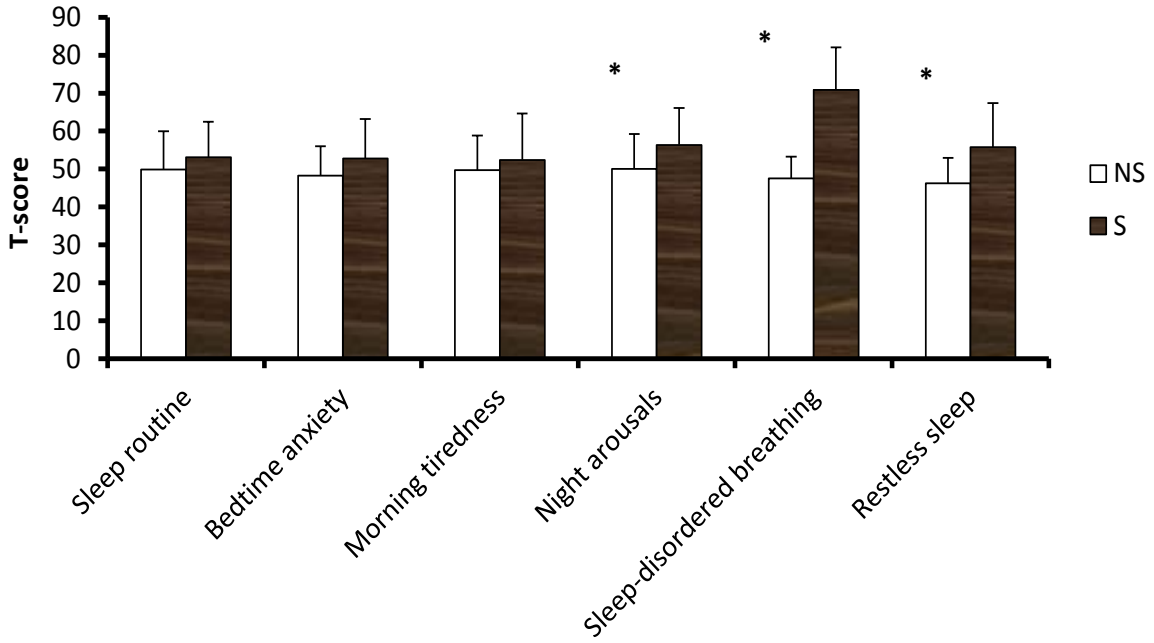


Figure 3.2 T-scores for co-morbid sleep problems between non-snorers (NS) and snorers (S), mean (SD)

Note. * Denotes $p < 0.01$

Non-snorers, infrequent and frequent snorers: Neurocognitive functioning and behavioural performance

Neurocognitive performance

Regardless of the snoring classification, ANOVA revealed that groups had a similar performance for all neurocognitive domains and subscales in both DAS and the NEPSY tests (Table 3.5).

Table 3.5 Mean (SD) DAS and NEPSY domain scores for non-snorers, infrequent and frequent snorers together with *t*-test and effect size values

Domain	Non-snorer (n = 62)		Infrequent snorer (n = 25)		Frequent snorer (n = 24)		*F-value*	Effect size (η^2_p)
	Mean	(SD)	Mean	(SD)	Mean	(SD)		
DAS								
Verbal Ability	102.9	(10.7)	101.0	(14.4)	101.1	(10.0)	0.47	.01
Non-verbal Reasoning Ability	98.6	(11.3)	97.2	(6.6)	97.8	(10.7)	0.18	.00
Spatial Ability	106.8	(11.2)	106.9	(8.9)	107.8	(10.3)	0.07	.00
General Cognitive Ability	102.6	(10.3)	102.0	(8.2)	102.2	(9.1)	0.08	.00
NEPSY								
Attention/Executive Function	100.4	(10.6)	103.1	(9.8)	103.9	(11.7)	1.37	.03
Language	103.7	(12.4)	104.6	(10.1)	103.8	(15.4)	0.04	.00
Memory	106.8	(16.0)	106.0	(15.4)	105.5	(19.9)	0.05	.00
Memory for faces	11.9	(2.9)	11.5	(2.4)	11.5	(2.9)	0.29	.00
Immediate recall	11.7	(3.1)	11.9	(2.7)	11.2	(3.1)	0.33	.01
Delayed recall	11.7	(2.7)	11.1	(2.1)	11.5	(2.9)	0.38	.01
Memory for names	10.8	(3.2)	10.2	(3.1)	9.7	(3.1)	0.93	.02
Immediate recall	11.0	(3.0)	10.2	(2.5)	10.1	(2.7)	1.01	.02
Delayed recall	10.6	(3.3)	10.8	(3.1)	9.5	(3.4)	1.11	.02
Narrative Memory	10.1	(2.7)	10.4	(3.3)	10.7	(3.4)	0.39	.01

Note. DAS = Differential Ability Scales; NEPSY = Developmental Neuropsychological Assessment

Behavioural performance

Results from this analysis (Table 3.6) revealed that groups had similar behavioural performance in the competence scales and most of the syndrome scales, except for somatic complaints. After Bonferroni correction, it was noted that infrequent and frequent snorers had significantly higher scores than non-snorers. Differences were also seen for thought problems, but after Bonferroni correction it was found that only frequent snorers had significantly higher scores than non-snorers. In contrast, among the DSM-oriented scales, groups differed for affective problems and somatic problems. Bonferroni correction showed that increased reports of affective and somatic problems were more common in infrequent and frequent snorers than in non-snorers.

Table 3.6 Mean (SD) Child Behavior Checklist scale scores across three snoring groups together with F-test and effect size

CBCL Scale	Non-snorer (n = 58)		Infrequent snorer (n = 25)		Frequent snorer (n = 22)		*F-value*	Effect size (η^2_ρ)
	Mean	(SD)	Mean	(SD)	Mean	(SD)		
Competence Scale								
Activity	47.5	(11.4)	46.6	(9.4)	46.6	(11.6)	0.08	.00
Social	48.3	(7.6)	49.5	(6.6)	45.0	(10.7)	1.96	.04
School	48.5	(5.7)	47.2	(7.3)	45.6	(7.1)	1.53	.03
Total Competence	48.8	(8.4)	47.9	(8.9)	44.4	(10.3)	1.68	.04
Syndrome Scales								
Internal Problems	49.4	(9.8)	54.0	(11.5)	54.8	(12.1)	2.81	.05
External Problems	50.5	(8.8)	51.0	(8.5)	53.7	(10.9)	0.98	.02
Total Problems	49.9	(9.2)	53.3	(9.2)	55.2	(11.7)	2.68	.05
Anxious/Depressed	53.6	(5.3)	56.0	(8.0)	56.4	(7.4)	2.14	.04
Withdrawn/Depressed	54.3	(5.6)	54.8	(5.9)	55.5	(6.2)	0.34	.01
Somatic complaints	54.4	(5.6)	58.8	(8.3)	59.9	(8.8)	**6.59****	.12
Social Problems	53.9	(4.6)	55.4	(4.5)	56.0	(6.8)	1.60	.03
Thought Problems	54.7	(5.3)	56.8	(7.3)	60.0	(9.8)	**4.48***	.08
Attention Problems	54.5	(5.5)	54.8	(4.8)	56.7	(7.8)	1.14	.02
Rule–breaking Behaviour	54.3	(4.9)	54.6	(4.9)	54.9	(7.6)	0.09	.00
Aggressive Behaviour	54.1	(5.1)	53.8	(5.3)	57.2	(8.1)	2.53	.05
DSM–oriented Scales								
Affective Problems	54.1	(4.9)	58.0	(7.8)	58.5	(7.6)	**5.75****	.10
Anxiety Problems	53.6	(5.6)	56.6	(8.2)	57.1	(8.9)	2.70	.05
Somatic Problems	54.1	(6.4)	59.1	(8.5)	59.9	(10.9)	**5.42****	.09
ADHD	53.8	(4.7)	53.6	(4.8)	56.5	(8.3)	2.03	.04
Oppositional Defiant	54.4	(5.3)	54.4	(5.6)	56.1	(6.8)	0.70	.01
Conduct Problems	54.2	(5.3)	55.0	(6.5)	55.2	(8.8)	0.24	.01

Note. Maladaptive behaviour is indicated by lower scores on the competence scale and higher scores on the syndrome and DSM-oriented scales; ADHD = Attention deficit hyperactive disorder
*denotes $p < 0.05$, **$p < 0.01$

Polysomnographic results

Results (Table 3.7) also revealed that groups were similar for most of the variables collected at PSG, except for WASO and obstructive apnoea-hypopnoea index. Post-hoc tests revealed that only frequent snorers had a higher WASO and obstructive index compared to non-snorers, $U = 471$, $r = –.27$ and $U = 453$, $r = –.29$ respectively.

Table 3.7 Mean (SD) polysomnographic values for three groups together with *t*-test and effect size values

Domain	Non-snorer (n = 65)		Infrequent snorer (n = 26)		Frequent snorer (n = 23)		*H or F-value*	Effect Size (η^2_ρ)[a]
	Mean	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**		
TST (mins)	423.6	(47.1)	425.6	(42.0)	405.2	(52.3)	F = 1.48	.03
Sleep efficiency (%)	80.3	(8.8)	80.7	(6.9)	75.6	(10.3)	F = 2.74	.05
REM (%)	19.6	(3.7)	20.6	(4.6)	20.3	(4.3)	F = 0.67	.01
SWS (%)	27.4	(5.5)	27.9	(4.0)	28.8	(6.1)	F = 0.63	.01
WASO (min)	49.1	(37.6)	52.3	(33.9)	72.9	(41.9)	**H = 7.11***	[a]
RAI (events/hr)	0.6	(0.5)	0.5	(0.4)	0.5	(0.3)	H = 0.07	[a]
SAI (events/hr)	7.9	(2.5)	7.0	(2.2)	7.0	(2.3)	F = 1.94	.03
3% ODI (events/hr)	0.8	(0.6)	0.9	(0.5)	0.9	(0.8)	H = 1.42	[a]
OAHI (events/hr)	0.2	(0.2)	0.3	(0.3)	0.4	(0.2)	**H = 8.85***	[a]
CAHI (events/hr)	0.5	(0.3)	0.4	(0.5)	0.5	(0.5)	H = 2.26	[a]
AHI (events/hr)	0.7	(0.4)	0.8	(0.5)	1.0	(0.7)	H = 0.55	[a]

Note. TST = total sleep time; REM = rapid eye movement sleep; SWS = slow wave sleep; WASO = wakefulness after sleep onset; RAI = respiratory arousal index; SAI = spontaneous arousal index; 3% ODI = the number of dips in oxygen saturation ≥ 3%; OAHI = obstructive apnoea-hypopnoea index; CAHI = central apnoea-hypopnoea index; AHI = apnoea-hypopnoea index

[a] $\eta\rho^2$ calculated only for F-tests;* denotes $p < 0.05$

Co-morbid sleep problems

When groups were classified into three groups (non-snorers, infrequent snorers and frequent snorers), differences were found for bedtime anxiety, night arousals, SDB and restless sleep (Figure 3.3). However, post-hoc tests revealed that only frequent snorers had higher scores for both bedtime anxiety and night arousals compared to non-snorers ($U = 445.0$, $r = –.32$ and $U = 431.0$, $r = –.34$, respectively). SDB differed across the three groups, with frequent snorers showing the highest scores for this scale compared to infrequent snorers and non-snorers ($U = 63.5$, $r = –.69$ and $U = 92$, $r = –.77$ respectively); and infrequent snorers had higher scores than non-snorers ($U = 92.5$, $r = –.72$). Restless sleep was significantly higher for frequent snorers compared to non-snorers ($U = 319.5$, $r = –.43$).

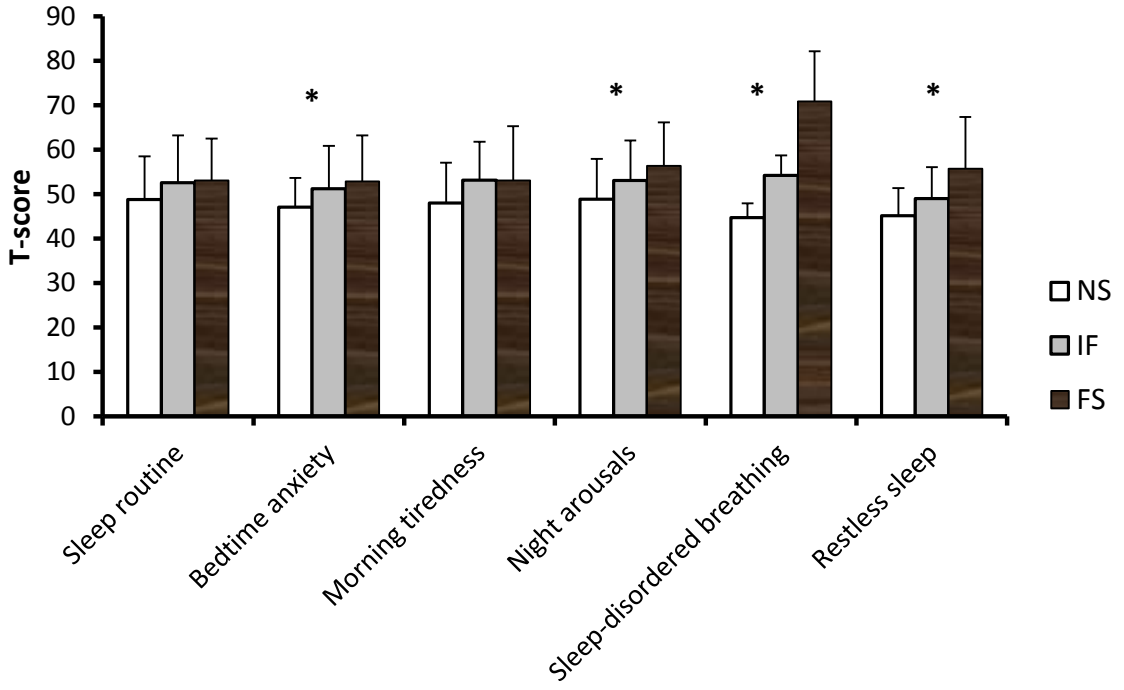


Figure 3.3 T-scores for co-morbid sleep problems between non-snorers (NS), infrequent snorers (IS) and frequent snorers (FS), mean (SD)

Note. * Denotes $p < 0.05$

Obstructive apnoea-hypopnoea Index classification: Neurocognitive functioning and behavioural performance

Neurocognitive performance

Table 3.8 presents neurocognitive results. In general, children with an OAHI > 0.32 had lower scores for all neurocognitive domains. However, only Memory scores were statistically significantly lower in children with an OAHI < 0.32, but while significant the effect size was small in magnitude. Much of the deficit in Memory scores can be accounted for by reduced Memory for Faces (Immediate and Delayed recall) subtest scores, which although significant, the effect sizes were also small in magnitude.

Table 3.8 Mean (SD) DAS and NEPSY domain scores according to OAHI classification together with *t*-test and effect size values neurocognitive performance

Domain	OAHI < 0.32 (n = 72)		OAHI > 0.32 (n = 44)		*t*-value	Effect Size (*r*)
	Mean	(SD)	Mean	(SD)		
DAS						
Verbal Ability	102.7	(11.7)	99.8	(10.5)	1.34	.12
Non-verbal Reasoning Ability	99.4	(11.2)	97.3	(9.0)	1.04	.10
Spatial Ability	107.8	(10.1)	105.4	(10.5)	1.25	.12
General Cognitive Ability	103.6	(9.8)	100.3	(8.8)	1.81	.17
NEPSY						
Attention Executive Functioning	102.1	(10.4)	101.2	(10.2)	0.43	.04
Language	104.0	(12.7)	104.7	(12.2)	–0.40	.04
Memory	108.8	(16.2)	101.4	(16.8)	**2.27***	.22
Memory for faces	12.3	(2.6)	10.8	(3.3)	**2.67****	.24
Immediate recall	12.2	(2.8)	10.6	(3.3)	**2.70****	.25
Delayed recall	11.9	(2.2)	10.9	(3.1)	**2.12***	.20
Memory for names	10.8	(3.2)	9.6	(3.2)	1.95	.19
Immediate recall	10.9	(2.9)	9.9	(2.8)	1.86	.18
Delayed recall	10.7	(3.3)	9.8	(3.2)	1.40	.14
Narrative memory	10.4	(3.1)	10.1	(2.8)	0.60	.06

Note. DAS = Differential Ability Scales, NEPSY = Developmental Neuropsychological Assessment,OAHI = Obstructive Apnoea-Hypopnoea Index
* Denotes $p < 0.05$; ** $p < 0.01$

Behavioural performance

Table 3.9 presents behavioural performance between the groups. Results showed that children with OAHI > 0.32 had a significantly lower score for the total competence scale than children with OAHI < 0.32. Children in the same group also had increased complaints of social problems from the syndrome scales and ADHD problems from the DSM-oriented scales.

Table 3.9 Mean (SD) CBCL scale scores according to OAHI classification together with *t*-test and effect size values

CBCB Scale	OAHI < 0.32 (n = 64)		OAHI > 0.32 (n = 40)		*t*-value	Effect Size (*r*)
	Mean	(SD)	Mean	(SD)		
Competence Scale						
Activity	47.8	(11.0)	46.2	(10.9)	0.71	.07
Social	48.6	(7.6)	46.5	(8.9)	1.27	.13
School	48.3	(6.1)	46.4	(7.1)	1.45	.15
Total Competence	49.2	(8.5)	45.1	(9.4)	**2.19***	.22
Syndrome Scales						
Internal Problems	51.1	(10.7)	52.6	(11.4)	–0.67	.07
External Problems	51.3	(9.7)	51.3	(8.5)	–0.01	.00
Total Problems	50.9	(10.1)	53.5	(9.8)	–1.31	.13
Anxious/Depressed	54.3	(6.1)	55.6	(7.4)	–0.96	.10
Withdrawn/Depressed	54.8	(5.7)	54.7	(6.0)	0.09	.01
Somatic complaints	56.1	(7.1)	57.5	(7.9)	–1.01	.10
Social Problems	53.6	(4.1)	56.6	(6.1)	**–2.71****	.33
Thought Problems	55.8	(6.8)	57.3	(8.0)	–1.02	.10
Attention Problems	54.3	(5.6)	56.3	(6.2)	–1.68	.16
Rule–breaking Behaviour	54.9	(5.8)	54.0	(5.1)	0.85	.08
Aggressive Behaviour	54.9	(6.2)	54.4	(5.6)	0.41	.04
DSM–oriented Scales						
Affective Problems	55.1	(6.1)	57.2	(7.2)	–1.59	.16
Anxiety Problems	54.8	(7.0)	55.6	(7.6)	–0.59	.06
Somatic Problems	56.1	(7.9)	57.1	(9.2)	–0.57	.06
ADHD	53.3	(5.3)	56.2	(6.1)	**–2.55***	.25
Oppositional Defiant	55.1	(6.1)	54.3	(5.1)	0.66	.07
Conduct Problems	55.1	(6.7)	54.0	(6.0)	0.89	.09

Note. ADHD = attention deficit hyperactive disorder problems; CBCL = Child Behavior Checklist; OAHI = obstructive apnoea-hypopnoea index
Maladaptive behaviour indicated by lower scores on the competence scale and higher scores on the syndrome/DSM-oriented scales; *denotes $p < 0.05$; ** $p < 0.01$

Polysomnographic results

Groups were matched for most of the PSG variables (Table 3.10), except as expected for AHI, which was higher among children with OAHI > 0.32.

Table 3.10 Mean (SD) polysomnographic values according to OAHI classification together with *t*-test and effect size values

Domain	OAHI < 0.32 (n = 74)		OAHI > 0.32 (n = 42)		*t*-value	Effect Size (*r*)
	Mean	(SD)	Mean	(SD)		
TST, mins	424.1	(41.2)	412.9	(55.6)	1.16	.13
Sleep efficiency (%)	80.5	(8.1)	78.6	(10.2)	1.09	.10
REM (%)	20.4	(3.8)	19.2	(4.4)	1.56	.14
SWS (%)	27.1	(4.3)	28.9	(6.4)	–1.80	.21
WASO (min)	49.2	(34.6)	61.9	(42.6)	–1.78	.16
RAI (events/hr)	0.6	(0.6)	0.6	(0.4)	0.63	.06
SAI(events/hr)	7.2	(2.6)	7.9	(2.3)	–1.58	.14
3% ODI	0.9	(0.7)	0.9	(0.7)	–0.68	.06
CAHI (events/hr)	0.5	(0.4)	0.6	(0.5)	–0.32	.03
AHI (events/hr)	0.7	(0.5)	1.1	(0.4)	**4.82***	.45

Note. OAHI = obstructive apnoea-hypopnoea index; TST = total sleep time; REM = rapid eye movement sleep; SWS = slow wave sleep; WASO = wakefulness after sleep onset; RAI = respiratory arousal index; SAI = spontaneous arousal index; 3% ODI = number of dips in oxygen saturation ≥ 3%; CAHI = central apnoea-hypopnoea index; AHI = apnoea-hypopnoea index
*denotes p < 0.05

Co-morbid sleep problems

Results revealed that groups had comparable co-morbid SAPSS-Q sleep problems scale scores (Figure 3.4), apart for the SDB scale, which was significantly higher in children with OAHI > 0.32 compared to children with OAHI < 0.32, $t(61.51) = -3.21$, $p < 0.05$, $r = .38$.

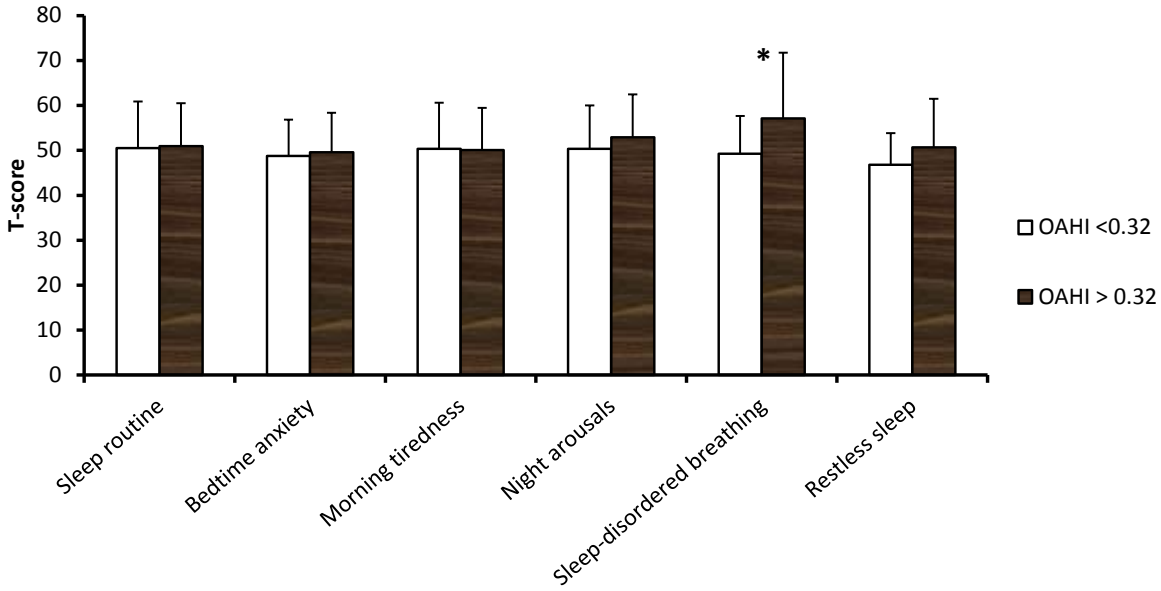


Figure 3.4 T-scores for co-morbid sleep problems between children with OAHI < 0.32 and children with OAHI > 0.32

Note. * Denotes *p* < 0.05

Correlations between demographic, respiratory variables and performance

Table 3.11 presents the findings from the correlational analyses exploring the relationship between PSG and neurocognitive domain values. In addition, Table 3.12 contains correlational analyses for the relationship between PSG variables and specific behavioural scales. Because there were no differences between groups for neurocognitive functioning, the key neurocognitive domains were included for analysis. Results revealed that most of the PSG variables were not correlated with the neurocognitive domains. Only one association was found between respiratory arousal index (RAI) and NVR; indicating that a higher RAI was correlated with decreased non-verbal scores. However, this correlation was small in magnitude. Table 3.12 includes the relationship between PSG variables and key behavioural scales. A higher OAHI was associated with lower competency scores. Additionally, a higher AHI was associated with higher Total Problems scores, but with lower Total Competence scores. No other PSG variables were correlated with any behavioural scale scores.

Table 3.11 Correlations (Pearson product-moment coefficient) between polysomnographic variables with neurocognitive domains for entire sample (n = 113)

	Verbal Ability	Non-Verbal Reasoning	Spatial	General Cognitive Ability	Attention/Executive Functioning	Language	Memory
Sleep Efficiency	–.03	.02	–.01	.06	.01	.06	–.13
WASO	.03	.02	.08	–.01	.12	.08	.07
RAI	–.13	**–.21***	.01	–.17	.08	–.11	–.04
3% ODI	–.08	.15	.03	.07	–.06	–.06	–.05
OAHI	–.10	–.08	–.13	–.15	–.09	–.02	–.16
CAHI	–.02	.17	.11	.12	.08	–.06	.04
AHI	–.08	.113	.03	.02	.00	–.08	–.06

Note. WASO = wakefulness after sleep onset; RAI = Respiratory Arousal Index; ODI = the number of dips in oxygen saturation ≥3%; OAHI = Obstructive Apnoea-Hypopnoea Index; CAHI = Central Apnoea/Hypopnoea Index; AHI = apnoea/hypopnoea index

* Denotes $p < 0.05$; ** $p < 0.01$

Table 3.12 Correlations (Spearman's correlation coefficient) between polysomnographic variables with behavioural scales for entire sample (n = 100)

	Internal Problem	External Problems	Total Problems	Total competence
Sleep Efficiency	.01	.00	–.00	–.02
WASO	.00	.08	.06	–.06
RAI	–.15	–.03	–.04	.18
3% ODI	.15	.07	.14	–.19
OAHI	.02	.07	.13	**–.26***
CAHI	.15	.17	.16	–.14
AHI	.17	.15	**.21***	**–.20***

Note. WASO = wakefulness after sleep onset; RAI = Respiratory Arousal Index; ODI = the number of dips in oxygen saturation ≥ 3%; OAHI = Obstructive Apnoea-Hypopnoea Index; CAHI = Central Apnoea/Hypopnoea Index; AHI = apnoea/hypopnoea index

* Denotes $p < 0.05$; ** $p < 0.01$

3.4. Discussion

In this study the relationship between PS, neurocognitive and behavioural functioning and sleep in children from a community setting was investigated using PSG and standardised psychometric measures. In general, little evidence was found supporting the proposition that neurocognitive and behavioural functioning would be reduced in children with PS and, moreover, this remained the case regardless of the criteria used to define PS. The findings from the present study are consistent with a recent report that has examined the impact of snoring on daytime functioning in children recruited from clinical settings (Jackman et al., 2012), but stand in contrast to the findings typically reported across studies conducted in children from clinical settings (Blunden et al., 2000; Miano, Paolino, et al., 2011).

The present findings are consistent with some (Beebe et al., 2012; Calhoun et al., 2009), but not all studies (Honaker et al., 2009; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004; O'Brien, Mervis, Holbrook, Bruner, Smith, et al., 2004) that have examined neurocognitive and behavioural functioning in children with PS recruited from a community setting. Of note is that both of the studies which report no neurocognitive and behavioural deficits used different criteria to those used in the present study. That is, the subject groups were defined by either level of AHI (less than 1 event/hr, 1–5 events/hr and greater than 5 events/hr) or a measure of snoring (technician report) and SDB combined (no snoring with AHI < 1, snoring with AHI < 1, no snoring with AHI ≥ 1 and snoring with AHI ≥ 1). The current study was unable to investigate the impact of these criteria due to insufficient cases, specifically for criteria including snoring with AHI ≥ 1. Despite the criteria used in the current study relying on parental self-report and OAHI, to a smaller scale an additional analysis was conducted (Appendix K) using Calhoun et al. (2009) criteria (i.e. four snoring groups). Findings revealed a similar neurocognitive and behavioural pattern between the groups. Additional to the equivalent neurocognitive functioning already reported in Calhoun's study, the current study also found a similar behavioural performance between groups. Despite the similar results, it is important to note that this analysis used a smaller sample and that all children with AHI ≥ 1 had AHI < 5. However, Calhoun's study included a small number of children with AHI ≥ 5 (n = 6), hence the present analysis is analogous.

To date, there are only two studies using community samples that have found neurocognitive differences in children with an objective diagnosis of PS (Honaker et al., 2009; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004). The children in the current study met similar criteria, allowing a comparison with the findings of those previous

studies (parental-report of snoring with OAI < 1, AHI < 5 and SpO_2 nadir > 90%). The similar criteria suggest that factors other than SDB status may explain why the current study did not find any neurocognitive deficits. A methodical review of the two previous studies showed that their participants had mixed ethnicity (≥20% of African American within the total sample), and younger children (i.e. average six-years-old). Additionally, they used a slightly different snoring definition—children classified as habitual snorers had parental self-report of snoring three–four times per week, while those with reports of ≥2 nights per week were classified as snorers only if they snored during PSG. In contrast, the current study included >90% of children with Caucasian ethnicity, a slightly older sample and a parental self-report of snoring of ≥ 2 nights per week as criteria for habitual snoring.

The inconsistency between the studies that investigated daytime performance in children who snore does raise concerns about the impact the criteria used for snoring may have on findings. In the majority of studies, children have tended to be dichotomised into snorers and non-snorers, with the frequency cut-off for snorers typically placed at snoring two or more nights per week (Bidad et al., 2006; Honaker et al., 2009; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004; Piteo, Lushington, Roberts, Martin, et al., 2011; Urschitz et al., 2004; Valery et al., 2004). The respiratory variables used to classify PS also vary between studies—pointing to the need for a consensus definition to be used amongst researchers. For example, O'Brien, Mervis, Holbrook, Bruner, Klaus, et al. (2004) classified children as PS if they had an OAI < 1and AHI < 5. In contrast, Honaker et al. (2009) and O'Brien, Mervis, Holbrook, Bruner, Smith, et al. (2004) diagnosed SDB using a composite score ≤ 3, which involved respiratory disturbance index (RDI), RAI and oxygen saturation in the blood (SaO_2 nadir > 90). The problem with relying on AHI as criteria for PS is that it may include a mixed group of children with central and obstructive apnoea. Instead of AHI, it would be preferable to employ OAHI as the method of classification as it avoids this problem. However, OAHI has not been used widely apart from Li et al. (2013), but they did not investigate either the neurocognitive or behavioural consequences. In an attempt to overcome these limitations, children in the present study were classified according to high and low obstruction based on a mean OAHI cut-off. Notably, and independent of parental-report of snoring frequency, the analyses comparing children with OAHI < 0.32 and OAHI > 0.32 did reveal a trend to reduced neurocognitive performance in children with OAHI > 0.32, especially for the Memory and Learning domain. This stands in contrast to the neurocognitive findings when classified according to parental-reported snoring. Although the differences did not reach significance, a child with OAHI > 0.32 also tended

to have a higher frequency of problematic behaviours. It would be useful for further research to investigate daytime performance using OAHI as a classification indicator, regardless of whether children are reported to snore or not on parental report, in order to corroborate these results.

Examination of behavioural performance in the current study revealed that snorers had increased frequency of somatic, thought and affective problems compared to non-snorers. These findings remained even when children who were infrequent snorers (i.e. snore once a week) were included as an additional group in further analyses. Although effects sizes were small in magnitude, this finding suggests that even mild snoring may impact on behavioural functioning. Despite most studies report an association between snoring and externalising behaviours, the association with internalising behaviours is not typically assessed. Additionally, children with conditions such as ADHD are not always excluded from studies One of the strengths of this study therefore, is that it included these types of behaviours.

The finding that even very minor levels of upper airway obstruction may impact on behavioural performance is consistent with previous research (Barnes et al., 2009). It suggests that mild upper airway obstruction and its impact on sleep quality is likely to explain the deficits in daytime performance. In the current study OAHI and AHI were found to be correlated with some behavioural scales, including Social Problems, Attention Problems, ADHD and Total Competence. In contrast, none of the neurocognitive variables were correlated with either OAHI or AHI. This finding is consistent with previous research—both reporting neurocognitive deficits (O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004; O'Brien, Mervis, Holbrook, Bruner, Smith, et al., 2004) and those who do not report deficits (Calhoun et al., 2009).

The association observed in the present study between mild levels of upper airway obstruction and daytime deficits raises the question as to whether OAHI alone may be sufficient to discriminate between cases. It is possible that some children in the sample may have upper airway resistance syndrome, and an assessment of such a possibility would be instructive in future studies. However, while desirable, this might remain impractical as the ‘gold standard’ for assessing upper airway resistance syndrome involves invasive procedures including esophageal catheter for esophageal pressure measurement, which might not be always tolerated by patients, particularly children (Bao & Guilleminault, 2004). A limitation of the majority of research that investigates mild conditions like PS in

both clinical and community populations is the assessment of upper airway obstruction itself; more is happening than we are currently able to easily assess (Jackman et al., 2012; Li et al., 2013; O'Brien, Mervis, Holbrook, Bruner, Smith, et al., 2004).

This study also examined the impact of snoring on co-morbid sleep problems. Reports of co-morbid sleep problems were more common among snorers compared to non-snorers and, likewise, when the children were reclassified into OAHI > 0.32 and OAHI > 0.32. Thus, regardless of the definition used to classify snoring, it was associated with additional sleep problems on parental report. As well, a dose-response relationship was observed, with the frequency of sleep problems tending to increase as the frequency of snoring increased for some sleep problems, but only problems with bedtime anxiety and night arousals reached significance, with frequent snorers more likely to report the latter problems compared to infrequent snorers and non-snorers. The present findings suggest that snoring is often concurrent with other sleep-related problems, and the findings are consistent with previous studies in children with SDB (Blunden et al., 2005; Goodwin et al., 2004).

Conclusion

This study used objective, validated and well-accepted sleep and neuropsychological instruments. In addition, complete PSG and neurobehavioural assessment was conducted on all participants. Snoring children were found to have similar neurocognitive functioning compared to non-snoring children. Conversely, snorers were found to have increased reports of behavioural and co-morbid sleep problems. These results are consistent with previous reports in other community-based samples. Finally, an alternative classification according to OAHI level (cut-off of 0.32) was used. Children classified as having an OAHI > 0.32 had decreased memory. This revealed that mild upper airway obstruction may be enough to impact sleep quality, hence explaining the deficits in daytime performance. However, these results need to be taken carefully, and further research should be conducted to confirm them. Finally, indications about what the difference is between clinical and community samples of children who snore remain unresolved and require further investigation. Factors including snoring severity, demographic and health characteristics may explain differences between samples.

Chapter 4 Factors associated with snoring in children recruited from a community-setting

4.1. Introduction

Habitual snoring is recognised as the key symptom of SDB across the severity spectrum (Blunden et al., 2000; Montgomery-Downs et al., 2004). Its prevalence is highly variable, with the research suggesting that a number of factors play an important role in its occurrence. Despite several studies having investigated the factors that predict SDB, including PS, the findings are incomplete and there is no clear consensus of the predisposing factors.

Both physiological and environmental factors are associated with SDB. However, most of the literature examining risk focuses on children with OSAS, while less attention is been paid to children with PS. In children with OSAS, the risk factors include male gender, exposure to tobacco smoke, SES, parental history of snoring, young age, ethnicity, history of atopic conditions, overweight and low birth weight. It is assumed that the same risk factors are important in PS, but this has yet to be fully established.

A factor commonly associated with a higher risk of snoring is male gender. Studies examining gender and snoring have mainly focused on children pre-puberty, and typically report a higher prevalence of snoring among males (Archbold et al., 2002; Kaditis et al., 2004; Kuehni et al., 2008; Mitchell & Thompson, 2003; Valery et al., 2004). Although less well explored, male gender is also reported to be risk factor for snoring in puberty, and is thought to be explained by the role of testosterone levels during this period, particularly on the development of the upper airway (Anuntaseree et al., 2005). Nevertheless, the effect of sex hormones on snoring is not completely accepted, and more recent research suggests that changes in the upper airway structure are not modulated by these hormones during puberty could explain the outcomes (Bandla et al., 2008). Other suggestions explaining the failure to associate male gender with increased risk for snoring may be the lack of statistical power or limited samples (Lumeng & Chervin, 2008).

Environmental factors have also been shown to play a key role in habitual snoring, especially exposure to tobacco and air pollution (Corbo et al., 2001; Kuehni et al., 2008; Li, Jin, et al., 2010; Mitchell & Thompson, 2003; Sahin et al., 2009). Tobacco exposure either during pregnancy or directly after birth has been associated with an increased risk of

snoring (Mitchell & Thompson, 2003; Sahin et al., 2009). However, not all studies report an association. Li, Au, So, et al. (2010) report in their study of 20,152 Chinese children aged five–12 years that household smoking was not associated with habitual snoring. This finding was explained by the tendency of parents to under-report smoking, due to cultural beliefs that smoking away from their children (e.g. in the bathroom) is adequate.

Ethnicity is also reported to be an important risk factor for habitual snoring. Several groups report that African-American and Hispanic children are more likely to develop snoring compared to Caucasian children (Goodwin et al., 2003; Goodwin et al., 2010; Montgomery-Downs et al., 2006; Rosen et al., 2003). For example, Goodwin et al. (2003) report that Hispanic children had increased reports of witnessed apnoeas, a higher frequency of snoring and EDS than their Caucasian peers. Differences between ethnic groups might be explained by variations in upper airway anatomy (Randerath et al., 2006). However, despite evidence of a link between ethnicity and snoring, a recent extensive review of the literature indicates that, while differences in the frequency of snoring are evident when comparing ethnic groups within a country, such differences are less evident when comparing the frequency of snoring between countries with differing ethnicity (Lumeng & Chervin, 2008).

Rather than ethnicity per se, low SES may explain the higher frequency of snoring in some ethnic groups. In the U.S. for example, minority groups such as African-American and Hispanic compared to Caucasian school-age children are more likely to be diagnosed with a sleep disorder including SDB (Meltzer et al., 2010). However, such minority groups are more likely to come from a low SES, which in itself is associated with an increased risk of habitual snoring in children (Corbo et al., 2001; Kuehni et al., 2008; Montgomery-Downs & Gozal, 2006). Bonuck et al. (2011) in a recent longitudinal study examining the natural history of SDB symptoms (habitual snoring, apnoea and mouth breathing), report that SES had a stronger association with the persistence of SDB symptoms than other factors including gender, gestational age or ethnicity.

In addition to SES factors, a number of studies suggest that the risk of habitual snoring is increased by atopic symptoms including rhinitis, eczema, and asthma (Kalra et al., 2006; Kuehni et al., 2008; Marshall et al., 2007) and it has also been associated with infections including frequent colds, otitis media (Kuehni et al., 2008), and tonsillitis (Li, Jin, et al., 2010). The increased risk for snoring as a result of some of these conditions may arise from several mechanisms that can cause inflamed airways (Kuehni et al., 2008).

Increased weight is linked to numerous health-related issues including SDB. Obesity seems to increase the risk for reductions in the pharyngeal size, thereby increasing the risk for upper airway collapsibility; hence snoring (Kargoshaie et al., 2009). A number of studies report that obesity is a risk factor for snoring (Bidad et al., 2006; Bixler et al., 2009; Chng et al., 2004; Corbo et al., 2001; Kargoshaie et al., 2009; Kuehni et al., 2008; Kulnis et al., 2000; Li, Au, So, et al., 2010; Li, Jin, et al., 2010; Marshall et al., 2007; Sahin et al., 2009; Sogut et al., 2009; Urschitz et al., 2004; Valery et al., 2004). However, contrary findings (Anuntaseree et al., 2001; Liukkonen et al., 2008; Marshall et al., 2007) raise questions regarding the relationship between obesity and snoring. Lumeng and Chervin (2008) in their extensive review indicate that differences in the way weight is recorded, cut-offs and variable definitions may contribute to the variability and difficult comparisons between studies. Additionally, Kohler and van den Heuvel (2008) highlight that factors such as age and ethnicity may play a role as modulating factors in the relationship between obesity and SDB.

A further issue when examining the relationship between risk factors and snoring is how snoring is defined. Variability in snoring definition has already been highlighted as a methodological issue when assessing snoring using parental-report questionnaires (Lumeng & Chervin, 2008). In addition to parental report, snoring is also assessed through objective tools (e.g. PSG). In previous chapters, different classifications have been used to explore differences between children. Therefore, in the current chapter, the analyses are divided based on parental report and OAHI level.

In summary, the aims of this study include investigating the relative contribution of demographic and health risk factors in children towards snoring. Based on the classifications used in previous chapters (i.e. parental report and OAHI level), factors were explored between groups.

4.2. Methodology

Chapter 3 provides a more detailed description of the methodology used in this sub-study.

Participants

Participating children underwent detailed neurocognitive, behaviour and PSG examination. Demographic data including parental education, SES, ethnicity, a detailed medical history and growth parameters were obtained. SES was determined using the Index of Relative Socio-economic Disadvantage from the SEIFA collected by the Australian Bureau of Statistics' 2006 national census data (Australian Bureau of Statistics, 2006). BMI was

determined by established growth charts, corrected for age and gender (Bellizi & Dietz, 1999); using height and weight measured on the PSG night. Chapter 2 provides more detailed information.

Materials

Demography and health

Demographic and health information was recorded through questions in the SAPSS-Q and during a face-to-face interview at the PSG assessment. BMI was determined by height and weight measurements on the PSG night. The centile was calculated using established growth charts, corrected for age and gender (Ogden et al., 2002).

Data analyses

Children were classified according to three criteria. First, to allow a comparison with previous research by O'Brien, Mervis, Holbrook, Bruner, Klaus, et al. (2004), who examined snoring in children recruited from a community setting, children were classified into two groups: non-snorers (never snoring or snoring once a week and OHAI < 1/hr.) and PS (snoring ≥ 2 nights/week and OAHI < 1/hr.). Second, because of previous research suggesting that non-habitual snorers (e.g. snoring once a week) also display neurocognitive-related deficits (Barnes et al., 2009); children were divided into three groups: non-snorers (never snoring), infrequent snorers (snoring once a week) and frequent snorers (snoring ≥ 2 nights/week), all groups were OAHI < 1/hr. Third, children were classified according to PSG criteria and, in particular, OAHI. Regardless of the patient-reported snoring status, children were classified according to the mean OAHI (0.32) into either OAHI < 0.32 or OAHI > 0.32.

Statistical analysis

Independent *t* tests were used to test group differences in continuous variables between non-snorers and PS, with *p* values adjusted for unequal variances when appropriate (Levene's test for equality of variances). Chi-square tests were performed when examining group differences in categorical variables. Kruskal-Wallis, Mann-Whitney tests or ANOVA were conducted to test for group differences in continuous variables for the analyses involving the comparison of non-snorer, infrequent snorer and frequent snorer children. Mann-Whitney tests were used to follow up significant results on Kruskall-Wallis tests. Data are presented as mean (SD) unless otherwise stated. Logistic regression models were used to test for associations between demographic variables previously reported in the literature to be associated with snoring (asthma, rhinitis, household smoking and age).

Due to the low frequency of asthma in the sample, a Fisher exact test was used instead of a logistic regression model for this variable. All analyses were conducted using the statistical package SPSS for windows version 21.

4.3. Results

Non-snorers versus snorers

Demographic and health outcomes

The main demographic characteristics of the sample are presented as mean (SD) in Table 4.1. Groups had no differences for age, ethnicity, gender, SES, gestational age, birth weight, BMI percentile and smoking at household. Although not shown, waist circumference was examined in a subsample of children. No significant differences for waist circumference were found between the different classifications: non-snorers versus snorers (mean 61.89 ± 8.2 versus 55.93 ± 16.2), OAHI < 0.32 versus OAHI > 0.32 (mean 59.9 ± 10.9 versus 62.4 ± 8.1), and non-snorers, infrequent snorers and frequent snorers (mean 61.5 ± 7.5, 62.7 ± 9.9 and 55.9 ± 16.2).

Groups were also similar for health characteristics including history of asthma, rhinitis, eczema, medications, other allergies (e.g. grass or cats) or respiratory symptoms during the night of PSG (including runny or blocked nose). However, groups differed for the number of mothers, fathers and siblings who snored. A significant association between the snoring status and the number of mothers, $\chi^2(1) = 6.54$, $p < 0.05$ and siblings, $\chi^2(1) = 7.63$, $p < 0.05$ who snored was found. These results seem to represent the fact that based on the OR, the odds of having a mother or a sibling who snored were 4.70 or 4.94 times higher for PS than non-snorers respectively. Analysis of factors commonly associated with snoring revealed that asthma ($p > 0.99$), rhinitis (OR = 2.81, 95% CI 0.82–9.61, $p = 0.10$), household smoking (OR = 1.92, 95% CI 0.67–5.51, $p = 0.23$) and age (OR = 0.81, 95% CI 0.61–1.07, $p = 0.14$) were not found to be statistically significant predictors of snoring. Additionally, there was a significant association between parental report of snoring status (control/snorer) and whether or not children were reported to snore during PSG (technician report), $\chi^2(1) = 6.25$, $p < 0.05$. Based on the OR, the odds of children who were classified as non-snorers at PSG were 3.34 times higher if they were classified as non-snorers than if they were classified as snorers.

Table 4.1 Demographic and health variables according to two snoring groups

Demographic	**Non-snorer (n = 92)**		**Snorer (n = 24)**		***t-value***
	Mean	**(SD)**	**Mean**	**(SD)**	
Age, years	8.2	(1.6)	7.7	(1.7)	2.23
Socioeconomic status	991.6	(72.1)	976.2	(80.2)	0.82
Gestational age (weeks)	39.3	(1.8)	39.0	(1. 2)	0.97
Child's birth weight (kg)	3.4	(0.4)	3.3	(0.4)	0.52
BMI percentile	64.2	(23.2)	62.3	(32.8)	0.09
	%	**(n)**	**%**	**(n)**	χ^2
Gender, male	41.3	(38)	33.3	(8)	0.51
Ethnicity, Caucasian	92.4	(85)	95.8	(23)	2.63
Paternal snoring					
Yes	71.6	(53)	94.1	(16)	3.81
No	28.4	(21)	5.9	(1)	
Maternal snoring					
Yes	34.7	(25)	71.4	(10)	**6.54***
No	65.3	(47)	28.6	(4)	
Sibling snoring					
Yes	28.8	(19)	66.7	(10)	**7.63****
No	71.2	(47)	33.3	(5)	
Smoking at household					
Yes	22.1	(17)	33.3	(6)	1.00
No	77.9	(60)	66.7	(12)	
Health information	**%**	**(n)**	**%**	**(n)**	χ^2
Asthma					
Yes	2.2	(2)	0	(0)	0.54
No	97.8	(88)	100.0	(24)	
Rhinitis					
Yes	9.1	(8)	22.7	(5)	3.14
No	90.9	(80)	77.3	(17)	
Eczema					
Yes	1.8	(2)	0.9	(1)	0.28
No	97.8	(88)	95.8	(23)	
Respiratory allergies					
Yes	6.1	(5)	4.5	(1)	0.07
No	93.9	(77)	95.5	(21)	
Taking any medication					
Yes	1.2	(1)	4.5	(1)	1.01
No	98.8	(81)	95.5	(21)	
Other allergies					
Yes	8.5	(7)	18.2	(4)	1.71
No	91.5	(75)	81.8	(18)	
Respiratory symptoms at PSG					
Yes	9.8	(8)	13.6	(3)	0.27
No	90.2	(74)	86.4	(19)	
Snoring status (technician report)					
Non-snorer	81.3	(74)	56.5	(13)	**6.24***

Note. BMI = body mass index; PSG = polysomnography
* Denotes $p < 0.05$, **$p < 0.01$, †$p < 0.001$

Non-snorers, infrequent and frequent snorers

Demographic and health outcomes

No differences were found when children were divided into three snoring groups for age, ethnicity, gender, SES, gestational age, birth weight, BMI percentile and smoking at household. However, groups differed for reports of maternal, paternal and sibling snoring, and other allergies (e.g. grass or cats). The variables that were significant in Table 4.2 were entered into a multinomial logistic regression model, and results revealed that only maternal or paternal snoring was found to be a statistically significant predictor of infrequent (OR = 0.30, 95% CI 0.10–0.88, $p < 0.05$) and frequent snoring status (OR = 0.14, 95% CI 0.04–0.54, $p < 0.05$), while sibling snoring was only predictive of frequent snoring (OR = 0.15, 95% CI 0.04–0.51, $p < 0.05$; and OR = 0.12, 95% CI 0.01–0.99, $p < 0.05$ respectively). Other allergies were also found to be statistically significant predictor of infrequent (OR = 0.12, 95% CI 0.02–0.65, $p < 0.05$) and frequent snoring (OR = 0.15, 95% CI 0.02–0.91, $p < 0.05$).

Table 4.2 Demographic and health variables according to three snoring groups

Demographic	**Non-snorer (n = 65)**		**Infrequent snorer (n = 27)**		**Frequent snorer (n = 24)**		**F-value**
	Mean	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**	
Age, years	8.2	(1.6)	8.2	(1.7)	7.7	(1.7)	1.11
Socioeconomic status	1000.4	(64.3)	970.4	(85.6)	976.2	(80.2)	2.02
Gestational age (weeks)	39.3	(1.9)	39.3	(1.2)	39.0	(1. 2)	0.48
Child's birth weight (kg)	3.4	(0.4)	3.4	(0.4)	3.3	(0.4)	0.25
BMI percentile	64.3	(22.1)	63.9	(26.3)	62.3	(32.8)	0.05
	%	**(n)**	**%**	**(n)**	**%**	**(n)**	χ^2
Gender, male	46.2	(30)	29.6	(8)	33.3	(8)	2.68
Ethnicity, Caucasian	92.3	(60)	92.6	(25)	95.8	(23)	2.95
Paternal snoring							
Yes	66.0	(35)	85.7	(18)	94.1	(16)	**6.99***
No	34.0	(18)	14.3	(3)	5.9	(1)	
Maternal snoring							
Yes	26.9	(14)	55.0	(11)	71.4	(10)	**11.26****
No	73.1	(38)	45.0	(9)	28.6	(4)	
Sibling snoring							
Yes	22.4	(11)	47.1	(8)	66.7	(10)	**10.95****
No	77.6	(38)	52.9	(9)	33.3	(5)	
Smoking at household							
Yes	19.6	(11)	28.6	(6)	33.3	(6)	1.67
No	80.4	(45)	71.4	(15)	66.7	(12)	
Health information	**%**	**(n)**	**%**	**(n)**	**%**	**(n)**	χ^2
Asthma							
Yes	1.6	(1)	3.8	(1)	0	(0)	1.10
No	98.4	(63)	96.2	(25)	100	(24)	
Rhinitis							
Yes	6.5	(4)	14.8	(4)	22.7	(5)	4.54
No	93.5	(58)	84.6	(22)	77.3	(17)	
Eczema							
Yes	1.6	(1)	3.8	(1)	4.2	(1)	0.65
No	98.4	(63)	96.2	(25)	95.8	(23)	
Respiratory allergies							
Yes	6.7	(4)	4.5	(1)	4.5	(1)	0.21
No	93.3	(56)	95.5	(21)	95.5	(21)	
Taking any medication							
Yes	0	(0)	4.5	(1)	4.5	(1)	2.78
No	100.0	(60)	95.5	(21)	95.5	(21)	
Other allergies							
Yes	3.3	(2)	22.7	(5)	18.2	(4)	**8.11***
No	96.7	(58)	77.3	(17)	81.8	(18)	
Respiratory symptoms at PSG							
Yes	8.3	(5)	13.6	(3)	13.6	(3)	0.75
No	91.7	(55)	86.4	(19)	86.4	(19)	

Health information	%	(n)	%	(n)	%	(n)	χ^2
Snoring status (technician report)							
Non-snorer	80.0	(52)	84.6	(22)	56.5	(13)	**6.46***
Snorer	20.0	(13)	15.4	(4)	43.5	(10)	

Note. * Denotes $p < 0.05$, ** $p < 0.01$, † $p < 0.001$

Obstructive apnoea-hypopnoea index classification

Demographic and health outcomes

Children were matched for age, SES, gestational age, BMI percentile, gender and ethnicity (Table 4.3). There were no differences for health conditions (e.g. asthma, eczema), nor for passive smoking or other demographic variables including parental and sibling history of snoring. Differences were found for birth weight, which was lower among children that had an OAHI > 0.32.

A significant association between parental report of snoring status and OAHI was found, $\chi^2(1) = 8.61$, $p < 0.05$. The odds of children who had an OAHI < 0.32 were 4.01 times higher if they were classified as non-snorers than if they were snorers. In contrast, there was no significant association between level of obstruction measured with OAHI and snoring reported by a technician during PSG, $\chi^2(1) = 3.04$, $p > 0.05$.

Table 4.3 Demographic variables according to obstructive apnoea-hypopnoea index classification

Demographic	OAHI < 0.32 (n = 72)		OAHI > 0.32 (n = 44)		*t*-value	Effect Size
	Mean	(SD)	Mean	(SD)		
Age, years	8.1	(1.5)	8.2	(1.8)	–0.47	.05
Socioeconomic status	986.8	(74.6)	993.9	(67.5)	0.05	.05
Gestational age (weeks)	39.4	(1.8)	38.9	(1.5)	1.51	.14
Child's birth weight (kg)	3.5	(0.3)	3.3	(0.5)	**2.12***	.22
BMI percentile	63.9	(23.8)	64.3	(27.4)	0.09	.01
	%	(n)	%	(n)	χ^2	
Gender, male	36.0	(27)	47.8	(22)	1.65	
Ethnicity, Caucasian	94.7	(71)	89.1	(41)	5.04	
Paternal snoring						
Yes	77.2	(44)	73.5	(25)	0.16	
No	22.8	(13)	26.5	(9)		
Maternal snoring						
Yes	38.6	(22)	44.8	(13)	0.31	
No	61.4	(35)	55.2	(16)		
Sibling snoring						
Yes	38.9	(21)	32.1	(9)	0.36	
No	61.1	(33)	67.9	(19)		
Smoking at household						
Yes	21.7	(13)	25.6	(10)	0.21	
No	78.3	(47)	74.4	(29)		
Health information	%	(n)	%	(n)	χ^2	
Asthma						
Yes	1.4	(1)	2.3	(1)	0.14	
No	98.6	(73)	97.7	(43)		
Rhinitis						
Yes	9.7	(7)	14.3	(6)	0.55	
No	90.3	(65)	85.7	(36)		
Eczema						
Yes	4.1	(3)	0	(0)	1.83	
No	95.9	(71)	100.0	(44)		
Respiratory allergies						
Yes	6.0	(4)	7.1	(3)	0.06	
No	94.0	(63)	92.9	(39)		
Taking any medication						
Yes	97.0	(65)	95.2	(40)	0.23	
No	3.0	(2)	4.8	(2)		
Other allergies						
Yes	9.0	(6)	11.9	(5)	0.25	
No	91.0	(61)	88.1	(37)		
Snoring status (parental report)						
Non-snorer	88.6	(62)	65.9	(29)	**8.16***	
Snorer	11.4	(8)	34.1	(15)		

Snoring status (technician report)					
Non-snorer	81.3	(61)	67.4	(31)	3.04
Snorer	18.7	(14)	32.6	(15)	

Note. OAHI = Obstructive Apnoea-Hypopnoea Index
* Denotes $p < 0.05$

4.4. Discussion

In line with previous research, the current study explored whether the demographic and health factors previously identified in the literature as risk factors were predictive of snoring in school-age children recruited from a community setting. Findings revealed that, among the different demographic and health factors normally associated with snoring, only a family history of snoring (mother and sibling) was predictive of snoring, and this association was only observed when children were classified according to a parental-reported history of snoring and not when they were classified according to objective measures of snoring such as can be obtained with OAHI.

Epidemiological research suggests that environmental, demographic and health characteristics are associated with an increased risk for snoring in children. In this study, the only factor that was found to explain snoring was a history of either maternal snoring or sibling snoring. A familial predisposition has been reported in SDB cases, with a greater risk, for example, among individuals (adults and children) who have other relatives with OSAS or symptoms including habitual snoring (Ovchinsky, Rao, Lotwin, & Goldstein, 2002; Redline et al., 1995). The heritability for OSAS has been described in particular ethnic groups such as African-American children (Redline et al., 1997), suggesting that genetic factors may contribute to the expression of OSAS. More recent research supports the potential role of genetic markers in SDB expression, specifically with AHI (Larkin et al., 2010). Family history of snoring could be additional information to be included in routinely clinical assessment. The inclusion of this information may help to predict whether a child is more or less susceptible to snoring or developing more severe forms of SDB.

Another factor commonly associated with snoring is passive smoking (Corbo et al., 2001; Kuehni et al., 2008; Sahin et al., 2009). However, in this study smoking was not found to be correlated with snoring status. There is evidence indicating that maternal smoking seems to have a higher impact on children, and hence an increased risk for snoring (Mitchell & Thompson, 2003; Montgomery-Downs & Gozal, 2006). These studies included younger children compared to those included in the current study (toddlers vs. school-age children). As older children may spend less time at home due to schooling, they

may be less exposed to tobacco smoke and hence the lack of an association in that age group.

Atopic conditions (e.g. rhinitis and asthma) are also described as risk factors for snoring in children (Chng et al., 2004; Kalra et al., 2006). In this sample, however, only a few children were reported to have atopic conditions. The lack of association between atopic conditions and snoring may be explained by the low frequency of atopic complaints in the current sample.

Another factor often reported in the literature as a key risk factor for snoring is age, with snoring more commonly reported in younger compared to older children (Bonuck et al., 2011). In the current study there was no association between age and snoring status (based on parental report). Nevertheless, children included in this study were school-age, and possibly they did not snore from an early age as did the children in Bonuck's study. Likewise, when children were classified according to the OAHI criteria (<0.32 or >0.32) no age differences were found between these groups.

Although obesity has been identified as a risk factor for snoring, BMI in the present study was not associated with snoring. This lack of association may be explained by demographic characteristics of the current sample. First, the majority of children included in this study were Caucasian and, second, most children were pre-puberty. Age and ethnicity are reported to mediate the relationship between obesity and SDB (Kohler et al., 2008; Kohler, Thormaehlen, et al., 2009). Kohler, Thormaehlen, et al. (2009), in their study examining the relationship between obesity and SDB, report that the relationship is stronger in older children, specifically after 12 years. In addition, a review of current literature demonstrating a relationship between obesity and SDB found that a positive association between them was more prevalent in studies which included African-American children (Kohler & van den Heuvel, 2008).

Conclusion

Findings in the current study suggest that school-age children reported to snore regularly are more likely to have a familial history of snoring compared to non-snoring children. Contrary to previous research, other demographic and environmental factors that are usually reported as correlated with snoring were not found to predict snoring in this study. Despite the current findings, further research with more objective methodologies should confirm the role of family history among children who snore, but who do not have OSAS.

Chapter 5 Assessment of snoring and correspondence between instruments of assessment

5.1. Introduction

A perennial problem when assessing snoring in children is its measurement. The most common approach is to use parental report; less commonly used are PSG assessment, sleep-technician report and objective measures such as video or audiometry (Lumeng & Chervin, 2008). Parental-reported questionnaires of children's symptoms of SDB (e.g. snoring) have been reported to be able to identify SDB reliably (Chervin et al., 2000). However, the correspondence between parental and sleep-technician reported snoring has not been well studied. Montgomery-Downs et al. (2004) compared parental and technician-report (i.e. presence of snoring on PSG) and their predictive discrimination when assessing snoring severity and SDB status in pre-school age children. The authors report that parental compared to technician-report during PSG was more predictive of SDB, especially when snoring frequency was within the highest levels. Thus, parental report of snoring is described as generally accurate, but it is suggested that the use of a composite score incorporating other sleep and wake behaviours could aid the prediction of SDB. However, Montgomery-Downs et al. (2004) also suggest that this kind of assessment tool should be developed based on the characteristics of each community. Because the SAPSS-Q was specifically constructed for the population used in the current study (Biggs et al., 2012), it could be useful to explore the correspondence of this tool with PSG measures in a sample of children with and without reports of snoring.

In summary, the aim of the present study was to explore whether subjective measures of snoring such as parental report on questionnaire may predict objective measures of PS, such as OAHI.

5.2. Methodology

Chapter 3 provides more detailed description of the methodology used in this sub-study.

Materials

Sleep questionnaire

Sleep was assessed using a purposed-designed questionnaire—the SAPSS-Q (Appendix A). The SAPSS-Q has six major robust scales used to assess co-morbid sleep problems such as Sleep Routine, Bedtime Anxiety, Restless Sleep, Night Arousals, SDB and

Morning Tiredness. Additionally for this study, for each scale parents were asked to rate whether they considered the sleep behaviour a problem or not. A particular interest was given for items in the SDB scale, including breathing heavily during the night, snoring frequently, snoring loudly, stopping breathing and gasping for air. Additional details about the questionnaire are previously given in Chapter 2.

Polysomnographic assessment

The reader is referred to the Chapter 2 for a more detailed description of the PSG assessment. In brief, overnight full-lab PSG was conducted without sedation or sleep deprivation and began at each child's usual bedtime. The following standard parameters were measured and recorded continuously: EEG (C3-A2, C4-A1, F3-A2, F4-A1, O1-A2 and O2-A1), left and right EOG, sub-mental and diaphragmatic EMG. Heart rate was assessed by ECG, leg movements by piezoelectric motion detection, oro-nasal airflow by thermistor and nasal pressure, respiratory movements of the chest and abdominal wall using uncalibrated RIP, arterial oxygen saturation (SpO_2) by pulse oximetry (Nellcor N595; tow–three second average time) and snoring via microphone. All data were digitised and stored for subsequent analysis. Each child was monitored continuously overnight via infrared camera by a paediatric sleep technician who also documented observations of sleep behaviour including the presence or absence of snoring (i.e. technician reporting of snoring). Sleep stages, respiratory variables, spontaneous and respiratory arousals were scored according to established criteria (Bonnet et al., 1992; Loughlin et al., 1996; Rechtschaffen & Kales, 1968).

Statistical analysis

Spearman's correlation coefficients were performed to test associations between SDB-related items from the SAPSS-Q, and demographic and respiratory variables on the PSG. The latter analysis was used to explore the correspondence between PSG variables and the variables in the SAPSS-Q. All analyses were conducted using the statistical package SPSS for windows version 21.

5.3. Results

Correlations between demographic variables and respiratory variables on polysomnography and SAPSS-Q scales

Table 5.1 presents the intercorrelation between PSG, demographic variables and respiratory-related items from the SAPSS-Q. Increased WASO was correlated with higher reports of 'child snoring loudly' and with 'child stops breathing'. Similarly, increased

number of dips in oxygen saturation ≥ 3% (3% ODI) was correlated with higher reports of snoring ('child snoring'). Finally, a higher OAHI was correlated with all four items used in the SDB scale; while an increased AHI was correlated only with 'child snoring'. There were no correlations between demographic variables with any of the respiratory-related items from the SAPSS-Q.

Table 5.1 Correlations (Spearman's correlation coefficient) between items from the Sleep-Disordered Breathing scale and demographic variables for the entire sample (n = 115)

	child snoring	**child snoring loudly**	**child stops breathing**	**child snorting/gasping**
Sleep Efficiency	–.02	–.16	–.18	–.09
WASO	.019	**.23***	**.19***	.03
RAI	–.04	.01	.08	.00
3% ODI	**.18***	.04	–.00	.05
OAHI	**.22***	**.29****	**.26****	**.18***
CAHI	.07	–.07	.09	.18
AHI	**.19***	.07	.15	.17
SES	–.09	–.14	–.05	–.08
BMI %	–.02	.01	.05	–.13
Age	–.06	–.10	–.11	–.06
Gestational age	–.11	–.13	–.15	.00
Birth weight	–.07	–.06	–.16	–.18

Note. WASO = wakefulness after sleep onset; RAI = respiratory arousal index; 3% ODI = number of dips in oxygen saturation ≥ 3%; CAHI = central apnoea-hypopnoea index; AHI = apnoea-hypopnoea index; SES = socioeconomic status; BMI = body mass index
* Denotes $p < 0.05$; ** $p < 0.01$

Table 5.2 shows the correlations between respiratory, demographic and the six co-morbid sleep problems scale scores derived from the SAPSS-Q. Increased Bedtime Anxiety was associated with lower sleep efficiency and longer WASO. Higher OAHI scores were correlated with increased scores on all the SDB scale scores.

Analysis between demographic variables and the SAPSS-Q scales revealed that a higher gestational age was associated with lower scores on the Nights Arousals scale. In contrast, a decreased birth weight was associated with higher scores for Night Arousals and Bedtime Anxiety. Nevertheless these associations were small in magnitude. There were no other significant correlations between demographic or respiratory variables and the six co-morbid sleep problems. Because the SAPSS-Q relies on parental perception of sleep behaviours, there is a need of examining the role of parental concern on snoring. Therefore, this analysis will be explored in the following chapter.

Table 5.2 Correlation (Spearman's correlation coefficient) between demographic and co-morbid sleep problems for the entire sample (n = 100)

	SR	BA	MT	NA	SDB	RS
Sleep Efficiency	–.02	**–.24***	–.00	–.12	–.09	.05
WASO	–.14	**.19***	–.11	.08	.10	–.07
RAI	.08	.14	–.02	–.06	–.02	.02
3% ODI	.10	.14	.14	.00	.08	.06
OAHI	–.00	.07	–.06	.12	**.22***	.12
CAHI	–.00	–.02	.01	.00	–.01	.08
AHI	–.03	–.01	–.04	.09	.09	.10
PLM episodes	.15	.08	–.01	.00	.02	.03
SES	–.05	–.09	–.06	.00	–.13	–.12
BMI %	–.07	–.06	–.15	–.04	.01	.02
Age	–.09	.02	–.17	.05	–.06	–.14
Gestational age	–.07	.01	.10	**–.27****	–.15	–.13
Birth weight	–.14	**–.20***	.03	**–.23***	–.08	–.08

Note. SR = Sleep Routine; BA = Bedtime Anxiety; MT = Morning Tiredness; NA = Night Arousals; SDB = Sleep-Disordered Breathing; RS = Restless Sleep; WASO = wakefulness after sleep onset; RAI = respiratory arousal index; 3% ODI = number of dips in oxygen saturation ≥ 3%; CAHI = central apnoea-hypopnoea index; AHI = apnoea-hypopnoea index; PLM = periodic limb movement; SES = socioeconomic status; BMI = body mass index
* denotes $p < 0.05$; ** $p < 0.01$

Finally, correlations between demographic variables and PSG variables are presented in Table 5.3. Age, gestational age and child's birth weight were found to be correlated with some of the PSG variables—younger age was correlated with increased sleep efficiency during PSG, reduced gestational age was correlated with increased CAHI and AHI, and lower birth weight was correlated with increased OAHI. The correlation between age and sleep efficiency was medium in magnitude, while the other correlations were small.

Table 5.3 Correlation (Spearman's correlation coefficient) between PSG variables and demographic variables

	Sleep Efficiency	WASO	RA	3% ODI	OAHI	CAHI	AHI
SES	.05	–.08	–.11	–.10	–.02	.10	.09
BMI %	–.01	.18	.03	.14	.06	–.01	.03
Age	**–.31****	.07	–.02	–.17	.06	.94	–.15
Gestational age	.02	.00	.12	–.02	**–.22***	**–.29****	–.11
Birth weight	.01	.00	–.11	.12	**–.21***	–.01	–.09

Note. SES = socioeconomic status; BMI = body mass index
* Denotes $p < 0.05$; ** $p < 0.01$

5.4. Discussion

A focus of the present study was the correspondence between parental self-report and PSG measures of PS. Children who were classified as non-snorers based on parent report were more likely to not snore during PSG, while more than half of children reported to snore did not snore during PSG.

Consistency between SAPSS-Q scales and polysomnography

In this chapter questionnaire items assessing SBD from the SAPSS-Q were correlated with PSG variables. Although the effect sizes were small, the 3% ODI was positively correlated with reports of snoring in children ('child snoring'), AHI was positively correlated with 'child snoring' and 'snorting and/or gasping' while OAHI was positively correlated with all four items in the SDB scale, as well as with the total scale overall (SAPSS-Q) . Despite AHI being commonly used when diagnosing SDB (Bixler et al., 2009; Calhoun et al., 2009; Kaditis et al., 2008; Morton et al., 2001), it may not be as specific as OAHI, because respiratory events with a central component are included in the diagnosis—hence this index may not be as representative of upper airway obstruction. Finally, when the correspondence between parental self-report and technician report of snoring was investigated, discrepancies between the two were found, especially for snoring children. A higher correspondence between objective (PSG) and subjective (parental report) was found for children classified as non-snorers (81% of children did not snore during PSG). In contrast, more than half of the children reported to snore (56%) did not snore during PSG, showing disagreement between subjective and objective assessments

Limited research has examined the agreement between subjective and objective assessment of snoring. For example, Stoohs et al. (1998) examined the agreement between self-report of snoring and a continuous measure of snoring (visually scored) in adults (younger vs. older adults). A higher agreement was seen between high frequencies of self-reported snoring and high values of the objective assessment among young adults. There is only one study that compares objective and subjective methods for snoring assessment and SDB in children (Montgomery-Downs et al., 2004). Their findings indicate that the agreement between parental report and snoring recorded on PSG was highest when the parental report corresponded to the highest frequency levels. Findings in the current study differed, suggesting that in this sample parental report of snoring does not completely correlate with snoring recorded during PSG. On the one hand, it may be possible that children in the present research did not have as severe levels of snoring as those reported in the other studies. On the other hand, no established criteria regarding assessment of snoring were followed when this was recorded during PSG. Additionally, the current study found that the SDB scale used from the SAPSS-Q was correlated with measures usually used to diagnose SDB, specifically OAHI. Finally, disagreement between parental report and recorded snoring during PSG highlights the need for more established criteria when assessing snoring frequency based on objective measures such as PSG.

Chapter 6 Parental concern regarding children with and without primary snoring from a community

6.1. Introduction

Much of the research examining the impact of snoring on daytime functioning in children has relied on parental self-report, especially when evaluating snoring severity and daytime behaviour (Ali et al., 1993; Bonuck et al., 2011; Ferreira et al., 2000). Parental self-report is known to be affected by several biases and, as argued by Owens (2005), factors such as parenting styles, cultural beliefs and education level are likely to play an important role in how sleep-related behaviours are evaluated by parents. For example, Biggs et al. (2010) report that the parents of Australian children with a Southeast Asian compared to a Caucasian heritage were more likely to endorse academic success at the expense of sleep and, moreover, to view snoring not as a problem but rather as a sign of health.

In general, an understanding of the clinical importance of snoring is underestimated in the general community Blunden et al. (2003) and Blunden et al. (2004) examined children attending their general practitioner and found that snoring and symptoms suggestive of SDB were not commonly reported, suggesting that snoring is not perceived to be a serious health risk by parents. Arguably, if parents do not perceive snoring to be a problem then they are less likely to report its presence and possibly underestimate severity. This raises the question about what factors influence parental reports of their child's snoring. Kai (1996), in a study examining parental concern when children become acutely ill, identifies two predictive factors: the parent's sense of personal control and, especially, the perceived threat of the illness.

To achieve a better understanding of those influences that prompt parents to report snoring, an important first step is to examine the extent to which parents perceive snoring to be a threat for their child—whether they see snoring as a problem that requires clinical assessment and treatment. Moreover, the extent to which the perception of snoring as a health risk may be modified by factors such parenting styles cultural beliefs and education level has yet to be examined.

Of the various factors that may potentially impact parental assessment of snoring, two are likely to be important; the child's age and parental sleep practices—especially co-sleeping. Parental perception of the threat that illness may pose to their child is known to decrease

with age. Slater et al. (2010) in a survey of 1202 Australian families asked parents to indicate the concerns they held about their children. Of particular note is the change in the ranking for concerns about health and wellbeing with age. Concerns about health and wellbeing (35%) was ranked highest by parents of pre-school-age children whereas in school-age children it was ranked second (25%), after child's education (38%) and likewise second in secondary school-age children (17%) after violence, drugs and alcohol (38%). Given this pattern of findings it would be expected that parental concern about snoring may follow a similar age-related trajectory.

A further factor that may influence parental reporting of snoring is the change in sleeping arrangements that accompany age: younger compared to older children are more likely to sleep in the same room or co-sleep with parents. This increases the likelihood of observing snoring in younger, compared to older, children. Ramos et al. (2007) examined the impact of co-sleeping on parental awareness of children's sleep habits. They divided parents into two co-sleeping groups: reactive co-sleepers (parents whose co-sleeping was a response to existing sleep difficulties) and those whose co-sleeping was based on personal or cultural factors. These two groups were compared to non-co-sleeping parents. Ramos et al. (2007) found that co-sleeping parents reported a higher frequency of child sleep problems, regardless of the reason for co-sleeping. However, despite an increase in the reporting of sleep problems, this was not associated with elevated levels of parental concern. However, Ramos et al. did not include snoring in their assessment of child sleep problems. It remains to be determined whether co-sleeping influences the frequency of reported snoring, and whether this is related to parental concern.

As discussed in previous chapters, there is good evidence that daytime functioning is reduced in children who snore who have been recruited from clinical settings, but not always from those recruited from general community settings. This inconsistency raises the question about whether the referral for a clinical review of a child who snores is predicated more by parental concern about daytime functioning rather than a history of snoring per se. At present it is simply unknown whether deficits in daytime functioning are elevated in parents who perceive snoring as a problem.

Thus, the aim of the present study was to explore the concordance between parental concern about snoring and parent's ratings about the severity of snoring, the impact of age and co-sleeping on parental concern about snoring, and whether parental concern about

snoring was related to the neurocognitive and behavioural functioning of both children who snore and non-snorers recruited from a community setting.

6.2. Methodology

Participants

Participant sample recruitment was described in Chapter 2 and Chapter 3. In this chapter, children who were assessed at Phase 2 were classified according to whether parental response considered snoring a problem (n = 13) or not (n = 68).

Materials

Sleep questionnaire

Sleep was assessed using a purposed-designed questionnaire—the SAPSS-Q (Biggs et al., 2012). As previously reported (Chapters 2 and 3), the SAPSS-Q has six major robust scales used to assess co-morbid sleep problems such as sleep routine, bedtime anxiety, restless sleep, night arousals, SDB and morning tiredness. These scales are derived from different items or sleep behaviours, with the inclusion of an additional question to determine the parent's perception of the sleep behaviour. In total, 26 items were included in this analysis, and particular emphasis was given to those items related to SDB. A single question ('Do you consider it a problem?') asked parents to provide a general subjective rating of the sleep behaviour in a four-point scale including 'not applicable', 'no', 'somewhat' and 'yes'.

Data and statistical analysis

Data regarding the parental perception of the sleep behaviours are presented dichotomously as 'no problem' ('no' responses to the question) and 'a problem' ('somewhat' and 'yes' responses collapsed). In order to avoid response bias, items considered 'not applicable' were considered missing data. An exploratory analysis (i.e. frequency of responses) was conducted in order to determine what sleep behaviours were considered problematic for the whole sample combined. Chi-square tests and, where appropriate, T-tests were used to test for the effect of age, SES and gender on parental sleep problem ratings ('not a problem' vs. 'problem'). Due to the low number of cases a Fisher's exact test was used to test for group differences.

Additionally, differences in neurocognitive, behaviour, PSG and co-morbid sleep problems (six scales from the SAPSS-Q) were also explored. Where appropriate, Chi-square for

categorical data or independent t-tests for continuous variables were used to explore group differences (using Lavene's test for homogeneity of variances).

Correlational analyses were conducted between items belonging to the SDB scale in the SAPSS-Q, and demographic, PSG respiratory variables and snoring report for the entire sample. Data are presented as mean (SD) unless otherwise stated. Analyses were conducted using the statistical package SPSS for windows version 21.

6.3. Results

Sample characteristics and demographic variables

In total, 81 children were included in this analysis. The mean age of the children was 8.2 ± 1.7 years, 33% were males and most were of Caucasian ethnicity (95%), with 1% Asian and 4% 'other' ethnicity. Groups were matched for age, SES, gestational age, child's birth weight and BMI z-score (Table 6.1).

Table 6.1 Mean (SD) and frequency of demographic variables between groups

Domain	**Snoring not a problem (n = 68)**		**Snoring is a problem (n = 13)**		***t-test***
Age (years)	8.3	(1.7)	7.9	(1.8)	0.67
SES	992.2	(76.4)	980.3	(72.3)	0.51
Gestational age (weeks)	39.2	(1.7)	39.3	(1.4)	0.13
Birth weight (kg)	3.5	(0.4)	3.3	(0.5)	0.76
BMI z-score	0.6	(0.9)	0.1	(1.3)	1.40
	%	**(n)**	**%**	**(n)**	χ^2
Gender (%male)	32.4	(22)	38.5	(8)	0.18
Ethnicity (%Caucasian)	95.6	(65)	92.3	(12)	5.81
Household smoking (yes)	23.2	(13)	22.2	(2)	0.00
Bed sharing (no)	90.0	(54)	85.7	(6)	0.09

Note. SES = socioeconomic status, BMI = body mass index

Parental perception of sleep behaviours

In general, slightly more than half (54%) of the children in the current study have experienced a sleep behaviour of any type considered as problematic by their parents, while 46% did not have sleep behaviours rated as problematic (Table 6.1).

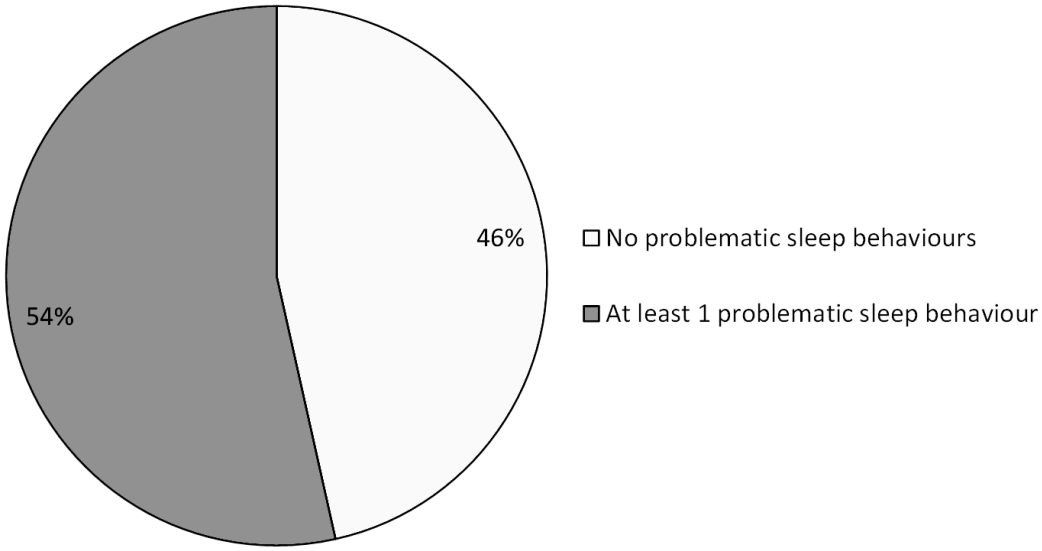


Figure 6.1 Proportion of children in the current study who have experienced a sleep behaviour problem of any type

Further analysis for the whole sample revealed that 11 sleep behaviours were considered problematic in more than 16% of parents from the whole sample (Table 6.2). Of these behaviours, four were related to Morning Tiredness, two to Night Arousals and Sleep Routine, and one to Restless Sleep, Bedtime Anxiety and SDB scales. Six sleep behaviours were rated as problematic by 10–15% of parents in the whole sample. Of these behaviours, two were associated with bedtime anxiety, two with SDB scale, one with Night Arousals, and another with Sleep Routine. Snoring as a problem was ranked 10th by parents while the other three items making up the SBD scale were ranked lowly at 15th, 16th and last.

Possible effects of age, SES and gender on the sleep behaviours were explored using a series of chi-square tests. No differences were found when children were divided according to age (five–eight years vs. >8 years), gender (male vs. female), or SES (high vs. low).

Table 6.2 Frequencies for twenty-six sleep behaviours and respective distribution according parental judgment (largest to smallest frequencies)

Sleep behaviour [a]	A problem	
	%	(n/total) [b]
You felt your child slept too little (SR)	30.3	(30/99)
Your child had difficulty getting out of bed in the morning (MT)	22.2	(20/90)
Your child was restless and moved lots during sleep (RS)	18.8	(19/101)
Your child seemed tired all the time (MT)	18.3	(15/82)
Your child took a long time to become alert in the morning (MT)	17.4	(15/86)
Your child woke in the morning in a negative mood (MT)	17.2	(15/87)
Your child was afraid of sleeping alone (BA)	17.1	(13/76)
Your child moved to someone else's bed during the night (NA)	17.1	(14/82)
Your child woke during the night (NA)	16.7	(16/96)
Your child currently snores (SDB)	16.0	(13/83)
Your child slept about the same amount each day (SR)	16.0	(15/97)
You felt your child slept the right amount (SR)	15.2	(15/99)
Your child struggled at bedtime (cried, refused to stay in bed, etc) (BA)	14.6	(12/82)
Your child woke alarmed by a frightening dream (NA)	13.4	(11/82)
Your child currently snores loudly (SDB)	11.9	(8/67)
Your child breathed heavily during the night (but did not snore) (SDB)	11.6	(10/86)
Your child needed parent in the room to fall asleep (BA)	10.7	(8/75)
Your child twitched/jerked violently during the night when asleep (RS)	9.4	(6/64)
Your child talked during sleep (RS)	5.9	(5/85)
Your child fell asleep within 20 minutes after going to bed (SR)	5.8	(5/86)
Your child went to bed at the same time every night (SR)	5.6	(5/90)
Your child fell asleep in parent's or sibling's bed (BA)	5.1	(4/78)
Your child woke at night screaming, sweating, was inconsolable (NA)	4.9	(3/61)
Your child fell asleep alone in own bed (BA)	3.2	(3/95)
Your child twitched or jerked when falling asleep (RS)	2.8	(2/71)
Your child snorted and/or gasped during sleep (SDB)	1.6	(1/61)

Note. SR = sleep routine, MT = morning tiredness; RS = restless sleep; BA = bedtime anxiety; NA = night arousals scale; SDB = sleep-disordered-breathing

[a] Items slightly reworded for presentation; [b] Differences on total number of children due to non-applicable responses were considered as missing data

Correspondence between snoring frequency and snoring is a problem

Table 6.3 reports the correlation between the frequency of snoring and whether parents consider snoring a problem. Although most parents in this study did not consider snoring a problem, the number of those who did (i.e. 'somewhat' or 'yes') increased proportionally with the frequency of snoring.

Table 6.3 Frequency of snoring (%(n)) according to parental perception of snoring (snoring considered a problem or not)

Snoring frequency	Snoring is a problem								Total	
	Not applicable		Not a problem		Somewhat a problem		Yes a problem			
	%	(n)	%	(n)	%	(n)	%	(n)	%	N
Never	38.7	(24)	61.3	(38)	0.0	(0)	0.0	(0)	57.4	62
Rarely (once/ week)	4.0	(1)	76.0	(19)	20.0	(5)	0.0	(0)	23.1	25
Sometimes (2–4 times/week)	0.0	(0)	73.3	(11)	26.7	(4)	0.0	(0)	13.9	15
Usually (5–7 times/ week)	0.0	(0)	33.3	(2)	33.3	(2)	33.3	(2)	5.6	6
Total	23	(25)	64.8	(70)	10.2	(11)	1.9	(2)		108

Parental perception of snoring

In parents who considered snoring a problem compared to those who did not, a significantly higher percentage considered the following items as also more problematic: child took long time to become alert; 'child woke up in a negative mood'; 'child currently snores loudly'; 'child breathed heavily'; 'child talked during the sleep'; child had difficulty getting out of bed'; child woke during the night'; 'child slept about the same time every night'; 'child struggled at bedtime'; child was restless during the night'; 'child seemed tired all the time'; and 'child needed a parent to fall asleep' (Table 6.4).

Table 6.4 Frequency of parental perception of problematic sleep behaviours (%(n)) according to parent's rating of snoring together with Fisher's exact test results

Sleep behaviour	Snoring not a problem		Snoring is a problem		*p-value*[*]
	%	(n)	%	(n)	
You felt your child slept too little					
Not a problem	75.4	(49)	50.0	(6)	0.090
It is a problem	24.6	(16)	50.0	(6)	
Your child had difficulty getting out of bed in the morning					
Not a problem	83.9	(52)	37.5	(3)	**0.009**
It is a problem	16.1	(10)	62.5	(5)	
Your child was restless and moved lots during sleep					
Not a problem	84.8	(56)	50.0	(6)	**0.013**
It is a problem	15.2	(10)	50.0	(6)	
Your child seemed tired all the time					
Not a problem	86.4	(51)	50.0	(5)	**0.016**
It is a problem	13.6	(8)	50.0	(5)	

Sleep behaviour	Snoring not a problem		Snoring is a problem		*p-value*[*]
	%	(n)	%	(n)	
Your child took a long time to become alert in the morning					
Not a problem	91.5	(54)	40.0	(4)	**0.001**
It is a problem	8.5	(5)	60.0	(6)	
Your child woke in the morning in a negative mood					
Not a problem	83.1	(49)	44.4	(4)	**0.020**
It is a problem	16.9	(10)	55.6	(5)	
Your child was afraid of sleeping alone					
Not a problem	83.9	(47)	60.0	(6)	0.098
It is a problem	13.6	(9)	40.0	(4)	
Your child moved to someone else's bed during the night					
Not a problem	85.2	(52)	75.0	(9)	0.403
It is a problem	14.58	(9)	25.0	(3)	
Your child woke during the night					
Not a problem	87.7	(57)	54.5	(6)	**0.018**
It is a problem	12.3	(8)	45.5	(5)	
Your child slept about the same amount each day					
Not a problem	87.7	(55)	58.3	(7)	**0.029**
It is a problem	12.7	(8)	41.7	(5)	
You felt your child slept the right amount					
Not a problem	84.6	(55)	75.0	(9)	0.415
It is a problem	15.4	(10)	25.0	(3)	
Your child struggled at bedtime (cried, refused to stay in bed, etc)					
Not a problem	89.7	(52)	58.3	(7)	**0.017**
It is a problem	10.3	(6)	41.7	(5)	
Your child woke alarmed by a frightening dream					
Not a problem	88.7	(55)	63.6	(7)	0.054
It is a problem	11.3	(70)	36.4	(4)	
Your child currently snores loudly					
Not a problem	98.2	(56)	25.0	(2)	**0.000**
It is a problem	1.8	(1)	75.0	(6)	
Your child breathed heavily during the night					
Not a problem	96.9	(63)	33.3	(4)	**0.000**
It is a problem	3.1	(2)	66.7	(8)	
Your child needed parent in the room to fall asleep					
Not a problem	93.0	(53)	60.0	(6)	**0.014**
It is a problem	7.0	(4)	40.0	(4)	
Your child twitched/jerked violently during the night when asleep					
Not a problem	90.6	(48)	85.7	(6)	0.514
It is a problem	9.4	(5)	14.3	(1)	
Your child talked during sleep					

Sleep behaviour	Snoring not a problem		Snoring is a problem		*p-value*[*]
	%	(n)	%	(n)	
Not a problem	96.7	(58)	62.5	(5)	**0.010**
It is a problem	3.3	(2)	37.5	(3)	
Your child fell asleep within 20 minutes after going to bed					
Not a problem	82.5	(52)	83.3	(10)	1.000
It is a problem	17.5	(11)	16.7	(2)	
Your child went to bed at the same time every night					
Not a problem	88.5	(54)	72.7	(8)	0.174
It is a problem	11.5	(7)	27.3	(3)	
Your child fell asleep in parents or siblings bed					
Not a problem	93.3	(56)	72.7	(8)	0.070
It is a problem	6.7	(4)	27.3	(3)	
Your child woke at night screaming, sweating, was inconsolable					
Not a problem	96.2	(51)	83.3	(5)	0.279
It is a problem	3.8	(2)	16.7	(1)	
Your child fell asleep alone in own bed					
Not a problem	96.8	(60)	91.7	(11)	0.417
It is a problem	3.2	(2)	8.3	(1)	
Your child twitched or jerked when falling asleep					
Not a problem	98.2	(54)	90.0	(9)	0.286
It is a problem	1.8	(1)	10.0	(1)	
Your child snorted and/or gasped during sleep					
Not a problem	100.0	(51)	85.7	(6)	0.121
It is a problem	0.0	(0)	14.3	(10)	

Note. * denotes *p* value for Fisher's exact test, values in bold are significant at $p < 0.05$

Child age and parental concern about snoring and other sleep disordered breathing variables

In order to explore whether parental concern regarding SDB-related sleep behaviours varied with age, the children were split into two age groups (five–eight years and >8 years). The results from chi-square tests indicated that parents of young and older children rated the various SDB items as similarly problematic (Table 6.5).

Table 6.5 Percentage (n) of parents who thought that sleep disordered breathing items were or were not a problem according to child age together with Chi-square results

Sleep disordered breathing items	5–8 years		>8 years		χ^2
	%	(n)	%	(n)	
Your child currently snores					
No problem	83.3	(35)	84.6	(33)	0.03
A problem	16.7	(7)	15.4	(6)	
Your child currently snores loudly					
No problem	88.2	(30)	87.9	(29)	0.00
A problem	11.8	(4)	12.1	(4)	
Your child breathed heavily during the night					
No problem	82.2	(37)	95.1	(39)	3.47
A problem	17.8	(8)	4.9	(2)	
Your child snorted and/or gasped during sleep					
No problem	100.0	(29)	96.9	(31)	0.92
A problem	0.0	(0)	3.1	(1)	

Although no significant differences were found, it was observed that regardless of the children's age more than 15% of parents considered snoring to be a problem. To a lesser extent, loud snoring was considered problematic by 12% of parents, and this was irrespective of the age group. Finally, parents tended to rate heavy breathing more problematic among younger than older children (17.8% vs. 4.9% respectively).

Co-sleeping and parental concern about snoring and other sleep disordered breathing variables

Among those parents who answered the co-sleeping item (n = 71), seven children (10%) were reported to co-sleep with someone else during the night, while 64 (90%) did not report co-sleeping. Table 6.6 presents Fisher's exact test results between single and co-sleepers across the different SDB-related variables.

Table 6.6 Percentage (n) of parents who thought that sleep disordered breathing items were or were not a problem according to co-sleeping together with Fisher Exact test results

SAPSS-Q Sleep breathing disorder items	No co-sleeping		Co-sleeping		*p-value*[*]
	%	(n)	%	(n)	
Your child currently snores					
Not concerned	84.4	(54)	85.7	(6)	1.00
Concerned	15.6	(10)	14.3	(1)	
Your child currently snores loudly					
Not concerned	87.5	(49)	100.0	(4)	1.00
Concerned	12.5	(7)	0.0	(0)	
Your child breathed heavily during the night					
Not concerned	89.9	(62)	85.7	(6)	0.55
Concerned	10.1	(7)	14.3	(1)	
Your child snorted and/or gasped during sleep					
Not concerned	98.0	(48)	100.0	(4)	1.00
Concerned	2.0	(1)	0.0	(0)	

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire
* denotes *p* value for Fisher's exact test

Neurocognitive functioning, behavioural performance, polysomnographic outcomes and co-morbid sleep problems

Neurocognitive functioning

Table 6.7 reports the neurocognitive results comparing children whose parents reported that snoring was or was not a problem. There was a general trend for lower neurocognitive scores in children whose parents considered snoring a problem. Despite this trend, the differences between groups were significant for only two variables: Verbal Ability and Memory.

Table 6.7 Mean (SD) neurocognitive scores in children whose parents reported that snoring was and was not a problem together with t-test and effect size results

Neurocognitive domain	Snoring not a problem (n = 65)		Snoring is a problem (n = 13)		*t-test*	Effect size
DAS						
Verbal Ability	102.3	(11.7)	94.62	(8.8)	**2.21**[*]	.25
Non-verbal Ability	99.1	(9.6)	96.5	(11.9)	0.75	.10
Spatial Ability	108.9	(10.6)	106.5	(7.9)	0.78	.09
GCA	103.7	(9.5)	98.7	(8.7)	1.73	.19
NEPSY						
Attention/Executive Function	101.9	(10.7)	102.4	(9.5)	0.14	.02
Language	104.8	(13.6)	100.2	(9.9)	1.16	.13
Memory	107.2	(15.6)	96.1	(19.7)	**2.09**[*]	.24

Note. * Denotes $p < 0.05$

Behavioural performance

In general, competency scores were lower and problematic behaviour scores were higher in children whose parents considered snoring a problem (Table 6.8). Specifically, they rated a higher frequency of syndromal problems with higher Withdrawn/Depressed, Social, Thought, Attention, Internal, External, and Total Problems scores. They also rated children higher on the following DSM-oriented scales: Affective and Anxiety related problems.

Table 6.8 Mean (SD) for behavioural scales on the Child Behavior Checklist together with t-test and effect size results

CBCL scale	Snoring not a problem (n = 63)		Snoring is a problem (n = 11)		*t-test*	Effect size
Competence Scale						
Activity	46.9	(9.1)	46.6	(14.7)	0.05	.02
Social	49.2	(7.9)	45.1	(10.8)	1.48	.17
School	47.1	(6.2)	44.2	(8.9)	1.34	.16
Total Competence	47.9	(8.4)	43.2	(11.9)	1.60	.19
Syndrome Scales						
Internal Problems	54.6	(6.4)	59.3	(8.6)	1.74	.20
External Problems	54.6	(5.7)	59.8	(5.9)	**2.75****	.31
Total Problems	56.5	(6.9)	63.6	(11.5)	2.00	.50
Anxious/Depressed	54.4	(4.6)	59.6	(6.8)	**3.16****	.35
Withdrawn/Depressed	55.2	(6.0)	65.4	(8.6)	**4.85****	.50
Somatic complaints	54.3	(5.2)	60.7	(6.8)	**3.64****	.39
Social Problems	54.4	(4.7)	57.4	(9.5)	1.03	.30
Thought Problems	54.2	(4.9)	60.0	(9.9)	1.89	.50
Attention Problems	51.4	(10.8)	60.7	(12.8)	**2.57***	.29
Rule–breaking Behaviour	51.1	(8.1)	57.5	(12.4)	**2.18***	.25
Aggressive Behaviour	51.3	(9.1)	61.8	(11.1)	**3.44***	.38
DSM–oriented Scales						
Affective Problems	55.4	(6.4)	63.1	(8.3)	**3.44****	.38
Anxiety Problems	55.2	(7.3)	60.6	(8.9)	**2.21***	.25
Somatic Problems	56.2	(7.4)	63.1	(15.0)	1.48	.41
ADHD	53.5	(4.5)	59.2	(9.0)	2.03	.53
Oppositional Defiant	54.6	(5.3)	58.5	(9.2)	1.35	.37
Conduct Problems	54.3	(5.7)	57.9	(11.1)	1.05	.33

Note. CBCL = Child Behavior Checklist; DSM = Diagnostic and Statistical Manual of Mental Disorders; ADHD = attention deficit hyperactivity disorder
Maladaptive behaviour is indicated by lower scores on the competence scale and higher scores on the syndrome and DSM-oriented scales; * denotes $p < 0.05$; ** $p < 0.01$

Polysomnographic assessment

Table 6.9 provides the mean (SD) PSG values for parents who rated snoring as a problem or not. The two groups were similar on PSG variables and no significant group differences were observed.

Table 6.9 Mean (SD) polysomnographic values for children whose parents reported that snoring was or was not a problem together with t-test and effect size results

Domain	Snoring not a problem (n = 66)		Snoring is a problem (n = 13)		*t-test*	Effect size
TST (min)	416.1	(46.6)	420.9	(56.9)	0.33	.04
Sleep Efficiency (%)	79.2	(8.7)	79.2	(12.0)	0.02	.00
REM (%)	19.9	(4.0)	21.6	(4.1)	1.35	.15
SWS (%)	28.3	(4.8)	29.6	(5.8)	0.91	.10
WASO (min)	57.1	(35.9)	62.0	(51.5)	0.42	.05
RAI (per hr)	0.6	(0.5)	0.5	(0.3)	0.64	.07
SAI (per hr)	7.8	(2.7)	6.4	(2.2)	1.74	.19
3% ODI (per hr)	0.9	(0.6)	1.1	(0.9)	0.79	.09
OAHI (events/hr)	0.3	(0.3)	0.4	(0.4)	0.77	.09
CAHI (events/hr)	0.5	(0.4)	0.7	(0.7)	1.18	.13
AHI (events/hr)	0.8	(0.5)	1.1	(0.9)	1.13	.13

TST = total sleep time; REM = rapid eye movement sleep; SWS = slow wave sleep; WASO = wakefulness after sleep onset; RAI = respiratory arousal index; SAI = spontaneous arousal index; 3% ODI = the number of dips in oxygen saturation ≥ 3%; OAHI = obstructive apnoea-hypopnoea index; CAHI = central apnoea-hypopnoea index; AHI = apnoea-hypopnoea index

To test the consistency between parental concern and child sleep behavious, further analysis were conducted exploring the top three ranked sleep behaviours and their correlation with total sleep time on PSG. (Table 6.2). However, none of the sleep behaviours was correlated with TST. The sleep behaviours examined: were 'the child slept too little' ($r = –.15, > 0.05$), 'the child had difficulty getting out of bed in the morning' ($r = –.03, > 0.05$) and 'the child seemed tired all the time' ($r = –.11, > 0.05$).

Co-morbid sleep problems

Table 6.10 presents the mean (SD) co-morbid SAPSS-Q scale scores. Analysis revealed that children whose parents considered that snoring was a problem had elevated sleep routine difficulties, night arousals and SDB scores compared to those who did not consider snoring problematic.

Table 6.10 Mean (SD) South Australian Paediatric Sleep Survey Database Questionnaire sleep problem scale scores together with t-test and effect size results

Sleep problem scale	Snoring not a problem (n = 68)		Snoring is a problem (n = 13)		*t-test*	Effect size
Sleep routine	49.8	(9.8)	57.2	(12.1)	**2.38***	.26
Bedtime anxiety	49.9	(9.3)	52.6	(8.8)	0.96	.11
Morning tiredness	50.4	(8.9)	57.4	(14.2)	1.69	.41
Night arousals	50.5	(9.6)	56.4	(9.2)	**2.03***	.22
Sleep-disordered breathing	51.8	(10.4)	67.8	(13.8)	**3.96****	.72
Restless sleep	47.7	(8.4)	53.1	(9.8)	1.99	.23

Note. *Denotes $p < 0.05$ and **$p < 0.01$

Correlations between factors and parental perception of sleep-breathing related behaviours

Severity of snoring (i.e. parental-reported frequency) was associated with three of the four SDB items from the SAPSS-Q (Table 6.11). In general, snoring frequency was associated with the SDB items being considered as more problematic. A significant and moderate association was found between snoring frequency and heavy breathing, snoring and loud snoring. However, apart for one exception, little relationship was observed between whether parents considered SDB items as problematic and PSG measures of SDB severity. The one exception was heavy breathing, which was associated with a >3% ODI, increased OAHI and CAHI. However, and despite the significant associations, the magnitude of these correlations were generally small. A small but significant association was observed between heavy breathing and age (i.e. the younger the child the more likely it was that parents perceived the sleep behaviour as problematic). Finally, a significant relationship was observed between snoring loudly as a problem and lower birth weight (i.e. parents of children with lower birth weight rated loud snoring as more problematic).

Table 6.11 Correlations (Spearman's correlation coefficient) between sleep-breathing related behaviours and demographic and polysomnographic respiratory variables

	Parental Ratings of 'How much of a problem' is							
	Heavy breathing		**Snoring**		**Loud snoring**		**Snorting/gasping**	
	r_s	**(n)**	r_s	**(n)**	r_s	**(n)**	r_s	**(n)**
Snoring report								
Severity of snoring (PR)	**.41****	(84)	**.47****	(81)	**.50****	(65)	.23	(60)
Snoring reported by tech	.04	(82)	.13	(79)	.24	(63)	.21	(59)
Polysomnographic variables								
Sleep Efficiency	.09	(82)	.05	(79)	.00	(63)	–.21	(59)
WASO	–.12	(82)	–.01	(79)	.04	(63)	.21	(59)
RAI	–.06	(82)	–.04	(79)	.24	(63)	.08	(59)
3% ODI	**.26***	(82)	.07	(79)	–.02	(63)	–.20	(59)
OAHI	**.22***	(82)	.05	(79)	.13	(63)	.17	(59)
CAHI	**.22***	(82)	.06	(78)	.11	(62)	.05	(58)
AHI	.28	(81)	.06	(78)	.11	(62)	.05	(58)
Demographic variables								
SES	–.11	(84)	–.07	(81)	–.06	(65)	.19	(60)
BMI z-score	–.14	(81)	–.15	(77)	.02	(63)	–.18	(58)
Age	**–.27***	(84)	–.08	(81)	.03	(65)	.12	(60)
Gestational age	–.11	(81)	–.00	(78)	.03	(63)	.18	(58)
Birth weight	–.13	(75)	–.15	(72)	**–.36****	(57)	–.14	(54)

Note. (PR) = parental report; WASO = wakefulness after sleep onset; RAI = respiratory arousal Index; ODI = the number of dips in oxygen saturation ≥ 3%; OAHI = obstructive apnoea-hypopnoea Index; CAHI = central apnoea-hypopnoea Index; AHI = apnoea-hypopnoea index; SES = socioeconomic status; BMI = body mass index Differences in the number of n's for each variable due to 'non-applicable' responses excluded from analysis

* Denotes $p < 0.05$; ** $p < 0.01$

6.4. Discussion

This study explored the association between parental ratings of child snoring severity and whether parents considered child snoring and its correlates as a problem. A modest

relationship was observed between snoring frequency and its rating as a problem. It was not universally the case that parents who reported that their child had frequent snoring thought that this was necessarily problematic. In general, SDB related symptoms were not considered particularly problematic when compared to other sleep disorder symptoms.

This study also explored the impact of age and co-sleeping on whether parents perceived snoring to be a problem. No impact of age and co-sleeping on parental responses was observed.

Finally, this study examined the relationship between whether parents considered child snoring a problem and daytime functioning. A tendency was observed for lower neurocognitive performance (especially Verbal Ability and Memory) and a higher frequency of problematic behaviours (both internalised and externalised) in children whose parents rated snoring as problematic.

Snoring was not ranked very highly by parents as a problem. This reflected a general trend for all SDB items which were ranked lower compared to those for other sleep disorders. For the whole sample combined, 54% of children had experienced at least a sleep related behaviour that was considered by their parents as problematic. Further analyses revealed that 11 behaviours were considered to be problematic for more than 16% of children, six sleep behaviours were considered problematic in 10–15% of children, and nine were considered problematic in less than 10% of children. Inspection of the items ranked highly as problematic by parents, revealed a high concern with items related to morning tiredness, followed by those related to sleep routine and night arousals. By contrast, parents were less concerned about problems to do with restless sleep and bedtime anxiety. Whether parents considered SDB as problematic came last in the ranking.

A particular focus of the present study was the potential association between parental concerns about snoring and daytime functioning. An association has been previously reported in the sleep literature between severity of snoring and daytime deficits in some (Gozal, 1998; Kennedy et al., 2004; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004), but not all studies (Calhoun et al., 2009). To date, however, no studies have directly investigated parental concern about snoring and its association with daytime performance in school-age children using objective measures including neuropsychological tests and PSG. Children whose parents considered that snoring was a problem were more likely to have lower neurocognitive performance and more behavioural complaints, especially Verbal Ability and Memory. The frequency of problematic behaviours were also more

common in children whose parents considered that snoring was a problem, especially problems to do with social ability, withdrawn/depressed, thought, attention, affective and anxiety. The findings using parental judgement are more consistent with previous literature than when children were classified based solely on snoring frequency (data presented in Chapter 3). The discrepancy between findings raises questions regarding the definition of snoring; particularly the role of parental perception and its impact on assessment. In other words, there is a question whether a negative parental perception of the child's behaviour could bias parental assessment of sleep and snoring for the same child.

The study also examined whether the frequency of co-morbid sleep problems (in addition to SDB) may differ between the children of parents who rated snoring as a problem or not. Parents who considered snoring a problem were more likely to also report that the following were problematic: the remaining SDB items (i.e. loud snoring and heavy breathing); morning tiredness (i.e. difficulty getting out of bed, taking too long to become alert in the morning and waking up in a negative mood); and to a lesser extent night arousals (i.e. sleep talking). Co-morbidity between sleep problems has been suggested for more than a decade in the child sleep literature. Smedje et al. (1999) examined Swedish children from a community setting and the distribution of sleep disorders. They found that 12% of children who had reports of snoring also had difficulty falling asleep at night. Moreover, 18% of children in the same group were reported to have restless sleep. Likewise, Archbold et al. (2002) examined children attending a general paediatric clinic and report that 55% of children with SDB symptoms (including snoring) also reported bedtime resistance, while 29% of children who reported excessive sleepiness also reported habitual snoring.

Despite the differences observed in the parental-reported frequency of co-morbid sleep problems between parents who thought snoring a problem or not, this was not reflected in the PSG analyses. Regardless of whether parents rated snoring as a problem or not the frequency of OAHI was similar between the two groups, as were the other PSG measures. Further, no significant relationships were observed between how problematic parents rated snoring and any PSG measure. In contrast to the findings for the snoring item, a higher frequency of heavy breathing was associated with PSG-SDB measures and, in particular, a greater number of 3% ODI, OAHI and CAHI.

It would be reasonable to assume that parents who are concerned about their child's snoring are more likely to discuss this issue at medical consultations which, in turn, explain

why such children are more likely to be diagnosed with SDB. This hypothesis remains to be examined, but parallels have been observed in other disorders. For example, the children of parents who are concerned about their child's mental health are more likely to meet criteria for a mental disorder at medical examination (Dulcan et al., 1990). Our knowledge of how parental concern may influence the assessment of child sleep problems is not well-explored. There is existing evidence that parents seldom discuss sleep problems at general practice visits (Blunden et al., 2004; Blunden et al., 2003) and, moreover, that general practitioners often fail to ask about sleep difficulties in the consultation (Chervin, Archbold, Panahi, & Pituch, 2001; Meltzer et al., 2010). These findings raise questions about why some children who have sleep problems are referred to a clinical setting (e.g. snoring children who are referred to ENT specialists) while others are not. Rather than a SDB problem per se, parental concern may be an important mediating factor. If this is the case, then improving knowledge about SDB and its consequences in the general community would be beneficial. Additionally, there is a need to include sleep questions during normal paediatric or general practitioner visits.

At present, little research has been undertaken specifically investigating the factors underlying the parental judgment of sleep symptoms, especially snoring. Although parental report is widely used to assess snoring frequency (Biggs et al., 2012; Chervin et al., 2000; Lumeng & Chervin, 2008; Montgomery-Downs et al., 2004), it might be influenced by other factors, and of these co-sleeping may be especially relevant. Ramos et al. (2007), in a study which investigated co-sleeping and the frequency of sleep-related behaviour, report that parents who co-slept tended to report higher frequencies of sleep problems. This was not observed in the present study. In the current study, the majority of children were reported to sleep in their own beds. Nevertheless, when the few children who did co-sleep were compared with children who did not, little difference was found in whether parents thought that snoring was a problem. The lack of statistical significance may be partially explained by the small sample sized used in the analysis.

The final interest of the current study was to explore the association between demographic factors and the parent's ratings of how problematic they perceived the various SDB symptoms. The correlation between higher snoring severity and perception of items including heavy breathing, snoring and loud snoring was strong. However, it remains unknown if parents are more aware of snoring because they consider such sleep behaviour as problematic, or whether increased levels of snoring trigger parental concern. Ramos et al. (2007) suggest that the problem could reside in the relationship between parents and

children, rather than the presence of the sleep problem per se (in this case snoring). In other words, a parent's expectations about what is normal could play an important role. This idea requires validation, however, and parental judgement of sleep behaviours requires systematic inclusion when assessing habitual snoring. For example, it could be useful to explore cultural and parental expectations about what is considered problematic sleep behaviour. This may be achieved by first exploring parental knowledge about sleep behaviours (the consequences and significance) in their children.

Conclusion

Irrespective of snoring frequency, parental perception of snoring was predictive of decreased neurocognitive functioning and a higher risk of behavioural complaints in children. This finding raises the question about whether parents notice additional characteristics that are not normally seen in children who snore during clinical observation. Moreover, contradictions between the findings from clinical and community settings need to be addressed, and comparisons between children with the same SDB condition from the two populations could assist in understanding the mixed findings. In sum, this study constitutes a first approach towards gaining a better understanding of how parents perceive snoring in children; further research is required to corroborate and expand the current findings.

Chapter 7 Sleep schedules in snoring and non-snoring children from a community sample

7.1. Introduction

There is good evidence that children are sleeping less than their counterparts in previous decades (Dollman, Ridley, Olds, & Lowe, 2007) with many thereby not meeting the recommended clinical guidelines for sleep length—five–10-year-olds = 10 to 11 hours and 10–17-year-olds = 8.5 to 9.25 hours (Kai, 1996). This shortfall is not without consequences, especially for daytime functioning, with evidence that shortened sleep is associated with both reduced neurocognitive functioning (Gruber et al., 2011) and an increased frequency of problematic behaviour (Paavonen et al., 2009). A less well appreciated change that has also occurred in child sleep patterns over the previous decades is the change in consistency of the timing of sleep with children reporting greater night-to-night variability in the timing of sleep onset and offset (Gruber, Sadeh, & Raviv, 2000; Mindell, Telofski, Wiegand, & Kurtz, 2009). Similar to the findings for shortened sleep but not as well-recognised, inconsistent sleep routines are also reported to negatively impact on daytime behaviour (Aronen, Paavonen, Fjällberg, Soininen, & Törrönen, 2000; Biggs et al., 2011; Wolfson & Carskadon, 1998). A noted sleep pattern irregularity is for children to report large differences in the timing of sleep on school versus weekend nights (Biggs et al., 2011; Wolfson & Carskadon, 1998). The delay in sleep timing on the weekend has been associated with long sleep latencies on school nights, which in turn have been associated with an increased frequency of problematic behaviour (Aronen et al., 2000). For example, Aronen et al. (2000) in a study of sleep and behaviour in 49 healthy children, report that children with extended sleep latencies were more likely to report aggressive/delinquent behaviour and attention difficulties. The relationship between sleep routine and daytime functioning remains to be examined and, in particular, whether aspects other than behaviour are also affected, such as neurocgnitive functioning.

As has been previously described in earlier chapters, children with SDB have a high frequency of co-morbid sleep problems such as bedtime anxiety, daytime sleepiness, and bedwetting (Alexopoulos et al., 2006; Ferreira et al., 2000). Although co-morbid sleep problems have been described, what is less clear in children with SDB, especially with PS, is whether sleep patterns are more or less variable than children without SDB. Surprisingly little has been reported on the sleep patterns of children with SDB, with most studies either

relying on questionnaire or focused on overnight PSG and respiratory functioning. Examination of sleep routine such as could be obtained from sleep diary reports would be instructive.

As has also been discussed in previous chapters, daytime functioning is reduced in children with SDB, especially children recruited from clinical settings (Brockmann, Urschitz, et al., 2012; Ferreira et al., 2000; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004). The extent to which other sleep deficits, such as shortened sleep and irregular sleep routines, may contribute to daytime deficits has not been well explored, and not at all in children from non-clinical settings such as those in the present study from the general community. Moreover, where studies have examined either sleep length or sleep routine they have mainly focused on behaviour and academic performance, and neglected other possible aspects of daytime functioning such as neurocognitive performance. A possible association between sleep length and sleep routine with neurocognitive deficits in children who snore recruited from clinical settings remains to be examined. The aim of the present study was to examine the sleep/wake routines in children with and without reports of snoring in order to investigate sleep consistency and its association with neurocognitive and behavioural performance.

7.2. Methods

Participants and materials

From the original baseline cohort of children who had been invited to participate in the two-year follow-up study examining the natural history of snoring and neurocognitive functioning, a sample of 116 children who provided sleep routine data were included in this analysis. Three sources of sleep routine data were collected.

First, parents were asked to complete the SAPSS-Q (Biggs et al., 2012), which generates six scales including a Sleep Routine scale. The Sleep Routine scale includes questions on the child's 'typical' bedtime, time they fall asleep and final wake-up time. Second, additional questions in the questionnaire asked parents to estimate 'earliest' and 'latest' bedtimes and wake-times. Parents were asked to provide estimates during the previous week separately for school (i.e. Sunday to Thursday nights) and non-school nights (i.e. Friday and Saturday nights). The above variables were further used to estimate total sleep time (TST), sleep latency onset (SOL) and time in bed (TIB). The consistency of child sleep was estimated using two sets of measures. The first set examined within (intra) night consistency by comparing the difference between 'earliest' and 'latest' bedtime and,

similarly, wake times (i.e. bedtime variability and wake time variability). These estimates were calculated separately for school and non-school nights. The second set of measures examined between (inter) night variability by comparing the consistency of sleep on school compared to non-school nights (i.e. school and non-school night differences in bed [school/non-school bedtime], wake [school/non-school wake time] and TST [school/non-school TST]). Finally, the third source of data used to examine sleep routine was obtained from sleep diary reports. A seven-day sleep diary was completed by parents in the week prior to their child attending PSG/neurocognitive assessment. Parents were asked to complete the diaries in the morning. The following sleep diary measures were collected; 'typical' (i.e. average) sleep onset time, 'earliest' and 'latest' bedtimes, 'typical' final wake-up time, 'earliest' and 'latest' wake up times, number of nocturnal awakenings and time spent awake during the night. Sleep diary responses were used to calculate TST, bed and wake-up times, SOL, TIB and WASO in minutes. Parents were also asked to rate the subjective level of alertness in the morning using a five-point scale.

As it was previously described in Chapter 4, estimates of parental concern about snoring were also collected. Parents were asked whether they consider snoring to be a problem or not using a four-point scale to determine ('not applicable', 'no', 'somewhat' or 'yes'). Children were then divided into groups: 'Did not consider their child's snoring a problem' ('no') or 'Did consider their child's snoring a problem' ('somewhat' or 'yes'). Children whose parents indicated 'not applicable' were excluded from the analyses.The sleep routine measures were correlated with the key composite behavioural scale scores from the CBCL/6-18, and the key composite neurocognitive scale scores from the DAS and the NEPSY. Chapter 2 details these instruments and their administration.

Data and statistical analyses

To investigate whether subjective versus objective criteria for PS might be informative, children were classified according to one of four sets of criteria. First, the children were classified according to parental-reported snoring frequency into either non-snorers ('never snoring' or 'snoring 1 night/week', n = 92) or snorers (snoring > 2 nights/week', n = 24). Second, they were divided into three groups according to parental report into non-snorers ('never snoring', n = 65), infrequent snorers ('snoring 1 night/week', n = 27) and frequent snorers ('snoring > 2 nights/week', n = 24). Third, to examine whether children's PS status might be better described using objective measures rather than parental report, the OAHI values obtained from PSG were used to reclassify participants. Children were classified into two groups based on their mean OAHI: OAHI < 0.32 (n = 67) and OAHI > 0.32

(n = 42). Fourth, to examine whether parental belief concerning whether snoring is problem might be a better predictor of daytime functioning, they were further classified into 'Did not consider their child's snoring a problem' ('no': n = 68) or 'Did consider their child's snoring a problem' ('somewhat' or 'yes': n = 13). Children whose parents indicated 'not applicable' were excluded from the analyses.

The National Sleep Foundation recommendations for sleep length according to age (five–10 years and >10 years) (National Sleep Foundation, 2010) and parental sleep diary estimates were used to classify children into those who did not meet (slept less than) or met the recommended guidelines for sleep length.

A similar set of sleep quality and sleep timing estimates obtained from the SAPSS-Q were also derived from sleep diary records. That is, estimates were obtained for school or non-school night; 'earliest' and 'latest' bedtime and wake times; TIB (bedtime to wake time); TST (sleep onset time to wake time minus time spent awake during the night); SOL (bedtime to sleep onset time). The school and non-school night averages were used in the analyses. Mean values according to group status were substituted for missing data.

As previously described by Biggs et al. (2011), the additional sleep timing items on the SAPSS-Q were used to estimate within night sleep consistency: bedtime ('earliest' bedtime from the 'latest' bedtime) and wake time ('earliest' wake time from the 'latest' wake time). These were calculated separately for school and non-school nights. Additionally, school/non-school shift for bedtimes and wake times was calculated. The school/non-school shift for TST was additionally calculated; obtained using the difference between the TST on school nights and the TST on non-school nights. Absolute values were used for the analysis, because the main interest was to determine whether TST differed between school nights.

A series of one between factor (group: non-snorer, infrequent snorer and frequent snorer or low and OAHI > 0.32; or not concerned and concerned) and one within factor (time: school and non-school night) ANOVAs were used to explore the impact of Group and Night on SAPSS-Q and sleep diary variables. The consistency between school and non-school night bedtimes and, likewise, wake times in children who snored compared to non-snorers was analysed using F-tests. Chi-square tests were used to examine group differences in the percentage of children who met or did not meet recommended sleep length guidelines, as well as the proportion of children sleeping longer during school versus non-school nights. Post-hoc tests included Bonferroni correction, which was used to

follow up significant results. The relationship between sleep routine and daytime functioning was assessed using Spearman's Correlation Coefficients.

Data are presented as mean (SD) unless otherwise indicated. All *p* values reported have a statistical significance set at < 0.05. As this was an exploratory study, no corrections were made for multiple comparisons. Analyses for data collected with the SAPSS-Q and the sleep diary were conducted using statistical software IBM SPSS, version 21.

7.3. Results

Parental-reported snoring (South Australian Paediatric Sleep Survey Database Questionnaire)

Non-snorers versus snorers

In general, sleep quality and timing was similar in children who snored compared to non-snorers on school and, likewise, non-school nights. The exception was bedtime and wake time variability, which tended to be greater in children who snored, especially on non-school nights (Table 7.1). Inspection of the school versus non-school night sleep values revealed that sleep length was shorter and the timing of sleep was later on non-school compared to school nights.

Table 7.2 presents the ANOVA results. ANOVA analyses revealed a significant main effect for Night (school/non-school), with parents reporting that children had later 'typical' bedtimes on non-school compared to school nights (20:53 (35) vs. 20:11 (51) hh:min (min)), later 'earliest' bedtimes (20:14 (52) vs. 19:48 (39) and later 'latest' bedtimes (21:35 (131) vs. 20:59 (48) hh:mm (min)). Parents also reported that children had later 'typical' wake times on non-school nights (7:23 (46) vs. 6:59 (0:28) hh:mm (min)). Children also slept less on non-school compared to school nights with shorter TIB (626.4 (48.6) vs. 646.2 (36.6), min (min)), SOL (10.0 (17.8) vs. 13.3 (18.7), min (min)) and TST (608.3 (55.5) vs. 624.0 (43.1), min (min)). In addition, children's sleep schedules were less consistent (i.e. difference between the 'latest' and 'earliest' time on non-school compared to school nights (77.6 (5.1) vs. 101.4 (6.2), min (min)). Only one main effect was observed for Group, with children who snored compared to non-snorers having greater difference in their 'earliest' versus 'latest' bedtimes (100.1 (9.1) vs. 79.0 (4.5), min (min)). No significant interaction effects were observed. The consistency of bedtimes and wake time on school compared to non-school nights was similar in children who snored and non-snorers (Table 7.3). No significant group differences were observed in any between night sleep consistency estimates.

Table 7.1 Mean (SD) sleep SAPSS-Q sleep routine and within night sleep consistency parameters and percentage (n/N) of children who met recommended clinical guidelines for sleep length for children snored and non-snorers on school and non-school nights

Sleep Variable	School night				Non-School night			
	Non-snorer (n = 92)		Snorer (n = 24)		Non-snorer (n = 92)		Snorer (n = 24)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
SAPSS-Q								
Typical bedtime (hh:mm (min))	20:12	(34)	20:09	(42)	20:52	(52)	21:02	(48)
Earliest bedtime (hh:mm (min))	19:50	(37)	19:43	(47)	20:17	(51)	20:13	(57)
Latest bedtime (hh:mm (min))	20:57	(47)	21:08	(53)	21:29	(142)	22:03	(61)
Typical wake time (hh:mm (min))	6:59	(29)	7:00	(25)	7:23	(47)	7:23	(43)
Earliest wake time (hh:mm (min))	6:29	(35)	6:26	(44)	6:50	(45)	6:48	(56)
Latest wake time (hh:mm (min))	7:30	(39)	7:36	(36)	8:04	(62)	8:22	(69)
Time-in-bed (min)	645.5	(34.5)	650.2	(46.0)	628.6	(49.1)	621.1	(47.8)
Sleep onset latency(min)	13.2	(19.2)	13.6	(17.0)	11.0	(19.2)	6.2	(10.0)
Total sleep time (min)	616.6	(55.9)	615.6	(64.8)	603.4	(64.6)	593.6	(68.9)
Within night sleep consistency								
Bedtime variability[a]	69.0	(41.2)	86.3	(52.7)	89.0	(51.4)	113.9	(61.2)
Wake time variability[a]	61.7	(46.8)	73.5	(43.8)	72.6	(45.0)	84.1	(60.7)
Sleep length guidelines	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**
Met recommended amount [b]	79.5	(70/88)	78.3	(18/23)	69.0	(60/88)	54.5	(12/23)

Note. SAPPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire
[a] Difference between the 'earliest' and 'latest' times; [b] Denominators vary due to some data were not reported, hence not all variables were calculated. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 7.2 ANOVA results examining the effect of Group (children who snored vs. non-snorer) and Night (school vs. non-school night) on SAPSS-Q sleep routine and within night sleep consistency parameters

SAPSS-Q Sleep variable	F-test Results		
	Group (Non-snorer/snorer)	Night	Group*Night
Typical bedtime	0.09	**161.73*****	3.27
Earliest bedtime	0.36	**63.88*****	0.21
Latest bedtime	1.64	**8.36****	0.64
Typical wake time	0.01	**31.71*****	0.00
Earliest wake time	0.05	**25.41*****	0.01
Latest wake time	1.06	**39.28*****	0.34
Time in bed	0.02	**23.78*****	1.69
Sleep onset latency	0.31	**5.96***	1.74
Total sleep time	0.15	**13.71*****	0.87
Within night sleep consistency			
Bedtime variability[a]	**4.33***	**21.00*****	0.53
Wake time variability[a]	1.58	3.13	0.00

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire
[a] Difference between the 'earliest' and 'latest' times;* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Although the majority of children met clinical guidelines for sleep, there was a trend for relatively fewer children to meet the guidelines on non-school compared to school nights (Table 7.1). The results of Chi-square analyses revealed that the percentage of children

who snored compared to non-snorers were similar on school nights ($\chi^2 = 0.02$) and, likewise, did not differ between children who snored and non-snorers on non-school nights ($\chi 2 = 1.62$). No differences between the groups were seen among variables regarding night sleep consistency (Table 7.3).

Table 7.3 Mean (SD) between night sleep consistency estimates for children who snored and non-snorers together with F-test results

Between night sleep consistency (SAPSS-Q)	**Non-snorer (n = 92)**		**Snorer (n = 24)**		***F-test***
	Mean	**(SD)**	**Mean**	**(SD)**	
School/non-school bedtime (min)[a]	41.4	(32.1)	55.4	(31.1)	3.36
School/non-school wake-time (min)[a]	27.4	(33.2)	27.7	(27.7)	0.00
School/non-school total sleep time (min)[a]	32.5	(27.4)	27.5	(32.8)	0.53

Note. SASSP-Q = South Australian Paediatric Sleep Survey Database Questionnaire
[a] Difference between 'typical' school and non-school bed and wake times and total sleep time

Non-snorers, infrequent and frequent snorers

Table 7.4 and Table 7.5 contain sleep schedules values for children classified according to non-snorers, infrequent snorers and frequent snorers. Regardless of snoring status, bedtime and wake time were slightly later, and children had shorter TST and spent less TIB on non-school compared to school nights.

ANOVA analyses revealed a significant main effect for Night with children reporting later 'typical' bedtimes (20:53 (35) vs. 20:11 (51), hh:mm (min)), later 'earliest' bedtimes (20:14 (52) vs. 19:48 (39), hh:mm (min)), later 'latest' bedtimes (21:35 (131) vs. 20:59 (48), hh:mm (min)), later wake times (7:23 (46) vs. 6:59 (28), min (min)), shorter TIB (647.4 (4.4) vs. 624.6 (5.8), min (min)), shorter TST (617.7 (6.1) vs. 598.9 (6.9), min (min)) and a greater difference between their 'earliest' versus 'latest' bedtimes (99.2 (5.5) vs. 75.8 (4.5), min (min)) and wake times (76.6 (5.0) vs. 65.4 (4.8), min (min)). No main effect was observed for snoring on any sleep parameters. A single significant main effect was observed for 'typical' bedtime with post-hoc testing revealing that children who snored (infrequently and frequently) had later bedtimes than non-snorers on non-school nights (Table 7.4).

Based on international guidelines for recommended sleep length, a similar percentage of non-snorers, infrequent and frequent snorers met the criteria on school nights and, similarly, met the criteria on non-school nights ($\chi^2(2) = 0.59$, $p > 0.05$ and $\chi^2(2) = 2.0$, $p > 0.05$, respectively). There was trend in all snoring groups for fewer children to meet the recommended sleep length guidelines on non-school nights (Table 7.4).

Table 7.4 Mean (SD) sleep SAPSS-Q sleep routine and within night sleep consistency parameters and percentage (n/N) of children who met recommended clinical guidelines for sleep length for children who were non-snorers, frequent snorers and infrequent snorers on school and non-school nights

Sleep Variable	School night						Non-school night					
	Non-snorer (n = 65)		Infrequent snorer (n = 27)		Frequent snorer (n = 24)		Non-snorer (n = 65)		Infrequent snorer (n = 27)		Frequent snorer (n = 24)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SAPSS-Q												
Typical bedtime (hh:mm (min))	20:12	(35)	20:14	(32)	20:09	(42)	20:48	(50)	21:04	(55)	21:02	(48)
Earliest bedtime (hh:mm (min))	19:51	(38)	19:48	(35)	19:43	(47)	20:16	(53)	20:20	(48)	20:13	(57)
Latest bedtime (hh:mm (min))	20:57	(47)	20:58	(50)	21:08	(53)	21:41	(57)	20:58	(255)	22:03	(61)
Typical wake time (hh:mm (min))	6:58	(28)	7:01	(32)	7:00	(25)	7:23	(49)	7:22	(45)	7:23	(43)
Earliest wake time (hh:mm (min))	6:26	(34)	6:35	(39)	6:26	(44)	6:47	(43)	6:57	(51)	6:48	(56)
Latest wake time (hh:mm (min))	7:28	(41)	7:35	(36)	7:36	(36)						
Time in bed (min)	644.6	(36.1)	647.6	(30.8)	650.2	(46.0)	632.6	(49.5)	618.8	(47.7)	621.1	(47.8)
Sleep onset latency(min)	15.3	(21.5)	8.4	(11.2)	13.6	(17.0)	11.9	(20.0)	8.8	(17.3)	6.2	(10.0)
Total sleep time (min)	613.5	(59.8)	624.1	(45.2)	615.6	(64.8)	605.9	(66.4)	597.3	(60.8)	593.6	(68.9)
Within night sleep consistency												
Bedtime variability[a]	66.6	(41.9)	74.6	(39.5)	86.3	(52.7)	84.8	(51.1)	99.1	(51.5)	113.9	(61.2)
Wake time variability[a]	62.1	(46.6)	60.7	(48.2)	73.5	(43.8)	72.1	(44.7)	73.9	(46.3)	84.1	(60.7)
Sleep length guidelines	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**
Met recommended amount [b]	77.4	(48/62)	84.6	(22/26)	78.3	(18/23)	71.0	(44/62)	64.0	(17/26)	54.5	(12/23)

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire

[a] Difference between the 'earliest' and latest times; [b] Denominators vary due to some data were not reported, hence not all variables were calculated

Table 7.5 ANOVA results examining the effect of Group (non-snorers, infrequent snorers and frequent snorers) and Night (school vs. non-school night) on SAPSS-Q sleep routine and within night sleep consistency parameters

SAPSS-Q Sleep variable	F-test Results		
	Group (non-snorers, infrequent and frequent snorers)	Night	Group*Night
Typical bedtime	0.49	**206.27*****	**3.63***
Earliest bedtime	0.18	**81.75*****	0.57
Latest bedtime	1.54	**6.07***	1.37
Typical wake time	0.01	**37.83*****	0.12
Earliest wake time	0.45	**34.8*****	0.01
Latest wake time	0.92	**47.38*****	0.61
Time in bed	0.18	**31.54*****	2.51
Sleep onset latency	0.97	**3.91**	1.34
Total sleep time	0.07	**20.41*****	2.56
Within night sleep consistency			
Bedtime variability[a]	2.79	**25.71*****	0.45
Wake time variability[a]	0.78	**4.31****	0.04

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire

[a] Difference between the 'earliest' and 'latest' times; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 7.6 Mean (SD) between night sleep consistency estimates for non-snorers, infrequent snorers and frequent snorers together with F-test results

Between night sleep consistency (SAPSS-Q)	Non-snorer (n = 65)		Infrequent snorer (n = 27)		Frequent snorer (n = 24)		*F-test*
	Mean	(SD)	Mean	(SD)	Mean	(SD)	
School/non-school bedtime (min)[a]	37.9	(29.8)	49.6	(36.1)	55.4	(31.1)	2.88
School/non-school wake-time (min)[a]	28.7	(34.6)	24.4	(29.8)	27.7	(27.7)	0.15
School/non-school Total sleep time (min)[a]	29.6	(27.5)	39.6	(26.4)	27.5	(32.8)	1.37

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire

[a] Difference between 'typical' school and non-school bed and wake times and total sleep time

Table 7.6 reports the mean between night sleep consistency estimates for the snoring groups. No significant effect of snoring group on any between night sleep consistency variables was observed. The difference in bedtimes between school and non-school nights was similar across groups and, likewise, the differences in wake times and TST.

Classification according Obstructive Apnoea-Hypopnoea Index levels

Table 7.7 presents the mean (SD) values for children classified according to OAHI criteria and Table 7.8 presents the ANOVA results. In general, children with an OAHI > 0.32 had later bedtimes, but earlier wake times with a trend of shorter TST and shorter TIB on both school and non-school nights.

ANOVA analyses revealed a significant main effect for Night with children on non-school compared to school nights having later 'typical' bedtimes (20:53 (35) vs. 20:11 (51) hh:mm (min)), later 'earliest' bedtimes (20:14 (52) vs. 19:48 (39) hh:mm (min)), later 'latest' bedtimes (21:35 (131) vs. 20:59 (48) hh:mm (min)), later wake times (7:23 (46) vs. 6:59 (28) hh:mm (min)), longer TST (614.1 (5.7) vs. 597.8 (6.4), min (min)), longer TIB (645.3 (3.7) vs. 624.6 (4.8), min (min)), and greater difference between 'earliest' and 'latest' bedtimes (92.2 (5.2) vs. 70.7 (4.2), min (min)) and wake times (74.1 (62.4) vs. 62.4 (4.5), min (min)). Only a single significant main effect was observed for Group—for TST with children with a OAHI < 0.32 sleeping longer than children with a OAHI > 0.32 (617.8 (7.1) vs. 594.1 (9.0), min (min)). A single significant OAHI Group by Night interaction was observed for TIB. Post-hoc tests revealed that children with a OAHI > 0.32 spent significantly less TIB than those with OAHI < 0.32 on school nights and, as well, on non-school nights (both $p < .05$).

Table 7.7 reports the percentage of children with OAHI < 0.32 and > 0.32 that met recommended clinical guidelines for sleep length on school and non-school nights. The majority of children met clinical guidelines for sleep on school nights, but fewer on non-school nights, especially children with OAHI > 0.32. Chi-square analyses revealed that a higher percentage of children with a OAHI < 0.32 compared to a OAHI > 0.32 met recommend sleep length guidelines on non-school nights (χ^2 (1) = 4.80).

Table 7.7 Mean (SD) sleep SAPSS-Q sleep routine and within night sleep consistency parameters and percentage (n/N) of children who met recommended clinical guidelines for sleep length according to child's OAHI level (OAHI < 0.32 vs. > 0.32) on school and non-school nights

Sleep schedule	School night				Non-school night			
	OAHI < 0.32 (n = 70)		OAHI > 0.32 (n = 44)		OAHI < 0.32 (n = 70)		OAHI > 0.32 (n = 44)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
SAPSS-Q								
Typical bedtime (hh:mm (min))	20:11	(36)	20:13	(35)	20:51	(53)	21:00	(48)
Earliest bedtime (hh:mm (min))	19:46	(39)	19:53	(39)	20:10	(53)	20:26	(50)
Latest bedtime (hh:mm (min))	21:04	(51)	20:54	(43)	21:28	(161)	21:46	(57)
Typical wake time (hh:mm (min))	7:02	(27)	6:55	(29)	7:30	(48)	7:12	(44)
Earliest wake time (hh:mm (min))	6:31	(34)	6:25	(41)	6:53	(45)	6:44	(51)
Latest wake time (hh:mm (min))	7:39	(40)	7:19	(33)	8:15	(62)	7:58	(66)
Time-in-bed (min)	648.8	(36.4)	642.0	(38.7)	636.1	(51.6)	613.3	(41.7)
Sleep onset latency(min)	14.2	(20.1)	11.3	(16.7)	10.7	(19.3)	8.7	(15.6)
Total sleep time (min)	622.3	(53.2)	605.8	(64.3)	613.3	(65.2)	582.5	(63.2)
Within night sleep consistency								
Bedtime variability[a]	79.2	(49.7)	62.3	(31.3)	99.2	(56.5)	85.2	(50.0)
Wake time variability[a]	69.6	(49.9)	55.3	(39.8)	79.2	(47.6)	69.0	(50.4)
Sleep length guidelines	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**
Met recommended amount [b]	80.6	(54/67)	76.2	(32/42)	74.2	(49/66)	53.7	(22/41)

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire

[a] Difference between the 'earliest' and 'latest' times; [b] Denominators vary due to some data were not reported; hence not all variables were calculated; * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$.

Table 7.8 ANOVA results examining the effect of Group (OAHI < 0.32 vs. > 0.32) and Night (school vs. non-school night) on SAPSS-Q sleep routine and within night sleep consistency parameters

SAPSS-Q Sleep schedule	F-test Results		
	Group (OAHI < 0.32/OAHI > 0.32)	Night	Group*Night
Typical bedtime	0.48	**190.46*****	1.01
Earliest bedtime	1.73	**90.10*****	2.49
Latest bedtime	0.06	**9.39****	1.27
Typical wake time	3.41	**41.77*****	2.65
Earliest wake time	0.83	**38.61*****	0.19
Latest wake time	**4.52***	**49.29*****	0.07
Time in bed	3.78	**28.23*****	**4.18***
Sleep onset latency	0.53	3.36	0.08
Total sleep time	**4.22***	**16.88*****	3.24
Within night sleep consistency			
Bedtime variability[a]	3.25	**25.49*****	0.12
Wake time variability[a]	2.51	**5.16***	0.15

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire
[a] Difference between the 'earliest' and 'latest' times;* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 7.9 provides the school versus non-school differences in bedtime, wake time and TST. No significant differences were observed in any of the between night sleep consistency measures.

Table 7.9 Mean (SD) between night sleep consistency estimates for children with OAHI < 0.32 and OAHI0.32 > together with F-test results

Between night sleep consistency (SAPSS-Q)	OAHI < 0.32 (n = 70)		OAHI > 0.32 (n = 44)		*F-test*
	Mean	(SD)	Mean	(SD)	
School/non-school bedtime (min)[a]	42.6	(33.2)	46.2	(31.4)	0.29
School/non-school wake-time (min)[a]	30.9	(36.7)	22.6	(22.8)	1.65
School/non-school total sleep time (min)[a]	34.09	(20.3)	25.7	(4.0)	1.57

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire
[a] Difference between 'typical' school and non-school bed and wake times and total sleep time

Parental concern about snoring

Table 7.10 presents the mean (SD) sleep values according to parental concern about snoring (i.e. snoring considered a problem or not) and Table 7.11 reports the ANOVA results. Bedtimes in general for both groups were later on non-school nights than on school nights. In addition, children spent less TIB and slept for a shorter of period of time during non-school nights than during school nights. The variability of bedtimes and wake times was higher in children whose parents who perceived snoring to be a problem compared to those who did not.

ANOVA analyses revealed a significant main effect of Night with children on non-school compared to school nights having later 'typical' bedtimes (20:53 (35) vs. 20:11(51) hh:mm (min)) later 'earliest' bedtime (20:14 (52) vs. 19:48 (39) hh:mm (min)), later 'latest' bedtimes (21:35 (131) vs. 20:59 (48) hh:mm (min)) and greater difference between 'earliest' vs. 'latest' bedtime (108.5 (8.0) vs. 79.4 (6.6), min (min)), but shorter TIB times (612.6 (15) vs. 643.8 (6.1), min (min)) and shorter TST (589.1 (10) vs. 616.5 (9.3), min (min)).

Only two significant Night by Group interaction effects were observed: 'typical' bedtime and TST. Post-hoc analyses revealed that 'typical' bedtimes were later and TST was shorter on non-school nights in children whose parents reported that snoring was a problem compared to those who did not (Table 7.10). The percentage of children who met recommended guidelines for sleep length in parents who considered snoring a problem compared to those who did not are reported in Table 7.10. Chi-square analyses revealed no significant differences between groups, either during school nights ($\chi^2(1) = 0.52$, $p > 0.05$) or non-school nights ($\chi^2(1) = 2.45$, $p > 0.05$).

Table 7.10 Mean (SD) sleep SAPSS-Q sleep routine and within night sleep consistency parameters and percentage (n/N) of children who met recommended clinical guidelines for sleep length according to whether parents perceive snoring to be problem or not on school and non-school nights

Sleep schedule	School night				Non-school night			
	Not a problem (n = 68)		Problem (n = 13)		Not a problem (n = 68)		Problem (n = 13)	
	Mean	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**
SAPSS-Q								
Typical bedtime (hh:mm (min))	20:12	(36)	20:18	(35)	20:54	(51)	21:30	(46)
Earliest bedtime (hh:mm (min))	19:48	(39)	19:58	(37)	20:17	(52)	20:22	(54)
Latest bedtime (hh:mm (min))	21:01	(48)	21:23	(53)	21:23	(161)	22:27	(67)
Typical wake time (hh:mm (min))	7:01	(29)	7:02	(28)	7:24	(46)	7:31	(64)
Earliest wake time (hh:mm (min))	6:28	(34)	6:34	(57)	6:50	(46)	7:06	(46)
Latest wake time (hh:mm (min))	7:29	(32)	7:36	(27)	8:04	(60)	8:30	(62)
Time in bed (min)	648.9	(36.8)	639.6	(47.3)	629.9	(47.6)	596.3	(47.5)
Sleep onset latency(min)	13.0	(18.7)	12.9	(20.5)	9.5	(16.7)	10.0	(18.5)
Total sleep time (min)	614.3	(62.0)	618.8	(42.8)	599.9	(67.7)	578.4	(53.0)
Within night sleep consistency								
Bedtime variability[a]	74.2	(45.0)	84.6	(38.3)	91.7	(53.6)	125.4	(50.3)
Wake time variability[a]	63.3	(36.9)	65.8	(47.6)	71.1	(44.8)	78.5	(62.3)
Sleep length guidelines	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**
Met recommended amount [b]	78.5	(51/65)	69.2	(9/13)	65.6	(42/64)	41.7	(5/12)

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire

[a] Difference between the 'earliest' and 'latest' times; [b] Denominators vary due to some data were not reported, hence not all variables were calculated; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 7.11 ANOVA results examining the effect of Group (snoring not a problem vs. a problem) and Night (school vs. non-school night) on SAPSS-Q sleep routine and within night sleep consistency parameters

SAPSS-Q Variable	F-test Results		
	Group (Not a problem/Problem)	Night	Group*Night
Typical bedtime	2.77	**130.19*****	**8.65****
Earliest bedtime	0.32	**28.81*****	0.27
Latest bedtime	2.82	3.68	0.90
Typical wake time	0.11	**19.23*****	0.29
Earliest wake time	0.70	**20.48*****	0.62
Latest wake time	1.43	**25.37*****	1.19
Time in bed	3.14	**25.16*****	3.83
Sleep onset latency	0.00	1.93	0.02
Total sleep time	0.21	**19.36*****	**4.34****
Within night sleep consistency			
Bedtime variability[a]	2.65	**24.48*****	3.90
Wake time variability[a]	0.22	1.51	0.08

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire
[a] Difference between the 'earliest' and 'latest' times;* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 7.12 reports the mean (SD) between night differences for patents who considered snoring a problem and those who did not. Parents who considered snoring a problem, compared to those who did not, reported a significantly greater difference in 'typical' bedtimes between school to non-school nights.

Table 7.12 Mean (SD) between night sleep consistency estimates for snoring not a problem versus a problem together with F-test results

Between night sleep consistency (SAPSS-Q)	Not a problem (n = 68)		Problem (n = 13)		*F- test*
	Mean	(SD)	Mean	(SD)	
School/non-school bedtime (min)[a]	43.6	(31.5)	71.1	(37.9)	**7.57***
School/non-school wake-time (min)[a]	25.7	(33.6)	36.2	(36.4)	0.96
School/non-school total sleep time (min)[a]	30.4	(28.4)	45.4	(36.3)	2.58

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire [a] Difference between 'typical' school and non-school bed and wake times
* denotes $p < 0.05$

Sleep diary

Similar to the previous sets of analyses, the following examine the different child classifications on sleep diary parameters. As discussed earlier in this chapter, due to incomplete records a reduced number of children were included in the analyses.

Non-snorers versus snorers

Table 7.13 reports the mean (SD) sleep diary parameters for children who snored compared to non-snorers, and Table 7.14 reports the ANOVA results. Inspection of the sleep diary values suggests that children slept slightly longer on non-school nights than on school nights, but had more consistent bedtimes and wake times.

A significant main effect was observed for Night, with children on school compared to non-school nights having later bedtimes (21:48 (71) vs. 21:05 (61) hh:mm (min)) and longer TIB times (649.7 (5.3) vs. 637.4 (4.7) min (min)), but greater differences between 'earliest' and 'latest' bedtimes (107.4 (7.9) vs. 37.0 (5.2), min (min)) and 'earliest' and 'latest' wake times (70.9 (5.6) vs. 37.0 (4.8), min (min)). No significant main effect was observed for Group. Only one significant Night by Group interaction was observed and this was for 'latest' bedtime, which was later among snorers compared to non-snorers during school nights, but significantly earlier during non-school nights.

Table 7.13 Mean (SD) sleep diary routine parameters according to parental-reported snoring frequency (non-snorer vs. snorer)

Sleep schedule	School night				Non-school night			
	Non-snorer (n = 75)		Snorer (n = 20)		Non-snorer (n = 75)		Snorer (n = 20)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Sleep Diary								
Typical bedtime (hh:mm (min))[a]	20:48	(68)	20:41	(66)	20:42	(62)	20:15	(58)
Earliest bedtime (hh:mm (min))a	20:15	(49)	19:59	(39)	20:24	(43)	20:00	(36)
Latest bedtime (hh:mm (min)) a	21:42	(73)	22:07	(60)	21:16	(64)	20:33	(42)
Typical wake time (hh:mm (min))	7:13	(54)	7:01	(57)	7:14	(55)	6:56	(46)
Earliest wake time (hh:mm (min))	6:51	(40)	6:31	(34)	6:56	(38)	6:47	(33)
Latest wake time (hh:mm (min))	8:03	(65)	(7:40)	(44)	7:31	(54)	7:24	(40)
Wake after sleep time (min)	1.9	(2.9)	6.5	(11.8)	2.1	(3.8)	4.7	(9.0)
Time in bed (min)	638.9	(36.6)	636.0	(45.8)	645.5	(34.4)	653.8	(56.5)
Sleep onset latency (min)	25.2	(17.4)	22.4	(12.8)	29.2	(27.6)	26.3	(25.2)
Total sleep time (min)	604.8	(39.4)	601.4	(36.7)	607.5	(39.6)	613.3	(42.8)
Within night sleep consistency								
Bedtime variability[b]	93.9	(58.9)	121.0	(73.1)	43.0	(44.5)	31.0	(28.5)
Wake time variability[c]	72.1	(45.4)	69.6	(36.1)	37.4	(38.8)	36.5	(32.8)
Sleep length guidelines	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**
Met recommended amount[c]	66.7	(50/75)	60.0	(12/20)	76.0	(57/75)	65.0	(13/20)

[a] (non-snorer, n = 60 and snorer, n = 16); [b] Difference between the 'earliest' and 'latest' times (non-snorers, n = 68 and snorers, n = 20);[c] (non-snorers, n = 71 and snorers, n = 19); * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 7.14 ANOVA results examining the effect of Group (non-snorers vs. snorers) and Night (school vs. non-school night) on sleep diary variables: sleep routine and within night sleep consistency parameters

Sleep Diary variable	F-test Results		
	Group (Non-snorer/Snorer)	Night	Group*Night
Typical bedtime	**5.72****	**4.78****	2.17
Earliest bedtime	2.57	1.05	0.66
Latest bedtime	0.34	**31.38*****	**9.74****
Typical wake time	**7.01****	0.19	0.43
Earliest wake time	2.47	**9.05****	2.86
Latest wake time	1.19	**14.60*****	1.57
Wake after sleep time (min)	**6.73***	2.44	3.87
Time in bed	0.09	**7.93****	1.69
Sleep onset latency	0.29	2.55	0.00
Total sleep time	0.02	2.41	0.93
Within night sleep consistency			
Bedtime variability[a]	0.71	**49.0*****	3.77
Wake time variability[a]	0.0.4	**31.11*****	0.02

Note. [a] Difference between the 'earliest' and 'latest' times;* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Non-snorers, infrequent snorers and frequent snorers

Table 7.15 presents the mean (SD) SAPSS-Q and sleep consistency data, and Table 7.16 presents the ANOVA results. There was a trend for all groups to have more variable bedtimes and wake times on school nights while TIB and TST were both longer on non-school nights. The 'earliest' bedtimes were similar on school and non-school nights, but by contrast the 'latest' bedtimes appeared to be later on school than non-school nights.

ANOVA analyses revealed a significant main effect of Group on typical bedtime, typical wake time and wake after sleep onset. Collapsed across Night, the mean (SD) typical bedtime for non-snorers was 20:33 (123), hh:mm (min), infrequent snorers was 20:32 (180), hh:mm (min) and frequent snorers was 20:27 (160), hh:mm (min). Typical wake time for snorers was 7:19 (51), hh:mm (min); infrequent snorers 7:34 (60), hh:mm (min) and frequent snorers was 7:10 (51), hh:mm (min); while wake after sleep onset for non-snorers was 1.8 (0.8), for infrequent snorers was 2.6 (1.2) and for frequent snorers was 5.6 (1.2), min (min). Post-hoc tests (i.e. Bonferroni correction) revealed that only frequent snorers significantly differed from non-snorers ($p < 0.05$).

A significant main effect for Night was also observed on TIB, 'latest' bedtime, SOL and bedtime variability ('latest' minus 'earliest'). Irrespective of their snoring status, children spent more TIB on non-school compared to school nights (647.1 (4.4) vs. 647.1 (4.5), min (min)) and longer SOL (23.0 (1.8) vs. 27.9 (3.1), min (min)); but earlier 'latest' bedtime

(21:05 (61) vs. 21:48 (71), hh:mm (min)) and higher bedtime variability (103.8 (7.4) vs. 43.2 (4.7), min (min)). A main effect of type of Night on wake time variability ('latest' minus 'earliest') was seen. Wake times were more variable during school nights than non-school nights (mean 73.6 (5.0) vs. 34.9 (4.3), min (min)).

Several significant interaction effects were also observed for the 'latest' bedtime; 'latest' wake time and wake-time variability. Post-hoc analyses revealed that the 'latest' bedtime on school nights was significantly later for both infrequent and frequent snorers compared to non-snorers, while on non-school nights the 'latest' bedtime was significantly earlier for frequent snorers than both non-snorers and infrequent snorers. In addition, a significant interaction effect on wake time variability was found. This result indicated that on school nights infrequent snorers had significantly higher wake time variability ('latest' minus 'earliest') than non-snorers and frequent snorers. However, this variability decreased on non-school nights and both non-snorers and frequent snorers had higher variability compared to infrequent snorers.

Table 7.15 Mean (SD) sleep diary routine parameters according to parental-reported snoring frequency (non-snorer, infrequent snorer and frequent snorer)

Sleep schedule	School night						Non-school night Mean (SD)					
	Non-snorer (n = 54)		Infrequent snorer (n = 21)		Frequent snorer (n = 20)		Non-snorer (n = 54)		Infrequent snorer (n = 21)		Frequent snorer (n = 20)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Sleep Diary												
Typical bedtime (hh:mm (min))	20:41	(75)	21:00	(73)	20:39	(66)	20:35	(57)	20:54	(68)	20:13	(58)
Earliest bedtime (hh:mm (min))[a]	20:10	(44)	20:27	(60)	19:59	(39)	20:25	(44)	20:23	(42)	20:00	(36)
Latest bedtime (hh:mm (min)) a	21:34	(70)	22:02	(78)	22:07	(60)	21:10	(59)	21:29	(73)	20:33	(42)
Typical wake time (hh:mm (min))	7:06	(49)	7:24	(60)	6:59	(57)	7:07	(53)	7:24	(57)	6:53	(46)
Earliest wake time (hh:mm (min))	6:47	(35)	7:01	(51)	6:31	(34)	6:53	(37)	7:02	(41)	6:47	(33)
Latest wake time (hh:mm (min))	7:53	(57)	8:27	(78)	7:40	(44)	7:33	(56)	7:28	(51)	7:24	(40)
Wake after sleep time (min)	1.7	(3.0)	2.5	(2.7)	6.5	(11.8)	1.9	(3.4)	2.7	(4.7)	4.7	(9.0)
Time in bed (min)	639.7	(41.3)	636.9	(21.1)	636.0	(45.8)	647.8	(29.9)	639.6	(44.5)	653.8	(56.5)
Sleep onset latency(min)	27.5	(18.6)	19.1	(12.6)	22.4	(12.8)	29.9	(28.8)	27.2	(24.9)	26.3	(25.2)
Total sleep time (min)	603.7	(42.6)	607.6	(30.4)	601.4	(36..7)	608.2	(39.1)	605.9	(42.0)	613.3	(42.8)
Within night sleep consistency												
Earliest versus latest bedtime (min)[b]	92.3	(57.5)	98.3	(64.3)	121.0	(73.1)	35.3	(39.3)	62.7	(52.7)	31.0	(28.5)
Earliest versus latest wake time (min)[c]	67.7	(42.8)	83.5	(50.9)	69.6	(36.1)	41.6	(42.1)	26.7	(26.8)	36.5	(32.8)
Sleep length guidelines	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**
Met recommended amount[d]	66.7	(36/54)	66.7	(14/21)	60.0	(12/20)	77.8	(42/54)	71.4	(15/21)	65.0	(13/20)

Note. [a] (NS, n = 41; IS, n = 19 and FS, n = 16); [b] Difference between the 'earliest' and 'latest' times (NS, n = 50; IS, n = 18 and FS, n = 20); [c] (NS, n = 51; IS, n = 20 and FS, n = 19)

Table 7.16 ANOVA results examining the effect of Group (non-snorers, infrequent and frequent snorers) and Night (school vs. non-school night) on sleep diary variables: sleep routine and within night sleep consistency parameters

Sleep diary variable	F-test Results		
	Group (non-snorer/infrequent/ snorer)	Night	Group*Night
Typical bedtime	**6.11****	3.73	1.06
Earliest bedtime	1.46	0.77	2.27
Latest bedtime	1.45	**27.42*****	**4.89***
Typical wake time	**8.43*****	0.11	0.19
Earliest wake time	1.97	6.01*	1.71
Latest wake time	1.18	**35.70*****	**5.99****
Wake after sleep time (min)	**3.49***	0.97	1.92
Time in bed (min)	0.23	5.80*	1.02
Sleep onset latency(min)	0.71	4.60*	0.63
Total sleep time (min)	0.01	1.31	0.67
Within night sleep consistency			
Bedtime variability[a]	1.83	**42.13*****	2.34
Wake time variability[a]	0.02	**52.7*****	**3.24****

Note. [a] Difference between the 'earliest' and 'latest' times; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Classification based on Obstructive Apnoea-Hypopnoea Index status

Table 7.17 presents the mean (SD) SAPSS-Q and sleep consistency data, and Table 7.18 presents ANOVA results. There was a trend for all groups to have slightly more later bedtimes on school nights; however, there was also a trend for children with OAHI > 0.32 to have later typical bedtimes than children with OAHI < 0.32. While TST was similar between Groups and across Nights, TIB was reduced and sleep onset was prolonged during non-school nights. The 'earliest' bedtimes were similar on school and non-school nights between groups, but the 'latest' bedtimes and wake times appeared to be later on school than non-school nights.

A significant main effect of Group on 'typical bedtime' revealed that children with OAHI > 0.32 had a later bedtime (20:55 (70), hh:mm (min)) compared to children with an OAHI < 0.32 (20:41 (62), hh:mm (min)). There was also a significant main effect of Group on TIB, indicating that children with an OAHI > 0.32 spent less TIB (635.2 (5.6), min (min)) than children with an OAHI < 0.32 (649.7 (4.4), min (min)).

In addition, a significant main effect of Night was found on TIB. Children spent less TIB during non-school nights than during school nights (647.8 (4.0) vs.637.1 (3.8), min (min)). Likewise, there was a main effect of Night on SOL, bedtime variability and wake time

variability. Irrespective of the condition of the children, they had prolonged sleep latency on non-school nights (24.2 (1.6) vs. 29.1 (2.9), min (min)), but increased variability for bedtimes (103.6 (6.5) vs. 40.7 (4.3), min (min)) and for wake times during school nights (71.8 (4.5) vs. 38.1 (3.8), min (min)). Finally, a significant main effect Night on the ‘latest’ bedtime revealed that during school nights the ‘latest’ bedtime was significantly later compared to non-school nights (21:48 (71) vs. 21:05 (61), hh:mm (min)).

Table 7.17 Mean (SD) sleep diary routine parameters according to OAHI level (OAHI < 0.32 vs. OAHI > 0.32)

Sleep schedule	School night				Non-school night			
	OAHI < 0.32 (n = 61)		OAHI > 0.32 (n = 39)		OAHI < 0.32 (n = 61)		OAHI > 0.32 (n = 39)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Sleep diary								
Typical bedtime (hh:mm (min))[a]	20:38	(66)	20:55	(68)	20:31	(55)	20:36	(67)
Earliest bedtime (hh:mm (min))[a]	20:08	(44)	20:15	(50)	20:19	(40)	20:17	(46)
Latest bedtime (hh:mm (min)) a	21:40	(69)	22:01	(73)	21:08	(54)	21:01	(72)
Typical wake time (hh:mm (min))	7:12	(51)	7:12	(59)	7:12	(43)	7:07	(63)
Earliest wake time (hh:mm (min))	6:52	(38)	6:43	(43)	6:58	(39)	6:51	(34)
Latest wake time (hh:mm (min))	8:05	(62)	7:52	(62)	7:31	(46)	7:31	(59)
Wake after sleep time (min)	2.4	(3.9)	3.4	(8.4)	1.9	(3.5)	3.6	(7.1)
Time in bed (min)	646.2	(35.1)	628.0	(41.4)	653.2	(30.9)	642.4	(50.5)
Sleep onset latency(min)	27.2	(16.5)	21.2	(16.1)	30.8	(29.4)	27.3	(25.7)
Total sleep time (min)	608.9	(41.9)	598.1	(33.1)	613.9	(34.5)	602.8	(46.9)
Within night sleep consistency								
Bedtime variability[b]	91.9	(53.9)	115.2	(72.1)	42.5	(42.6)	38.8	(39.4)
Wake time variability[c]	72.0	(44.7)	71.7	(41.0)	33.5	(31.2)	42.7	(43.7)
Sleep length guidelines	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**
Met recommended amount [b]	65.5	(40/61)	64.1	(25/39)	78.7	(48/61)	66.7	(26/39)

Note. OAHI = Obstructive Apnoea-Hypopnoea Index

[a] (OAHI < 0.32, n = 50 and OAHI > 0.32, n = 31); [b] Difference between the 'earliest' and 'latest' times (OAHI < 0.32, n = 54 and OAHI > 0.32, n = 38); [c] (OAHI < 0.32, n = 57 and OAHI > 0.32, n = 37);* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 7.18 ANOVA results examining the effect of Group (OAHI < 0.32 vs. OAHI > 0.32) and Night (school vs. non-school night) on sleep diary variables: sleep routine and within night sleep consistency parameters

Sleep diary variable	F-test Results		
	Group (OAHI < 0.32/OAHI > 0.32)	Night	Group*Night
Typical bedtime	**4.28****	**4.85****	0.99
Earliest bedtime	0.06	2.29	1.27
Latest bedtime	0.39	**25.24*****	2.30
Typical wake time	0.28	0.12	0.28
Earliest wake time	0.98	5.85*	0.02
Latest wake time	0.38	**29.94*****	1.68
Wake after sleep time (min)	1.55	0.17	0.64
Time in bed	**4.14***	**9.18****	1.11
Sleep onset latency	1.26	**5.73***	0.38
Total sleep time	2.37	1.64	0.00
Within night sleep consistency			
Bedtime variability[a]	1.71	**57.3*****	2.65
Wake time variability[a]	0.41	**47.54*****	0.92

Note. Obstructive Apnoea-Hypopnoea Index
[a] Difference between the 'earliest' and 'latest' times;* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Parental concern about snoring

Table 7.19 presents the mean (SD) SAPSS-Q and sleep consistency data, and Table 7.20 reports ANOVA results. Groups in general seemed to have similar sleep schedules during both school and non-school nights. However, a greater bedtime variability (latest minus earliest) was noted for children whose parents considered snoring a problematic sleep behaviour, particularly during school nights. This difference, however, was not observed on non-school nights (Table 7.19).

There were no main effects on any of the sleep schedule variables. In contrast, ANOVA results revealed a significant main effect of Night on the 'latest' bedtime and wake time. There was also a significant main effect of Night on bedtime and wake time variability. The 'latest' bedtime was significantly later during school nights than during non-school nights (mean 21:48 (71) vs. 21:05 (61), hh:mm (min)). Similarly, during school nights, bedtimes (109.4 (9.9) vs. 41.3 (7.3), min (min)) and wake times (67.7 (7.0) vs. 31.9 (6.8), min (min)) were more variable compared to non-school nights (Table 7.20).

Table 7.19 Mean (SD) sleep diary routine parameters according to parental perception of snoring (not concerned vs. concerned)

Sleep schedule	School night				Non-school night Mean (SD)			
	Not a problem (n = 55)		Problem (n = 11)		Not a problem (n = 55)		Problem (n = 11)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Sleep diary								
Typical bedtime (hh:mm (min))[a]	20:45	(67)	21:00	(71)	20:39	(63)	20:49	(52)
Earliest bedtime (hh:mm (min))[a]	20:16	(48)	19:56	(36)	20:21	(42)	20:03	(34)
Latest bedtime (hh:mm (min))[a]	21:35	(65)	22:10	(65)	21:09	(62)	20:57	(39)
Typical wake time (hh:mm (min))	7:13	(51)	7:26	(68)	7:17	(54)	7:13	(45)
Earliest wake time (hh:mm (min))	6:48	(42)	6:40	(33)	6:50	(38)	6:54	(34)
Latest wake time (hh:mm (min))	7:52	(58)	7:53	(78)	7:28	(58)	7:20	(45)
Wake after sleep time (min)	3.9	(7.6)	4.1	(6.1)	2.3	(5.8)	4.8	(6.8)
Time in bed (min)	636.8	(37.1)	636.2	(32.5)	647.3	(631.2)	631.2	(44.4)
Sleep onset latency(min)	21.1	(16.2)	21.9	(14.1)	24.7	(21.4)	22.4	(15.1)
Total sleep time (min)	603.0	(38.2)	599.8	(36.5)	610.1	(41.0)	601.2	(36.4)
Within night sleep consistency								
Bedtime variability[b]	87.8	(51.8)	131.1	(73.0)	44.9	(42.7)	37.7	(26.2)
Wake time variability[c]	64.6	(36.1)	70.8	(52.6)	37.8	(39.9)	26.1	(23.2)
Sleep length guidelines	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**	**%**	**(n/N)**
Met recommended amount[d]	65.5	(36/55)	54.5	(6/11)	810.0	(44/55)	54.5	(6/11)

Note. [a] (snoring not a problem, n = 46 and snoring a problem, n = 9); [b] Difference between the 'earliest' and 'latest' times (snoring not a problem, n = 52 and snoring a problem, n = 9); * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 7.20 ANOVA results examining the effect of Group (snoring not a problem vs. a problem) and Night (school vs. non-school night) on sleep diary variables: sleep routine and within night sleep consistency parameters

Sleep diary variable	F-test Results		
	Group (Not a problem/Problem)	Night	Group*Night
Typical bedtime	1.63	0.87	0.06
Earliest bedtime	1.29	0.68	0.04
Latest bedtime	0.34	**14.36*****	3.36
Typical wake time	0.43	0.28	1.15
Earliest wake time	0.03	2.67	1.55
Latest wake time	0.03	**12.75****	0.30
Wake after sleep time (min)	0.35	0.38	3.01
Time in bed	0.53	0.24	1.93
Sleep onset latency	0.11	0.12	0.04
Total sleep time	0.27	0.53	0.22
Within night sleep consistency			
Bedtime variability[a]	2.75	**24.5*****	3.36
Wake time variability[a]	0.05	**20.91*****	1.32

Note. [a] Difference between the 'earliest' and 'latest' times;* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Correlations between sleep routine variables and behaviour or neurocognitive variables

Table 7.21 presents the relationship between sleep schedule variables from the SAPSS-Q and CBCL scale scores. Of particular note is that TIB, shift in school to non-school bedtime and TST were the sleep variables most frequently correlated with behavioural variables. A shorter TIB on non-school nights was associated with higher Social and Affective Problems scores; a shorter TST on non-school nights associated with higher Affective Problems; a greater shift in school to non-school bedtimes was associated with higher Social and Affective Problems scores; and finally, longer SOL times on school nights was associated with a higher frequency of Somatic Complaints. Several other statistically associations were observed, but these were small in magnitude.

Table 7.22 presents the relationships between sleep schedule variables (SAPSS-Q) and neurocognitive domain scores. Only two significant but small in magnitude correlations were observed, and these can be explained by chance (sleep onset time and Verbal Ability, and the shift from school to non-school bedtimes and Memory).

Table 7.21 Correlations between sleep/wake patterns (SAPSS-Q) and Child Behavior Checklist syndrome, competence and DSM-oriented scales for the total sample

SAPSS-Q Variable	Syndrome scales								Competence scales				DSM-oriented scales				
	Anxious/ Depression	Somatic complaints	Social	Thought	Attention	Aggressive	Internal	External	Total	Activities	School	Social	Affective	Anxious	Somatic	ADHD	Oppositional	Conduct
Time in bed																		
School	–.05	**.22***	–.03	–.02	.14	.12	.07	.12	.09	.14	**–.24***	–.00	–.04	–.03	**.25***	.13	.16	.07
Non-school	**–.20***	–.01	**–.28****	–.17	–.15	–.14	–.15	–.16	–.21*	.05	–.047	.05	**–.30****	**–.21***	.04	–.15	–.15	–.07
Total sleep time																		
School	–.07	–.05	–.10	–.17	.02	–.03	–.11	–.04	–.08	**.19***	–.07	.00	**–.21***	–.11	.02	.01	–.04	–.01
Non-school	–.18	–.13	**–.22***	**–.20***	–.11	–.16	**–.21***	–.18	**–.22***	.15	–.01	–.01	**–.32****	**–.23***	–.05	–.12	**–.21***	–.04
Sleep onset																		
School	–.08	**.29****	.00	–.06	.11	–.00	.10	.01	.06	.06	–.12	.03	–.00	–.11	**.22***	.09	.02	–.01
Non-school	–.25*	.14	**–.20***	–.12	–.04	–.08	–.08	–.04	–.07	–.08	–.04	.10	–.14	**–.21***	.18	–.06	–.02	–.03
Bedtime variability																		
School	.09	.08	.09	–.04	–.03	.06	.03	.10	.06	–.01	.05	–.18	.04	.01	.08	.04	–.02	.13
Non-school	.14	.18	**.24***	.10	.06	.16	.12	.15	.17	.05	–.04	–.11	.08	.11	.17	.06	.04	**.21***
Wake time variability																		
School	.00	–.06	.04	.05	–.02	.13	–.02	.14	.05	.06	.03		.02	.04	–.07	.01	.07	.14
Non-school	–.04	–.03	.02	.04	.01	.05	–.07	–.01	.00	.14	.07		.01	–.06	.03	.09	–.05	.16
School/Non-school shift																		
Bedtime	.17	**.22***	**.28****	**.23***	.14	.11	**.22***	.10	.19	–.00	–.17	–.12	**.36****	.16	**.21***	.17	.09	.03
Wake time	–.02	.07	–.02	–.00	–.03	–.17	–.00	–.19	–.10	.03	.00	–.09	–.02	–.07	.12	–.01	**–.21***	–.05

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire; ADHD = attention deficit hyperactivity disorder
* denotes $p < 0.05$, ** $p < 0.01$; Effect size (r): small = .10; medium = .30; large = .50

Table 7.22 Correlations between sleep/wake patterns (SAPSS-Q) and neurocognitive domains for the total sample

SAPSS-Q Variable	Differential Ability Scale				Developmental Neuropsychological Assessment		
	Verbal Ability	Non-verbal reasoning ability	Spatial Ability	General Cognitive Ability	Attention Executive Functioning	Language	Memory
Time in bed							
School	.08	–.04	.06	.03	.08	–.05	–.09
Non-school	.10	.04	.05	.08	.06	–.07	.03
Total sleep time							
School	.04	–.05	.04	.03	.04	–.12	–.13
Non-school	.10	.01	–.00	.07	.06	–.14	.01
Sleep onset							
School	**.21***	.03	.11	.15	–.03	–.08	.06
Non-school	.11	.04	.15	.11	–.11	–.08	–.03
Bedtime variability							
School	–.10	–.12	.02	–.08	–.09	–.06	–.02
Non-school	–.15	–.15	–.01	–.12	–.02	–.08	–.04
Wake time variability							
School	–.07	–.17	.00	–.10	.01	–.00	–.09
Non-school	–.10	–.15	.02	–.08	–.11	–.06	–.02
School/Non-school shift							
Bedtime	–.16	–.12	–.19	–.16	–.09	–.05	**–.21***
Wake time	–.03	.01	–.14	–.00	–.02	–.15	–.05

Note. SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire

* denotes $p < 0.05$, ** $p < 0.01$; Effect size (r): small = .10; medium = .30; large = .50

Table 7.23 presents the relationship between sleep schedule variables from the sleep diary and CBCL scale scores. Most of the sleep schedule variables drawn from the sleep diary were frequently correlated with behavioural variables, particularly bedtime consistency, sleep onset, TST and to a lesser extent TIB. In contrast, wake time variability was not associated with any behavioural scale.

Medium in magnitude, higher bedtime variability during school nights was associated with increased Attention Problems and ADHD scores from the CBCL. Higher variability was also associated with increased Social and Thought Problems scores; however these were small in magnitude.

In addition, a shorter TST was associated with increased scores for several problematic scales (e.g. Anxious/Depressed, Aggressive, Affective and External Problems), particularly during school nights. In contrast, higher SOL was associated with increased scores for numerous problematic scales during both school and non-school nights (e.g. Somatic Complaints, Attention, Internal and Affective Problems). However, the majority of these associations were small in magnitude. Finally, shorter TIB was correlated with increased Social Problems scores, while a longer TIB was associated with higher scores on the Social Competence scale.

Table 7.23 presents the relationships between sleep schedule variables (sleep diary) and neurocognitive domain scores. Similar to the pattern seen for the SAPSS-Q, a few correlations were seen between sleep schedule variables and neurocognitive domains. Higher bedtime and wake time variability was associated with Memory and Verbal domains respectively. Despite this association, the magnitudes of the correlations were small.

Table 7.23 Correlations between sleep/wake patterns (sleep diary) and Child Behavior Checklist syndrome, competence and DSM-oriented scales for the combined sample

Sleep diary variable	Syndrome scales									Competence scales				DSM-oriented scales				
	Anxious/ Depression	Somatic complaints	Social	Thought	Attention	Aggressive	Internal	External	Total	Activities	School	Social	Affective	Anxious	Somatic	ADHD	Oppositional	Conduct
Time in bed																		
School	–.08	.05	**–.13****	–.03	–.05	–.08	–.00	–.09	–.05	–.01	.07	**.12***	–.03	–.01	.04	–.02	–.06	–.06
Non-school	.00	.09	–.09	.07	–.03	–.05	.04	–.09	–.04	.01	–.01	.13	.02	.04	.04	.01	–.12	–.09
Total sleep time																		
School	**–.12***	–.03	**–.10***	**–.10***	–.06	**–.12***	–.08	**–.10***	–.08	–.00	.04	.04	**–.12***	–.02	–.04	–.05	**–.11***	–.04
Non-school	–.09	–.05	–.08	–.08	–.03	–.06	–.06	–.07	–.08	.01	–.06	.06	–.12	–.01	–.08	–.01	**–.17***	.01
Sleep onset																		
School	**.10***	**.14****	–.01	**.13****	**.10***	.05	**.13****	.03	.07	–.08	.03	.02	**.12***	.08	**.17****	.08	.08	–.03
Non-school	.09	**.20***	–.02	**.20***	.02	–.01	.14	–.02	.05	–.05	.07	–.01	**.20***	.04	**.21****	.06	.07	**–.15***
Bedtime variability																		
School	.14	.18	**.25***	**.24***	**.32****	.05	.12	.08	.19	–.04	**–34****	–.20	.11	.12	**.23***	**.35****	–.01	.03
Non-school	.01	–.08	–.01	.00	–.07	.03	–.01	.12	.05	.09	–.02	–.06	.08	.01	–.04	–.11	.04	.16
Wake time variability																		
School	–.03	.06	.04	.07	.06	–.03	.03	.02	.05	–.02	–.03	–.01	.19	–.09	.03	.13	.01	.01
Non-school	–.08	–.01	–.01	.00	.03	–.09	–.12	–.11	–.12	**.22***	–.01	.04	–.02	–.09	.01	.03	–.10	–.10

Note. * denotes $p < 0.05$, ** $p < 0.01$; Effect size (r): small = .10; medium = .30; large = .50

Table 7.24 Correlations between sleep/wake patterns (sleep diary) and neurocognitive domains for the total sample

Sleep diary variable	Differential Ability Scale				Developmental Neuropsychological Assessment		
	Verbal Ability	Non-verbal reasoning ability	Spatial Ability	General Cognitive Ability	Attention Executive Functioning	Language	Memory
Time in bed							
School	.06	–.01	.04	.01	.07	–.05	–.01
Non-school	–.04	–.01	–.04	–.04	.02	–.06	–.01
Total sleep time							
School	.06	–.03	.03	.01	.06	–.07	–.04
Non-school	.01	.01	.03	.03	.08	–.08	–.05
Sleep onset							
School	.07	.02	–.03	.01	.00	.08	.06
Non-school	–.06	.02	–.14	–.10	–.06	.08	.08
Bedtime variability							
School	–.15	–.01	–.07	–.11	–.19	–.11	**–.21***
Non-school	–.09	–.16	–.03	–.12	–.05	–.07	**–.23***
Wake time variability							
School	**–.21***	.12	.00	–.06	–.01	–.09	–.09
Non-school	–.08	–.05	–.04	–.11	–.20	–.18	–.12

Note. * denotes $p < 0.05$, ** $p < 0.01$; Effect size (r): small = .10; medium = .30; large = .50

7.4. Discussion

In this study, sleep routine on questionnaire and diary was examined in non-snoring and snoring children recruited from the community. In general, only a few differences were observed—mostly related to typical bedtimes, and to a lesser extent the variability in the timing of sleep on school compared to non-school nights. The impact of different classification criteria for 'snoring' on sleep routine estimates was also explored. Overall, and regardless of how children were classified, only a few differences were observed between groups in sleep routine and sleep quality both on sleep diary and sleep questionnaire.

The two key sleep routine parameters examined in the present study were the variability in typical bedtimes and wake times (non-school minus school night difference; earliest minus latest school night values; and earliest minus latest non-school night values). These measures were examined using both questionnaire and sleep diary. Apart from one exception, no significant differences were found between children when classified according to snorers/non-snorers, OAHI and non-snorers/infrequent/frequent snorers. The one exception was in the comparisons involving the classification of children according to parental report of snoring (non-snorers vs. snorers), where on questionnaire children classified as snorers had a greater variability in typical bedtimes.

The two key variables used to examine sleep length in the present study were TST and TIB; additional measures of sleep quality such as SOL, WASO and latest and earliest betimes and wake times were also examined. In general, and regardless of the criteria used to define the children, few group differences were observed in either sleep length or the additional sleep quality measures. The only exceptions of note were that on sleep questionnaire but not diary children with OAHI > 0.32 reported a shorter TST and earlier 'latest' wake times, while on sleep diary children who snored on parental report reported longer WASO and later typical wake times. These findings may raise some questions regarding objective versus subjective definitions. The two definitions may not be completely comparable, because one relies on PSG physiological results; while the other relies on parental perception.

Previous studies have reported that irregular sleep routines and short sleep are both associated with problematic behaviour (Gruber et al., 2012; Paavonen et al., 2009; Pesonen et al., 2010). In the present study only a few associations were observed between sleep routine and daytime behaviour. In addition, neither the number nor magnitudes of the

associations were more evident in those correlations involving sleep routine versus sleep length. These trends were evident for both sleep questionnaire and sleep diary data. The only exceptions of note were that on questionnaire greater bedtime variability (school vs. non-school nights) was associated with increased complaints of social and affective problems, and shorter TST on non-school nights was associated with more affective, anxiety and oppositional complaints; while on sleep diary greater bedtime variability on school nights was associated with increased attentional and ADHD problems. Having a regular routine is a synonym of adequate sleep hygiene; which is important for children because it could give them a sense of security by decreasing anxiety during bedtime. Also, it provides the opportunity to reinforce appropriate bedtime behaviours in the child and train underlying circadian rhythms (Galland & Mitchell, 2010). Similar findings have been previously described among both healthy children and those with behavioural difficulties. On one hand, Witcher et al. (2012) in their examination of the relationship between sleep hygiene and problematic behaviours in children with reports of habitual snoring and non-snorers, found that an inconsistent bedtime routine was correlated with increased hyperactivity-impulsivity related behaviours and problematic behaviours in general. In contrast, Gruber et al. (2000) in their examination of children with ADHD who were assessed during five consecutive nights through actigraphy monitoring, found that sleep onset time and length of sleep were more variable across the nights compared to the control group. In the frame of the current study, only children who did not have a diagnosis of behavioural problems were included. Inconsistent sleep schedules, therefore, may be a result of the variable set bedtimes usually determined by parents. Komada et al. (2009) propose that an irregular sleep routine by parents is associated with increased sleep problems in their children, as well as daytime tiredness. Because children included in this study are in the school-age years, it would be reasonable to expect that parents influence their sleep habits. However, parent's sleep routines were not assessed in this study.

To date, this study is the first to explore the relationship between sleep routine and neurocognition in objectively assessed children who snore. In contrast to the findings examining the relationship between sleep and behavioural complaints, only a few significant, albeit weak, associations were found between sleep and neurocognitive performance. Poor sleep routine was associated with reduced verbal ability and memory performance. Interestingly, in the sleep literature there is a variety of evidence that links these cognitive areas with the sleep process itself, and so deficits in these domains are perhaps not surprising (Bonnet & Arand, 2003; Siegel, 2001, 2005; Walker, 2008).

A limitation of the present study, however, is that sleep was assessed using self-report (diary and questionnaire); in future research it would desirable to include more objective measures (e.g. actigraphy monitoring) in conjunction with subjective reports in order to assess more precisely sleep and wake patterns in children who snore, moreover, to control for any potential bias in parental reporting, which may tend to overstate sleep problems in children with behavioural problems.

Conclusion

There is emerging evidence that children are sleeping less than they might have in the past (Dollman et al., 2007; Spilsbury et al., 2004). This assumption raises the question as to whether children who snore might be at greater risk of shorter sleep. Based on recommended clinical guidelines for sleep length it was found that regardless of how children were classified, about a fifth of the total sample slept less than the recommended time during school nights and one-third on non-school nights. Based on the literature, the consequences of reduced sleep length on daytime functioning include an impact on neurocognitive functioning (Gruber et al., 2011) and an increased frequency of problematic behaviour (Paavonen et al., 2009). This association is supported by findings in the current study, which show that a decreased sleep time was associated with increased scores in a number of problematic behaviour scales.

Consistent with previous research, a relationship between sleep inconsistency and increased problematic behaviour was found. The occurrence of both upper airway obstruction and a poor sleep routine may increase the risk for daytime difficulties, such as problematic behaviour. These findings need to be explored in further detail in order to understand whether upper airway obstruction, hence snoring, is directly related to behavioural problems or indirectly through sleep inconsistency; which potentially may increase parental awareness of disruptive behaviours Table 7.1.

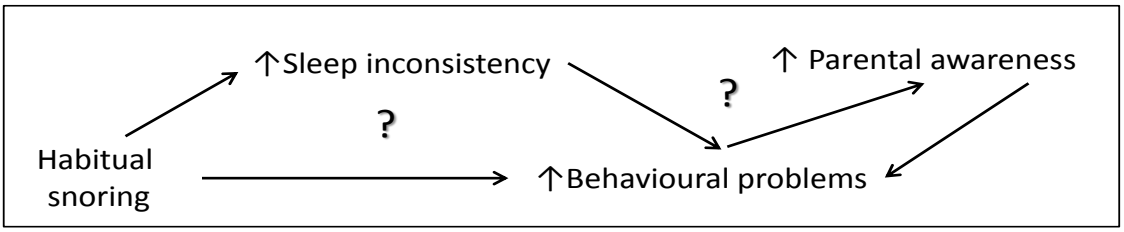


Figure 7.1 Association between level of obstruction (Obstructive Apnoea-Hypopnoea Index), hence snoring; sleep routine and increased complaints of behavioural problems

Chapter 8 Natural history of reported snoring in school-age children and associated daytime performance

8.1. Introduction

There is accumulating evidence that children who snore are at greater risk of neurocognitive and behavioural deficits, and snoring has thus become a focus of interest amongst researchers and practitioners. Many of these associations are cross-sectional in nature, and it is unclear whether a child who snores at time one is likely to snore at time two. This change in status is important because treatment is often predicated on a history of snoring, but if snoring naturally resolves by itself then it may be better to wait rather than intervene. However, there is limited research investigating the consequences of PS if left untreated in the general community.

To date, seven studies have investigated the natural history of snoring in children drawn from community settings (See Table 1.6 from Chapter 1). Snoring has been commonly assessed by parental report of symptoms including frequency and loudness of the snoring. Only three studies used objective measures to confirm SDB status—Li et al. (2013) performed a full PSG with EOG, bilateral EMG (submental and legs), and ECG, respiratory airflow, respiratory effort and arterial oxyhemoglobin saturation, while Anuntaseree et al. (2005) collected PSG only for a reduced number of snorers, and Löfstrand-Tideström and Hultcrantz (2007) undertook limited PSG (modified PSG protocol consisting of oxymetry, position sensor, thermistors for nose and mouth and an electrostatic mattress). Of studies which relied on parental report, the majority report that snoring resolves with half or more of the children who snore at time one having stopped snoring at time two over time lengths ranging from one to 6.7 years (Ali et al., 1994; Anuntaseree et al., 2005; Bonuck et al., 2011; Löfstrand-Tideström & Hultcrantz, 2007; Piteo, Lushington, Roberts, Martin, et al., 2011; Urschitz et al., 2004). In contrast, Li et al. (2013), in the only study to have reliably documented SDB with PSG, report a more conservative rate of resolution; that only 26% of the cases improve after a four-year interval. Six studies which examined the natural history of snoring also report the frequency with which cases appear de novo, and the frequency with which mild has progressed to severe SDB. Three studies which have relied on parental report to obtain a history of snoring report that 4%–9% of children who snore progress to moderate/severe levels of snoring. Despite reports of a worsening condition, it was not possible to

corroborate deterioration in their SDB status due to the lack of PSG evaluation in two of the studies (Anuntaseree et al., 2005; Urschitz et al., 2004). Again, and contrary to the latter findings, Li et al. (2013) report that the severity of SDB increased in a higher percentage of children, with 37% of children progressing to OSAS. Recent research (Marcus et al., 2013) investigating the effects of adenotonsillectomy in children with mild OSAS (OAI ≥ 1 or AHI > 2), randomly left untreated 203 children for a period of seven months. At follow-up it was found that 46% of participants had improved (i.e. OAI <1 or AHI < 2). The authors found that being non-obese and from a non-black ethnic group was associated with OSAS improvement. Although objective techniques were used to assess SDB, Marcus et al study did not report any information regarding snoring frequency. Such information is relevant because even if children improved SDB status on PSG, some of them could have continue snoring; hence they could have been classified as having PS. To date, the limited data available suggests that the natural history of snoring is highly variable and that parental report and PSG evaluations of the natural history of snoring may not be consistent.

A further issue is that little attention has been paid to the long-term consequences of snoring on daytime functioning when this condition is left untreated. While a number of studies have examined the long-term consequences of SDB after surgical treatment (Chervin et al., 2006; Friedman et al., 2003; Hogan, Hill, Harrison, & Kirkham, 2008; Kohler, Lushington, et al., 2009; Wei et al., 2007), only two studies have examined the impact of untreated snoring on later cognitive development (Ali et al., 1994; Piteo, Lushington, Roberts, Martin, et al., 2011). The latter studies report, on one hand, that decreased cognitive development remains after 12 months of initial assessment in children who are reported to snore soon after birth (Piteo, Lushington, Roberts, Martin, et al., 2011), and on the other, decreased sleepiness is associated with the improvement of snoring (Ali et al., 1994). Additional data in children with mild OSAS (Marcus et al., 2013) evaluated neurocognitive and behavioural performance after seven months of a watchful waiting group and adenotonsillectomy group. Results at follow-up indicated that attention and executive functioning (measured by NEPSY) improved in both groups, but did not differ between the two. Moreover, no changes were found for generalised intellectual functioning (measured using DAS) in any group. Based on these limited data, it is not clear whether the resolution of snoring objectively assessed with PSG is accompanied by a resolution of any daytime deficits.

To better address the limitations described above, the aim of this study was to examine the natural history of snoring and its association with neurocognitive and behavioural functioning over a two-year period: baseline and 24-month follow-up (including parental-reported sleep parameters, PSG and neurocognitive and behavioural testing) and 12-month assessment of parental-reported sleep parameters.

8.2. Methods

Participants and procedure

This study involves data from Phase 2 (baseline), Phase 3 (12-month follow-up) and Phase 4 (24-month follow-up) of a large project which at Phase 1 examined sleep/wake patterns in children from South Australia (Biggs, 2009). The general description of the methodology used in this study is described in Chapter 2. In brief, similar assessment was conducted on Phases 2 and 4 including neurocognitive, behavioural and objective sleep measures (PSG). In Phase 3 an additional assessment of snoring status was conducted through an abbreviated version of the SAPSS-Q, as well as behavioural assessment through a behaviour checklist.

Detailed information of Phase 2 (baseline) has been previously described in Chapter 3. A sample of 116 was included in the Phase 2 analysis. Then, an abbreviated version of the SAPSS-Q was posted to each child with a reply-paid envelope (Phase 3). If parents failed to return the questionnaire, a reminder letter was sent with a new copy of the questionnaire. If parents failed again to return the questionnaire, they were contacted via telephone in order to verify the address to send the questionnaire. A total of 84 children returned completed questionnaires. In Phase 4 a higher number of children attended assessment sessions, so this sample was bigger compared to Phase 3. Children who underwent final assessment, but who had incomplete or no data (questionnaire) in the previous phase were still included in this analysis.

Children and parents were contacted for final assessment and were scheduled to undergo a neurocognitive testing session and a repeated full-night sleep study. After Phase 2, one child underwent adenotonsillectomy and 12 children declined to participate in the final assessment. In total, 103 children underwent PSG at the Sleep Disorders Unit, Women's and Children's Hospital in Adelaide, South Australia. From these children, two were found to have SDB (OAHI $\geq$ 1); hence, they were excluded from this analysis. Data from a final sample of 101 children at Phase 4 were incorporated in this study (Figure 8.1).

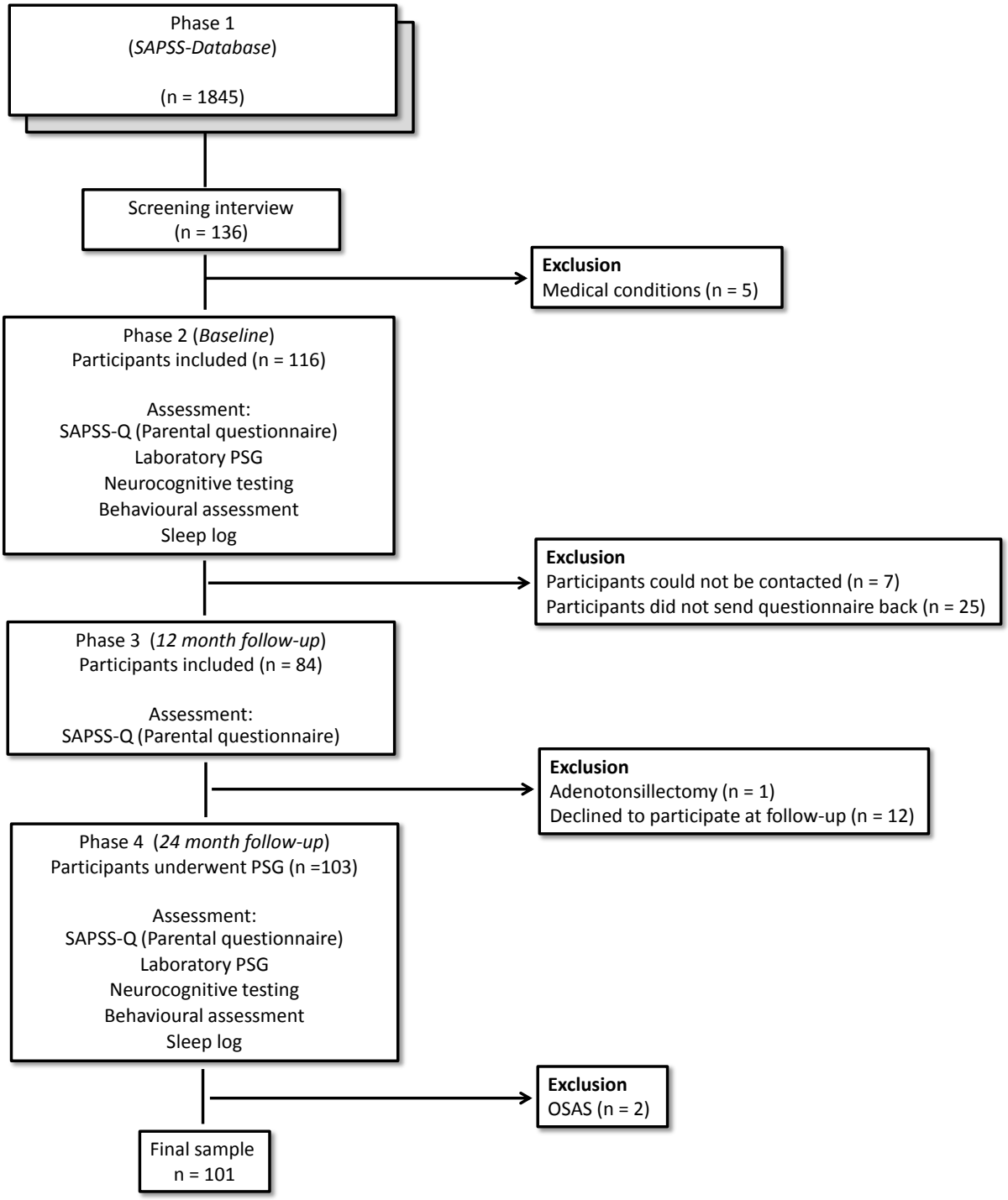


Figure 8.1 Participants and procedure of the study (Phases 2 to 4 included in this analysis)

Note. SAPSS = South Australian Paediatric Sleep Survey Database, SAPSS-Q = South Australian Paediatric Sleep Survey Database Questionnaire; OSAS = obstructive sleep apnoea syndrome

Materials

Snoring frequency, co-morbid sleep problems, sleep, neurocognitive functioning and behavioural performance were assessed in this study. Materials (see Chapter 2 for a detailed description of these materials) included a parental-report questionnaire (SAPSS-

Q), PSG, standardised neurocognitive tests including the NEPSY and the DAS and behavioural performance using the CBCL/6-18.

Data analysis

Consistent with the classification used in previous chapters, children were divided according two indicators—either parental-reported severity of snoring or the level of obstruction according to the OAHI (OAHI < 0.32 or OAHI > 0.32). In the first set of analyses, children were classified into two groups according to parental-reported snoring frequency: non-snorers (never snoring or 1/week) and snorers (snoring ≥ 2 nights). In the second set of analyses, children were classified according to OAHI. Regardless of the snoring status, children were also divided according to the level of obstruction at each assessment point with the mean score at baseline used to define OAHI status: OAHI < 0.32 and OAHI > 0.32.

Statistical analysis

Prior to analyses, variables were examined for accuracy of data entry and missing values. Tests for this particular section were conducted by a senior statistician (TS) using statistical package SAS version 9.3 (SAS Institute Inc., Cary, NC, USA). McNemar tests were used to test for changes in the proportion of children snoring (parental or technician report) over time, as well as changes of the OAHI status (low or high). Due to the nature of the data, linear mixed effects models were used to compare changes in outcomes (neurocognition, behaviour, PSG variables and co-morbid sleep problems) over time between non-snorers and snorers, or between OAHI < 0.32 and OAHI > 0.32 groups at baseline. In the model 'group' (non-snorer/snorer or OAHI < 0.32/OAHI > 0.32), 'time' (baseline, 12-month follow-up and 24-month follow-up) and the interaction between 'group' and 'time' were fitted as fixed effects, while 'child' was fitted as a random effect. When the interaction between 'group' and 'time' was not statistically significant, a second model excluding the interaction term was fitted so that the main effects of 'group' and 'time' could be interpreted. Where the outcome was not age standardised, age was included as a covariate in the model, to control for any age-related differences in the scale (PSG outcomes). Because of the use of linear mixed models, data are presented as estimated mean (SE) followed by F-test results. Finally, the relationships between the change in OAHI classification (i.e. OAHI at baseline was subtracted from the OAHI 24-month follow-up) and the change in neurocognitive and behavioural outcomes (scores at baseline were subtracted from scores at 24-month follow-up) were assessed using Pearson product-moment correlation coefficients. Additionally, a sub-analysis using ANOVA was

performed according to the change on OAHI classification from baseline to 24-month follow-up. The correlational and ANOVA analyses were conducted using the statistical package SPSS for windows version 21.

8.3. Results

Natural history of snoring

Changes in snoring status (parental self-report)

Analyses between baseline and 24-month follow-up revealed that 96% of children in the non-snoring group remained in the same group two years later, while only 4% were reported to snore. In contrast, 63% of children who were reported to snore at initial assessment (baseline) no longer did at follow-up (24-month follow-up), but 37% continued snoring (Figure 8.2).

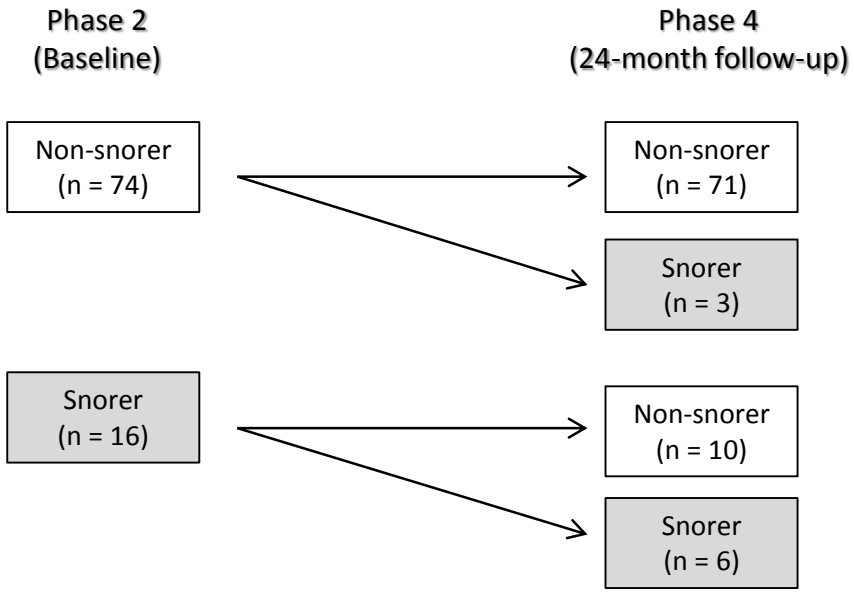


Figure 8.2 Progression of reported snoring from Phase 2 (baseline) to Phase 4 (24-month follow-up)

Due to a reduced number of children with complete data for all three phases, Figure 8.3 presents changes in the snoring status for the subset of children with data for the three phases. McNemar tests revealed that there was no evidence for a difference in the proportion of snorers between baseline and 12-month follow-up (11/76 vs. 13/76; $p = 0.75$), between baseline and 24-month follow-up (16/90 vs. 9/90; $p = 0.92$) or between 12-month follow-up and 24-month follow-up (8/63 vs. 5/63; $p = 0.51$). According to parental report, 89% of children who were initially classified as non-snorers remained in the same group at 12-month follow-up and at 24-month follow-up. In contrast, only 25% of

children who were originally reported to snore remained in the same group, while 38% of children who were reported to snore at baseline no longer did.

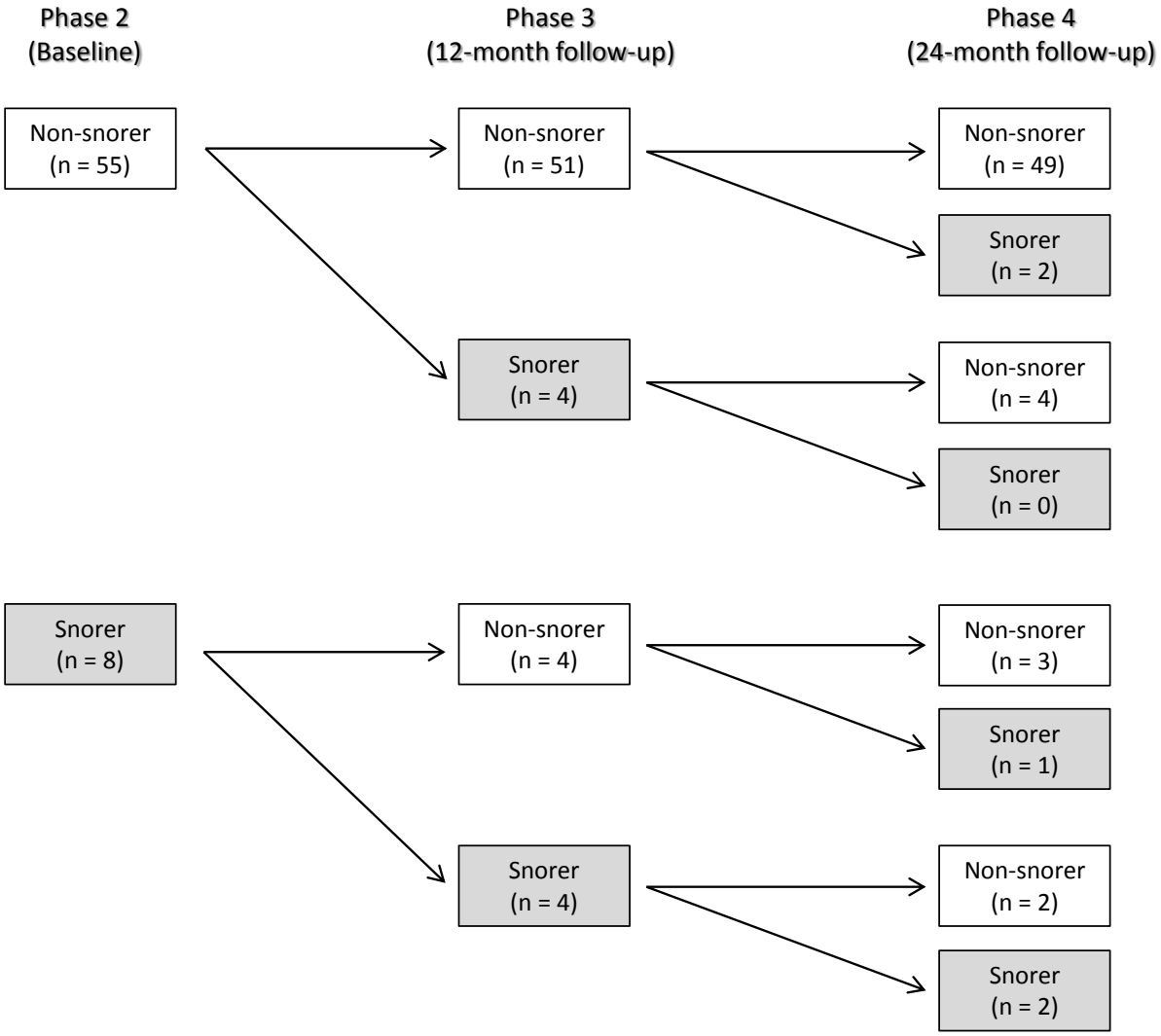


Figure 8.3 Natural history of reported snoring during Phase 2 (baseline), Phase 3 (12-month follow-up) and Phase 4 (24-month follow-up) in a subset of children with complete data

Changes in obstructive apnoea-hypopnoea index classification

Analyses for changes in OAHI indicated that 66% of children classified in the OAHI < 0.32 group remained with the same status 24 months after initial evaluation, while 48% of children in the OAHI > 0.32 group remained in the same group at 24-month follow-up (Figure 8.4). McNemar tests indicated no difference in the proportion of children with OAHI > 0.32, between 12 and 24-month follow-up (31/89 vs. 35/89; $p = 0.61$).

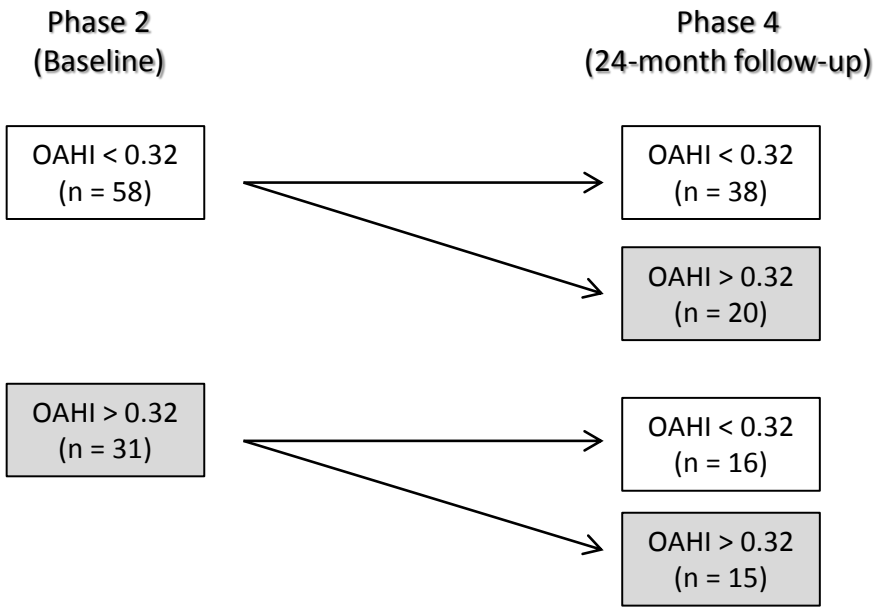


Figure 8.4 Changes according OAHI classification (OAHI < 0.32 versus OAHI > 0.32) between Phase 2 (baseline) and Phase 4 (24-month follow-up)

Note. OAHI = Obstructive apnoea-hypopnoea Index

Changes in sleep-disordered breathing status

To permit comparison with the findings from other studies which have examined the change in SDB status over time using PSG, a surrogate measure of SDB status was calculated by combining parental self-report of snoring (non-snorer or snorer) and PSG data (i.e. OAHI). Results indicated that 59 children (97%) in the non-snoring group remained as non-snorers ('no snoring' or 'snoring 1/week' and OAHI < 1) at 24-month follow-up assessment; and only two (3%) developed PS ('snoring ≥ 2 nights/week' and OAHI < 1). In contrast, seven children (50%) with PS resolved at follow-up, while five (36%) remained with PS, and only two children (14%) developed SDB ('snoring ≥ 2 nights/week' and OAHI ≥ 1) at 24-month follow-up. As the numbers of cases for each of the latter subgroups were too small to permit analyses, SDB status was not used in further analyses.

Additional to changes in SDB status, weight changes were also examined. As described earlier, weight status was only measured in phases 2 and 4. However, there were no differences between groups at baseline or at follow-up assessments. In order to test the relationship between weight change and SDB status change, a Pearson's coefficient correlation test was used. Results showed that SDB changes were not correlated to weight changes (r = .12, p > 0.05).

Non-snorers and snorers

Neurocognitive and behavioural performance

Neurocognitive functioning

Table 8.1 presents the estimated mean (SE) neurocognitive test values and Table 8.2 presents the F-test results. Analyses revealed that there were no interactions between 'group (snorer/non-snorer)' and 'time' for any of the neurocognitive variables. When the interaction term was excluded from the analysis, differences were seen for some of the variables. Irrespective of the snoring status of the child, there was a main effect of 'time' on Non-Verbal Reasoning, General Cognitive Ability, Attention/Executive Functioning and Memory. These domains were significantly higher at 24-month follow-up than baseline.

Table 8.1 Estimated mean (SE) for DAS and NEPSY test scores for children who snored and non-snorers at baseline and 24-month follow-up

Neurocognitive Domain	Non-snorer				Snorer			
	Baseline		24-month follow-up		Baseline		24-month follow-up	
	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)
DAS								
Verbal Ability	102. 7	(1.3)	103.2	(1.5)	101.0	(2.4)	104.6	(3.7)
Non-verbal Reasoning Ability	98.3	(1.1)	102.1	(1.3)	98.2	(2.2)	100.9	(3.4)
Spatial Ability	107.2	(1.2)	108.4	(1.4)	107 .5	(2.3)	106.3	(3.5)
General Cognitive Ability	102.8	(1.1)	105.0	(1.2)	102.3	(2.1)	104.5	(2.9)
NEPSY								
Attention/Executive Functioning	101.7	(1.1)	106.8	(1.2)	103.9	(2.1)	107.7	(2.7)
Language	104.7	(1.3)	104.8	(1.4)	103.6	(2.6)	102.8	(3.1)
Memory	106.4	(1.9)	110.1	(1.9)	104.63	(3.6)	108.8	(4.3)

Note. DAS = Differential Ability Scales; NEPSY = Developmental Neuropsychological Assessment test scores

Table 8.2 Linear mixed model F-test results examining the effect of group (snorer/non-snorer) and time (baseline/24-month follow-up) on DAS and NEPSY test scores

Neurocognitive Domain	F-test Results		
	Group (snorer/non-snorer)	Time	Group*Time
DAS			
Verbal Ability	0.16	0.43	0.65
Non-verbal Reasoning Ability	0.03	**7.30****	0.08
Spatial Ability	0.02	0.46	0.41
General Cognitive Ability	0.06	**4.46***	0.00
NEPSY			
Attention/Executive Functioning	0.71	**13.16****	0.13
Language	0.27	0.00	0.08
Memory	0.19	**4.29***	0.01

Note. DAS = Differential Ability Scales; NEPSY = Developmental Neuropsychological Assessment test scores
* Denotes $p < 0.05$; ** $p < 0.01$

Behavioural performance

Table 8.3 and Table 8.4 present the estimated mean (SE) behavioural performance values and F-test results respectively. Results revealed no significant difference between the non-snoring and the snoring group between baseline and 24-month follow-up. When the interaction term was excluded a significant main effect of 'group' was found for Somatic Complaints, Thought, Affective, Somatic and ADHD problems; with children who snored having higher scores than non-snorers.

Moreover, there was a significant main effect of 'time' for behavioural scales including Anxious/Depressed, Withdrawn/Depressed, Somatic complaints, Social problems, Thought problems, Rule breaking behaviour, Internal, External and Total Problems, and Affective and Anxiety Problems. Post-hoc tests revealed that scores during baseline were significantly higher than 12 and 24-month follow-ups, while no differences were found between 12 and 24-month follow-ups (i.e. baseline > 12-month follow-up = 24-month follow-up). In contrast, post-hoc tests for Oppositional and Conduct problems revealed that scores were higher at baseline than at 24-month follow-up.

Table 8.3 Estimated mean (SE) for CBCL/6-18 scale scores for children who snored and non-snorers at baseline,12-month follow-up and 24-month follow-up

CBCL Scale	Non-snorer						Snorer					
	Baseline		12-month follow-up		24-month Follow-up		Baseline		12-month follow-up		24-month follow-up	
	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)
Competence Scale												
Activity	47.6	(1.1)	46.5	(2.5)	48.6	(1.1)	46.9	(2.1)	41.3	(5.3)	47.2	(2.4)
Social	48.6	(0.9)	50.9	(1.8)	50.3	(0.9)	45.8	(1.7)	49.0	(3.5)	49.7	(1.9)
School	48.1	(0.7)	48.7	(0.9)	48.1	(0.7)	45.9	(1.4)	49.6	(1.9)	48.8	(1.5)
Total Competence	48.5	(1.0)	49.6	(2.2)	49.5	(1.1)	45.8	(2.1)	49.3	(4.3)	48.9	(2.2)
Syndrome Scales												
Internal Problems	50.9	(1.1)	44.8	(1.9)	47.7	(1.1)	54.0	(2.1)	53.6	(3.9)	51.9	(2.3)
External Problems	50.5	(0.9)	45.2	(1.7)	45.6	(0.9)	52.8	(1.9)	53.1	(3.6)	48.9	(2.0)
Total Problems	51.1	(1.0)	45.6	(1.8)	46.1	(1.0)	54.1	(1.9)	52.4	(3.6)	50.8	(2.1)
Anxious/Depressed	54.4	(0.6)	52.8	(0.8)	53.0	(0.7)	56.0	(1.2)	56.0	(1.6)	54.8	(1.4)
Withdrawn/Depressed	54.4	(0.6)	52.1	(1.1)	52.6	(0.6)	55.2	(1.1)	53.2	(2.3)	54.5	(1.2)
Somatic complaints	55.7	(0.6)	52.8	(1.2)	53.6	(0.7)	59.4	(1.3)	57.0	(2.6)	58.0	(1.4)
Social Problems	54.4	(0.5)	53.5	(0.9)	52.7	(0.6)	55.6	(1.0)	51.0	(1.7)	53.8	(1.2)
Thought Problems	55.5	(0.7)	52.9	(1.4)	53.1	(0.7)	59.4	(1.3)	53.2	(2.9)	56.6	(1.4)
Attention Problems	54.7	(0.6)	55.2	(0.9)	53.7	(0.7)	56.3	(1.2)	56.9	(1.9)	55.9	(1.4)
Rule–breaking Behaviour	54.5	(0.5)	52.3	(0.9)	52.4	(0.6)	54.7	(1.0)	55.3	(1.9)	54.5	(1.1)
Aggressive Behaviour	54.0	(0.5)	52.7	(0.9)	51.9	(0.6)	56.8	(1.1)	57.4	(1.9)	52.8	(1.2)
DSM–oriented Scales												
Affective Problems	55.3	(0.6)	53.3	(0.9)	53.4	(0.7)	58.0	(1.2)	55.8	(1.9)	56.5	(1.4)
Anxiety Problems	54.5	(0.7)	53.6	(0.8)	53.0	(0.7)	56.6	(1.3)	53.3	(1.6)	55.3	(1.4)
Somatic Problems	55.7	(0.7)	52.9	(1.6)	54.4	(0.8)	59.2	(1.5)	57.7	(3.3)	57.8	(1.7)
ADHD	53.9	(0.6)	54.1	(1.3)	52.8	(0.6)	55.9	(1.2)	59.9	(2.6)	56.4	(1.3)
Oppositional Defiant	54.5	(0.5)	53.4	(1.1)	52.7	(0.6)	55.8	(1.1)	58.1	(2.3)	53.1	(1.2)
Conduct Problems	54.5	(0.6)	52.7	(1.2)	52.4	(0.6)	55.0	(1.2)	55.9	(2.5)	53.6	(1.3)

Note. CBCL/6-18 = Child Behavior Checklist for 6-18 years; DSM = Diagnostic and Statistical Manual of Mental Disorders; ADHA = attention deficit hyperactivity disorder. Maladaptive behaviour is indicated by lower scores on the competence scale and higher scores on the syndrome and DSM-oriented scales

Table 8.4 Linear mixed model F-test results examining the effect of group (snorer/non-snorer) and time (baseline/12-month follow-up/24-month follow-up) on the (BCL/6-18 scores

CBCL Scale	F-test Results		
	Group (snorer/non-snorer)	**Time**	**Group*Time**
Competence Scale			
Activity	0.31	0.99	0.31
Social	1.29	3.10	0.37
School	0.50	1.38	2.06
Total Competence	0.68	1.15	0.38
Syndrome Scales			
Internal Problems	3.15	**7.52****	0.94
External Problems	2.28	**18.90****	1.14
Total Problems	3.65	**16.06****	0.65
Anxious/Depressed	1.68	**3.11***	0.77
Withdrawn/Depressed	1.28	**6.59****	0.35
Somatic complaints	**11.50****	**5.26****	0.06
Social Problems	1.21	**5.64****	2.43
Thought Problems	**7.26****	**8.96****	0.66
Attention Problems	2.47	2.09	0.07
Rule–breaking Behaviour	1.07	**5.94****	1.56
Aggressive Behaviour	3.71	**10.44****	2.14
DSM–oriented Scales			
Affective Problems	**5.75***	**5.73****	0.06
Anxiety Problems	3.19	**3.51***	2.42
Somatic Problems	**6.73***	2.04	0.07
ADHD	**5.98***	2.04	1.32
Oppositional Defiant	1.07	**7.45****	1.40
Conduct Problems	0.59	**5.22****	0.51

Note. CBCL/6-18 = Child Behavior Checklist for 6-18 years; DSM = Diagnostic and Statistical Manual of Mental Disorders; ADHA = attention deficit hyperactivity disorder
* Denotes $p < 0.05$; ** $p < 0.01$

Polysomnographic results

Table 8.5 and Table 8.6 report the estimated mean (SE) PSG values scores for children who snore and non-snorers and F-test results. Linear mixed models revealed no difference between children who were reported to snore and non-snorers over time in any PSG variable. When excluding the interaction term, however, there was a significant main effect of 'time' for REM%, spontaneous arousal index (SAI), 3% ODI and OAHI. Analyses revealed that values among these variables were significantly higher at baseline than at 24-month follow-up.

Table 8.5 Estimated mean (SE) for polysomnographic results for children who snored and non-snorers at baseline and 24-month follow-up

Domain	Non-snorer				Snorer			
	Baseline		24-month follow-up		Baseline		24-month follow-up	
	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)
TST (min)	414.8	(4.8)	414.6	(6.6)	402.6	(10.2)	423.0	(11.4)
REM (%)	19.6	(0.5)	20.9	(0.5)	19.5	(0.9)	20.8	(0.9)
SWS (%)	27.1	(0.5)	28.3	(0.7)	27.6	(1.1)	28.2	(1.2)
RAI (per hr)	0.6	(0.1)	0.7	(0.1)	0.5	(0.1)	0.6	(0.1)
SAI (per hr)	7.4	(0.3)	9.4	(0.3)	6.8	(0.5)	8.7	(0.6)
3% ODI (per hr)	0.9	(0.1)	0.6	(0.1)	0.9	(0.2)	0.6	(0.2)
OAHI (events/hr)	0.3	(0.0)	0.2	(0.0)	0.5	(0.1)	0.2	(0.1)
CAHI (events/hr)	0.6	(0.6)	0.5	(0.1)	0.5	(0.1)	0.4	(0.1)
AHI (events/hr)	0.9	(0.1)	0.8	(0.1)	1.0	(0.1)	0.7	(0.2)

Note. TST = total sleep time; REM = rapid eye movement sleep; SWS = slow wave sleep; RAI = respiratory arousal index; SAI = spontaneous arousal index; 3% ODI = the number of dips in oxygen saturation ≥ 3%; OAHI = obstructive apnoea-hypopnoea index; CAHI = central apnoea-hypopnoea index; AHI = apnoea-hypopnoea index

Table 8.6 Linear mixed model F-test results examining the effect of group (snorer/non-snorer) and time (baseline/24-month follow-up) on polysomnographic results

Domain	F-test Results		
	Group (snorer/non-snorer)	Time	Group*Time
TST (min)	0.34	0.01	3.01
REM (%)	0.01	**4.18***	0.00
SWS (%)	0.06	2.04	0.17
RAI (per hr)	0.55	0.71	0.18
SAI (per hr)	1.79	**28.51****	0.04
3% ODI (per hr)	0.22	**10.05***	0.02
OAHI (events/hr)	2.06	**7.20****	2.03
CAHI (events/hr)	0.29	0.73	0.18
AHI (events/hr)	0.02	3.82	1.08

Note. TST = total sleep time; REM = rapid eye movement sleep; SWS = slow wave sleep; RAI = respiratory arousal index; SAI = spontaneous arousal index; 3% ODI = the number of dips in oxygen saturation ≥ 3%; OAHI = obstructive apnoea-hypopnoea index; CAHI = central apnoea-hypopnoea index; AHI = apnoea-hypopnoea index
* Denotes $p < 0.05$; ** $p < 0.01$

Co-morbid sleep problems

Table 8.7 and Table 8.8 respectively report the estimated mean (SE) SAPSS-Q co-morbid sleep scale scores for children who snore and non-snorers and F-test results. There was a significant difference between groups over time only for the Bedtime Anxiety domain. Post-hoc analysis revealed that children who snored had significantly higher scores for Bedtime Anxiety than non-snorers at baseline, but during subsequent phases scores were similar between the groups. In addition, there was a significant main effect of 'group' and

also of 'time' on Night Arousals domain scores. That is, children who snored had higher scores on the Night Arousals domain and the frequency of co-morbid sleep problems was higher at baseline than either at 12-month and at 24-month follow-ups. Finally, children who snored compared to non-snorers had higher Restless Sleep scores.

Table 8.7 Estimated mean (SE) for co-morbid sleep problems T-scores for children who snored and non-snorers at baseline and 24-month follow-up

Sleep Problem Domain	Non-snorer						Snorer					
	Baseline		12-month follow-up		24-month follow-up		Baseline		12-month follow-up		24-month follow-up	
	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)
Sleep Routine	49.9	(0.9)	50.1	(1.0)	48.5	(0.9)	54.5	(1.8)	51.2	(2.17)	51.9	(2.1)
Bedtime Anxiety	48.1	(0.7)	48.4	(0.8)	46.4	(0.8)	53.0	(1.4)	48.3	(1.59)	48.4	(1.6)
Morning Tiredness	49.5	(0.9)	49.5	(1.1)	48.1	(1.0)	52.9	(1.9)	53.1	(2.27)	49.9	(2.2)
Night Arousals	50.4	(0.9)	46.3	(1.0)	49.1	(0.9)	56.1	(1.8)	49.2	(2.18)	52.8	(2.1)
Restless Sleep	46.4	(0.8)	46.6	(0.9)	45.7	(0.9)	55.5	(1.6)	52.2	(1.89)	53.6	(1.9)

Table 8.8 Linear mixed model F-test results examining the effect of group (snorer/non-snorer) and time (baseline/24-month follow-up) on co-morbid sleep problems T-scores

Domain	F-test Results		
	Group (snorer/non-snorer)	Time	Group*Time
Sleep Routine	3.82	2.09	1.08
Bedtime Anxiety	4.58	5.34	**5.09***
Morning Tiredness	2.56	2.31	0.35
Night Arousals	**7.43****	**12.35****	0.75
Restless Sleep	**25.11****	0.72	1.88

NB: * Denotes $p < 0.05$; ** $p < 0.01$

Level of obstruction using obstructive apnoea-hypopnoea index

Neurocognitive and behavioural performance

Neurocognitive functioning

Table 8.9 and Table 8.10 present neurocognitive data. No significant changes were observed in any of the neurocognitive domains from baseline to 24-month follow-up when children were classified according to the level of obstruction. When excluding the interaction, a significant main effect of 'time' was seen for Non-Verbal Reasoning, General Cognitive Ability, Attention/Executive Functioning and Memory domains; which were higher at 24-month follow-up compared to baseline. Additionally, there was a significant main effect of 'group' for Spatial Ability and Memory, which were lower among those children in the OAHI > 0.32 compared to the OAHI < 0.32 group.

Table 8.9 Estimated mean (SE) for DAS) and NEPSY test scores for children classified according OAHI classification at baseline and 24-month follow-up

Neurocognitive domain	OAHI < 0.32				OAHI > 0.32			
	Baseline		24-month follow-up		Baseline		24-month follow-up	
	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)
DAS								
Verbal Ability	102.8	(1.4)	103.5	(1.7)	99.9	(1.9)	102.1	(2.3)
Non-verbal Reasoning Ability	99.5	(1.3)	102.6	(1.6)	97.5	(1.7)	101.7	(2.1)
Spatial Ability	107.9	(1.3)	110.5	(1.6)	105.2	(1.8)	103.3	(2.2)
General Cognitive Ability	103.6	(1.2)	105.9	(1.4)	100.4	(1.6)	102.9	(1.9)
NEPSY								
Attention Executive Functioning	102.1	(1.3)	106.9	(1.4)	101.7	(1.7)	106.3	(1.8)
Language	103.7	(1.5)	104.9	(1.6)	104.9	(1.9)	103.2	(2.0)
Memory	108.7	(2.2)	111.4	(2.3)	100.6	(2.8)	105.4	(2.9)

Note. DAS = Differential Ability Scales; NEPSY = Developmental Neuropsychological Assessment OAHI = Obstructive apnoea-hypopnoea Index

Table 8.10 Linear mixed model F-test results examining the effect of group (OAHI < 0.32/OAHI > 0.32) and time (baseline/24-month follow-up) on DAS and NEPSY test scores

Neurocognitive domain	F-test Results		
	Group (OAHI < 0.32/OAHI > 0.32)	Time	Group*Time
DAS			
Verbal Ability	1.26	0.80	0.26
Non-verbal Reasoning Ability	0.59	**5.85***	0.28
Spatial Ability	**4.23***	0.72	2.83
General Cognitive Ability (GCA)	2.95	**4.60***	0.01
NEPSY			
Attention Executive Functioning	0.10	**12.88****	0.00
Language	0.00	0.00	1.62
Memory	**5.28***	3.73	0.31

Note. DAS = OAHI = Obstructive apnoea-hypopnoea Index; Differential Ability Scales; NEPSY = Developmental Neuropsychological Assessment
* Denotes $p < 0.05$; ** $p < 0.01$

Behavioural performance

Table 8.11 and Table 8.12 respectively present the mean (SE) CBCL values for children with an OAHI < 0.32/OAHI > 0.32 and linear mixed model F-test results. Analyses revealed that there was a significant interaction effect between 'group' and 'time' for three behavioural scales. First, post-hoc analyses revealed that children in the OAHI > 0.32 group had significantly higher Social Problems scores at baseline compared to their scores at the 12-month and 24-month follow-up times, and also higher scores than the OAHI < 0.32 group at baseline. Second, Rule-Breaking Behaviour domain scores were found to systematically decline over time in the OAHI < 0.32 group. Third, analyses revealed that

Conduct problems domain scores in the OAHI < 0.32 group significantly decreased from baseline to subsequent phases, while scores for children in the OAHI > 0.32 group increased at 12-month follow-up, but then decreased again at 24-month follow-up.

A significant main effect of 'time' was found for a number of domains including Social Competence, Internal, External and Total Problems, Withdrawn/Depressed, Somatic Complaints, Thought, Aggressive Behaviour, Affective and Oppositional Defiant domains. Scores on these domains were significantly higher at baseline compared to following time phases. Moreover, a main effect of 'group' was found for Somatic and ADHD domains; revealing that regardless of the time phase, children in the OAHI > 0.32 group had significantly higher scores compared to children in the OAHI < 0.32 group.

Table 8.11 Estimated mean (SE) for behavioural performance using the CBCL/6-18 scale scores for children classified according OAHI classification at baseline and 24-month follow-up

CBCL Scale	OAHI < 0.32						OAHI > 0.32					
	Baseline		12-month follow-up		24-month follow-up		Baseline		12-month follow-up		24-month follow-up	
	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)
Competence Scale												
Activity	47.3	(1.3)	46.2	(3.0)	48.7	(1.3)	47.1	(1.7)	44.4	(4.7)	46.5	(1.9)
Social	48.5	(1.0)	51.8	(1.8)	50.3	(1.0)	46.9	(1.4)	49.6	(2.6)	49.6	(1.5)
School	48.1	(0.8)	49.0	(1.1)	48.6	(0.8)	46.3	(1.1)	48.7	(1.6)	46.7	(1.1)
Total Competence	48.7	(1.2)	48.9	(2.6)	49.7	(1.3)	46.0	(1.7)	49.5	(3.8)	47.5	(1.7)
Syndrome Scales												
Internal Problems	50.9	(1.3)	44.9	(2.3)	47.7	(1.2)	53.8	(1.6)	51.3	(3.4)	50.9	(1.8)
External Problems	51.2	(1.1)	45.8	(2.0)	46.1	(1.1)	51.4	(1.4)	51.2	(3.1)	48.2	(1.5)
Total Problems	50.7	(1.2)	45.3	(2.1)	46.1	(1.2)	53.8	(1.5)	51.1	(3.2)	49.8	(1.7)
Anxious/Depressed	54.3	(0.7)	52.8	(0.9)	53.4	(0.7)	55.9	(0.9)	56.2	(1.2)	53.9	(1.1)
Withdrawn/Depressed	54.7	(0.7)	52.9	(1.2)	52.7	(0.7)	55.0	(0.9)	51.8	(1.9)	53.9	(0.9)
Somatic complaints	55.9	(0.8)	53.2	(1.4)	53.6	(0.8)	57.8	(1.0)	56.1	(2.2)	56.3	(1.1)
Social Problems	53.6	(0.6)	53.5	(0.9)	52.5	(0.6)	56.8	(0.8)	52.3	(1.4)	53.9	(0.9)
Thought Problems	55.8	(0.8)	52.7	(1.7)	53.6	(0.8)	57.8	(1.0)	52.1	(2.6)	54.6	(1.1)
Attention Problems	54.3	(0.7)	55.1	(1.1)	53.7	(0.7)	56.4	(0.9)	57.4	(1.7)	55.3	(1.1)
Rule–breaking Behaviour	54.9	(0.6)	52.6	(0.9)	52.7	(0.6)	53.6	(0.8)	55.2	(1.4)	53.3	(0.9)
Aggressive Behaviour	54.9	(0.6)	52.7	(1.2)	51.9	(0.6)	54.4	(0.8)	55.6	(1.8)	53.2	(0.9)
DSM–oriented Scales												
Affective Problems	55.0	(0.8)	53.4	(1.0)	53.4	(0.8)	57.3	(0.9)	54.7	(1.5)	54.9	(1.1)
Anxiety Problems	54.6	(0.8)	53.3	(1.0)	53.1	(0.8)	56.0	(1.0)	54.4	(1.5)	54.9	(1.1)
Somatic Problems	56.0	(0.9)	53.8	(1.8)	53.8	(0.9)	57.4	(1.2)	56.6	(2.8)	57.3	(1.3)
ADHD	53.2	(0.7)	53.6	(1.5)	52.6	(0.7)	56.2	(0.9)	58.9	(2.3)	55.1	(0.9)
Oppositional Defiant	55.1	(0.6)	53.0	(1.3)	52.7	(0.6)	54.3	(0.8)	56.7	(2.1)	53.5	(0.9)
Conduct Problems	55.0	(0.7)	52.6	(1.1)	52.5	(0.7)	53.3	(0.9)	57.1	(1.7)	53.4	(0.9)

Note. CBCL/6-18 = Child Behavior Checklist for 6-18 years; OAHI = obstructive apnoea-hypopnoea Index; DSM = Diagnostic and Statistical Manual of Mental Disorders; ADHD = attention deficit hyperactivity disorder. Maladaptive behaviour is indicated by lower scores on the competence scale and higher scores on the syndrome and DSM-oriented scales

Table 8.12 Linear mixed model F-test results examining the effect of group (OAHI < 0.32/OAHI > 0.32) and time (baseline/24-month follow-up) on CBCL/6-18 scale scores

CBCL Scale	F-test Results		
	Group (OAHI < 0.32/OAHI > 0.32)	Time	Group*Time
Competence Scale			
Activity	0.37	0.59	0.40
Social	0.75	**3.48***	0.17
School	2.62	1.59	0.51
Total Competence	1.69	0.70	0.26
Syndrome Scales			
Internal Problems	2.33	**6.04****	0.56
External Problems	0.50	**15.94****	1.40
Total Problems	3.93	**13.31****	0.29
Anxious/Depressed	0.78	2.07	3.20
Withdrawn/Depressed	0.50	**6.50****	0.73
Somatic complaints	**4.63***	**4.65***	0.19
Social Problems	8.22	4.45	**3.76***
Thought Problems	1.55	**8.94****	0.46
Attention Problems	3.18	2.05	0.10
Rule–breaking Behaviour	0.24	4.76	**3.23***
Aggressive Behaviour	0.16	**9.71****	1.94
DSM–oriented Scales			
Affective Problems	3.28	**5.36****	0.21
Anxiety Problems	1.99	3.05	0.13
Somatic Problems	3.86	1.61	0.63
ADHD	**8.29****	1.69	0.52
Oppositional Defiant	0.01	**6.04****	2.30
Conduct Problems	0.09	4.54	**5.08***

Note. OAHI = Obstructive apnoea-hypopnoea Index; CBCL/6-18 = Child Behavior Checklist for 6-18 years; DSM = Diagnostic and Statistical Manual of Mental Disorders; ADHD = attention deficit hyperactivity disorder
* Denotes $p < 0.05$; ** $p < 0.01$

Polysomnographic assessment

No significant interaction effects were observed between 'group' and 'time' for any of the PSG variables (Table 8.13 and Table 8.14). When the interaction term was excluded from the model, a significant main effect of 'time' was found for REM%, SAI and the 3% ODI. For all children combined, REM% per total sleep time and number of spontaneous arousals were higher, while the 3% ODI decreased at the 24-month follow-up compared to baseline.

Table 8.13 Estimated mean (SE) for polysomnographic results for children classified according OAHI classification at baseline and 24-month follow-up

Domain	OAHI < 0.32				OAHI > 0.32			
	Baseline		24-month follow-up		Baseline		24-month follow-up	
	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)
TST (min)	418.8	(6.0)	415.2	(7.2)	406.8	(7.8)	421.8	(9.0)
REM (%)	19.9	(0.5)	20.8	(0.6)	19.0	(0.7)	21.5	(0.8)
SWS (%)	26.3	(0.6)	27.9	(0.7)	28.4	(0.8)	27.7	(0.9)
RAI (per hr)	0.4	(0.0)	0.5	(0.0)	0.4	(0.0)	0.5	(0.1)
SAI (per hr)	7.1	(0.3)	9.1	(0.4)	7.9	(0.4)	9.3	(0.5)
3% ODI (per hr)	0.6	(0.0)	0.4	(0.0)	0.6	(0.1)	0.4	(0.1)
CAHI (events/hr)	0.4	(0.0)	0.3	(0.0)	0.4	(0.0)	0.4	(0.1)

Note. OAHI = Obstructive apnoea-hypopnoea Index;TST = total sleep time; REM = rapid eye movement sleep; RAI = respiratory arousal index; SAI = spontaneous arousal index; 3% ODI = the number of dips in oxygen saturation ≥ 3%; CAHI = central apnoea-hypopnoea index

Table 8.14 Linear mixed model F-test results examining the effect of group (OAHI < 0.32/OAHI > 0.32) and time (baseline/24-month follow-up) on polysomnographic results

Domain	F-test Results		
	Group (OAHI < 0.32/OAHI > 0.32)	Time	Group*Time
TST (min)	0.32	0.15	2.18
REM (%)	0.20	**4.52***	2.14
SWS (%)	1.87	1.23	3.42
RAI (per hr)	0.05	1.61	0.11
SAI (per hr)	1.55	**21.59****	0.76
3% ODI (per hr)	0.82	**15.37****	0.03
CAHI (events/hr)	0.45	0.14	0.02

Note. OAHI = Obstructive apnoea-hypopnoea Index; TST = total sleep time; REM = rapid eye movement sleep; RAI = respiratory arousal index; SAI = spontaneous arousal index; 3% ODI = the number of dips in oxygen saturation ≥ 3%; CAHI = central apnoea-hypopnoea index
* Denotes $p < 0.05$; ** $p < 0.01$

Co-morbid sleep problems

Results for co-morbid sleep problems (Table 8.15 and Table 8.16) revealed that there were no interaction effects for most of the co-morbid problems domains. However, a significant main effect of 'time' was found for Bedtime Anxiety and Night Arousals domains. Scores for these two domains were higher at baseline compared to scores during 24-month follow-up.

Table 8.15 Estimated mean (SE) for co-morbid sleep problems T-scores for children classified according OAHI classification at baseline and 24-month follow-up

Domain	OAHI < 0.32						OAHI > 0.32					
	Baseline		12-month follow-up		24-month follow-up		Baseline		12-month follow-up		24-month follow-up	
	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)	EM	(SE)
Sleep Routine	50.7	(1.1)	50.4	(1.2)	48.8	(1.1)	51.7	(1.4)	52.4	(1.6)	50.1	(1.5)
Bedtime Anxiety	48.8	(0.8)	48.9	(0.9)	46.8	(0.9)	49.9	(1.1)	47.8	(1.2)	47.6	(1.2)
Morning Tiredness	50.4	(1.1)	50.6	(1.3)	49.1	(1.2)	50.3	(1.5)	50.5	(1.7)	47.7	(1.6)
Night Arousals	50.2	(1.1)	46.8	(1.2)	49.9	(1.1)	53.1	(1.4)	46.9	(1.6)	48.8	(1.5)
Restless Sleep	47.0	(1.1)	47.7	(1.2)	47.1	(1.1)	51.4	(1.4)	49.4	(1.6)	48.3	(1.5)

Note. OAHI = Obstructive apnoea-hypopnoea Index

Table 8.16 Linear mixed model F-test results examining the effect of group (OAHI < 0.32/OAHI > 0.32) and time (baseline/24-month follow-up) on co-morbid sleep problems T-scores

Co-morbid Sleep Domain	F-test Results		
	Group	Time	Group*Time
Sleep Routine	0.76	2.81	0.15
Bedtime Anxiety	0.21	4.51	1.67
Morning Tiredness	0.10	2.75	0.29
Night Arousals	0.36	**10.32****	2.02
Restless Sleep	3.08	0.86	1.96

Note. OAHI = Obstructive apnoea-hypopnoea Index
* Denotes $p < 0.05$; ** $p < 0.01$

Correlational analysis and group differences according to obstructive apnoea-hypopnoea index changes between baseline and 24-month follow-up

Correlational analysis between OAHI change and daytime functioning were performed. Analysis revealed that change in OAHI classification from baseline to 24-month follow-up was only associated with the change in Attention/Executive Function domain, Language domain and the Total Competence domain. Results indicated that a higher OAHI change from baseline to 24-month follow-up is associated with a higher change on Attention/Executive Function ($r = .56$, $p < 0.05$), Language ($r = .70$, $p < 0.05$) and Total Competence ($r = .29$, $p < 0.05$).

Table 8.17 Correlation values for the change in OAHI versus change in neurocognitive/behavioural variables (24-month follow-up minus baseline)

Change in neurocognitive domain	Change in OAHI
DAS	
Verbal Ability	.01
Non-verbal Reasoning Ability	.12
Spatial Ability	–.07
General Cognitive Ability	–.06
NEPSY	
Attention Executive Functioning	**.56****
Language	**.70****
Memory	.02
CBCL	
Total Competence	**.29***
Internal Problems	–.16
External Problems	–.14
Total Problems	–.16

Note. OAHI = Obstructive apnoea-hypopnoea Index; DAS = Differential Ability Scales; NEPSY = Developmental Neuropsychological Assessment; CBCL = Child Behavior Checklist for 6-18 years. Effect size (*r*): small = .10; medium = .30; large = .50

Change in obstructive apnoea-hypopnoea index status and daytime functioning

In order to further assess whether a change in OAHI status might be related to performance, an additional set of analyses (one-way ANOVA) were undertaken examining the performance of children on key neurocognitive and behavioural measures with children divided into four groups according to the change in OAHI status from baseline to 24-month follow-up: OAHI < 0.32 to OAHI < 0.32 (remained OAHI < 0.32 condition); OAHI < 0.32 to OAHI > 0.32 (condition deteriorated); OAHI > 0.32 to OAHI < 0.32 (condition improved); and OAHI > 0.32 to OAHI > 0.32 (remained OAHI > 0.32 condition). The mean (SD) values and ANOVA results for the key neurocognitive domain and for the key behavioural scale scores are presented in Table 8.18. The analysis revealed no significant main effects for groups on any of the neurocognitive domains or behavioural scale scores.

Table 8.18 Mean (SD) for key neurocognitive and behavioural domain scores at 24-month follow-up for participants separated into four groups according to their change in OAHI status (OAHI classification from baseline to 24-month follow-up) together F-test results and effect size values

Neurocognitive/ behavioural domain	Remained OAHI < 0.32 (n = 38)		Deteriorated OAHI < 0.32 to > 0.32 (n = 20)		Improved OAHI > 0.32 to < 0.32 (n = 16)		Remained OAHI > 0.32 (n = 15)		F-test	Effect size (η^2_p)
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)		
DAS										
Verbal Ability	102.0	(15.2)	109.1	(11.1)	103.8	(11.9)	104.6	(11.3)	0.89	.05
Non-verbal Reasoning Ability	102.1	(12.4)	108.1	(11.4)	101.9	(8.4)	104.5	(11.2)	0.94	.05
Spatial Ability	111.8	(15.0)	112.1	(11.1)	102.1	(12.1)	108.6	(11.4)	0.22	.08
General Cognitive Ability	106.2	(12.9)	111.6	(10.2)	103.0	(10.0)	106.9	(9.0)	0.30	.06
NEPSY										
Attention Executive Functioning	106.8	(10.9)	106.5	(11.9)	106.2	(12.3)	106.5	(11.1)	0.99	.00
Language	103.8	(12.3)	109.8	(13.9)	106.2	(8.7)	101.0	(10.8)	1.77	.06
Memory	108.1	(22.8)	118.3	(15.9)	106.1	(17.8)	100.4	(13.8)	2.48	.09
CBCL										
Total Competence	51.1	(8.4)	47.7	(12.9)	50.6	(10.9)	45.8	(8.9)	1.09	.05
Internal Problems	47.4	(8.2)	46.5	(10.4)	50.3	(9.4)	51.0	(11.7)	0.81	.03
External Problems	45.5	(8.5)	44.2	(7.3)	50.3	(8.4)	47.1	(9.4)	1.26	.05
Total Problems	45.6	(8.7)	44.3	(9.0)	51.1	(7.6)	49.4	(12.5)	1.62	.06

Note. OAHI = Obstructive apnoea-hypopnoea Index; DAS = Differential Ability Scales; NEPSY = the Developmental Neuropsychological Assessment; CBCL = Child Behavior Checklist. Effect size (η^2_p): small = .01; medium = .06; large = .14

8.4. Discussion

In this study the natural history of snoring was examined over a two-year period. There is limited research with this length of follow-up and including comprehensive measures to assess daytime performance and sleep. The natural history was found to differ depending on two factors. First, whether the child was a 'snorer' at baseline or not. Second, whether children were classified according to either subjective criteria such as parental report or objective criteria such as OAHI. Regardless of whether children were classified according to either parental report or OAHI, 'snoring status' demonstrated greater variability in children who at baseline were snorers (or OAHI < 0.32) compared to non-snorers (or OAHI > 0.32). Taking the latter into account and regardless of snoring severity at baseline, parental report compared to OAHI estimates of snoring severity showed more consistency over the two-year period. An additional focus of this study was the relationship between snoring and daytime functioning, and if changes in snoring severity were accompanied by changes in daytime functioning. Although the natural history of snoring in children drawn from the general community has been examined in the literature, to date only Bonuck et al.

(2012a) have examined the relationship between the natural history of snoring and daytime functioning and only for behaviour. This relationship was investigated in the present study, as well as possible changes in neurocognitive performance and co-morbid sleep problems. The study also examined whether the classification of children according to either parental report (snorer vs. non-snorer) or objective PSG criteria (OAHI < 0.32 vs. OAHI > 0.32) might impact the trajectory of snoring status and its relationship to behavioural and neurocognitive performance. In general, there was a trend for neurocognitive performance to improve over time in both children who snored and non-snorers and, likewise, for the frequency of problematic behaviour to decrease over time in both groups. This was regardless of whether the children were classified according to parental report of snoring or OAHI.

A major finding of the present study was that the natural history of snoring varied according to whether parental report or OAHI was used to classify snoring status. The first set of analyses examined the natural history of snoring in children according to parental report. The results from that set of analyses indicated that the majority of children who do not snore on parental report at baseline tended to remain non-snorers at the 12- and 24-month follow-ups. This is contrary to the findings by Ali et al. (1994), who also used parental report and found that more than 50% of non-snorers commenced snoring at 24-month follow-up, but similar to the findings of several groups who have also used parental report to classify children—that the majority of 'non-snorers' remain 'non-snorers' (Ali et al., 1994; Anuntaseree et al., 2005; Bonuck et al., 2011; Löfstrand-Tideström & Hultcrantz, 2007; Piteo, Lushington, Roberts, Martin, et al., 2011). In contrast to the findings in children who on parental report did not snore at baseline, the variability of 'snoring status' was found to be much higher in children who were reported to snore at baseline, with most having ceased snoring at the 24-month follow-up. Indeed, more than half of the children who snored on parental report at baseline were reported to have stopped snoring at 12 months, and of those who continued to snore at 12-month follow-up more than half again were reported to have stopped at 24-month follow-up. This 50% decrease in the percentage of children who snore is consistent with findings from previous studies which have also examined the change of parental reported snoring over 12- to 24-month intervals (Ali et al., 1994; Anuntaseree et al., 2005; Bonuck et al., 2011; Löfstrand-Tideström & Hultcrantz, 2007; Urschitz et al., 2004). This decrease in the frequency of snoring over time may be explained by an age-related change in upper airway structures with a decrease in the relative ratio between tonsil and airway size (Casselbrant, 1999),

making obstruction less likely, and hence upper airway obstruction and snoring less severe in older children.

The second criterion used to classify children in this study was OAHI. As with the findings for parental report, relatively more children with an OAHI < 0.32 at baseline continued to have an OAHI < 0.32 at follow-up, whereas children with a OAHI > 0.32 at baseline showed less stability and were equally likely to have a high or OAHI > 0.32 at the 24-month follow-up. However, compared to the estimates for parental report, snoring status at the 24-month follow-up was much more variable for both children with OAHI < 0.32 and OAHI > 0.32. For example, more than half (66%) of the children with OAHI < 0.32 at baseline continued to have an OAHI < 0.32 at the 24-month follow-up while almost half (48%) of the children with OAHI > 0.32 at baseline continued to have an OAHI > 0.32 at follow-up.

In addition to the dichotomous criteria used in the present study of parental report and, likewise, OAHI, a surrogate measure of SDB was also examined—a history of snoring on parental report combined with an OAHI ± 1. This classification was undertaken to allow a comparison with other studies that have examined changes in SDB status using PSG criteria, but was not used in the analyses because of the sample subject numbers in some cells. Based on this modified criteria, the 24-month follow-up found 36% of children with PS continued to be primary snorers, while 50% resolved spontaneously and 14% developed mild OSAS, and 4% of the non-snoring children developed PS. Li et al. (2013), in a recent investigation, is the only other group to have used a comparable methodology to assess PS, but it was over a four-year period. Li et al. report that 31% of children who had PS continued to be primary snorers at 24-month follow up, 26% had resolved while 37% worsened and met the criteria for OSAS. Li's findings suggest that the rate of resolution is lower while the likelihood of increased severity is higher than those estimates reported in the present study. Two factors may explain the inconsistencies between Li's and the present results. First, children in Li's study were recruited from a community survey investigating OSAS, while children in the current study were included from a community survey investigating PS—the greater SDB severity of the children in Li's study may explain the higher frequency of SDB at follow-up. Second, the two studies differed as to the definition used to classify PS, with Li's group having a more inclusive cut-off (i.e. at least one–two nights per month) compared to the present study (i.e. or ≥2 nights per week) making it more likely that children were classified as primary snorers under these criteria. Taken together, the present results indicate that if objective sleep measures such as OAHI

are included into the classification of snorer then the majority of children who snore are likely to be snoring two years later.

In addition to parental report and OAHI, the natural history of snoring based on technician-report of snoring was collected during PSG. Specifically, PSG technicians were asked to indicate snoring by recording whether snoring was noted on the microphone trace, which was later confirmed by audio signal. Unlike parental report, a higher percentage of children who did not snore at baseline were found to snore at the 24-month follow-up (23%) while a higher percentage of children who initially snored were found to have ceased at follow-up (38%). Given that PSG technicians are more likely to be directly observing the children across the night than parents; this may be a more realistic reflection of snoring frequency. Nevertheless, previous research (Montgomery-Downs et al., 2004) indicates that parental self-report and objectively recorded snoring are generally equivalent, especially for cases with the highest frequency of snoring.

Natural history of snoring and associated daytime performance

In the present study little evidence was found to support the proposition that if snoring resolved then so would any neurocognitive and behavioural deficits. Moreover, this was regardless of how 'snoring' was defined. Instead it was found that behaviour and neurocognitive functioning improved over the two-year period. This finding is consistent with recent research (Marcus et al., 2013) where children with mild OSAS with and without treatment had increased scores for attention and executive functioning in the NEPSY. The frequency of behavioural problems is known to decline with age and this may explain the improvements observed in the present study (Gregory & O'Connor, 2002). The increase in neurocognitive function which was observed in all children remains unexplained. It could be accounted for by a learning effect as test scores improve following repeated administration, but two years is generally considered sufficient to control for any learning effects (Brooks, Sherman, & Strauss, 2009; Kronenberger, Pisoni, Henning, Colson, & Hazzard, 2011).

The impact of 'snoring' on daytime functioning was minimal. Nonetheless, a few significant group differences in neurocognitive functioning were observed when children were classified according to OAHI but not parental report. Specifically, S and Memory Performance was reduced in children with an OAHI > 0.32 at baseline and this group continued to have reduced performance at follow-up. Further analysis was conducted to test whether the children with OAHI > 0.32 both at baseline and 24-month follow-up

differed to those children who improved (i.e. OAHI > 0.32 at baseline but OAHI < 0.32 at 24-month follow-up) , deteriorated (OAHI < 0.32 at baseline but OAHI > 0.32 at follow-up) or remained 'non-snorers' (OAHI < 0.32 at both baseline and follow-up). That is, to explore whether the deficits in spatial ability and memory at follow-up were more evident in the children who continued to have an OAHI > 0.32 compared to those that improved. Results of this analysis revealed no significant group difference in any of the key neurocognitive or behavioural variables. Alternatively, SDB and daytime deficits may not be causally related; Calhoun et al. (2009) in their robust study had already suggested that impaired neurocognitive functioning in the presence of mild SDB should be considered co-morbid and not causal.

Despite the lack of significant group differences between snorers and non-snorers, correlational analysis exploring the relationship between the change in OAHI and change in daytime functioning from baseline to 24-month follow-up did reveal several significant associations. Correlational analyses revealed that an increase in OAHI was associated with a decrease in attention and executive functioning, language ability and competency. Typically studies do not report an association between PSG measures of SDB such as OAHI and daytime performance (Melendres et al., 2004; O'Brien, Mervis, Holbrook, Bruner, Smith, et al., 2004). However, the latter studies are typically cross-sectional in design and it may be possible that longitudinal research may reveal a more nuanced relationship.

A further possible explanation for the failure to find significant group differences in daytime functioning may be due to either the duration of snoring or age of snoring onset. Neither of these measures were collected in the present study. It may simply be the case that the impact of snoring on daytime functioning happens much earlier in life and, thereby, is not related to snoring status later in life. Consistent with this explanation, Piteo, Lushington, Roberts, Martin, et al. (2011) report that children who snore in the first month of life have reduced cognitive functioning at 12-months-old, suggesting that early onset and chronicity may be important. Bonuck et al. (2012a) in a robust longitudinal study (from six months to 18-months-old) of SDB symptoms (including snoring) and associated behavioural performance, (measured through the Strengths and Difficulties Questionnaire, SDQ) over several years in children from the general community report evidence that the effects of early childhood SDB are apparent when children are tested several years later. Bonuck's group report that high frequency of snoring, apnoea and mouth breathing at four years of age predicts hyperactivity at seven years of age.

Limitations of the current study and future research

One limitation of the present study is that due to limited time and resources it was not possible to objectively assess neurocognitive functioning and sleep at all three time points. However, this is the first study examining children who snore using objective and validated instruments to assess associated daytime functioning over time. Results from the current research need to be taken carefully and reproducibility will be necessary to confirm them with larger numbers in other community settings.

Another limitation is the lack of unified criteria for both parental report and PSG estimates of snoring and SDB. Nevertheless, this is a problem not only for the current study, but for the SDB literature in general. Lumeng and Chervin (2008) in their extensive review of SDB have highlighted the variability in the way snoring is defined, especially in those studies which have relied on subjective reports. The inconsistency in criteria used to define snoring raises the need for a unified definition that uses similar questionnaire items for assessing snoring but also standardised cut-offs when classifying children as snorers. The same also applies to the use of PSG variables to classify 'snorers' and especially the importance of OAHI to define cases, rather than AHI which includes both central and obstructive events. A final limitation when assessing children with mild SDB is that children are not typically screened for the presence of UARS, and hence studies may be conflating varying subgroups when examining 'children who snore'.

Conclusion

This is the first study examining long-term neurocognitive and behavioural consequences in children reported to snore from the community using objective and validated measures. For this group of school-age children drawn from the community and who were assessed twice, snoring (i.e. mild SDB) was not related to long-term neurocognitive or behavioural problems. Further, a change in snoring status was not accompanied by a change in neurocognitive or behavioural status. However, this does not exclude the possibility that some children may be more sensitive to the impact of snoring than others, and additional mediating factors remain to be examined (for example ethnicity and upper airway structure). Additional to demographic and physical characteristics, other factors including the role of plasticity or resilience among children with sleep disturbances may also provide further information. For example, Chatburn, Coussens, and Kohler (2014) recently suggested that resilience plays a mediator role between sleep disturbances and increased risk for problematic daytime behaviours.

Chapter 9 Sleep and neurobehavioural functioning in children who snore recruited from a clinical setting versus a community setting

9.1. Introduction

As has been discussed in preceding chapters, evidence supporting an association between snoring and reduced daytime functioning is stronger in children recruited from clinical settings (e.g. ENT wait list, sleep clinic) (Blunden et al., 2000; Bourke et al., 2011) compared to community settings (e.g. field survey) (Brockmann, Urschitz, et al., 2012; Calhoun et al., 2009; Emancipator et al., 2006; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004). As also discussed in previous chapters, and consistent with earlier findings in community samples, children who snored in the present study did not demonstrate reduced daytime functioning compared to non-snorers.

An explanation for the different pattern of findings in children from clinical versus community settings is unclear and raises concerns as to the understanding of the impact of upper airway obstruction on daytime functioning. The sleep fragmentation and possible inflammatory processes of the vascular system associated with upper airway obstruction (Gozal, McLaughlin, et al., 2007) and brain vasculature may underlie the daytime deficits in children with even mild SDB, such as PS (Calhoun et al., 2009). It may simply be the case that children recruited from clinical settings are more likely to be referred for clinical evaluation because they have more severe PS and hence are more likely to demonstrate daytime deficits. To help explore this possibility it would be instructive to compare the profile of children recruited from community versus clinical settings.

To aid in that investigation our group also investigated daytime functioning in children recruited from clinical settings; that is, referred to an ENT clinic for the evaluation of snoring (Kohler et al., (2009). This provided the opportunity to compare demographics, sleep and daytime functioning in children who snore from the same population background (i.e. South Australian schoolchildren), but who have been recruited either from the community or clinical setting. This chapter presents a preliminary investigation comparing the demographics, sleep, and neurocognitive and behaviour functioning in these two sets of children.

9.2. Methods

Sleep, neuropsychological and demographic data were collected prospectively in three independent groups across two separate studies and retrospectively compared.

Participants

Chapter 2 provides details of the community sample (index and controls), while Kohler, et al. (2009) describe the clinical sample more fully. In brief, the latter were recruited from a surgical waiting list containing children with a history of snoring who had been scheduled for adenotonsillectomy for treatment of upper airway obstruction. The children in the clinical sample underwent comprehensive neuropsychological and behavioural testing and a full night of PSG. Children with OSAS were excluded, and the remainder had a confirmed diagnosis of PS.

Evaluation of snoring

The snoring item from the Sleep Disturbance Scale for Children (SDSC) (Bruni et al., 1996) was used to assess snoring frequency in children from the clinical sample, and likewise the snoring item from the SAPSS-Q was used to assess children from the community sample (Biggs et al., 2012). These two questionnaires overlap but use slightly different snoring items and response keys. The SDSC asks parents to rate snore frequency over the past six months ('Your child snores?') using a five-point frequency scale (1 = 'never', 2 = 'occasionally' (once or twice a month), 3 = 'sometimes' (once or twice a week), 4 = 'often' (three to five times a week), to 5 = 'always') while the SAPSS-Q asks parents to rate snore frequency over the last week ('Does your child currently snore?') using a four-point frequency scale (1 = 'never', 2 = 'rarely'—once per week, 3 = 'sometimes' (two to four times per week), and 4 = 'usually' (five to seven times per week). To achieve consistency in the classification of children who snore, snorers were defined as those who snored more than one night per week (i.e. rated three or above on the SDSQ or two and above on the SAPSS-Q). In addition, these children had to meet objective requirements for PS with an OAHI < 1 and mean $SaO_2 \geq 90\%$. Twenty-one children with PS were identified in the community sample ($Community_{PS}$) and 15 in the clinical sample ($Clinic_{PS}$). To enable a comparison group of non-snorers; children from $Community_{PS}$ who reported never snoring on the SAPSS-Q and had normal PSG results (OAHI < 1 and mean $SaO_2 \geq 90\%$) were identified. Then, 25 non-snorers were randomly selected from the list ($Community_{NS}$)

All children underwent equivalent testing including neurocognitive, behavioural and PSG assessment. Both groups completed the CBCL and the NEPSY, and PSG was conducted at the same paediatric sleep unit using the equivalent protocol. The following demographic and health information was also collected in all groups: asthma, craniofacial abnormalities, cleft palate, eczema, and neuromuscular disorders; family history of snoring and smoking at the household; ethnicity, level of parental education, SES and BMI percentile.

Materials

Polysomnographic assessment

Chapter 2 provides a complete description of the PSG variables and the specifications of the methods used. In brief, the Compumedics E-Series System (Melbourne, Australia) was used to record EEG (e.g. C3-A2 and C4-A1), EOG (left and right), EMG (sub-mental and diaphragmatic), ECG, leg movement, oro-nasal airflow and nasal pressure, chest and abdominal respiratory movements, and arterial oxygen saturation (SaO_2). All sleep studies were conducted in a paediatric sleep unit at the Women's and Children's Hospital, North Adelaide, Australia. A full-night PSG was conducted with continuous monitoring of the child by a trained paediatric sleep technician, who documented observations involving sleep behaviours such as snoring.

Neurocognitive and behavioural assessment

A neuropsychological test and a validated behaviour checklist were used to assess neurobehaviour. The NEPSY was administered to all children and the CBCL/6-18 was completed by the parents on the night of the PSG. Chapter 2 presents a detailed description of these two instruments. The NEPSY was selected to measure Planning and Problem Solving, Auditory and Visual Attention, Language, and Memory and Learning. A psychologist blinded to the status of the child administered the test. The CBCL/6-18 was used to assess competent behaviour (school, social and activity) and problematic behaviour, including internal and external problems (syndrome scales), and behaviour problems against DSM-diagnostic criteria.

Data analysis

All PSG data were digitised and stored for subsequent analysis. Two trained sleep technicians (SC and the PhD candidate DCN) scored the sleep studies from clinically-referred and non-referred participants respectively. Sleep staging and breathing functioning were according to standardised sleep and ventilatory criteria (see Chapter 2 for a detailed

description). Epoch-by-epoch sleep stage inter-scorer reliability between technicians was >90%.

Statistical analysis

ANOVA were conducted to characterise the relationships between potential risk factors and the different groups for continuous variables. Significant main effects ANOVA tests were followed by simple planned contrasts to test between-group differences ($Community_{NS}$ vs. $Community_{PS}$, $Community_{NS}$ vs. $Clinical_{PS}$, and $Community_{PS}$ vs. $Clinical_{PS}$). In the case of scales which were significantly skewed and not amenable to normalisation, Kruskall-Wallis tests were used. Significant Kruskall-Wallis results were followed by Mann-Whitney tests in order to explore between-group differences. The effect size estimate (*r*) was calculated for significant results in order to test the magnitude of the effect on the dependent variable. For categorical variables Chi-square analyses were performed.

A Pearson's product-moment correlation was undertaken to explore the association between PSG and demographic factors with key neurocognitve and behavioural variables. In addition, the demographic variables that were significantly different between groups in ANOVA were entered into a hierarchical multiple regression model with two steps to explore whether the demographic variables added significantly to the prediction of the key neurocognitive and behavioural outcomes over and above that which is explained by 'sample' (i.e. whether children were drawn from a community or a clinical context). Step 1 included 'sample' and Step 2 included SES. The same procedure was repeated, but this time birth weight was included in Step 2. A reduced sample was included in this second analysis, as 18 participants did not report information about birth weight—eight from the $Community_{NS}$, four from the $Community_{PS}$ and six from the $Clinical_{PS}$.

The values of R^2 are presented to indicate how much of the variability in each key variable is accounted for by the predictors (i.e. sample, SES or birth weight). Data are presented as mean (SD) unless otherwise stated. Analyses were conducted using the statistical package SPSS for windows version 21. As this was an exploratory study no correction was made for multiple comparisons.

9.3. Results

Sample characteristics

A total of 61 children were included in this analysis. Of these, 46% were male and the majority of children were Caucasian (95%) with the remainder identifying as Hispanic (2%), Asian (2%) or 'Other' (1%). Children in this study had a mean (SD) age of 8.2 (1.6) years, BMI percentile of 61.4 (26.6), and birth weight of 3.4 (0.5) kg. None of the children had a history of tonsil or adenoid surgery. Other than a history of snoring, all children were healthy at the time of assessment.

Demographic and health outcomes

The demographic data are reported in Table 9.1. Analysis revealed that the groups had similar age and BMI percentile, but not SES and birth weight. Planned contrasts revealed that $Clinical_{PS}$ had lower SES [$t(58) = -2.56$, $p < 0.05$ (2-tailed), $r = .32$] than $Community_{NS}$ and were lighter at birth [$t(50) = -4.59$, $p < 0.001$ (2-tailed), $r = .55$]. $Clinical_{PS}$ also had lower birth weight than $Community_{PS}$ [$t(50) = -2.38$, $p < 0.05$ (2-tailed), $r = .32$]. Additionally, $Community_{PS}$ had lower birth weight compared to $Community_{NS}$ [$t(50) = -2.35$, $p < 0.05$ (2-tailed), $r = .32$].

Gender, ethnicity, paternal and sibling snoring, cleft palate and facial abnormalities did not differ between groups. However, they differed for maternal snoring, smoking in the household and asthma. Maternal snoring was more often reported for $Community_{PS}$, followed by $Community_{NS}$, and it was reported least for $Clinical_{PS}$. Smoking in the household was most often reported in $Clinical_{PS}$, followed by $Community_{PS}$, and was reported least in $Community_{NS}$. Four $Clinical_{PS}$ children reported non-medicated asthma.

Table 9.1 Demographic and health variables according to snoring group with Chi-square (χ^2) or F-test results for categorical and interval data respectively

Demographic	$Community_{NS}$ (n = 25)		$Community_{PS}$ (n = 21)		$Clinical_{PS}$ (n = 15)		F-test
	Mean	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**	
Age (years)	8.4	(1.4)	8.0	(1.7)	8.5	(1.5)	1.53
SES	990.2	(53.6)	970.2	(78.6)	929.1	(23.4)	**3.30***
Child's birth weight (kg)	3.6	(0.3)	3.3	(0.4)	2.9	(0.7)	**10.88****
BMI percentile	65.4	(22.2)	58.7	(33.5)	65.9	(26.2)	0.44
	%	**n**	**%**	**n**	**%**	**n**	χ^2
Gender (male)	43	12	28	8	29	8	0.89
Ethnicity (Caucasian%)	96	24	95	20	93	14	7.93
Paternal snoring (yes)	37	15	40	16	23	9	4.21
Maternal snoring (yes)	32	6	52	10	16	3	**9.26****
Sibling snoring (yes)	29	6	47	10	24	5	4.38
Household smoking (yes)	13	2	37	6	50	8	**8.28***
Asthma (yes)	0	0	0	0	31	4	**15.18****
Cleft palate (yes)	0	0	0	0	8	1	3.90
Facial abnormalities (yes)	0	0	0	0	8	1	3.90

Note. $Community_{PS}$ = primary snorers from community sample, $Community_{NS}$ = non-snorers from community sample and $Clinical_{PS}$ = primary snorers from clinical sample, BMI = body mass index
*Denotes $p < 0.05$ and **$p < 0.001$

Neurocognitive and behavioural performance

Neurocognitive performance

Table 9.2 presents the data for neurocognitive performance. No significant group differences were observed in any of the Attention/Executive function domain or subscale scores. By contrast, significant group differences were observed in Language and Memory performance.

Planned contrasts for the Language domain revealed that $Community_{NS}$ and $Community_{PS}$ had similar scores, while $Clinical_{PS}$ had significantly lower scores compared to $Community_{NS}$ [$t(56) = -2.71$, $p < 0.05$ (2-tailed), $r = .34$] and also compared to $Community_{PS}$ [$t(56) = -2.08$, $p < 0.05$ (2-tailed), $r = .27$]. The group difference in the Language total domain scores could be largely accounted for by the significant group differences in Phonological Processing [$F(2, 56) = 4.02$, $p < .05$]. Planned contrasts indicated that $Clinical_{PS}$ had significantly lower Phonological Processing than the $Community_{NS}$ [$t(56) = -2.80$, $p < 0.05$ (2-tailed), $r = .35$] and also than the $Community_{PS}$ [$t(5) = -2.01$, $p < 0.05$ (2-tailed), $r = .26$].

The $Clinical_{PS}$ children had lower Memory total domain scores than $Community_{NS}$ children [$t(53) = -2.25$, $p < 0.05$ (2-tailed), $r = .30$], which could largely be accounted for by the significant group difference between $Clinical_{PS}$ and $Community_{NS}$ in Memory for Names

[$t(53) = -2.80$, $p < 0.01$ (2-tailed), $r = .36$] and between $Community_{PS}$ and $Community_{NS}$ [$t(53) = -2.65$, $p < 0.05$ (2-tailed), $r = .34$]; but specifically Memory for Names Immediate Recall, which was lower in the $Community_{PS}$ compared to the $Community_{NS}$ group [$t(53) = -2.68$, $p < 0.01$ (2-tailed), $r = .35$], and also lower in $Clinical_{PS}$ compared to $Community_{NS}$ [$t(5) = -3.21$, $p < 0.05$ (2-tailed), $r = .40$]. The $Clinical_{PS}$ and $Community_{PS}$ children had similar Memory scores.

Table 9.2 Neurocognitive performance using the NEPSY test across snoring groups with Chi-square or F-test results for categorical and ordinal data respectively

NEPSY Variables	$Community_{NS}$ N = 25		$Community_{PS}$ N = 21		$Clinical_{PS}$ N = 15		F-test
	Mean	(SD)	Mean	(SD)	Mean	(SD)	
Attention/Executive Function							
Total Attention/EF domain	103.2	(10.5)	103.4	(9.9)	104.4	(15.3)	0.13
Tower	12.4	(2.5)	12.5	(2.2)	11.5	(3.0)	1.26
Auditory Att. Response Set	9.5	(1.2)	9.0	(1.9)	9.0	(2.0)	0.43
Auditory Attention	9.8	(1.6)	9.7	(1.4)	9.5	(2.7)	0.29
Inhibition	8.9	(1.5)	8.4	(2.2)	9.1	(2.0)	0.06
Visual Attention	9.4	(2.4)	10.0	(2.0)	11.3	(3.1)	2.62
Language							
Total Language domain	104.9	(11.4)	102.4	(14.8)	93.6	(2.6)	**3.85***
Phonological Processing	11.0	(2.2)	10.3	(3.3)	8.2	(3.6)	**4.02***
Speeded Naming	10.2	(1.9)	10.1	(2.1)	8.8	(2.2)	3.66
Comprehension of Instructions	11.1	(2.9)	10.7	(3.3)	10.2	(2.9)	0.71
Memory							
Total Memory domain	114.3	(16.0)	106.7	(20.1)	101.5	(13.3)	**3.43***
Faces	12.6	(2.8)	11.9	(3.3)	12.1	(2.4)	0.35
Faces Immediate	12.4	(2.9)	11.5	(3.1)	11.7	(2.8)	5.04
Faces Delayed	12.2	(2.2)	11.8	(2.9)	11.7	(1.5)	0.31
Names	12.3	(2.8)	9.7	(3.2)	9.4	(3.2)	**5.22****
Names Immediate	12.6	(2.7)	10.2	(2.8)	9.5	(3.2)	**6.20****
Names Delayed	11.7	(3.6)	9.4	(3.3)	9.5	(2.7)	2.81
Narrative Memory	11.2	(3.0)	10.8	(3.2)	9.1	(3.1)	2.16

Note. $Community_{PS}$ = primary snorers from community sample, $Community_{NS}$ = non-snorers from community sample and $Clinical_{PS}$ = primary snorers from clinical sample, NEPSY = Developmental Neuropsychological Assessment
*Denotes $p < 0.05$ and **$p < 0.01$

Child Behavior Checklist

Table 9.3 reports the mean (SD) CBCL results. In general, the frequency of problematic behaviour was higher in $Clinical_{PS}$ compared to $Community_{PS}$ who were higher than $Community_{NS,}$ while competency was lower in $Clinical_{PS}$ compared to $Community_{PS}$ who were lower than $Community_{NS}$.

Competence scale scores

No significant group differences were observed in Social and Activity competency scores. In contrast, School Competency and Total Competence scores were significantly lower in $Clinical_{PS}$ versus $Community_{NS}$ ($U = 35$, $r = –.61$, and $U = 85$, $r = –.48$, respectively). Additionally, $Clinical_{PS}$ children had lower scores for the School Competency scale compared to the $Community_{PS}$ group ($U = 63$, $r = –.38$). Total Competence scores were similar for $Clinical_{PS}$ versus $Community_{PS}$ and $Community_{PS}$ versus $Community_{NS}$.

Problematic behaviour

A significant effect of group was observed for Internalizing Problems (i.e. internalised problematic behaviour) [$F(2, 56) = 6.36$, $p < .01$]. Planned contrasts revealed that the $Clinical_{PS}$ children had significantly higher Internalizing Problem scores than $Community_{NS}$ children [$t(56) = 3.53$, $p < .01$ (2-tailed), $r = .43$]. No significant difference was observed in Internalizing Problem scores between $Community_{PS}$ and $Clinical_{PS}$ children or between $Community_{PS}$ and $Community_{NS}$ children.

A significant effect of group was also observed in Externalizing Problems (i.e. externalised problematic behaviour) [$F(2, 56) = 4.90$, $p > .05$]. Planned contrasts revealed that the $Clinical_{PS}$ children had significantly higher Externilizing Problem scores than $Community_{NS}$ children [$t(17.9) = 3.12$, $p < .01$ (2-tailed), $r = .59$]. No significant difference, however, was observed in Externalizing Problem scores between $Community_{PS}$ and $Clinical_{PS}$ children or between $Community_{PS}$ and $Community_{NS}$.

Finally, a significant effect of group was observed in Total Problem scores [$F(2, 56) = 6.44$, $p < .01$]. Planned contrasts revealed that Total Problem scores were higher in the $Community_{PS}$ group compared to $Community_{NS}$ [$t(56) = 2.14$, $p < 0.01$ (2-tailed), $r = .28$] and also in the $Clinical_{PS}$ compared to the $Community_{NS}$ children [$t(56) = 3.51$, $p < 0.01$ (2-tailed), $r = .42$]. No significant difference was observed for Total Problem scores between $Community_{PS}$ and $Clinical_{PS}$ children.

Syndrome scales

Kruskal-Wallis analyses revealed no significant main effect for group on Withdrawn/Depressed, Social Problems and Aggressive Behaviour scores. By contrast, significant main effects for group were observed on Somatic Complaints, Thought Problems, Attention Problems and Rule-Breaking Behaviour scores. Planned comparisons revealed that $Clinical_{PS}$ compared to $Community_{NS}$ children had significantly higher scores

for Somatic Complaints (U = 57, r = –.55), Thought Problems (U = 47, r = –.57) and Attention Problems (U = 80, r = –.43). $Clinical_{PS}$ children also had significantly higher Rule-Breaking Behaviours scores than both $Community_{NS}$ (U = 60, r = –.51) and $Community_{PS}$ (U = 61, r = –.46) scores.

Diagnostic and Statistical Manual of Mental Disorders-orientated scales

The groups were matched for two of the six DSM-oriented scales: Anxiety Problems and Oppositional Defiance, but a significant main effect for group was found for Affective Problems, Somatic Problems, Conduct Problems and ADHD. Planned contrast revealed that $Clinical_{PS}$ compared to $Community_{NS}$ children had significantly higher Affective Problem scores (U = 68, r = –.51) and similarly $Community_{PS}$ compared to $Community_{NS}$ children (U = 147, r = –.36). $Clinical_{PS}$ compared to $Community_{NS}$ children also had significantly higher Somatic Problems (U = 44, r = –.61), ADHD symptoms (U = 80, r = –.44) and Conduct Problems (U = 63, r = –.50) scores. The $Clinical_{PS}$ compared to $Community_{PS}$ children also had significantly higher Conduct Problem scores (U = 66, r = –.44).

Table 9.3 Mean Child Behavior Checklist scores together with H-value or F-value according to snoring groups; H-test results for non-parametric analyses or F-test results for parametric analyses

CBCL domain	$Community_{NS}$ N = 25		$Community_{PS}$ N = 21		$Clinical_{PS}$ N = 15		H or F-test value
	Mean	(SD)	Mean	(SD)	Mean	(SD)	
Competence Scale							
Activity	49.9	(9.4)	45.3	(10.6)	42.4	(7.2)	**H = 7.62***
Social	45.9	(13.7)	47.8	(12.1)	42.3	(7.7)	H = 3.54
School	48.9	(7.7)	45.7	(10.1)	45.3	(8.4)	F = 1.53
Total Competence	49.8	(4.2)	45.7	(7.1)	41.9	(6.0)	**H = 14.13****
Syndrome Scales							
Internal Problems	53.7	(6.1)	56.7	(7.6)	59.5	(9.1)	**H = 6.21***
External Problems	53.8	(5.9)	55.5	(6.4)	60.0	(8.8)	H = 4.19
Total Problems	53.6	(4.9)	59.1	(8.9)	66.2	(12.0)	**H = 12.42****
Anxious/Depressed	53.0	(4.2)	56.2	(7.0)	59.6	(8.6)	H = 5.29
Withdrawn/Depressed	54.3	(5.8)	60.5	(9.8)	64.7	(8.8)	**H = 12.91****
Somatic complaints	53.9	(4.5)	56.9	(7.9)	62.2	(9.7)	**H = 6.68***
Social Problems	53.4	(4.9)	54.4	(7.4)	62.5	(9.5)	**H = 10.73****
Thought Problems	52.2	(3.2)	56.7	(8.0)	62.5	(13.5)	H = 5.00
Attention Problems	47.3	(10.8)	54.2	(12.3)	61.7	(13.5)	**F = 6.36****
Rule–breaking Behaviour	47.7	(8.1)	52.4	(11.4)	59.4	(14.4)	**F = 4.90***
Aggressive Behaviour	47.2	(9.9)	54.7	(12.2)	60.9	(13.2)	**F = 6.44****
DSM–oriented Scales							
Affective Problems	53.2	(3.9)	58.5	(7.7)	63.7	(10.4)	**H = 12.01****
Anxiety Problems	52.9	(5.2)	57.5	(8.9)	58.4	(9.8)	H = 2.81
Somatic Problems	51.2	(5.7)	58.4	(10.4)	67.1	(12.4)	**H = 13.93****
ADHD	53.3	(4.4)	56.8	(8.4)	59.5	(7.0)	**H = 7.79***
Oppositional Defiant	52.8	(3.5)	55.9	(7.0)	52.5	(9.8)	H = 4.98
Conduct Problems	52.9	(4.7)	54.4	(8.1)	63.5	(10.8)	**H = 10.12****

Note. $Community_{PS}$ = primary snorers from community sample, $Community_{NS}$ = non-snorers from community sample and $Clinical_{PS}$ = primary snorers from clinical sample, CBCL = Child Behavior Checklist, ADHD = attention deficit hyperactivity disorder

Maladaptive behaviour is indicated by lower scores on the competence scale and higher scores on the syndrome and DSM-oriented scales. *Denotes $p < 0.05$ and **$p < 0.01$

Polysomnographic results

The PSG results are reported in Table 9.4. Groups were matched for all measures except for REM%, SWS% and OAHI. Although in the expected range (i.e. OAHI < 1), planned comparisons revealed that OAHI was significantly higher in $Community_{PS}$ compared to both $Community_{NS}$ (U = 107, r = –.51) and $Clinical_{PS}$ (U = 70, r = –.47) children. Although REM% differed significantly between groups, post-hoc analyses revealed only a non-significant trend for a lower REM% in $Clinical_{PS}$ compared to both $Community_{PS}$ and $Community_{NS}$. Finally, SWS% was significantly higher in the $Clinical_{PS}$ compared to the $Community_{NS}$ children [$t(19.7) = 3.22$, $p < 0.05$ (2-tailed), $r = .59$] and also compared $Community_{PS}$ children [$t(25.4) = 2.15$, $p < 0.05$ (2-tailed), $r = .39$].

Table 9.4 Mean (SD) for polysomnographic results across snoring groups with H-test results for non-parametric analyses or F-test results for parametric analyses

Domain	$Community_{NS}$ N = 25		$Community_{PS}$ N = 21		$Clinical_{PS}$ N = 15		H or F-test
	Mean	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**	
TST (mins)	427.5	(44.9)	402.2	(54.9)	421.8	(45.8)	F = 1.67
REM (%)	20.1	(2.7)	19.6	(4.1)	17.0	(5.3)	**F = 3.25***
Stage 1 (%)	3.4	(1.4)	3.8	(1.6)	3.0	(2.3)	F = 0.915
Stage 2 (%)	49.5	(6.4)	47.7	(6.9)	45.8	(5.9)	F =1.51
SWS (%)	26.9	(4.6)	29.0	(6.2)	34.3	(8.0)	**F = 6.72****
RAI (per hr)	0.8	(0.6)	0.6	(0.3)	0.5	(0.5)	H = 1.62
SAI (per hr)	8.2	(3.0)	7.2	(2.2)	9.0	(2.0)	F = 2.26
SaO_2 desats $\geq$ 3%/hr	0.9	(0.7)	1.1	(0.8)	0.6	(0.5)	H = 2.94
OAHI (events/hr)	0.2	(0.2)	0.5	(0.3)	0.2	(0.3)	**H = 14.11****
CAHI (events/hr)	0.5	(0.4)	0.6	(0.5)	0.4	(0.4)	H = 1.30
AHI (events/hr)	0.7	(0.5)	1.2	(0.7)	0.7	(0.6)	H = 4.92

Note. $Community_{PS}$ = primary snorers from community sample, $Community_{NS}$ = non-snorers from community sample and $Clinical_{PS}$ = primary snorers from clinical sample
TST = total sleep time; REM = rapid eye movement sleep; RAI = respiratory arousal index; SAI = spontaneous arousal index; OAHI = obstructive apnoea-hypopnoea index; CAHI = central apnoea-hypopnoea index; and AHI = apnoea-hypopnoea index.*Denotes $p < 0.05$ and **$p < 0.01$

Correlational results

The key PSG variables REM%, SWS% and OAHI and key demographic factors SES and birth weight were entered into a correlation matrix with the key NEPSY neurocognitive (Table 9.5) and CBCL behavioural variables (Table 9.6). Correlational analyses were performed on the whole sample combined. Only two significant but weak associations were observed between PSG/demographic and NEPSY variables: higher SWS% associated with lower Language total domain scores, while higher birth weight was associated with higher Total Memory scores. Four significant and modest relationships were observed between PSG/demographic and CBCL variables: higher REM% was associated with higher Total Competence scores; higher SES with lower External Problem and Total Problems scores; and a higher birth weight with higher Total Competence scores.

Table 9.5 Correlation results of the relationship between key polysomnographic and demographic with key NEPSY variables for the whole sample combined

Key polysomnographic and demographic variables	NEPSY					
	Total Attention/Executive Function domain		Total Language domain		Total Memory domain	
	r_s	(n)	r_s	(n)	r_s	(n)
Polysomnography						
REM%	–.05	(57)	.06	(59)	–.11	(56)
SWS%	–.15	(57)	**–.28***	(59)	–.04	(56)
OAHI	.04	(57)	–.12	(59)	–.08	(56)
Demographic						
SES	.16	(57)	.16	(59)	.16	(56)
Birth weight	.12	(49)	.17	(51)	**.31***	(49)

Note. NEPSY = Developmental Neuropsychological Assessment
*Denotes p <0.05 and ** p < 0.01

Table 9.6 Correlation results of the relationship between key polysomnographic and demographic with key Child Behavior Checklist variables for the whole sample combined

Key polysomnographic and demographic variables	Child Behavior Checklist							
	Total Competence		Internal Problems		External Problems		Total Problems	
	r_s	(n)	r_s	(n)	r_s	(n)	r_s	(n)
PSG								
REM%	**.37****	(53)	–.13	(59)	.00	(59)	–.05	(59)
SWS%	–.04	(53)	.01	(59)	–.04	(59)	–.01	(59)
OAHI	–.21	(53)	–.08	(59)	–.18	(59)	–.10	(59)
Demographic								
SES	.15	(53)	–.17	(59)	**–.37****	(59)	**–.28***	(59)
Birth weight	**.36***	(47)	–.25	(52)	–.24	(52)	–.26	(52)

Note. *Denotes p <0.05 and ** p < 0.01

Regression analysis

A hierarchical multiple regression analysis was conducted to determine whether SES or birth weight add significantly to the prediction of neurognitive and behavioural outcomes; over and above that which is explained by community versus clinical setting (Table 9.7 and Table 9.8). Setting was entered as a dichotomous variable (community = 0 and clinical =1) and SES/birth weight as continuous variables. Setting was entered as an independent variable in Step 1 and SES/birth weight in Step 2.

When the contribution of setting and SES was explored, setting was found to significantly explain a small proportion of the variance in the Total Language and Total Memory domain, and Internal, External and Total Problem scales with no additional contribution of SES to the predictive power. The regression results revealed that when both setting and birth weight were entered into the analyses, only setting was predictive in explaining a significant but small proportion of the variance in the Total Language domain and Internal

Problem scale scores. Birth weight was also shown to explain a significant proportion of variance in the Total Memory domain and External Problem scale scores.

Key neurocognitive domains

None of the predictors explained the variance in Attention/Executive Function domain scores. Results revealed that setting explained 11% of the variance in Total Language domain scores, $F(1,57) = 7.35$, $p = 0.01$. The addition of SES to the model slightly improved the prediction (12%), $F(2, 56) = 3.74$, $p = 0.03$. However, the beta for the relationship between SES and Total Language domain did not reach statistical significance. By contrast, when the contribution of setting and birth weight was explored, setting explained 9% of the variance in Total Language domain scores, $F(1, 49) = 4.56$, $p = 0.04$. However, when birth weight was included the model was no longer significant and not predictive any of the variance in the score, $F(2, 48) = 2.27$, $p = 0.11$.

Neither setting nor SES significantly explained any of the variability in Total Memory domain scores. However, when setting and birth weight were examined, the addition of birth weight to the model (i.e. Step 2) was found to significantly improve the prediction of Total Memory domain scores (2% to 10%), F of change $(2, 46) = 2.57$, $p = 0.09$. The beta for the relationship between birth weight and Total Memory at the second step was .33, $t(46) = 2.07$, $p < 0.05$.

Table 9.7 Regression coefficients for demographic variables (socioeconomic status and birth weight) and setting (community vs. clinical) and their contribution on key neurocognitive domains from the Developmental Neuropsychological Assessment

	Total Attention/Executive Function domain					**Total Language domain**					**Total Memory domain**				
	B	SE	β	R^2	ΔR^2	B	SE	β	R^2	ΔR^2	B	SE	β	R^2	ΔR^2
Step 1															
Setting	1.35	3.51	.05	.00	.00	–10.12	3.73	**–.31***	.11	.11	–9.29	5.17	–.23	.05	.05
Step 2															
Setting	3.19	3.69	.12	.04	.04	–9.53	3.95	**–.31***	.12	.00	–7.95	5.53	–.20	.07	.00
SES	0.03	0.02	.21			0.01	0.02	.06			0.02	0.03			
Step 1															
Setting	–3.34	3.83	–.13	.02	.02	–8.83	4.13	**–.29***	.09	.09	–5.35	5.86	–.13	.02	.02
Step 2															
Setting	–2.21	4.39	–.08	.02	.01	–8.18	4.77	–.27	.08	.00	0.99	6.45	.03	.10	.08
Birth weight	1.91	3.58	.08			1.06	3.77	.04			10.86	5.26	**.33***		

NB: ΔR^2 = R^2 change; * Denotes $p < 0.05$

Table 9.8 Regression coefficients for demographic variables (socioeconomic status and birth weight) and setting (community vs. clinical) and their contribution on key problematic behavioural scales from the Child Behavior Checklist

	Internal Problems					**External Problems**					**Total Problems**					**Total Competence**				
	B	SE	β	R^2	ΔR^2	B	SE	β	R^2	ΔR^2	B	SE	β	R^2	ΔR^2	B	SE	β	R^2	ΔR^2
Step 1																				
Setting	11.18	3.78	**.36***	.13	.13	9.47	3.41	**.35***	.12	.12	10.24	3.66	**.35***	.12	.12	–5.53	3.14	–.24	.06	.06
Step 2																				
Setting	10.13	3.99	**.33***	.14	.01	6.48	3.39	.23	.23	.11	8.24	3.81	**.28***	.16	.04	–4.78	3.42	–.21	.06	.01
SES	–0.02	0.02	–.11			–0.05	0.02	–.34			–0.04	0.02	–.22			0.01	0.02	.08		
Step 1																				
Setting	9.15	4.01	**.31***	.09	.09	7.34	3.78	.27	.07	.07	7.93	4.02	.27	.07	.07	–5.74	3.38	–.25	.06	.06
Step 2																				
Setting	5.64	4.48	.18	.14	.05	3.33	4.17	.12	.14	.07	4.16	4.47	.14	.13	.06	–2.22	3.94	–.09	.12	.06
Birth weight	–5.85	3.53	–.25			–6.68	3.28	**–.31***			–6.28	3.52	–.27			4.88	2.95	.28		

NB: ΔR^2 = R^2 change; * Denotes $p < 0.05$

Key problematic behaviour scales

The regression analyses revealed that setting explained 13% of the variance in the Internal Problems scale scores, $F(1, 57) = 8.72$, $p = 0.01$. The addition of SES to the model slightly improved the prediction of these scores (14%), F of change $(2, 56) = 4.68$, $p = 0.01$, but did not contribute to predictive power in the model. In contrast, the regression analyses involving setting and birth weight had a different pattern. Setting was found to explain 9% of the variance in Internal Problems scores, $F(1, 50) = 5.18$, $p = 0.03$. However, when birth weight was added to the model, neither setting nor birth weight was predictive of internal problems.

The regression analysis examining External Problems revealed that setting explained 12% of the variance in this scale, $F(1, 57) = 7.70$, $p = 0.01$. When SES was added to the model, however, the proportion of the variance on External Problems scale scores was no longer explained by setting, nor by SES. By contrast, when the contribution of setting and birth weight were analysed, the sample only predicted 7% of the variance in the External Problems scale, $F(1, 50) = 3.73$, $p > 0.05$. The predictive power improved when birth weight was added to the model (14%), F of change $(2, 49) = 4.07$, $p = 0.02$; however, only the beta value for the relationship between birth weight and the External Problems scale was statistically significant, $t(48) = 2.35$, $p < 0.05$.

Some of the variance in the Total Problem scale (12%) was explained by setting, $F(1, 57) = 7.79$, $p = 0.01$. The addition of SES to the model added an additional 4% to the prediction of the outcome, F of change $(2, 56) = 5.41$, $p = 0.01$. Although the model explained 16% of the variance in the Total Problem scale, only setting was found to contribute to the predictive power, $t(56) = 2.16$, $p < 0.05$. On the other hand, when setting and birth weight were analysed it was found that none of these variables explained the variance in the Total Problem scale. Finally, any predictor explained the variance in the Total Competence scale scores.

9.4. Discussion

Frequent snoring is a commonly reported symptom in children, with recognised consequences for health and wellbeing (Montgomery-Downs et al., 2003; Piteo, Lushington, Roberts, van den Heuvel, et al., 2011; Umana et al., 2007). However, not all children who snore are referred for clinical evaluation; thus raising the question—what differentiates referred from non-referred children? This study represents the first of its kind, presenting a direct comparison of children with PS referred for treatment and those

who also have PS but not referred for treatment on measures of sleep and breathing, as well as neurocognitive and behavioural assessment.

In general children with PS, and especially those recruited from the clinical compared to community setting, had more impaired neurocognitive and behavioural performance. In comparison to the non-referred PS and non-snoring groups, the children with PS from the clinical setting especially performed worse on neurocognitive measures of language, with specific problems in their ability to recognise word structure and sounds (i.e. phonological processing). The latter results are consistent with previous findings (Bourke et al., 2011) and, in particular, the deficits in language skills reported in children with SDB (Honaker et al., 2009). The children with PS from the clinical setting also had a higher frequency of problematic behaviour compared to children with PS from the community sample. The behavioural deficits were diffuse and included a range of both internalised and externalised problematic behaviours. The trend towards greater behavioural deficits in children with PS is consistent with previous reports of increased behavioural complaints in children who snore (Blunden et al., 2000; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004). The two PS groups also differed in their sleep measures, but not in the expected direction. Unexpectedly, the children with PS in the clinical compared to the community sample had both deeper sleep (higher SWS %) and fewer obstructions (lower OAHI). These findings raise questions whether genetic predisposition may explain why some children are more susceptible than others; or whether some have a better adaptation to the effects of snoring.

The PSG findings suggest that the children in the clinical group may be at the less, not more severe, end of the PS spectrum (i.e. less severe upper airway obstruction). Notably, and despite having less upper airway obstruction, it was the children with PS in the clinical sample who performed worse on measures of both neurocognitive and behavioural performance than children with PS in the community sample. Figure 9.1 provides an overview of the findings in children who snored from the clinical versus the community setting.

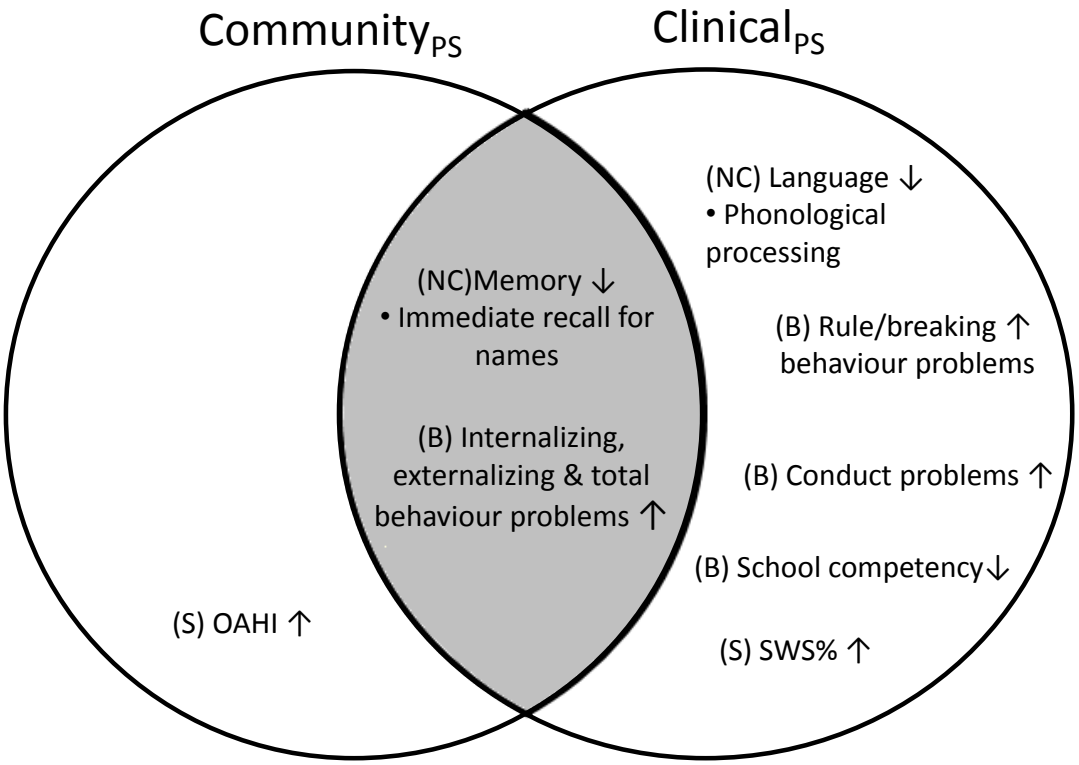


Figure 9.1 Summary of compromised neurocognitive performance (NC), behavioural problems (B) and sleep (S) characteristics within snoring groups (Community$_{PS}$ vs. Clinical$_{PS}$) based on ANOVA

Note. the shaded part of the figure represents the overlap of problematic areas across the snoring groups; ↓ = decreased; ↑ = increased

Despite children with PS having significantly lower neurocognitive scores than non-snorers, mean scores were typically within the normal range. Although these differences were small, the long-term impact on both academic and cognitive development may be greater than is typically realised (Campbell, Pungello, Miller-Johnson, Burchinal, & Ramey, 2001). In the present study a surrogate measure of academic performance was used, namely 'School Competency'. This was lower in children with PS from the clinical setting and suggests that small deficits may have a long-term impact on academic performance. An increased frequency of problematic behaviours has been well described in children who snore (Blunden et al., 2000). Further, evidence from longitudinal studies suggests that there is a strong and persistent association between SDB and problematic behaviour and that this association is particularly persistent when SDB occurs at an early age (Bonuck et al., 2012a).

Children with PS from the clinical sample had worse neurocognitive performance, a higher frequency of problematic behaviours and lower school/academic competency than both

children with PS and, likewise, non-snorers from the community sample. The presence of poor daytime functioning may be a precipitating factor in parents seeking help from their general practitioners, and may possibly explain why children who snore and have such deficits might be more likely to be referred to specialist units for evaluation. An association between poor academic performance, snoring and health practitioner referral has been noted in the literature. Urschitz et al., (2003) in their study which recruited participants from a community setting, reported those parents of children who struggled at school were more likely to be aware of health issues and hence more likely to observe snoring. Conversely, Meltzer et al. (2010) in a study examining the concordance between sleep disorders in general and child behaviour in paediatric health care facilities report that sleep disorders are more likely to be diagnosed in children with concurrent behavioural problems, such as a history of ADHD. The tendency for general practitioners to associate health problems with reduced daytime functioning (and visa-versa) coupled with parental concern may underlie the tendency for a link to be made between snoring and disruptive behaviour and, thereby, increase the likelihood of such children to be referred to ENT and sleep clinics for evaluation. Such referral biases, however, remain to be examined.

Similar to previous studies, SES was lower in children with PS regardless of whether they were recruited from the community or clinical setting (Montgomery-Downs & Gozal, 2006). Due to insufficient participant numbers the inclusion of SES as an additional factor in the between-group analyses was not possible, and it is possible that SES may explain some of the variance observed in the difference between children with PS compared to non-snorers. Also, it may be related to awareness of health issues and whether help is sought. As discussed below this is likely, as indicated by the findings from the regression analyses when SES (and birth weight) were entered as additional predictors of daytime functioning in addition to whether children were from a community or clinical setting.

Intriguingly, the two PS groups differed on several demographic factors. Children with PS from the clinical sample had lower birth weights and were more likely to come from households who smoked. This is somewhat paradoxical, given that the frequency of household smoking was higher in children with PS from the clinical sample. Low birth weight even in the absence of prematurity, is associated with increased susceptibility of developing long-term conditions including asthma (Seidman, Laor, Gale, Stevenson, & Danon, 1991) while a link between maternal cigarette smoking and low birth weight has also been noted (Bjerg, Hedman, Perzanowski, Lundbäck, & Rönmark, 2011; Kramer, 1987), as has an association with snoring in children (Kuehni et al., 2008; Li, Jin, et al.,

2010; Marshall et al., 2007; Zhang et al., 2004). In addition, it was noted that the BMI among children from $Community_{PS}$ group was the lowest, but most variable compared to the clinical group. However, the limited sample did not allow exploring in detail this issue. Future studies could investigate whether variability in BMI and different cut-offs might explain differences between samples.

The association between parental snoring and child snoring was also investigated in this study. A familial association for snoring has been reported, especially for more severe SDB conditions such as OSAS. El Bayadi et al. (1990) investigated the prevalence of sleep apnoea-related symptoms in a family with three generations with OSAS. Their results indicated that the majority of family members (seven to 66 years) snored habitually, even in the absence of significant respiratory obstruction. Family environment may explain some of the association, but inheritable factors such as airway and other anatomical structure are also likely to account for the presence of snoring in some family groups. In the present study the association between children with PS recruited from the community sample were more likely to report a higher frequency of snoring in mother and siblings. Comparing the patterns of findings in children who snore from clinical and community settings raises the possibility that they are distinct groups and that snoring may have different origins in each. In the present study we were not able to explore morphological features, but this would be a valuable area for future research.

Additional analysis was undertaken to explore the possible contribution of SES and birth weight on neurocognitive and behavioural outcomes in addition to that which is explained by whether children were recruited from the clinical or community setting. Setting (i.e. community vs. clinical) explained a small proportion of the variance in Total Language and Memory domain, Internal, External and Total Problem scale scores with no additional contribution of SES. In contrast, when the contribution of setting and birth weight was explored, the sample only explained some of the variance in Total Language domain and Internal Problem scale scores. However, an additional contribution of birth weight was found, especially for Total Memory domain and External Problem scale scores. Based on the findings, sample and birth weight may be key contributors of compromised neurocognitive and behavioural performance. Nevertheless, the proposed model was weak and these exploratory results need to be confirmed using a bigger sample in order to generalise to the entire population.

A possible additional limitation of the present study is that the small participant numbers precluded an examination of the relative contribution of additional factors known to impact snoring and, in particular, rhinitis and eczema (Chng et al., 2004; Kalra et al., 2006; Kuehni et al., 2008). A higher number of children with PS from the clinical sample had a history of asthma on questionnaire, which suggests that this group differs in the medical profile from the children with PS recruited from the community sample. In addition, while mild, the children with PS from the clinical sample also had a higher frequency of anatomical abnormalities (cleft palette and facial abnormalities). In future studies the examination of anatomical factors would be of merit in children with PS, especially tonsil size and the presence of upper airway narrowing. Further, and as a consequence, it remains possible that, while OAHI was not elevated in children with PS from the clinical sample, UARS may nonetheless be elevated. In the present study UARS was not evaluated, but this is also a limitation of the majority of previous investigations examining children with mild SDB (Li et al., 2013; O'Brien, Mervis, Holbrook, Bruner, Smith, et al., 2004).

A strength of the current study was the inclusion of objective sleep measures (i.e. PSG). However, it is generally accepted that PSG measures are not substantially altered in children with PS and the association between PSG and daytime measures are typically weak (Friedman et al., 2003; Katz & Marcus, 2005a). Thus, the reliance on traditional PSG measures poses a possible limitation and more subtle measures not typically examined in traditional PSG may be more informative. For example, CAP analysis is an alternative method that has been used as a marker of unstable sleep. In snoring children, whose sleep architecture is preserved, specific CAP rate has been found to differ from non-snorers (Lopes & Guilleminault, 2006; Miano, Paolino, et al., 2011). For example, children who snore regularly and who do not meet clinical criteria for severe SDB forms such as OSAS are reported to have an increased CAP rate with an abnormal sleep structure, particularly during SWS; suggesting a higher propensity to disruption or instability during this period (Lopes & Guilleminault, 2006). The use of CAP analysis and other quantitative EEG measures (e.g. power spectral analysis) may provide additional insight into the impact of PS on brain function, and its link with daytime deficits and may further differentiate children who snore from clinical versus community settings.

Despite the limitations discussed above, this is the first study to date to directly compare sleep, health and neuropsychological outcomes in children with PS from both clinical and non-clinical populations. Future research should expand this analysis in order to determine why some children who snore are referred to specialist clinics while others are not. In

summary, this study suggests that children who snore and who are scheduled for adenotonsillectomy are more likely to have daytime performance deficits, but not necessarily worse upper airway obstruction. Thus, why upper airway obstruction may lead to greater daytime deficits in some but not all children remains a challenging question. It is likely that demographic and individual differences may play a role, but other overlooked and as yet under-explored features of sleep such as UARS and CAP may be informative, and remain important future research and health-related areas of investigation.

Chapter 10 General discussion

SDB has received intensive interest in the sleep community over the previous three decades not only because of its prevalence in the general community but also because of the increasing realisation of the very significant morbidity associated with it. The focus has been mainly on adults where the implications of SDB for health have been well studied and especially for obstructive sleep apnoea syndrome which falls at the severe end of the SDB spectrum. In the past twenty years the research focus in the sleep field has expanded to include children where the findings regarding the morbidity of SDB have tended to parallel those in adults. Latterly it has become clear that even in children with relatively mild SDB, significant sequelae ensue. Therefore the investigation of the impact of mild SDB and particularly primary snoring on children's well-being has attained a heightened impetus. Much of the current evidence suggests that children with PS have a range of behavioural and neurocognitive deficits. However, close inspection of the findings suggests that this relationship may not be straightforward. Most studies reporting deficits in children who snore have tended to recruit children from clinical populations. In contrast, the findings are less consistent when children are recruited from community populations. These mixed findings raise questions as to the reliability of the findings and whether there are some important mediating variables that have been overlooked which may explain why the impact of SDB may differ between clinical and community populations. A further issue is that despite the extensive body of epidemiological literature examining snoring in children, a detailed examination of the natural history of snoring remains limited as does an understanding of whether the associations between snoring and daytime deficits change over time. In particular, if snoring stops do daytime deficits resolve?

The aim of the current study was to more clearly delineate the natural progression of snoring and its association with daytime deficits in children recruited from community settings. This study included a group of 116 Australian children aged 5 - 12 years, who were assessed on two occasions 24 months apart. On each occasion, a full-night polysomnography was conducted and neurocognitive and behavioural assessment were performed using validated and well-known instruments. Additional snoring and behavioural assessments were conducted at 12 months post the baseline assessment. Finally, a comparison of daytime performance, demographic and sleep outcomes was conducted between a sample of snoring children recruited from a clinical setting and

children from the community. One of the main findings was that neurocognitive functioning was comparable between snoring and non-snoring children objectively assessed by PSG. A possible explanation for the inconsistent results with previous literature as regards the dichotomy between neurocognitive findings may be the mixed criteria used to define snoring.

As it has previously been highlighted, a wide number of definitions have been used to define snoring (Lumeng & Chervin, 2008). The different criteria used to define snoring have made comparisons between studies difficult. In order to explore the impacted of snoring criteria on between group comparisons, snoring in the current study was defined according to one of three sets of criteria. These are summarized in Table 10.1 together with the criteria used by other authors who examined snoring in children recruited from community settings. Using similar criteria to those employed in earlier studies, little support was found for a difference in daytime performance in children with or without primary snoring. The present findings are contradictory with those in some of the studies where the criteria used to define snoring are directly comparable to those used in the present study (Honaker et al., 2009; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004), but not with all (Calhoun et al., 2009). Moreover, discrepancies were also found with those which are indirectly comparable (Piteo, Lushington, Roberts, Martin, et al., 2011), but consistent with few neurocognitive and particularly behavioural domains. In the few comparable results it is to be noted that group differences while significant, these were small in magnitude and limited to a few neurocognitive and behavioural domains.

Table 10.1 Classification criteria used in the current study with comparable and some studies examining primary snoring and performance in children from community settings

Definition and group classification		
Current study	**Directly comparable studies**	**Indirectly comparable studies**
Criteria one		
Parental-self report (dichotomous classification): non-snorers: never or 1/week; snorers: ≥ 2 nights/week	O'Brien, Mervis, Holbrook, Bruner, Klaus, et al. (2004) Controls: never or 1/week; primary snorers snoring ≥ 2 nights/week	Ferreira et al. (2000) Non-snorers: never; loud snorers: occasionally, frequently and always.
	Honaker et al. (2009) Controls: never and 1/week; habitual snorers: ≥ 2 or ≥ 3 nights/week	Arman et al. (2005) Controls: never or occasionally; primary snorers: often or always
		Witcher et al. (2012) Non-snorers: never; primary snorers: frequently to almost always
		Emancipator et al. (2006) Non-snorer: never; snorers: ≥ 1-2 nights/week

Current study	Directly comparable studies	Indirectly comparable studies
Criteria two		
Parental-self report (frequency levels): non-snorers: never; infrequent snorers: 1/week; frequent snorers: ≥ 2 nights/week	No comparable studies	Barnes et al. (2009) Controls: never; non-habitual snorers: rarely or occasionally Urschitz et al. (2003) Never, occasionally, frequently and always Piteo, Lushington, Roberts, Martin, et al. (2011) Controls: never in the absence of a cold; infrequent snorers: 1-2 nights/week; frequent snorers: ≥ 3 nights/week
Criteria three		
Alternative criteria using objective measures: OAHI < 0.32 and OAHI > 0.32 Additional sub-analysis: AHI < 1; snoring and AHI < 1; non-snoring and AHI ≥ 1; snoring and AHI ≥ 1	Calhoun et al. (2009) Non-snoring and AHI < 1; snoring and AHI < 1; non-snoring and AHI ≥ 1; snoring and AHI ≥ 1	Key et al. (2009) SDB (AHI ≥ 5/hr); SDB sub-clinical levels (AHI = 0.12–3.37/hr) Brockmann, Urschitz, et al. (2012) Primary snorers AHI/RDI < 1and O_2 desaturation < 4; UARS AHI < 1, RDI ≥ 1; OSA AHI ≥ 1
'Criteria four'		
Parental judgement: snoring is not a problem; snoring is a problem	No comparable research	N/A

The classification systems included in the current thesis examined a range of modalities which included subjective measures of parental self-report of snoring, measures of global attributions held by parents about their child's health such as whether parent's regarded snoring as a problem and finally objective polysomnographic measures of the degree of upper airway obstruction associated with the parental reported snoring. Irrespective of how snoring was defined there was little evidence that snoring in this community sample was associated with significant neurocognitive and behavioural deficits. These findings suggest that the consequences for well-being may be minimal in children who snore in the community and who are at the mild end of the SDB spectrum and are in direct contrast to findings by other groups who studied snoring children (Honaker et al., 2009; O'Brien, Mervis, Holbrook, Bruner, Klaus, et al., 2004; Urschitz et al., 2003), particularly by groups who studied children recruited from clinical settings (Blunden et al., 2005; Kennedy et al., 2004; Miano, Paolino, et al., 2011).

To date the most comprehensive study of snoring and neurocognitive functioning in children recruited from the community has been undertaken by Calhoun et al. (2009). In this thesis a similar methodology to that of Calhoun (i.e. technician report of snoring on the night of the PSG and objective PSG findings was also utilised) was additionally explored.

Consistent with that study's findings no deficits were found in neurocognitive functioning and while the sample size was smaller in the present study this replication does raise concerns as to what the 'true' implication is regarding the morbidity sequelae of snoring in otherwise healthy children in the general community.

An explanation is needed as to why some children with primary snoring or mild SDB in the general community do not display neurocognitive deficits whereas those in the clinical setting do have deficits. By definition, primary snoring does not involve gas exchange abnormalities (e.g. hypoxic events); such as usually seen in OSAS with resulting cortical dysfunction (Gozal, Row, Schurr, & Gozal, 2001). Thus differences in the level of hypoxia are an unlikely explanation in the current setting. A possible explanation is that another factor in conjunction with snoring may be present, for example, systemic inflammation has been noted in some children with mild SDB (Gozal, McLaughlin, et al., 2007; Lui et al., 2009). The combination of snoring and systemic inflammation has led Calhoun et al. (2009) to indicate that children with SDB can be divided in two subtypes according the presence or not of systemic inflammation and associated neurocognitive deficits. This suggests that children with primary snoring may not be a homogenous population and there may be two or more types of snoring disorders. Gozal, Sans-Capdevila, et al. (2007) had reported how in children with OSAS, but especially in those with neurocognitive deficits particular genetic determinants (APOE ε4) were associated with both OSAS and neurocognitive dysfunction. The possibility that genetic markers could explain why some children with SDB develop neurocognitive problems might explain why even if snoring is a common symptom, only a subgroup could get inflammation resulting in impaired daytime functioning which may increase awareness of parents; hence a higher likelihood of seeking medical aid.

Compared to the other variables the only classification that was found to predict neurocognitive deficits was parental perception of snoring (i.e. parental concern). Irrespective of the severity of the snoring, children whose parents perceive that snoring is a problem tend to have decreased verbal ability and memory, and increased behavioural complaints. The lack of evidence for the association between snoring severity whether it is measured objectively (by PSG) or subjectively (parentally-reported severity) raises question regarding how snoring is defined. Parental concern may be a key indicator of neurobehavioural deficits and therefore remain unmeasured when utilizing methodologies such as polysomnography. However, it is not clear what particular aspects of children's functioning have raised parental concerns regarding their child's snoring. For example if a

child is struggling at school parents overall concern will be heightened and thus they may notice behavioural issues at home that previously were unrecognised. Alternatively they may notice that their child is waking unrefreshed in the morning or that their child's sleep pattern is impacting on them (e.g. loud snoring disrupting their sleep) which may disrupt their normal functioning at home (i.e. the sleep behaviour does not meet their expectations).

The majority of studies examining parental concern in children with sleep disorders have mainly focused on its influence on quality-of-life, with most studies conduct in children with OSAS (Baldassari, Mitchell, Schubert, & Rudnick, 2008; Georgalas, Babar-Craig, Arora, & Narula, 2007; Georgalas, Tolley, & Kanagalingam, 2004). Parental concern has been shown to mediate level of quality-of-life ratings in children with OSAS (Baldassari et al., 2008). A frequently reported concern is that parents are anxious about their child's breathing; which in of itself may significantly impact parental sleep routines and subsequent daytime functioning, hence further increase their concerns as to the severity of the disorder (Baldassari et al., 2008; Georgalas et al., 2007). Because primary snoring does not involve abnormal respiratory characteristics (e.g. gasping for air) then anxiety about breathing is unlikely to underpin parental concern to the same degree, and it may be related to a more generalized anxiety about their child's well-being (Katz & D'Ambrosio, 2010). However, the lack of research in mild SDB limits a better understanding of the role that parental concern may play in parental ratings of snoring severity. This is an extremely important issue as it is parental concern that is the genesis for subsequent specialist referral with all the implication for health utilization. In future studies it will be instructive to examine in greater detail the issue of parental concern given its pivotal importance to the diagnostic process as outlined above. The importance of parental perception applies not only to community-based research, but also to clinical research. It is suggested that success with therapy of paediatric sleep problems depends on subjective parameters, such as identification of parental concerns, agreement on treatment goals, examination of opportunities and difficulties, and continuous discussion of concerns over time (Owens, 2008). It is likely that focussing on parental perceptions/concern will significantly improve the clinical assessment of children suspected to have SDB.

A further aim of the current study was to investigate the relationship between snoring and sleep routine and particularly variability in sleep/wake schedules. Analyses were conducted using both questionnaire and sleep diary and groups were compared according to three classifications systems: parental self-report, level of obstruction and parental

judgment as to whether snoring is a problem. Additional examination of the relationship between sleep routine variables and neurocognitive and behavioural performance was also conducted. This was undertaken as previous research has indicated that short sleep and irregular sleep routines are both associated with daytime deficits (Biggs et al., 2011; Gruber et al., 2012; Paavonen et al., 2009; Pesonen et al., 2010). Apart for a few exceptions, sleep routine was not associated with either neurocognitive or behavioural performance. Of note were the associations on questionnaire between higher school/non-school bedtime shift (i.e. the variability in bedtimes from school to non-school nights) with increased social and affective problems and shorter TST on non-school nights with increased affective, anxiety and oppositional-defiant problems. Noteworthy are the findings on sleep diary, that greater bedtime variability on school nights was associated with increased attention and ADHD problems. This is consistent with recent research on the impact of sleep hygiene on daytime behaviour in habitual snorers which suggests that inconsistent bed routines are associated with hyperactivity-impulsivity (Witcher et al., 2012). Although the sample size was limited, the present findings suggest that the combination of snoring and inconsistent sleep routines may place children at greater risk of developing behavioural problems. This remains to be more fully explored.

Because of the possible role of parental concern in explaining why some children who snore but not others come to the attention of their general practitioners it would instructive in future studies to explore what are the difference between cohorts that are seen in the clinic compared to the general community. To explore whether demographic and health factors might predict why some children who snore are referred to a specialist clinic, a further study was undertaking comparing sleep, health and demographics in children from the community sample with children from a clinical sample previously examined in our laboratory. Although the number of demographic variables explored was limited, low birth weight and exposure to tobacco smoke were more common in children referred to the specialist clinic, but surprisingly indicators of upper airway obstruction (i.e. OAHI) were lower in the children referred to the specialist clinic than the children who snored in the community sample. These findings suggest that snoring *per se* may not explain why these children are more likely to seek medical treatment. Children referred to the specialist clinic, however, did have worse memory and language performance than the children who snored in the community sample. This raises the possibility that children who ‘snore’ visit their doctor because their parents may be concerned about their poor academic performance and perhaps health in general. As a consequences these children may be more

likely to be referred to a specialist clinic and as a further consequence studies examining children who both snore and who have learning difficulties, perhaps predictably, find a link between them.

Although demographic and health characteristics differed between the clinical and community samples, this study did not explore the reasons why parents sought medical advice and particularly about their child's snoring—the clinical details in the notes of the referred patients suggesting whether the reason for referral was for the evaluation of snoring rather than a detailed evaluation of parental concern. In one of the few studies to examine referral patterns Bhattacharjee, Dayyat, Kheirandish-Gozal, Sans-Capdevila, and Gozal (2009) suggests that a difference between children who are referred by their paediatricians to either to an ear, nose and throat (ENT) clinic versus a sleep clinic for assessment of snoring is the presence of upper airway abnormalities and particularly enlarged tonsils. In the current study tonsil size was not measured and it is to be noted that children in the clinical setting had been schedule for adenotonsillectomy, while none of the children in the community setting had history of adenotonsillectomy. Additional evidence from studies examining the frequency that sleep problems are raised at general practitioner visits has revealed that parents seldom discuss their concerns about their child's sleep problems including snoring with their general practitioners (Blunden et al., 2004). Again this would suggest that it is not snoring per se is not the factor which may lead a child to be referred to a specialist clinic. This remains to be examined.

A final aim of the current study was to investigate natural history of snoring and associated daytime performance in children. Using validated neurocognitive instruments and polysomnography, children with and without reports of snoring were assessed two years apart. In the children who were reported to snore at baseline, half remained primary snorers at follow-up with only just a few going on to develop OSAS. Almost all the children who did not snore at baseline remained non-snorers at follow-up. In this study, a change in snoring status between baseline and follow-up was not associated with any change in either neurocognitive or behavioural performance. It was not the case that if snoring improved then daytime performance improved or visa-versa.

In summary, three main hypotheses were followed for this project. Opposite to what is what described in the first hypothesis, this study provides additional evidence that habitual snoring is not associated with reduced daytime performance in otherwise healthy school-aged children in a community setting. Additionally, the current thesis expands the existent

literature on the natural history of snoring and offers additional information about its association with daytime performance. The present findings suggest that a change in snoring severity is not associated with a concomitant change in daytime performance. Despite the limited sample size, a particular strength of the current study was that it included controls, as well as objective assessments of sleep, snoring and neurocognitive and behavioural performance which were assessed on two separate occasions. Finally, children with PS recruited from this community setting differed from those who were recruited from a clinical context, not only in daytime performance, but also in a few demographic variables. Nevertheless, it remains to be determined more fully in future studies why the findings in children with PS from community settings are inconsistent to those conducted in children from clinical settings.

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Appendices

Appendix A South Australian Pediatric Sleep Survey Questionnaire (SAPSS-Q)

Government of South Australia
Children, Youth and Women's Health Service

Women's & Children's Hospital

THE UNIVERSITY OF ADELAIDE AUSTRALIA

Child Sleep, Health and Behaviour Questionnaire



Thank you for your valuable time. By completing the following questionnaire, you agree to provide information about the sleep, health and behaviour of your child. All questions are voluntary, however we ask that you complete as much of the questionnaire as possible, as all information is useful.

Sleep Disorders Unit, WCH,
Level 2, Good Friday Building, 72 King William Road,
North Adelaide, South Australia 5006; Phone: 8161 6456.

Note: THERE ARE NO WRONG ANSWERS. If you are not sure how to answer a particular question, pick the answer that seems MOST APPROPRIATE to your child's situation at the present time. ALL INFORMATION PROVIDED IS CONFIDENTIAL. If you have any questions or concerns, please contact the Sleep Disorders Unit, on (08) 8161 6456.

Section 1: General Information

This section will provide the researchers with some important details about your child. It WILL NOT be used to identify you or your child in any way.

Today's Date _____/_____/_____

Child's gender (please circle): Male / Female

Child's date of birth: _____/_____/_____

Length of pregnancy (example: 38 weeks) _____ weeks

Child's birth weight _____ kg or _____ lbs _____ oz

Child's current height: _____cm **Please measure current height and weight for accuracy**

Child's current weight: _____ kg

Your relationship to the child (please circle): Mother / Father / Guardian / Care Giver

Number of children in the family: _____

Birth order of this child (example: eldest, 2nd, youngest etc) _____

Your postcode: _____

Child's ethnicity (please circle): Caucasian / Indigenous / African / Asian / Polynesian / Caribbean / Other _____

Note: THERE ARE NO WRONG ANSWERS. If you are not sure how to answer a particular question, pick the answer that seems MOST APPROPRIATE to your child's situation at the present time. ALL INFORMATION PROVIDED IS CONFIDENTIAL. If you have any questions or concerns, please contact the Sleep Disorders Unit, on (08) 8161 6456.

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Child's birth weight _____ kg or _____ lbs _____ oz

Child's current height: _____cm **Please measure current height and weight for accuracy**

Child's current weight: _____ kg

Your relationship to the child (please circle): Mother / Father / Guardian / Care Giver

Number of children in the family: _____

Birth order of this child (example: eldest, 2nd, youngest etc) _____

Your postcode: _____

Child's ethnicity (please circle): Caucasian / Indigenous / African / Asian / Polynesian / Caribbean / Other _____

Section 2: Sleep Habits

This section is about your child's sleep. When answering these questions, think about the **last school week** in your child's life. If recent weeks were unusual for any reason (such as school holidays, or your child had a cold and did not sleep well, etc), answer for the most recent typical school week.

NEVER = did not occur
RARELY = occurred **1 time** during the week.
SOMETIMES = occurred **2-4 times** in the week;
USUALLY = occurred **5 or more times** in the week;

Also, please indicate whether or not you consider the sleep habit a problem by marking the box under "Not Applicable (N/A)", "No", "Somewhat", or "Yes". Please attempt to answer all questions.

Please indicate your answer by placing an ☒ in the appropriate box	How Often				Do you consider it a problem?			
During the most recent typical school week:	Never	Rarely 1/week	Sometimes 2-4/week	Usually 5-7/week	N/A	No	Somewhat	Yes
1. Your child went to bed at the same time every night	☐	☐	☐	☐	☐	☐	☐	☐
2. Your child fell asleep within 20 minutes after going to bed	☐	☐	☐	☐	☐	☐	☐	☐
3. Your child shared a bedroom with siblings/parents	☐	☐	☐	☐	☐	☐	☐	☐
4. Your child fell asleep alone in own bed	☐	☐	☐	☐	☐	☐	☐	☐
5. Your child fell asleep in parent's or siblings bed	☐	☐	☐	☐	☐	☐	☐	☐
6. Your child needed parent in the room to fall asleep	☐	☐	☐	☐	☐	☐	☐	☐
7. After going to bed, your child spent time watching TV/DVD/Video in their bedroom	☐	☐	☐	☐	☐	☐	☐	☐
8. After going to bed, your child spent time listening to music in their bedroom	☐	☐	☐	☐	☐	☐	☐	☐
9. After going to bed, your child spent time talking to friends on the phone	☐	☐	☐	☐	☐	☐	☐	☐
10. After going to bed, your child spent time playing electronic games (Xbox/ Playstation/PC games/Gameboy)	☐	☐	☐	☐	☐	☐	☐	☐
11. Your child struggled at bedtime (cried, refused to stay in bed etc)	☐	☐	☐	☐	☐	☐	☐	☐
12. Your child was afraid of sleeping in the dark	☐	☐	☐	☐	☐	☐	☐	☐
13. Your child was afraid of sleeping alone	☐	☐	☐	☐	☐	☐	☐	☐
14. Your child's bedroom was noisy (could hear road or outside noise, TV etc)	☐	☐	☐	☐	☐	☐	☐	☐

Section 2: Sleep Habits (Continued)

Please indicate your answer by placing an ☒ in the appropriate box

During the most recent typical school week:

	How Often				Do you consider it a problem?			
	Never	Rarely 1/week	Sometimes 2-4/week	Usually 5-7/week	N/A	No	Somewhat	Yes
35. Your child sweated excessively when **falling asleep**	☐	☐	☐	☐	☐	☐	☐	☐
36. Your child sweated excessively **after falling asleep**	☐	☐	☐	☐	☐	☐	☐	☐
37. Your child woke during the night	☐	☐	☐	☐	☐	☐	☐	☐
a. In total, how long did your child usually stay awake during the night? (no awakenings = 0 minutes)	_____ mins							
38. Your child woke up by him/herself	☐	☐	☐	☐	☐	☐	☐	☐
a. If your child usually woke up by themselves, did this happen on (please circle): Weekdays / Weekends / Both ?								
39. Parent (or sibling) woke your child up in the morning	☐	☐	☐	☐	☐	☐	☐	☐
40. An alarm clock woke your child up in the morning	☐	☐	☐	☐	☐	☐	☐	☐
41. Your child usually woke up in a negative mood	☐	☐	☐	☐	☐	☐	☐	☐
42. Your child had difficulty getting out of bed in the morning	☐	☐	☐	☐	☐	☐	☐	☐
43. Your child took a long time to become alert in the morning	☐	☐	☐	☐	☐	☐	☐	☐
44. Your child seemed tired all the time	☐	☐	☐	☐	☐	☐	☐	☐

45. Please indicate your child's level of sleepiness during each of the following activities:

	Not Sleepy	Slightly Sleepy	Very Sleepy	Falls Asleep
a. Watching T.V.	☐	☐	☐	☐
b. Riding in the car on a short trip	☐	☐	☐	☐
c. At school	☐	☐	☐	☐
d. Reading a book	☐	☐	☐	☐

Section 2: Sleep Habits (Continued)

During the most recent typical school nights, weekends nights and school holidays, please estimate to the nearest 5 minutes (eg 8:35pm). For each question, please indicate a specific time rather than a range.

	On school days (Sun-Thurs)	On school weekends (Fri & Sat)	On school holidays
46. Bedtime			
a. Usual time your child went to bed at night			
b. Usual time the light was turned out			
c. Usual time your child went to sleep at night			
d. The **earliest** time your child went to bed			
e. The **latest** time your child went to bed			
47. Napping:			
Did your child nap during the day (please circle)? Yes / No			
If yes:			
a. At what time of day did your child usually nap			
b. In total, how much time did your child spend napping per day (non-nappers = 0 minutes)			
48. Waketime			
f. Usual time your child woke up in the morning			
g. The earliest time your child woke up			
h. The latest time your child woke up			

49. Please write any further comments about your child's sleep below:

_____

_____

_____

_____

_____

Note: Please consult your family doctor if you have any immediate concerns about your child's health.

Section 3: Activity

This section is about the level of activity in children. Please give your answers based on your child's activity **over the last typical school week**. If unsure about any question, please ask your child.

Please indicate your answer by placing an ☒ in the appropriate box

Over the last typical school week:	How Often			
	Never	**Sometimes 1-2/week**	**Usually 3-4 /week**	**Often 5 or more /week**
1. How often did your child play sport?				
a. At school, organised by teachers or parents				
b. At school, unorganised with friends				
c. Outside of school, either organised or unorganised				
2. How often did your child participate in any activity (excluding sport) that made them breathe hard?				
How often did your child do the following during lunch-time at school?				
a. Sit and talk to friends				
b. Train for school sports teams				
c. Walk around the school grounds				
d. Ride or walk home for lunch				
e. Read or do homework				
f. Play quietly				
g. Play running type games with friends (eg chasey, basketball, soccer, footy, etc)				

3. What organised sport or sports did your child play regularly? (Please answer on the line below)

_____

During the most recent typical school days, weekends and school holidays, please estimate to the nearest 5 minutes:	**On school days (Mon – Fri)**	**On school weekends (Sat - Sun)**	**On school holidays**
1. The amount of time your child spends in front of a screen (eg TV, computer, video games, etc)			
2. The amount of time your child spends doing homework per day (eg 65 minutes)			
3. The usual time your child finishes their homework (eg 8:35pm)			

Section 4: Behaviour (Continued)

Please indicate your answer by placing an ☒ in the appropriate box

Over the last three months, your child has been:

	Not True	Somewhat True	Certainly True
20. Often volunteering to help others (parents, teachers, other children)	☐	☐	☐
21. Thinking things out before acting	☐	☐	☐
22. Stealing from home, school or elsewhere	☐	☐	☐
23. Getting along better with adults than with other children	☐	☐	☐
24. Easily scared, has many fears	☐	☐	☐
25. Having a good attention span, sees tasks through to the end	☐	☐	☐
26. Having problems doing anything that is physically demanding	☐	☐	☐
27. Happy doing chores around the house when asked	☐	☐	☐
28. Often missing school due to illness	☐	☐	☐
29. Having trouble paying attention at school	☐	☐	☐
30. Seeming to enjoy life	☐	☐	☐

Section 4: General Medical History

This section is about any breathing or health complaints your child may have which can affect sleep or behaviour.

Please indicate your answer by placing an ☒ in the appropriate box.

	Unsure	No	Yes
1. Has your child ever snored?	☐	☐	☐
If YES, at what age did you first notice your child's snoring? _____			
2. Do any of the following family members snore?			
a. Mother	☐	☐	☐
b. Father	☐	☐	☐
c. Siblings	☐	☐	☐
d. Grandparents	☐	☐	☐

Section 5: General Medical History (Continued)

Please indicate your answer by placing an ☒ in the appropriate box	Unsure	No	Yes
3. If YES to Question 2 (family members snore), are any being treated for sleep apnoea with Continuous Positive Airway Pressure (CPAP)?	☐	☐	☐
4. Has your child ever been diagnosed with a sleep breathing disorder?	☐	☐	☐
5. Has your child had their tonsils taken out?	☐	☐	☐
6. Has your child had their adenoids taken out?	☐	☐	☐
7. Has your child been diagnosed with any of the following:			
a. Facial abnormalities that affects their breathing	☐	☐	☐
b. Cleft palate	☐	☐	☐
c. Neurological disorders	☐	☐	☐
d. Muscular dystrophy	☐	☐	☐
e. Intellectual delay	☐	☐	☐
f. Developmental delay	☐	☐	☐
g. Behavioural disorders	☐	☐	☐
8. In the last 12 months, has your child experienced any of the following medical conditions?			
a. Hayfever	☐	☐	☐
b. Asthma	☐	☐	☐
c. Eczema	☐	☐	☐
d. Rhinitis (Runny nose without a cold)	☐	☐	☐

9. Please list any prescriptive medication your child is currently taking (including ointments)?

_____

_____

10. How many cigarettes are smoked per week (in total) by members of the immediate household (anyone currently living in the house)? Please answer even if smoking occurs outside the house.

_____

Note: Please consult your family doctor if you have any immediate concerns about your child's health.

Thank you for completing this questionnaire

Please complete the next section if you wish to receive further information regarding future sleep research

We will be asking a small number of families to participate in further research. If you would like further information on current sleep studies at the Adelaide Women's and Children's Hospital (WCH), please complete the section below. **The information that you provide in this section will be removed so that neither your or your child will be identified with the information provided in the questionnaire.**

We will be calling families who have filled out this section in the near future. Alternatively, to register your interest in future sleep research, you can call the Sleep Disorders Unit on (08) 8161-6456 during business hours, or email and request information from: sleep.studies@adelaide.edu.au.

Your full name: _____

Your child's name: _____

Your relationship to the child (eg: mother/father/carer) _____

Your address: _____

_____

Your daytime telephone number: _____

Please place the completed questionnaire and consent form in the envelope provided and return it to school with your child.

Thank you again



Appendix B SAPSS-Q Profile

SAPSS-Q SLEEP DISTURBANCE PROFILE - MALE

NAME: _____

IDCODE: _____

DATE: ____/____/____

DOB: ____/____/____

A T-score above 70 is considered in the problem range

	Younger (5-7 years)						Older (8-10 years)					
T	SR	BA	MT	NA	SDB	RS	SR	BA	MT	NA	SDB	RS
100+								12		11+		
99												
98												
97										10		
96	17+							11				
95							18					
94												
93	16		12									
92							17			9		
91								10				
90	15										11+	
89							16					
88			11									
87	14			10+	10+							
86		12					15	9		8	10	
85												12
84			10									
83	13	11			9		14		12			
82				9				8				
81						11+					9	11
80	12						13			7		
79		10	9						11			
78					8	10						
77	11			8			12	7			8	10
76		9							10			
75			8							6		
74	10				7	9	11					
73				7				6			7	9
72		8							9			
71	9		7				10					
70						8						
69		7			6					5		8
68				6			9	5	8		6	
67	8											
66			6			7						
65		6			5		8		7			7
64	7									4	5	
63				5				4				
62			5			6	7					
61	6	5			4				6			6
60											4	
59				4			6	3				
58	5	4	8			5				3		
57									5			5
56					3		5					
55											3	
54	4	3		3		4		2				
53			3				4		4			4
52					2					2		
51	3	2									2	
50						3	3	1	3			
49			2	2								3
48	2											
47		1			1		2			1	1	
46						2			2			
45				1				0				2
44	1	0	1				1					
43					0							
42						1			1		0	
41	0						0			0		1
40			0	0								
39						0			0			
38												
37												0

Appendix B (Continues)

SAPSS-Q SLEEP DISTURBANCE PROFILE - FEMALE

NAME: _____

IDCODE: _____

DATE: ____/____/____

DOB: ____/____/____

A T-score above 70 is considered in the problem range

	Younger (5-7 years)						Older (8-10 years)					
T	SR	BA	MT	NA	SDB	RS	SR	BA	MT	NA	SDB	RS
100+					12					9+	12	
99												
98				12								
97					11						11	
96												
95								12				
94										8		
93				11							10	
92					10							
91	14+							11				
90												
89												
88	13			10						7	9	
87					9		14+	10				12
86												
85			12									
84	12	12		9		12	13					11
83											8	
82			11		8			9	12			
81		11				11	12			6		
80	11											10
79				8								
78			10		7			8	11		7	
77	10	10				10	11					
76												
75									10			9
74		9	9	7			10	7		5		
73	9				6	9					6	
72												
71							9		9			8
70		8						6				
69	8		8	6		8				4	5	
68					5							
67		7					8		8			7
66	7		7									
65						7		5				
64		6		5			7		7			
63					4						4	6
62	6		6									
61						6	6	4		3		
60		5							6			
59	5			4								5
58			5		3						3	
57		4				5	5	3	5			
56												
55	4			3						2		
54		3	4				4					4
53					2	4		2	4		2	
52	3											
51			3				3					
50		2		2		3			3			3
49												
48	2				1			1		1	1	
47		1	2				2					
46						2			2			2
45	1			1								
44		0					1	0			0	
43			1		0							
42						1			1			1
41	0						0			0		
40				0								
39			0									
38						0			0			0
37												

Appendix C Research information sheet

Saturday, 5 April 2014

Project Manager
C/- Sleep Disorders Unit
Lv 2 Good Friday Building
Women's and Children's
Hospital
72 King William Road
North Adelaide SA 5006
Ph: 8161 6456

Thank you for participating in the first stage of my research and expressing interest in participating further. As mentioned, sleep problems have been connected to more serious problems such as behavioural difficulties and deficits in academic performance. The purpose of this stage of the research is to determine how snoring effects daytime behaviour and academic performance.

This part of the research involves identifying a number of children who snore or have snored in the past, as well as an equal number of healthy, non-snoring children, and involving them in a small number of non-invasive tests. The first of these is called a Polysomnography or PSG. A PSG is just a fancy name for sleep study. This study will be done at the Sleep Disorders Unit at the Women's and Children's Hospital and involves staying overnight in the laboratory. When there, your child will be connected, through small electromagnetic pads placed on the skin, to a special machine and our qualified technicians will monitor his/her sleep and breathing patterns throughout the night. PSG's have been used as a standard measure of sleep for many years and are non-invasive. Once at the lab the researchers will explain the process in detail to ensure you are comfortable in continuing with the study. However, should you require any further information about the PSG before agreeing to participate, please contact me on 8161 6456 or email.

Once the information on his snoring has been analysed, your child will be invited back the Sleep Disorders Unit at the Women's and Children's Hospital to participate in intelligence, memory, attention and behavioural testing. This will occur within approximately two weeks of the PSG. Upon your consent, we will also be asking your child's teacher to complete a questionnaire regarding his/her academic performance and behaviour in class. Then, approximately 2 years after the initial testing, we would like to complete all the testing again so that we can determine what changes occur over this time. Please note, all information will be kept confidential and in no way will you or your child be identified in the analysis or reporting of this research. Also, you are permitted to withdraw from the research at any time without explanation.

Below I have answered some of the most common questions that are asked in regards to research. If you have any other questions, or require any further information, please do not hesitate to contact me either on by phone (8161 6456) or through email.

Will my child and I be able to remain anonymous?
All sleep, health and behavioural information will be grouped with results from other children and reported together. We can guarantee that any information gathered will remain completely confidential.

Do I have to participate?
NO. You are under no obligation to continue with the research, however by doing so, you will be integral in contributing to research that improves the health and well-being of children in the community.

What will happen with the information I supply?
All information will be entered into a database and analysed by the researchers with the view to determining how snoring may relate to behaviour problems and academic performance. In addition, the information provided will assist in determining the natural history of snoring. This information will also have a huge impact on how snoring in children is managed both at home and by health professionals.

Will I have access to the results of any testing or assessments done on my child?
YES. You will be entitled to any results pertaining to your child. This includes all results of the PSG, intelligence, memory, attention and behavioural testing conducted at the Women's and Children's Hospital, as well as any classroom-based assessment completed by your child's teacher.

Will I be informed of the results of this study?
Absolutely. it is the intention of the research team to publish the results through the Department of Education and Children's Services newsletter and on their website. In addition, you can request your child's individual results to be sent to you.

How do I know this research is legitimate?
This research has been approved by the **Children, Youth & Women's Health Service** and **Adelaide University** Ethics Committee and the **Department of Education and Children's Services**. Should you wish to discuss the approval process with a representative of the Ethics committee, or have any concerns about the ethics of this study, please contact Ms Brenda Penny, Secretary of the CYWHS Research Ethics Committee, on 8161 6521.

Will I be paid to participate?
You will not be paid to participate, however we will reimburse you for out-of-pocket expenses incurred as a result of travelling to the Women's and Children's hospital for the purposes of this study (up to $50 for the PSG, and $25 for the intelligence testing).

Yes, I want my child to participate. What do I do now?
Someone will be in touch with you within the next two weeks to ask your decision. If you agree for your child to participate, we will schedule a suitable night for you and your child to come into the Women's and Children's Hospital for a sleep study and intelligence test.

Thank you for taking the time to consider this request. Your participation in this stage of the research is highly appreciated and will provide valuable information for the health and well-being of children. Should you have any further questions or require any additional information regarding this research, please contact me on **8161 6456.**

Yours sincerely

Project Manager
Paediatrics department – Sleep research
University of Adelaide

Appendix D Copy of the consent form sent to parents

THE CONSENT FORM

I (name)_____

hereby consent to my child's involvement in second stage of the research project entitled:

Prevalence of Primary Snoring in a Community Sample of Children Aged 5 to 10 years and its effects on neurocognitive and behavioural functioning.

	Please Tick ✓
• I have read and understood the Information Sheet on the above project and understand that my child is being asked to participate in Polysomnographic (PSG) sleep monitoring, neurocognitive and behavioural testing.	☐
• I understand that my child or I may not directly benefit by taking part in this research.	☐
• I understand that while information gained in the study may be published, neither my child nor I will be identified and all individual information will remain confidential.	☐
• I understand that I have access to the results from any testing or assessments relating to my child.	☐
• I understand that I can withdraw my child from the study at any stage up until the end of the collection of data.	☐
• I understand that there will be no payment, except for out-of-pocket reimbursement, for taking part in this part of the study.	☐
• I consent for my child's teacher to provide information about my child's academic performance and behaviour in class.	☐

Name of teacher nominated to complete the Teacher Questionnaire: _____

Name of Child: _____

Parent/Guardian's Signature: _____

Your Relationship to Child (mother/father/guardian etc): _____

Date: _____

Contact Number: _____

Appendix E Information letter to the parents

C/- Sleep Disorders Unit
Women's & Children's Hospital
Lv2 Good Friday Building
72 King William Street
North Adelaide SA 5006
Tel 08 8161 6456
Fax 08 8161 7050

www.cywhs.sa.gov.au

Research Information Sheet

Dear Parent / Guardian

I am writing to introduce myself and to invite you to participate in a unique research project aimed at enhancing the lives and well-being of children in South Australia. It has recently been discovered that the quality of a child's sleep may have an effect on more serious problems such as obesity and behavioural disorders (eg hyperactivity). While we know that this issue can cause developmental problems for children, we don't actually know how many kids in the community have sleep disturbances. Thus, it is the purpose of this project to see how extensive this problem might be, and to gather a bit more information about how sleep may relate to behaviour and activity.

The research project involves gathering information on sleep habits of children from approximately 5000 families around Adelaide. If you agree to participate, you will be required to complete one questionnaire for each of your children between the ages of 5 and 10 years (inclusive). This questionnaire asks about your child's sleep habits, health, behaviour, activity levels, and some general information for statistical purposes. The questionnaire should take approximately 20 minutes to complete. **All information gathered will be kept confidential and in no way will you or your child be identified in the analysis or reporting of this research.**

Below I have answered some of the most common questions that are asked in regards to research. If you have any other questions, or require any further information, please do not hesitate to contact a member of the research team either by phone (8161 6456) or through email (sleep.studies@adelaide.edu.au).

Do I have to participate?
NO. Although we would be grateful for any information you could provide us, and by participating you will be contributing to research on improving the lives of children, you are under no obligation to complete the questionnaire.

Will my child and I be able to remain anonymous?
YES. Neither you nor your child will be identified in any way in the analysis. Information about your child's sleep, health and behaviour will be grouped with responses from other parents and reported together. Not even the school your child attends will be identified. Although there will be some identifying information on the questionnaires that will allow us to contact you if you consent to participate further, we can guarantee that any information you supply will remain completely confidential.

What will happen with the information I supply?
All information will be entered into a database and analysed by the researchers with the view to determining how prevalent childhood sleep problems are and give us a better idea of how this may relate to behaviour problems and activity levels. This information will have a huge impact on how sleep, weight and behaviour in children is managed both at home and by health professionals.

PTO

Will my child or I have to do anything else beside complete the questionnaire?
That is completely up to you and your child. This research is the first stage of a larger project. Depending on your responses to the questionnaire, your child may be eligible to participate in the next phase of the research, but again, participation is voluntary. After the initial questionnaire study is completed, we will be collecting more information on the effects of sleep on daytime functioning by conducting further assessments of brain function and behaviour in our sleep laboratory. This phase of the study will involve things such as:

- Sleep study in the sleep laboratory
- Intelligence testing
- Memory and attention testing
- Behaviour monitoring

If you wish for your child to participate in the second stage of this study, all you need to do is complete the appropriate section at the bottom of the questionnaire. A researcher will then contact you and will give you more in-depth details about what is involved. In the mean time however, if you have any questions about any part of the study, please contact a member of the research team (8161 6456) for further information. It is important to note that if you do not wish to continue with the study, you can withdraw your consent at any time without explanation and we will immediately remove all information that you have provided on your child (or children) from our records.

Will I be informed of the results of this study?
Absolutely. It is the intention of the research team to provide participating schools with a report of the results. We will also be available to make presentations upon request. In addition, you can request your child's individual results to be sent to you.

How do I know this research is legitimate?
This research has been approved by the **Children, Youth & Women's Health Service** and **Adelaide University** Ethics Committee's. Should you wish to discuss the approval process with a representative of the Ethics committee, or have any concerns about the ethics of this study, please contact Ms Brenda Penny, Secretary of the CYWHS Research Ethics Committee, on 8161 6521.

Will I be paid to participate?
No, your participation in the first phase of the study is entirely voluntary.

Yes, I want my child to participate. What do I do now?
If you agree for your child to take part, a Consent Form is attached for you to sign and the questionnaire is enclosed. Once the consent form is signed and the questionnaire completed, please place them **both** in the envelope provided and return them to school with your child.

Thank you for taking the time to consider this request. Your participation in this research is highly appreciated and will provide valuable information for the health and well-being of children. Should you require any additional information regarding this research, please contact a member of the research team on **8161 6456** or **sleep.studies@adelaide.edu.au.**

Yours sincerely

Project Manager
Discipline of Paediatrics
University of Adelaide

Appendix F Letter sent at follow-up assessment

Saturday, 5 April 2014

Project Manager
C/- Sleep Disorders Unit
Lv 2 Good Friday Building
Women's and Children's Hospital
72 King William Road
North Adelaide SA 5006
Ph: 8161 6456

«CGFIRSTNAME» «CGLASTNAME»
«STADDRESS»
«SUBURB» SA «POSTCODE»

Dear «CGFIRSTNAME»

I trust this letter finds you well. It has now been 2 years since «CHFIRSTNAME» came in for his/her sleep study. As you may remember, our ongoing study aimed at gaining an understanding of how sleep affects behaviour and daytime functioning and how this may change over time. Thus, we would like to invite «CHFIRSTNAME» to repeat the sleep and psychological testing that he/she underwent two years ago.

In about one week's time someone will be contacting you to discuss the study further and arrange appointments for another sleep study and IQ test. Please note that participation is voluntary and if you no longer wish to be involved, you do not have to. However, we would greatly appreciate your and «CHFIRSTNAME»'s continued involvement as we feel this is very important research for improving the well-being of children.

If you would like to advise us of a new phone number to reach you on or if you have any questions, please do not hesitate to contact me on 8161 6456 or email me. If you cannot reach me at the above telephone number simply leave a message and I will get back to you as soon as possible. I look forward to speaking with you soon.

Kind regards

Project Manager
Discipline of Paediatrics
University of Adelaide

«QUESTNO»

Appendix G Description of polysomnography session

Saturday, 5 April 2014

C/- Sleep Disorders Unit
Lv 2 Good Friday Building
Women's and Children's Hospital
72 King William Road
North Adelaide SA 5006
Ph: 8161 6456

«CGFIRSTNAME» «CGLASTNAME»
«STADDRESS»
«SUBURB» SA «POSTCODE»

Dear «CGFIRSTNAME»

Thank you for agreeing to participate in our research investigating the association between sleep and daytime functioning in children. As discussed, your appointments for the (1) sleep study and (2) psychological testing are

1. for the overnight sleep study
2. with our research Psychologist

Enclosed is a map showing the location of the sleep disorders unit, where both appointments will be. Also enclosed is a sleep diary to be completed for seven (7) days before the *psychological* testing.

On the day of the psychological testing, please arrive a few minutes early so that we can all get settled. The testing takes approximately 1½ to 2 hours to complete so you may like to bring something to read. Drinks and snacks will be provided for «CHFIRSTNAME».

On the night of the overnight sleep study, we ask that you arrive at 7.30pm. Please make arrangements to eat dinner before you arrive. Please bring something along for breakfast the next morning. The sleep disorders unit is located on the second floor of the Good Friday Building. When you get to the closed glass doors, please press the intercom button beside the door and the staff will let you in. Remember, one parent or guardian must stay with «CHFIRSTNAME» at all times during the night. A bed will be provided the parent/guardian to sleep in. The study will finish the next morning at 7am.

You will not need to bring any linen or towels, however you might like to bring any items which will help make yourself or «CHFIRSTNAME» feel more comfortable. This can range from special pillows, favourite toys, bedtime stories or games. Please note, there is no TV in the sleep lab.

If you have any questions, or need to change an appointment, please do not hesitate to contact me on 8161 6456. There is an answering machine if I am not in the office. Can you please contact me if your child becomes unwell prior to the sleep study appointment, as we will need to reschedule.

Yours sincerely

<<Project Manager>>

Appendix H Questionnaire reminder letter

Saturday, 5 April 2014

Project Manager
C/- Sleep Disorders Unit
Lv 2 Good Friday Building
Women's and Children's Hospital
72 King William Road
North Adelaide SA 5006
Ph: 8161 6456

«CGFIRSTNAME» «CGLASTNAME»
«STADDRESS»
«SUBURB» «POSTCODE»

RE: Questionnaire Reminder

Dear «CGFIRSTNAME»

A short time ago we sent you a questionnaire titled ***"Child Sleep, Health and Behaviour Questionnaire: 12 Month Follow-Up"*** as part of «CHFIRSTNAME»'s ongoing participation in the Sleep and Daytime Functioning study. As we have not yet received the completed questionnaire, please find enclosed another copy in the event that it has been misplaced or not received. I understand that your time is precious, however it is important that we get an idea of how «CHFIRSTNAME»'s sleep and behaviour has changed over the past year and would really appreciate you taking a few minutes to complete the questionnaire. If you have recently sent back the follow up questionnaire or would prefer not to provide the information, please disregard this letter. Otherwise, once you have completed the questionnaire, please place it in the reply paid envelope provided and put it in the nearest postbox. You do not need a stamp.

«CGFIRSTNAME», should you have any questions regarding the questionnaire or would like any further information, please do not hesitate to contact me.

Kind regards

Project Manager
Discipline of Paediatrics
University of Adelaide

«QUESTNO»

Appendix I Copy of Sleep Diary

CHILD SLEEP DIARY INSTRUCTIONS

A. Please ensure your child's name is printed at the top of the Sleep Diary and place the diary in a location where you will remember to fill it out each day (eg. fridge, beside bed, toilet door, etc.). The diary needs to be completed each day for at least 7 days in a row, but there is no set time of the day when this has to be done (often first thing in the morning works well). For each question on the diary answer as best you can remember or guess. We only need a general idea of your child's sleep habits.

B. For each day record the date and day. List the number of naps the child had during the day and the total time of all naps combined for that day.

C. Record the time your child went to bed and went to sleep on this night. The next day record the time they woke up, the time they got out of bed, the number of times they woke up during the night and the total amount of time they were awake during these awakenings.

D. Record how your child was woken (eg. by themselves, a sibling, etc.), and whether they shared a bedroom or bed with someone else during the night.

E. The mood scale involves you rating from 1 to 5 how alert and refreshed you think your child is each morning. The scale is listed below:

1 = Very sleepy, irritable and unresponsive. Needs to go back to sleep

2 = Tired and not very enthusiastic. Will need to take it easy today

3 = Relaxed, not at full alertness. May need a little while to wake up fully

4 = Able to concentrate, quite happy. Able to handle a normal day

5 = Active, very happy, full of energy. The perfect start if your child had to be out and busy all day

An example entry is provided on the first line of the sleep diary.

F. On the last page of the diary you are asked to list anything you consider important and which may have affected your child's sleep. It is best to do this at the same time as completing each daily diary entry. You are also asked to tell us if any night was an unusual night for your child compared to normal, and give reasons.

If there was anything you consider important for us to know about which may have affected your child's sleep during the above period please provide details in the table below:

Date	Please Specify

If you do not consider your child's sleep pattern on any night during the above period to be a reasonable example of their normal sleep behaviour please give reasons in the table below:

Date	Please Specify

Thank you for completing your child's Sleep Diary. Please bring the completed diary with you to your next appointment at the Sleep Disorders Unit or return it in the reply paid envelope if you have been supplied with one.

CHILD SLEEP DIARY

Child's Full Name							Office use only Study ID:							
Date	Day	Number of daytime naps	Total time of all daytime naps (mins)	Time went to bed in evening	Time went to sleep	Time woke up next morning	Time got out of bed	Number of awakenings during night	Total time awake during night (minutes)	Total' hours of sleep	Child woken by self, parent, sibling, alarm or other?(specify)	Did your child share a bedroom with anyone? (Y/N)	Did your child share a bed with anyone? (Y/N)	Mood scale (refer to instructions)
27/03	*Wed*	*1*	*30*	*8:15pm*	*8:45pm*	*7:15am*	*7:30am*	*2*	*20 minutes*		*self*	*Yes-brother*	*No*	*4*

Appendix J Neurocogntive report after assessment

Saturday, 5 April 2014

Project Manager
C/- Sleep Disorders Unit
Lv 2 Good Friday Building
Women's and Children's Hospital
72 King William Road
North Adelaide SA 5006
Ph: 8161 6456

«FirstName» «LastName»
«Address1»
«City» «State» «PostalCode»

Dear «FirstName»

Thank you once again for participating in our research regarding sleep and daytime functioning in children. As promised, please find following a report describing the results of «childname»'s psychological testing. If you have any questions about this report, please do not hesitate to contact me on 8161 8394.

This report signifies the completion of stage two of this research as well as you and «childname»'s involvement in the study. The data we have gathered from «childname»'s various testing sessions will help us to generate important scientific knowledge and consequently contribute to improving children's sleep health. As such we are very appreciative of you and «childname» giving up so much of your time to assist us in this research. At this stage we will not be requiring you or «childname» to provide us with any further data, however if circumstances change it may be deemed appropriate to contact you again. As such if any of your details change, please complete the tear off section below and return it to:

Sleep Disorders Unit
Lv 2, Good Friday Building
Women's & Children's Hospital
72 King William Road
NORTH ADELAIDE SA 5006

Thank you, I wish you and «childname» all the very best.

Change of Contact Details

Research Study: Prevalence of primary snoring and its effects on neurocognitive functioning

Name of parent: _____

Name of child participating: _____

New address: _____

_____

New contact number: _____

Neurocognitive Test Results for «childname» «LastName»

What was studied:

Over the course of the two hours, a number of different areas of brain functioning were studied. To help you understand the report, I have put together a brief description of each of the areas.

Please note: All psychological tests must be interpreted with caution. These scores indicate how your child performed ON THE DAY of the test. It is not necessarily an indication of their ability or level of intelligence.

Ability Studied	Description
1. Verbal ability	This measures the child's language development.
2. Non-verbal ability	This measures the child's ability to take abstract concepts and apply relationships or patterns to them. This is usually an indication of higher processing.
3. Spatial ability	This measures the child's ability to use perceptual reasoning to reproduce visual information.
4. Attention/Executive Function	This measures the child's ability to maintain attention. It also measures their ability to plan and execute mental strategies, monitor their own performance and make any necessary adjustments, and to be able to build and use mental patterns for problem solving.
5. Memory and Learning	This measures the child's ability to learn new information and retrieve this information from memory.
6. General Conceptual Ability	This is calculated from the above results and gives an overall IQ score. **Please note: An IQ score does not indicate how 'smart' your child is. A full rating of intelligence requires more detailed testing.**

«childname»'s Results:

Due to a number of different factors that may influence the testing, the scores for all of the tests are given as a range and are not presented as an absolute score. The classification shows where «childname» sits compared with all other children of the same age.

Psychological domain	«childname»'s Score Range	Classification
1. Verbal ability	«Verbal»	Average
2. Non-verbal ability	«nonverb»	Average
3. Spatial ability	«spatial»	Average
4. Attention/Executive Function	«attention»	Average
5. Memory and Learning	«memory»	Average
6. General Conceptual Ability (IQ)	«GCA»	Average

«FirstName», should you have any questions regarding this report or would like any further information on the specifics of the scoring, please do not hesitate to contact me.

Kind regards

Project Manager
Discipline of Paediatrics
University of Adelaide

Appendix K Analysis of neurocognitive and behavioural performance according to previous snoring criteria used by Calhoun et al. (2009)

Additional to the analyses presented in Chapter 3, an analysis for neurocognitive and behavioural performance was conducted using comparable criteria previously described by Calhoun et al. (2009). This was an exploratory analysis that attempted to compare previous classification relying on objectively assessment of snoring and apnoea-hypopnoea index (AHI). Of note is that all children classified as AHI ≥ 1 in the current study had AHI < 5. Because the majority of the sample was from Caucasian ethnicity (93%) the current study did not use ANCOVA, but ANOVA to test group differences. Moreover, partial eta squared (η^2_ρ) was calculated as a measure of effect size. Key neurocognitive domains and behavioural scales were included in this analysis and results are presented in Table 11.1 and Table 11.2 respectively.

Results for neurocognitive data revealed no significant differences ($p > 0.05$) between groups on any the domains neither for DAS nor NEPSY. Likewise, results for behavioural data indicated that all groups had similar scores for the four key behavioural scales. Discussion of this analysis is presented in Chapter 3.

Table 11.1 Mean (SD) DAS and NEPSY key domain scores according to previous classification by Calhoun et al. (2009) together with F-test and effect size values

Key domain	AHI < 1				AHI ≥ 1				F-value	Effect Size (η^2_ρ)
	No snoring (n = 55)		Snoring (n = 19)		No snoring (n = 33)		Snoring (n = 8)			
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)		
DAS										
Verbal Ability	101.9	(11.4)	102.7	(12.5)	101.4	(11.7)	100.0	(5.4)	0.12	.00
Non-verbal Reasoning Ability	98.2	(10.8)	98.2	(11.1)	98.6	(10.0)	102.6	(10.3)	0.414	.01
Spatial Ability	106.9	(11.4)	108.3	(9.4)	105.5	(9.2)	110.0	(8.5)	0.54	.01
General Cognitive Ability	102.2	(10.6)	103.1	(9.8)	101.8	(8.1)	104.8	(8.2)	0.24	.01
NEPSY										
Attention Executive Functioning	101.9	(10.9)	102.0	(10.0)	101.0	(9.2)	105.8	(9.2)	0.48	.01
Language	105.4	(13.7)	104.3	(11.6)	102.0	(11.8)	106.5	(7.9)	0.58	.01
Memory	106.6	(18.1)	106.3	(18.9)	105.8	(14.0)	104.6	(15.6)	0.04	.00

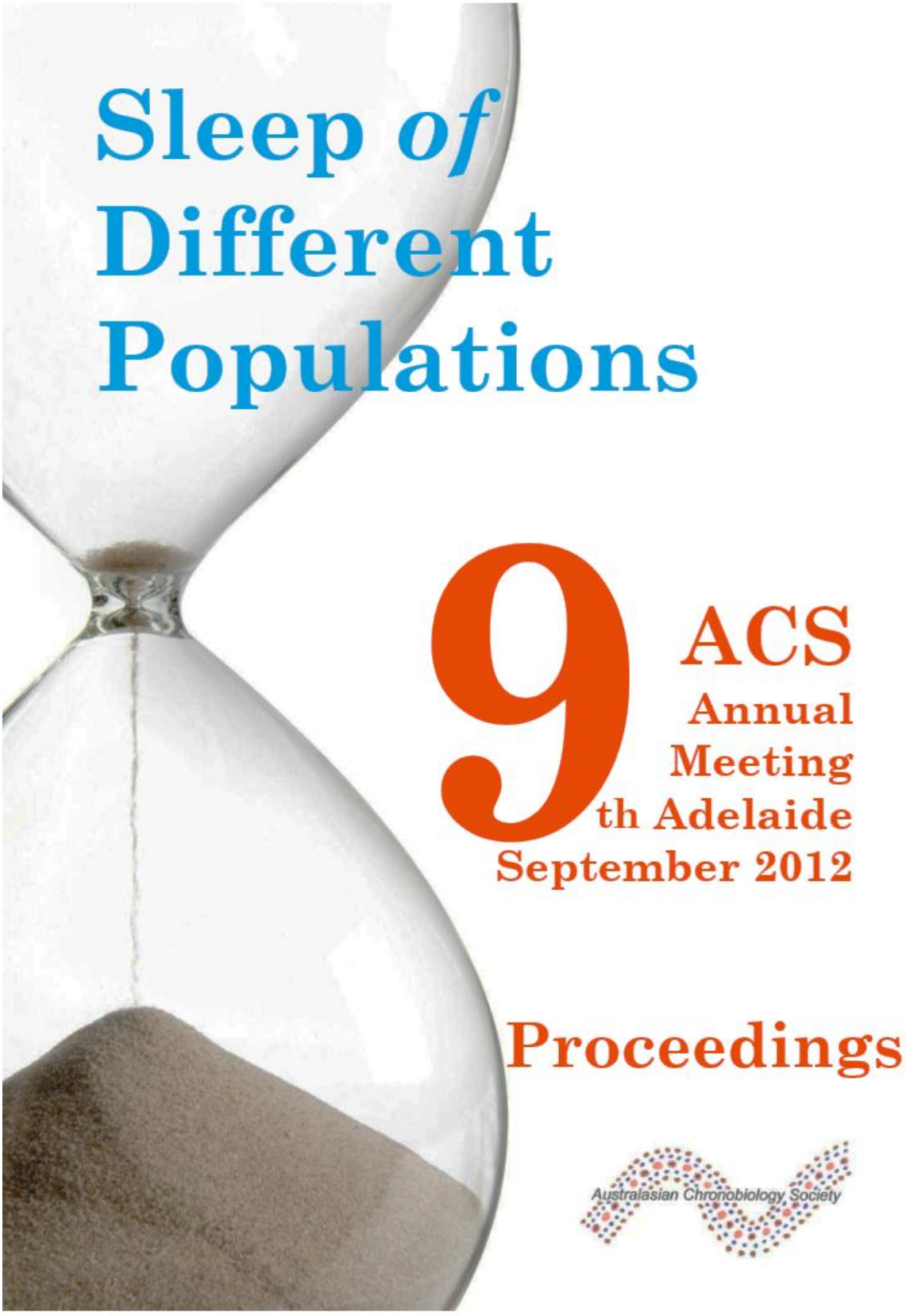
Note. DAS = Differential Ability Scales, NEPSY = Developmental Neuropsychological

Table 11.2 Mean (SD) key CBCL scale scores according to previous classification by Calhoun et al. (2009) together with F-test and effect size values

Key CBCL scale	AHI < 1				AHI ≥ 1				F-value	Effect Size (η^2_ρ)
	No snoring (n = 44)		Snoring (n = 14)		No snoring (n = 31)		Snoring (n = 6)			
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)		
Total Competence	48.3	(9.8)	49.2	(7.9)	46.4	(8.3)	45.7	(11.1)	0.51	.01
Internal Problems	51.3	(10.7)	48.6	(11.5)	54.5	(10.7)	48.7	(13.2)	1.30	.03
External Problems	50.5	(8.4)	51.1	(11.9)	53.0	(9.2)	49.1	(10.2)	0.58	.02
Total Problems	50.8	(9.0)	50.2	(12.8)	54.8	(9.4)	51.1	(11.9)	1.25	.04

Note. CBCL = Child Behavior Checklist

Appendix L Copy of partial published data (peer reviewed conference proceeding)



9th Annual Meeting of the Australasian Chronobiology Society

Sleep of Different Populations

ISBN 978-0-646-59218-3
Printed in Adelaide, Australia 2012 by the Australasian Chronobiology Society

Editors
Xuan Zhou, PhD
Charli Sargent, PhD

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Chapter 1

Sleep Complaints and Sleep Schedules in Snoring Children from a Community Sample

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2 Monash Institute of Medical Research, Monash Medical Centre, Monash University, Clayton, VIC, Australia.
3 Children's Research Centre, University of Adelaide, Adelaide, SA, Australia.
4 Respiratory and Sleep Medicine, Women's and Children's Hospital, North Adelaide, SA, Australia.

Aims *Children with habitual snoring are reported to have morning tiredness and restless sleep. However, little is known about other possible comorbid sleep problems and most findings are based on evidence from clinical samples and less is known about community-based samples. Accordingly, the aim of the current study is to examine co-morbid sleep problems and sleep routine in non-snoring versus snoring children recruited from a community sample.* ***Methods*** *Children from a previous epidemiological study examining prevalence of sleep complaints and sleep/wake behaviours in South Australia were included in this sample (N = 94). Children were identified as non-snorers (N = 54, 8.2 ± 2 yr, 37% males), infrequent snorers (N = 22, 8 ± 2 yr, 31.8% males), and frequent snorers (N = 18, 8 ± 2 yr, 39.8% males). Comorbid sleep problems were assessed through The Pediatric Sleep Problems Survey Instrument with additional sleep routine questions.* ***Results*** *Compared to non-snorers, snorers (frequent and infrequent) had increased bedtime anxiety [$F(2, 91) = 4.0$, $p < 0.05$] and night arousals [$F(2, 91) = 4.1$, $p < 0.05$] while frequent snorers had elevated morning tiredness [$F(2, 91) = 3.2$, $p < 0.05$], restless sleep [$F(2, 91) = 6.0$, $p < 0.01$] and poorer sleep routine [$F(2, 91) = 4.0$, $p < 0.05$]. No differences were reported for school/non-school night routines (e.g. bedtime). Regardless of snoring status, all children ≥ 10 yr (n = 17) slept the recommended amount.* ***Discussion*** *Frequent and infrequent snorers were found to have elevated co-morbid sleep problems compared to non-snorers. No group differences were observed in sleep routine, but frequent snorers showed an increased trend in sleep routine variability. Regardless of snoring status, all children ≥ 10 yr (n =17) slept the recommended amount. Consistent with findings from clinical samples, comorbid sleep problems are similarly elevated in snorers from community samples.*

Citation: Cicua-Navarro DC, Lushington K, Kohler M, Biggs SN, Martin J, Kennedy D (2012). Sleep complaints and sleep schedules in snoring children from a community sample. In: Zhou X, Sargent C (Eds). *Sleep of Different Populations*. Australasian Chronobiology Society, Adelaide, Australia, pp.1-5.

Sleep-disordered breathing is often associated with increased frequency of comorbid sleep problems especially morning tiredness, restless sleep and irregular sleep routine [1]. However, most of this information comes from clinical samples [2, 3]. As well, most studies have only examined a limited range of comorbid sleep problems. A further issue is whether children are meeting recommended clinical guidelines for sleep (i.e. 5-10 yr = 10 to 11 hours and 10-17 = 8.5 to 9.25 hours [4]) especially given recent trends indicating

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reduced sleep length over the last few decades [5] and the association between shortened sleep and worse neurocognitive functioning [6]. The aim of this study therefore, was to examine if snoring children display more co-morbid sleep problems and poorer sleep routine compared to non-snoring children from a community setting.

Methods

Participants & Apparatus From a baseline sample of 1845 children from the South Australian Paediatric Sleep Survey Database [7], 149 children were invited to participate in a two year follow-up study examining the natural history of snoring and neurocognitive functioning. Children underwent a screening telephone interview and we excluded children on psychotropic medication (e.g. antidepressants, mood stabilizers, medications for ADHD), and those with psychological or medical conditions known to affect nocturnal ventilation, sleep or neurocognition, spoke English as other than their first language. Twenty children were excluded for medical conditions (e.g. neurodevelopmental delay, asthma, and rhinitis), 7 had incomplete data and 28 declined further testing). A final sample of 94 children underwent detailed neurocognitive testing, sleep diary, questionnaire and polysomnographic examination. Body mass index (BMI) was determined by height and weight measurements on the polysomnographic night. The centile was calculated using established growth charts, corrected for age and gender [8].

Parents were asked to complete the Pediatric Sleep Problems Survey Instrument during the polysomnographic night to investigate sleep behavior. The Pediatric Sleep Problems Survey Instrument is validated for assessing sleep problems in children from a community setting [7]. The Pediatric Sleep Problems Survey Instrument contains 26 items and generates six scales: Sleep Routine; Bedtime Anxiety; Restless Sleep; Night Arousals; Sleep-Disordered Breathing and Morning Tiredness. For each scale parents were asked to rate whether they considered the sleep behavior a problem on a four point scales (0 = Never, 1 = once a week, 2 = 2-4 nights per week and 3 = 5 or more nights per week). In addition, we asked parents to estimate in general bedtimes (earliest and latest) and wake-times (earliest and latest) during the previous week according to school and non-school nights (Friday and Saturday night).

The study was approved by the Human Research Ethics Committees of the University of South Australia and the Child, Youth, and Women's Health Service.

Data Analysis Participants were classified based on snoring frequency: non-snorers ("never snoring", N = 54), infrequent snorers ("snoring 1 night/week", N = 22) and frequent snorers ("snoring > 2 nights/week", N = 18). All raw scores were converted into T scores for analysis. Sleep schedule, estimated total sleep time, and sleep consistency were calculated using similar analysis conducted in a previous study [9]. In brief, differences between latest and earliest bedtimes were used to calculated sleep consistency, likewise for wake times. Analyses were conducted using statistical software IBM SPSS, version 18. One-way ANOVA and when appropriate Chi-squared test were used to explore non-snorer/snorer group differences. A factorial ANOVA was used to explore school day/non-school day and non-snorer/snorer differences interaction. All P values reported have a statistical significance set at < 0.05. Data are presented as means ($\pm$ SD) unless otherwise indicated. Data reported in this text are part of a larger study investigating the relationship between habitual snoring, neuropsychological functioning, and sleep in children who snore from the community.

Results

From a sample of 94 children (37.6% males)

Table 1: Demographic Data

Demographic	NS (n=54)	IS (n=22)	FS (n=18)	P Value
Age, years	8.2 ± 2.0	8 ± 2.0	8 ± 2.0	ns
Socioeconomic status	999.5 ± 60.0	972.1 ± 83.0	968.0 ± 82.0	ns
Gender, male %	37	31.8	38.9	ns
Gestational age	39.4 ± 20.0	39.2 ± 2	39 ± 1.4	ns
Child's Birth weight	3.5 ± 0.4	3.5 ± 0.4	3.3 ± 0.4	ns
Ethnicity, Caucasian%	92.6	95.5	94.4	ns
BMI percentile	63.5 ± 21.6	64.5 ± 27.2	58 ± 33.1	ns

NS = non-snorers; IS = infrequent snorers; FS = frequent snorers.

with a mean age (± SD) of 8.1 (± 1.5) years were divided into three groups based on snoring frequency: non-snorers (N = 54); infrequent snorers (N = 22); and frequent snorers (N = 18). The main demographic characteristics of the sample are presented as mean ± SD unless otherwise indicated (Table 1). Groups were matched for age, gender, BMI percentile, gestational age and socioeconomic status.

Parental reports of co-morbid sleep problems (Table 2) showed that frequent and infrequent snorers had elevated bedtime anxiety [$F(2, 91) = 4.0$, $p < 0.05$] and night arousals [$F(2, 91) = 4.1$, $p < 0.05$]. On the other hand, only frequent snorers differed from non-snorers showing increased morning tiredness [$F(2, 91) = 3.2$, $p < 0.05$] and restless sleep [$F(2, 91) = 6.0$, $p < 0.01$], and poorer sleep [$F(2, 91) = 4.0$, $p < 0.05$]. As expected, Sleep Disordered Breathing T-scores were elevated in both snoring groups compared to controls [$p = 0.000$].

Bedtimes and wake times were similar between groups for both school and non-school nights. As well, weekday and weekend times did not significantly vary. Sleep consistency (i.e. difference between the latest bedtime and earliest bedtime and similarly for wake-time) was also similar between groups. School versus non-school bedtimes and wake times also did not significantly differ between groups. Factorial repeated-measures ANOVA results showed no effect of snoring status on bedtimes (week/weekend) [$F (2, 91) = 0.46$ $p > 0.05$].

Regardless of snoring status, all children ≥ 10 years-old slept the amount recommended by international guidelines during school days; and only one child did not meet these. On the other hand, analysis conducted for children 5 to 10 years-old showed that although not significant during school-nights up to 21% of children slept less than the recommended; and, up to 44% during non-school nights.

Discussion

In this study we compared co-morbid sleep problems and sleep routine in non-snoring and snoring children recruited from the community. Consistent with previous findings from community and clinical samples, children who snored in the present study had more restless sleep, nighttime arousals and morning tiredness [1, 10], and bedtime anxiety. These findings raise questions whether increased sleep problems and snoring are associated or not. More research needs to be done therefore, in order to test this relationship.

No group differences were observed in sleep schedules or total sleep time. However, it was noted that a high percentage of children less than 10 years of age slept less than the recommended amount by international guidelines; 21% on school nights and 44% on non-school nights. Whereas all children greater than 10 years slept the recommended amount [6]. The finding of shortened sleep in younger children has clear implications for less than optimal daytime functioning [6]. These findings however, need to be validated using more objective measures such sleep diaries an actigraphy.

Table 2: Sleep Parameters across Snoring Groups

Sleep Parameter	NS (n=54)	IS (n=22)	FS (n=18)	P Value	Post Hoc
Sleep Routine	48 ± 9	53 ± 10	55 ± 12	0.025	FS > NS
Bedtime Anxiety	47 ± 6	51 ± 10	52 ± 10	0.026	FS = IS > NS
Morning Tiredness	48 ± 9	52 ± 8	53 ± 13	0.047	FS > NS
Night Arousals	49 ± 8	53 ± 9	54 ± 10	0.019	FS = IS > NS
Sleep-Disordered Breathing*	45 ± 3	55 ± 4	72 ± 13	0	FS > IS > NS
Restless Sleep	46 ± 6	48 ± 7	52 ± 10	0.004	FS > NS
Sleep schedule					
School nights/days					
Typical bedtime (hh:mm)	20:10 ± 36	20:08 ± 29	20:15 ± 44	ns	
Earliest bedtime (hh:mm)	19:46 ± 37	19:42 ± 35	19:51 ± 43	ns	
Latest bedtime (hh:mm)	20:59 ± 50	21:00 ± 44	21:12 ± 54	ns	
Typical wake time (hh:mm)	06:59 ± 27	07:01 ± 32	07:02 ± 22	ns	
Time in bed (h)	11.0 ± 1	11.0 ± 2	11.0 ± 1	ns	
Bedtime latency (min)	14.2 ± 25	11.1 ± 14	14.0 ± 18	ns	
Estimated sleep time (h)	10.4 ± 1	10.2 ± 2	10.4 ± 1	ns	
5-10yr sleeping recommended amount (%)	82.1	82.4	78.6	ns	
>10yr sleeping recommended amount (%)	100	100	100	ns	
Non-school nights/days					
Typical bedtime (hh:mm)	20:53 ± 55	20:50 ± 52	21:06 ± 50	ns	
Earliest bedtime (hh:mm)	20:12 ± 51	20:05 ± 43	20:20 ± 54	ns	
Latest bedtime (hh:mm)	21:17 ± 187	21:59 ± 76	22:12 ± 65	ns	
Typical wake time (hh:mm)	07:26 ± 50	07:16 ± 37	07:30 ± 46	ns	
Time in bed (h)	11.0 ± 1	10.1 ± 2	10.4 ± 1	ns	
Bedtime latency (min)	9.4 ± 2.5	12.1 ± 21	7.0 ± 11	ns	
Estimated sleep time (h)	10.3 ± 1	10.0 ± 2	10.0 ± 1	ns	
5-10yr sleeping recommended amount (%)	71.8	56.3	64.3	ns	
>10yr sleeping recommended amount (%)	100	100	100	ns	
Sleep consistency					
Bedtimes on school nights (min) [1]	74.1 ± 44	77.3 ± 33	81.2 ± 46	ns	
Wake times on school days (min) [1]	76.0 ± 47	81.3 ± 48	102.0 ± 62	ns	
Bedtimes on non-school nights (min) [1]	92.5 ± 50	113.4 ± 62	115.2 ± 61	ns	
Wake times on non-school days (min) [1]	93.0 ± 51	102.0 ± 59	110.2 ± 58	ns	
School/non-school bedtime (min) [2]	42.0 ± 33	42.0 ± 31	53.0 ± 35	ns	
School/non-school wake-time (min) [2]	31.4 ± 39	19.1 ± 25	31.0 ± 30	ns	

NS = non-snorers; IS = infrequent snorers; FS = frequent snorers.*SDB parameter included item used to classified participants (snoring frequency). [1] Difference between the earliest and latest times. [2] Difference between typical school and non-school bed and wake times.

Findings from this study suggest that the pattern of co-morbid sleep disorders in children from the community who snore is comparable to those reported in children from clinical samples. This suggests that the sleep findings are not influenced by whether the sample is recruited from a clinical or community context. A limitation of the present study is that snoring was assessed by parental report. Although not reported, snoring status was confirmed on polysomnography. These data has yet to be analysed and it will be reported in later studies.

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