Sleep *of* Different Populations

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Chapter 1

Sleep Complaints and Sleep Schedules in Snoring Children from a Community Sample

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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.*

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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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Chapter 2

Training Schedules in Elite Swimmers: No Time to Rest?

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Aims *Sleep is considered an essential component of the pre and post-exercise recovery process. Research has indicated that training schedules have a significant effect on elite athletes' behaviours such as the timing of food consumption and social schedules, yet few studies have documented the impact training schedules have upon elite athletes sleep/wake behaviours. The aim of this study was to examine the impact of training start times on the sleep/wake behaviour of Olympic swimmers prior to the 2012 Olympic Games.* ***Methods*** *Ten elite swimmers (8 male, 2 female) (mean age $\pm$ SD: 22.9 $\pm$ 4.4 yr) participated in this study 16 weeks prior to the 2012 Olympic Games. Participants' sleep/wake behaviours were monitored using wrist activity monitors and self-report sleep diaries for a 2 week period. Training schedules varied according to individual training programmes. Linear mixed models were conducted to examine the main effect of timing of training on sleep/wake behaviours.* ***Results*** *For training sessions before 06:00, athletes spent less time in bed ($p < 0.01$), obtained less sleep ($p < 0.05$) and woke up earlier ($p < 0.001$) compared to when training sessions were after 06:00. Bedtime and sleep efficiency did not differ significantly.* ***Discussion*** *Findings indicated that training start times influenced sleep/wake behaviours of athletes. Earlier training start times negatively affected athletes' get-up times, and sleep duration. Given that cumulative sleep restriction may affect recovery and performance, these results suggest that repeated early-morning training may inhibit training and performance gains in elite athletes.*

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Sleep has been documented as critical for establishing the balance between optimal performance and recovery, making it a vital component of athletic performance [1, 8]. However, several factors influence the sleep behaviour of elite athletes, including transmeridian travel [11], pre-competition anxiety and unfamiliar sleep environments [3], and training and competition schedules [5]. In an attempt to maximise and maintain performance, coaches and athletes employ rigorous training schedules [1, 10].

Elite endurance sports such as swimming, rowing, and cycling require regular and prolonged training for athletes to maintain their level of performance. To maximise training gains, daily training schedules involve an early-morning high-intensity session and late afternoon high-intensity session [1, 5, 10]. This often results in sleep loss, in response to which athletes employ strategies to counteract the negative effects of sleep restriction on performance [1, 9].

Napping is a common strategy used by athletes to overcome the effects of irregular sleeping patterns and sleep restrictions, and has been recognized as a recovery tool [2, 5]. However research on the effects of training

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schedules on sleeping patterns, and the use of napping as a counter-measure in elite athletes is notably sparse [6]. It is imperative that the effects of training schedules on elite athletes' sleep behaviours are explored, and potential counter-measures to sleep-deprivation, such as daytime napping, are further investigated with regard to the impact of sleep deprivation on recovery and performance. The aim of this study was to examine the interactions between training schedules, sleep/wake behaviours, and the use of strategies to overcome sleep restriction in elite swimmers selected for the Australian Olympic team, over a two-week period.

Methods

Participants Ten participants (8 male, 2 female) (mean age $\pm$ SD: 22.9 $\pm$ 4.4 yr) from the 2012 Australian Olympic swimming team were recruited with the aid of a senior physiologist, through the Australian Institute of Sport. Written informed consent was obtained following a team meeting describing the purpose and aims of the study. Participants were excluded if not training due to illness or injury. This study was approved by the Australian Institute of Sport Research Ethics Committee.

Measures Wrist activity monitors were used to capture a number of variables relating to sleep. The activity monitor is a lightweight (15g) device worn around the wrist of the non-dominant arm. Using an internal piezoelectric accelerometer, the activity monitor records body movement of the wearer at short regular intervals (stored in 1-minute epochs for this study). An A4 sleep diary booklet was also used for participants to record information (e.g. bedtime, get-up time) for all sleep periods (night-time sleep, daytime naps). Information regarding all training sessions was recorded using training diaries. Data collected from wrist activity monitors, subjective sleep diaries, and training diaries allowed for the attainment of the following variables:

- Bedtime (hh:mm): The self-reported time a participant went to bed to attempt to sleep.
- Get-up time (hh:mm): The self-reported time a participant got out of bed to end a sleep period.
- Time in bed (h): The amount of self-reported time in bed between bedtime and get-up time.
- Total sleep time (h): The total amount of time spent asleep by participant over a night sleep period.
- Total nap time (hh:mm): The total amount of time spent asleep during a daytime nap period.
- Training start time (hh:mm): The time at which a training session commenced.

Design A cross-sectional design was employed for the purposes of this study. Independent variables were training session time, and number of training sessions, determined by training diaries. Dependent variables were bedtime, get-up time, time in bed, total sleep time, and sleep efficiency.

Procedure The 14-day study commenced 16 weeks prior to the 2012 Olympic Games. Participants underwent training in preparation for the Olympic Games, training schedules varying according to individual training programmes. In the training diaries, participants recorded training type, pre-training fatigue, start- and end-times of training sessions, and training intensity. Athletes' sleep/wake behaviours were monitored using wrist activity monitors and self-report sleep diaries, in which athletes recorded type of sleep, bedtime, get-up time, and subjective sleep quality for all sleep periods.

Data Analysis For statistical analyses, study days were categorised as one of five types: days on which the initial training session commenced prior to 06:00, days on which the initial training session commenced between 06:00 and 09:00, days on which the initial training session commenced between 09:00 and 12:00, days on which training commenced after 12:00, and rest days (i.e. days on which no training sessions

Table 1: Athletes' sleep/wake behaviours preceding varying study day types (Mean ± SD)

Measures	Training				Rest	F-value	df
	>06:00	06:00-09:00	09:00-12:00	>12:00			
Bedtime (hh:mm)	21:48 (± 00:24)	22:00 (± 00:18)	21:30 (± 00:42)	22:00 (± 00:24)	23:18 (± 00:24)	5.28**	4, 98
Get-up time (hh:mm)	5:18 (± 00:24)	6:06 (± 00:18)	7:06 (± 00:36)	7:06 (± 00:18)	7:30 (± 00:18)	9.53**	4, 98
Time in bed (h)	7.7 (± 0.3)	8.2 (± 0.2)	9.3 (± 0.7)	9 (± 0.3)	8.2 (± 0.3)	2.73*	4, 98
Total sleep time (h)	5.4 (± 0.4)	6.1 (± 0.3)	7.4 (± 0.8)	6.9 (± 0.4)	6.5 (± 0.4)	2.66*	4, 98
Sleep efficiency (%)	81.3 (± 2.3)	84.7 (± 2)	87 (± 3.1)	84.5 (± 2.2)	86.7 (± 2.2)	3.14*	4, 98
Total nap time (hh:mm)	1:06 (± 00:18)	0:24 (± 00:12)	0:00 (± 00:00)	1:06 (± 00:30)	0:18 (± 00:24)	2.73	3, 23

**p<0.001; *p<0.05

occurred).

Results

Participants on average went to bed at 22:06 (± 01:22), woke at 06:25 (± 01:30), spent 8.3 hours (± 1.4) in bed, and slept 6.3 hours (± 1.5) during a night-time sleep period. Participants' average sleep efficiency was 85.5%, (± 6.2). Participants reported napping on 24 out of 103 days. In those instances, participants napped an average of 00:56 (± 00:42).

Overall, training which commenced prior to 06:00 had the greatest impact on participants' sleep/wake behaviours. On nights preceding training sessions commencing prior to 06:00, participants went to bed at 21:48 (± 00:24), and woke at 05:18 (± 00:24). These were significantly earlier than on nights prior to training sessions starting between 06:00 and 09:00, after 12:00, and rest days (Table 1). There was a significant main effect of study day type on total sleep time and sleep efficiency. On nights preceding training sessions which began prior to 06:00, athletes slept an average of 5.4 hours (± 0.4) and maintained 81.3% (± 2.3) sleep efficiency, whereas athletes slept up to an average 7.4 hours (± 0.8) and maintained 87.0% (± 3.1) sleep efficiency on days when the first training session began between 09:00 and 12:00 (Table 1). Post hoc analyses were conducted, but no significant differences between different study day types by total sleep time and different study day types by sleep efficiency were found. Given that there were only five cases when training began between 09:00 and 12:00 and 20 cases when training began before 06:00, it is possible that the post hoc analyses were underpowered.

Discussion

The aim of the present study was to examine the effects of training on sleep/wake behaviours in Australian Olympic swimmers. Results indicate that training influenced sleep/wake behaviours of elite swimmers. Participants went to bed and woke up earlier on nights prior to early-morning training sessions than on rest days, indicating that participants shifted their night-time sleep to compensate for earlier training. However, they spent less time asleep on nights prior to early-morning training compared with nights before later training, and rest days. The shift in night-time sleep may not adequately address recovery time lost as a result of early-morning training schedules. Findings concerning sleep/wake behaviours were consistent with past research, indicating that athletes' sleep/wake behaviours are influenced by training [1, 9]. As negative effects of sleep restriction on cognitive and motor performance have been well documented [4, 7], shorter night-time sleep on nights preceding early-morning training may impair athletes' training gains.

Training was related to napping behaviours. Participants predominantly napped on days involving early-morning training sessions, suggesting that athletes and coaches recognise the need for adequate recovery. However, athletes may also be napping during the day to recover lost night-time sleep. This implies that afternoon sessions may result in more optimal performance gains due to daytime napping, whereas early-morning sessions may restrict night-time sleep and recovery time. Nap behaviours corresponded with past findings, with athletes and coaches employing daytime napping primarily as a recovery tool on days involving early-morning as well as afternoon training [2, 9]. Outcomes of studies on naps as a countermeasure have highlighted that the quantity and quality of sleep obtained during daytime naps may be overestimated [2, 9]. Thus, whilst napping is an effective recovery tool, it may not sufficiently account for night-time sleep loss, particularly over prolonged periods of time [2, 9].

This study had minor limitations to be considered when interpreting results. Overtraining, competitive anxiety, and travel, which were not accounted for, may influence athletes' sleep parameters [3, 6, 10, 11]. The number of participants was limited by the size of the Australian Olympic swimming team, and willingness of athletes to participate in the study during their preparation for the Olympic Games. However past studies involving elite athletes have typically employed sample sizes comparable to those in this study, ensuring that findings are relevant in the scope of sport research [2, 9]. The use of wrist activity monitors over polysomnography (PSG) to record sleep activity of athletes is also a limitation, though wrist activity monitors have been deemed comparable to PSG regarding the recording of sleep length [12], and have also been commonly employed in similar field-based studies on elite athletes [1, 9].

Early-morning training schedules are commonly employed by athletes and coaches, particularly in endurance sports [1, 5, 9, 10]. However, this practice is not supported by research, previous findings on sleep and training schedules indicating that early-morning training reduces restorative sleep [1, 9]. Daytime napping is employed by athletes to counteract sleep restriction, and is influenced by training schedules and sleep. The amount of recovery time obtained through napping however does not account for the disparity between athletes' sleep, and healthy sleep requirements. Without evidence to support early-morning training it may be most effective for initial training sessions to occur later in the morning, to improve sleep/wake behaviours, recovery, and potential performance gains of elite athletes.

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Chapter 3

With Age Comes Knowledge? Sleep Knowledge in Australian Children

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Aims *With the approach of adolescence, significant changes in sleep patterns and physiology occur. Sleep hygiene is a well documented influence on sleep patterns. However little research has investigated sleep knowledge, which affects sleep hygiene. In particular, it is not known what level of sleep knowledge children and adolescents have. Sleep knowledge refers to information about sleep hygiene, as well as recommended sleep duration and patterns. This study aimed to establish the level of sleep knowledge in a group of pre-adolescent and adolescent children. Furthermore, it evaluated sleep knowledge across the ages, to investigate the potential effect of age on sleep knowledge.* ***Methods*** *Self-report data were collected from 643 children aged 9 to 15 years old, using a general 'Health and Wellbeing' questionnaire. Data were collected from three schools in South Australia (two public, one private). Sleep Knowledge scores were calculated using related sections of the true/false questionnaire, one point per correct answer. One-way ANOVA was used to evaluate survey responses.* ***Results*** *Results showed a mean sleep knowledge score of 6.4 (out of a possible 10). However, for four out of the ten questions, scores were low, with less than 50% of children correctly answering them. There were no significant differences in Sleep Knowledge between any of the ages.* ***Discussion*** *While there were no significant differences in sleep knowledge across ages, the level of knowledge across the participants in certain areas was alarmingly low. However, this measure of sleep knowledge has not yet been standardized, therefore conclusions are tentative. Future research is needed in this area, to assess the requirement for sleep education in this population. Further studies could also identify potential need to direct education to particular areas or schools, in order to effectively improve sleep knowledge for pre-adolescent and adolescent children.*

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Sleep has been well acknowledged as having significant influence on children's development, cognition, general health, and behaviour. However, recent figures suggest an abundance of sleep difficulties in the child and adolescent population, with sleep disorders estimated to now affect one third of all children [1, 2]. Although many of these sleep disorders are physically or respiratory based (e.g. restless leg syndrome, obstructive sleep apnoea), there is also a significant proportion of children (20-40%) affected by behavioural sleep disorders [1]. These are classified as 'Behavioural insomnia of Childhood' by the American Academy of Sleep Medicine, and include disorders such as adjustment sleep disorder, sleep onset association disorder and inadequate sleep hygiene [3].

Of particular interest for the adolescent population has been inadequate sleep hygiene. Good sleep hygiene is defined as the practice of behaviours which facilitate sleep, and the avoid-

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ance of behaviours which inhibit or decrease quality of sleep [4]. Examples of poor sleep hygiene practice include; engaging in stimulating activities before bedtime, using the bed for activities other than sleep (e.g. playing, watching television), consumption of caffeine or sugar near (2 hours before) bedtime, or sleeping in an uncomfortable environment (too hot, cold, bright, noisy). Inconsistent bedtimes and excessive napping are also a major contributor to the problem [4, 5]. Good knowledge of sleep hygiene has been found to be associated with good sleep hygiene practices and good sleep quality [5]. However, little is known about the direct effect of sleep knowledge (especially children's knowledge) on sleep patterns. Given that sleep knowledge has such potential for change, further investigation of the concept of sleep knowledge, especially in relation to children's sleep, is needed.

Although the significant impact of sleep problems for children has been extensively noted [8, 9, 10, 11], awareness of this in the community is low [2]. As sleep education programmes are being developed and implemented across the world [12], parental knowledge about sleep and sleep hygiene is being evaluated [13]. Whilst this is important for children's early years, and is likely to be a strong influence on children's sleep knowledge and patterns, little attention has been paid to what children themselves know about sleep. It has been suggested that as children approach adolescence, they begin to have more control over their sleep schedules and sleep hygiene. Furthermore, increased study, work and social demands increase the likelihood that sleep hygiene, duration and quality in this age group will be detrimentally affected [14].

To effectively increase awareness and tackle behaviorally based sleep disorders, we must investigate children's own sleep knowledge. Therefore, the aim of this study was to gauge the level of sleep knowledge in pre-adolescent and adolescent children. Furthermore, it aimed to evaluate differences in sleep knowledge across 9 to 15 year olds, and whether this increases with age, as children begin to have more control over their own sleep hygiene.

Methods

To determine the sleep knowledge of pre-adolescent and adolescent children in South Australia, a self-report questionnaire was designed. It was delivered to 643 participants (233 male) from three South Australian schools. The schools were selected based on previous involvement with the researchers. Two of the schools were public (government run), and one of the schools was a catholic, co-education school. For the purpose of this paper, the age range of 9 to 15 years will represent both pre-adolescent and adolescent children. Therefore, students in this age range were included in the study, with no exclusion based on sex.

As there are no current validated measures of sleep knowledge for this age group, sleep knowledge was determined through the "Children's Wellbeing Questionnaire" (developed collaboratively by one of the current researchers alongside other field experts). The "Children's Wellbeing Questionnaire" was developed to assess children's knowledge through a range of questions relating to general health, exercise, and sleep behaviours. Despite not yet being validated, the survey has been used in previous studies with children. It contains a range of questions but for the purpose of this study, only the 10 true/false questions relating to sleep are reported (see results for full range of questions). Further detail on the full survey design and non-sleep topics is reported elsewhere [11].

Informed consent was gained from the schools, the parents, and the children before data collection. At all times it was made clear to parents and children that the surveys are not a test, and would not affect their school grades in any way. Participants anonymously completed the pen-and-paper questionnaire during school class time. Total completion time ranged from

Table 1: Proportions of incorrect and correct scores per question on the Sleep Knowledge Scale

Question	% Scored Correct	% Scored Incorrect
1) Sleep helps me remember things	69.2	30.8
2) Doing something calm before bed can help me fall asleep	84.6	15.4
3) I should go to bed at the same time every night	72.3	27.7
4) Watching TV before bed can make it hard for people to sleep	60.0	40.0
5) Not getting enough sleep can make people overweight	24.6	73.8
6) I need more than 9 hours of sleep each night	75.4	24.6
7) Exercising every day can help me sleep better	70.8	29.2
8) Boys have deeper sleep than girls	23.1	75.4
9) Doing exercise before bed helps me fall asleep	32.3	66.2
10) How many hours should you sleep every night to be healthy?	69.2	30.8

approximately 20 to 30 minutes.

All analyses were performed with Statistical Package for the Social Sciences (SPSS Inc, Chicago, IL) version 19.0. The ten questions relating to sleep knowledge were converted into a 'sleep knowledge' score. Correct answers were given a score of 1, and incorrect or 'don't know' responses a score of 0. A one-way ANOVA was used to determine differences in sleep knowledge across age.

Results

Results indicated that sleep knowledge across these pre-adolescent and adolescent children was normally distributed with a minimum score of 0 and maximum of 10 ($M = 6.4$, $SD = 1.80$). Four questions were of particular interest, as they were answered incorrectly by more than half of the sample. These questions included question four ('watching TV before bed can make it hard for people to sleep'), question five ('not getting enough sleep can make people overweight'), question eight ('boys have deeper sleep than girls') and question nine ('doing exercise before bed helps me fall asleep'). For these questions, the average correct response rate was 44%. For those questions with more than 50% correct responses, the average was 75%. The percentage of correct and incorrect scores for each question, along with full range of questions, is shown below in Table 1.

In relation to the second aim, to investigate differences in sleep knowledge across age, results from a one-way ANOVA, comparing sleep knowledge across all ages, showed no significant difference between ages ($p > .05$; see Table 2).

Table 2: Distribution of total sleep knowledge scores across Age

Age	N	Mean Score
9	24	6.13
10	23	5.55
11	31	6.10
12	36	6.58
13	193	6.45
14	172	6.24
15	164	6.67
Total	643	6.36

Repeated measures ANOVA showed that TST estimated using the Actical was not longer than TST determined by PSG at either the low or medium threshold for wake [$F(1, 9) = 4.1$, $p = .07$]. Similarly, repeated measures ANOVA revealed no significant differences from PSG for SE [$F(1,9) = 4.3$, $p = .07$] or for WASO [$F(1, 9) = 3.4$, $p = .10$] at either threshold for wake.

Discussion

This study has contributed to the understanding of sleep knowledge in pre-adolescent and adolescent children. On average, participants scored 6.4 out of a possible 10. However, as there are no previous benchmarks for sleep knowledge in children, it is difficult to conclude the adequacy of this sample. Furthermore, although one previous study on adult sleep knowledge showed very similar levels of knowledge to these children, the study used a different sleep knowledge questionnaire, therefore is not comparable [12]. Limited research on sleep knowledge in the adult and pediatric populations, as well as a lack of validated sleep knowledge scales, make these data difficult to discuss in a wider context. Future research could address this gap and assist in gaining a clearer picture of sleep knowledge in both populations.

Further results showed that four out of the ten questions had low percentages of correct responses. This indicates that there could be deficits in children's knowledge surrounding sleep-inhibiting behaviour before bed, such as watching TV or exercising, and the effect of sleep quality on overall health, especially on weight. Sleep knowledge was not found to differ across the age range of 9 to 15 years. This could indicate that despite the physical changes in sleep, as well as increased school, social and work demands that adolescent children experience, they are no more aware or knowledgeable about recommended sleep duration and behaviours than younger or pre-adolescent children. Furthermore, results could indicate that the scale is not sensitive enough to detect age differences in sleep knowledge.

Like most research, this study was not without limitations. As previously mentioned, the Sleep Knowledge scale that was used is not validated as yet. Development and validation of sleep knowledge scales for a range of ages and applications is needed, if sleep education programmes are to be employed and evaluated successfully. Furthermore, when assessing the problem of childhood behavioural sleep disorders, there are many other factors which are known to influence behaviour and beliefs, such as culture, school, and parents. Future research could further investigate these influences, as well as the interaction between childhood or parental sleep knowledge and actual sleep patterns.

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Chapter 4

Two for One? Validating an Energy Expenditure Monitor against Polysomnography for Sleep/Wake Measurement

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Aims *Gold standard sleep measurement, polysomnography (PSG), is not always practical for field-based research due to time and expense. Wristwatch-like activity monitors that estimate sleep from wrist movement are often used instead. The Actical is an activity monitor designed to estimate energy expenditure. While not specifically designed to measure sleep, it records and stores data in a similar fashion to devices that are. Dual functionality could be useful for research spanning sleep and exercise behaviours, and thus the aim was to evaluate the Actical as an alternative to PSG for field research.* ***Methods*** *Ten participants spent one night in bed (22:00-07:30 h) in temperature-controlled (21 ± 1°C) bedrooms. Each wore an Actical, set to record activity in 30-s epochs, on their non-dominant wrist, and electrodes were placed in the 10-20 arrangement for PSG. PSG data were manually scored as sleep/wake in 30-s epochs. Software provided sleep/wake estimates for Actical epochs at a medium- (default) and a low-activity threshold for wake. Actical sleep/wake data were compared with data from PSG on an epoch-by-epoch basis and in terms of total sleep time (TST), sleep efficiency (SE), and wake after sleep onset (WASO).* ***Results*** *Actical identified 97 ± 2% (M ± SD) and 98 ± 1% of PSG-determined sleep epochs, at the low threshold and medium threshold for wake, respectively. Identification of PSG-determined wake was 31 ± 13% and 22 ± 9%, and overall agreements were 89 ± 10% and 88 ± 11%, respectively. TST was overestimated by 25 ± 47 and 36 ± 52 min, and SE by 5 ± 8% and 6 ± 9%; WASO was underestimated by 25 ± 52 and 36 ± 57 min, respectively.* ***Discussion*** *Results suggest that overall epoch agreement between Acticals and PSG is good and identification of sleep is equally high at both thresholds; however, the lower threshold is better than the default for identifying wake. In addition, the biases of sleep parameters calculated using the Actical were smaller at the low threshold. The results indicated that the Actical is a satisfactory alternative tool for measuring sleep, particularly in field research.*

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The gold standard for sleep measurement, polysomnography (PSG), is not always practical in field-based research as it is both costly and time-intensive [1]. Although they cannot provide the same breadth of sleep information as PSG, wrist-worn activity monitors designed for sleep/wake estimation are popular alternatives outside the laboratory because they are portable and simple to use [1]. These devices contain accelerometers and

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indirectly estimate sleep quality and duration from frequently sampled wrist activity. The premise behind this is the negative correlation that exists between sleep and movement. Although activity monitors designed for sleep/wake measurement, such as the Actiwatch (Philips Respironics, Inc., Bend, Oregon, USA) and the Mini-MotionLogger Actigraph (Ambulatory Monitoring, Inc., Ardsley, NY), tend to overestimate sleep and underestimate wake, they have been validated as viable alternatives to PSG for sleep estimation in numerous studies [e.g., 2, 6, 7].

Activity monitors are widely used to study the sleep/wake patterns of people who work around the clock or constantly have to travel as part of their job, and those for whom PSG may be a great inconvenience or unwelcome distraction. Examples of these situations include research with truck drivers, pilots, and elite athletes in training or competition [1, 8, 10]. Sleep/wake data collected using activity monitors can inform changes to occupational health and safety policy and lead to better lifestyle choices. However, sleep measurement is not the only function for which activity monitors are used. The Actical (Philips Respironics, Inc., Bend, Oregon, USA) is a device that has been specifically developed and validated to estimate the energy expenditure of physical activity [4]. Given that sleep deprivation and a high prevalence of health problems are known to co-exist in shiftworkers [1, 8, 12], studying energy expenditure in conjunction with sleep behaviours in these populations could prove invaluable.

While not developed specifically for sleep measurement, Actical activity monitors record and store data in a similar manner and format to activity monitors which have been developed for this purpose. These similarities allow for the potential to measure sleep with this device by applying sleep algorithms to Actical activity data. If valid, dual functionality would allow researchers the flexibility to concurrently study both exercise and sleep using a single device. To date, several studies have evaluated the Actical for sleep measurement and have supported their use in healthy infant, adolescent and adult populations [3, 9, 11]. These studies have shown significant correlations between sleep parameters calculated by the Actical and PSG, as well as revealing the extent of a tendency to overestimate sleep duration about 30 min. Only one of these validation studies reported statistical measures of agreement – sensitivity, specificity and accuracy – to demonstrate the Actical's ability to correctly identify epochs of sleep and wake in infants with fragmented sleep [3]. This study reported high epoch-by-epoch agreement with the Actical, but it is not clear how well these results could be generalised to other populations.

The aim of this study was to determine whether the Actical is a valid alternative to PSG for sleep estimation in healthy adults, with particular focus on statistical measures of epoch-by-epoch agreement. Total sleep time (TST), sleep efficiency (SE) and wake after sleep onset (WASO) were also factored in the evaluation. A secondary aim of this study was to determine which of two activity thresholds was the better option for sleep/wake monitoring with the Actical.

Methods

Participants Ten healthy males with a mean age of 24.4 ($\pm$ 4.2) years and a mean body mass index of 22.1 ($\pm$ 1.9) kg/m2 were recruited. To minimise sleep difficulty during the protocol, participants were screened for consistent bedtimes (22:00-24:00 h), normal sleep durations (7-9 h per night), and no transmeridian travel in the previous month using a questionnaire.

The CQUniversity Human Research Ethics Committee granted ethics approval following National Health and Medical Research Council of Australia guidelines.

Materials & Measures Sleep was monitored using PSG and the Actical concurrently. PSG was conducted using the the Siesta Portable EEG system (Compumedics, Victoria, Australia), GrassTM gold-cup electrodes (Astro-Med, Inc., Rhode Island, USA) and standard scoring criteria to distinguish sleep from wake [5].

The Actical (Philips Respironics, Inc., Bend, Oregon, USA) contains an omnidirectional accelerometer that can detect low frequency (0.5 Hz) forces of 0.05 G and samples movement at 32 Hz. The Actical records the mean of activity sampled each second; these 1-s means are summed to create activity counts for epochs of a user-specified duration. Epochs corresponding to increased activity have higher counts. Actical software (Philips Respironics, Inc., Bend, Oregon, USA) was used to set-up the Acticals and download data. Actiwatch software (Actiware, Philips Respironics, Inc., Bend, Oregon, USA) was used to generate weighted scores for each epoch based on the activity count recorded during that epoch and the surrounding 2-min [6]. Epochs with scores above a set threshold are classified as wake.

Protocol Acticals were set-up to record activity in 30-s epochs and were time-synchronised with the PSG system. Before bedtime (lights out at 22:00), participants were given an Actical to wear on their non-dominant wrist and PSG electrodes were placed on their scalp and face following the standard 10-20 arrangement [1]. Participants were provided a 9.5-h sleep opportunity in separate, temperature-controlled (21 $\pm$ 1°C), bedrooms and woken at 07:30 h.

Data Analysis PSG recordings for each participant were manually scored in 30-s epochs as sleep or wake, following standard criteria [5], by an experienced sleep technician. Actical outputs were reformatted so they were compatible with the Actiware software. Sleep data were extracted from the software after applying two different thresholds to the algorithm: the default medium threshold (>40 counts = wake) and the low threshold (>20 counts = wake).

Corresponding Actical and PSG epochs were classified into one of four categories based on whether the Actical agreed/disagreed with PSG-determined sleep or whether it agreed/disagreed with PSG-determined wake (see Table 1). Three statistical measures of epoch-by-epoch agreement were calculated for the Actical:

- Sensitivity = [TP/(TP+FN)]*100 = ability to correctly detect sleep
- Specificity = [TN/(TN+FP)]*100 = ability to correctly detect wake
- Accuracy = [(TP+TN)/(TP+FN+TN+FP)]*100 = ability to correctly detect sleep and wake

Table 1: Matrix of sleep/wake agreement with polysomnography

	Polysomnography	
Actical	Sleep	Wake
Sleep	True Positive (TP)	False Positive (FP)
Wake	False Negative (FN)	True Negative (TN)

Sleep parameters were derived from PSG and the Actiware software:

- TST was defined as the number of minutes in bed spent in any stage of sleep;
- SE was defined as the percentage of time asleep while in bed; and
- WASO was defined as the number of minutes spent awake during a sleep period.

Results

Epoch-by-epoch Comparisons At the default medium activity threshold, the Actical was highly sensitive at identifying PSG-determined sleep epochs (Table 2). Despite being found to have low specificity, overall accuracy remained high at this threshold. Epoch-by-epoch agreement with PSG was almost identical at the low activity threshold, but it had better specificity and correctly identified about 10% more epochs of wake.

Sleep Parameter Comparisons Descriptive results from this study show that the Actical overestimated TST by 25 $\pm$ 47 and 36 $\pm$ 52 min, and

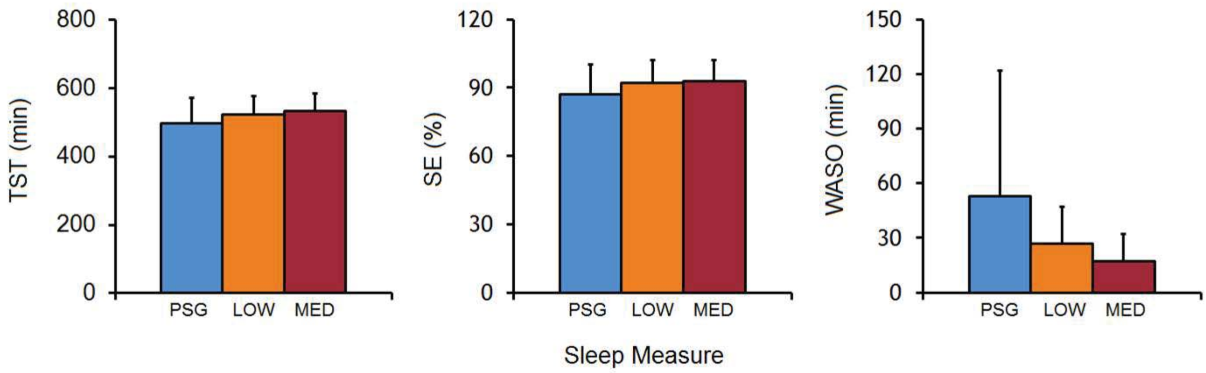

Figure 1: Sleep parameters recorded by polysomnography and the Actical at the low- and medium-activity thresholds. TST = total sleep time, SE = sleep efficiency, WASO = wake after sleep onset.

SE by 5 ± 8% and 6 ± 9%, at the low threshold and medium threshold, respectively (Fig. 1). Conversely, the Actical underestimated WASO by 25 ± 52 (low threshold) and 36 ± 57 min (medium threshold).

Table 2: Epoch-by-epoch agreement of Actical and PSG by activity threshold

Epoch agreement	**Activity Threshold**	
	Low	Medium
Sensitivity (%)	97 ± 2	98 ± 1
Specificity (%)	31 ± 13	22 ± 9
Accuracy (%)	89 ± 10	88 ± 11

Data are expressed as Mean±SD

Repeated measures ANOVA showed that TST estimated using the Actical was not longer than TST determined by PSG at either the low or medium threshold for wake [F(1,9)=4.1, p=.07]. Similarly, repeated measures ANOVA revealed no significant differences from PSG for SE [F(1,9)=4.3, p=.07] or for WASO [F(1,9)=3.4, p=.10] at either threshold for wake.

Discussion

The results of this study support the use of the Actical for sleep measurement. Its sensitivity in detecting sleep epochs and its overall accuracy are equally high at both activity thresholds. The specificity of the Actical is considerably lower, but at the low-activity threshold the result is closer to specificities previously reported for devices marketed for sleep measurement (34-44%) [2].

With regard to the estimation of sleep parameters, the tendency for activity monitors to overestimate sleep and underestimate wake is evident despite no significant differences from PSG at either threshold for wake. Also demonstrated for each sleep parameter is a smaller bias at the low-activity threshold compared to the medium-activity threshold for wake. These are also consistent with findings from other activity monitors which have biases compared to PSG of about 25 min for TST and 5% for SE [11].

Low specificity and the bias for overestimating sleep found in this study partly reflect a limitation of activity monitors generally to distinguish quiescent wakefulness from sleep. However, unlike activity monitors such as the Actiwatch, the Actical records mean activity per second instead of peak activity per second, resulting in lower scores overall when summed per epoch [9]. This explains why a low-activity threshold is better for wake detection and why the default medium-threshold in the Actiwatch sleep software is not satisfactory for the Actical. A very low threshold could result in even better wake detection but, given trade-offs previously found between specificity and sensitivity between thresholds [6], it is unclear to what extent this would affect sensitivity.

In this study, Acticals were validated with young healthy adults in a sleep laboratory. This improved the validity of the results by removing confounding influences such as noise, temperature and light, which influence sleep behaviour. Future research could add to these findings, however, by evaluating the Actical in specific populations of interest [e.g., 3] in ecologically valid environments, such as participants' homes. In addition, future research could apply a lower, customised, threshold to the algorithm used in the Actiware software and evaluate the effect of this on agreement with PSG.

In conclusion, the combined findings of this study indicate that the Actical is a satisfactory measure for sleep, provided that an appropriate activity threshold is chosen. The implication of sleep measurement as an additional function of the Actical is that researchers can concurrently explore the relationship between sleep and energy expenditure with a single device, at no extra inconvenience to participants.

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Australasian Chronobiology Society
9th Annual Scientific Meeting
Conference Program

1000 – 1050 Registration

1050 – 1100 Opening

1100 – 1145 **Key Note Address**
[Chair: Sally Ferguson]
Life in a 24/7 society: The consequences of rhythm disruption during pregnancy
Dr Tamara Varcoe

1145 – 1230 **Session 1: Circadian Physiology**
[Chair: Sally Ferguson]

1145 – 1200 *The oviduct is ticking: Rhythmic gene expression during the pre-implantation period*
Dr Michael Boden

1200 – 1215 *Circadian variations in gastric vagal afferent mechanosensitivity and satiety signalling*
Stephen Kentish

1215 – 1230 *Chronotherapeutic approaches to immune modulation in chronic diseases including cancer: Important common clinical observations*
Dr Martin Ashdown

1230 – 1315 **Lunch**

1315 – 1415 **Session 2: Sleep and Health**
[Chairs: Jessica Paterson, Larissa Clarkson]

1315 – 1330 *Poor sleep quality in Australian adults with psychological distress and co-morbid physical illness*
Dr Jessica Paterson

1330 – 1345 *Co-morbid sleep problems and sleep routine in snorers from a community setting*
Diana Cicua-Navarro

1345 – 1400 *Prevalence of excessive daytime sleepiness in the Australian population*
Amie Hayley

1400 – 1415 *Randomised controlled trial of cognitive behavioural therapy for insomnia (CBT-I) in co-morbid insomnia and depression*
Damon Ashworth

1415 – 1430 **Short Break**

1430 – 1545 **Session 3: Sleep Quality, Quantity and Knowledge**
[Chairs: Bradley Smith, Kirrilly Thompson]

1430 – 1445 *Should we let sleeping dogs lie…with us?*
Drs Bradley Smith, Kirrilly Thompson

1445 – 1500 *Do athletes sleep poorly prior to competition?*
Michele Lastella

1500 – 1515 *Training schedules in elite swimmers: No time to rest?*
Alex Forndran

1515 – 1530 *Validation of two activity-based devices for sleep measurement*
Anastasi Kosmadopoulos

1530 – 1545 *With age comes knowledge: Effect of age on sleep knowledge in Australian children*
Tessa Benveniste

1545 – 1615		**Afternoon Tea**
1615 – 1715		**Session 4: Shiftwork** **[chairs: Xuan Zhou, Anastasi Kosmadopoulos]**
	1615 – 1630	*The role of sleep and circadian phase on crew safety, performance and psychological health during long-term analog space missions* **Dr Tracey Sletten**
	1630 – 1645	*Commuting and sleepiness in shiftworkers in Central Queensland* **Associate Professor Naomi Rogers**
	1645 – 1700	*The impact of shift schedule on dietary intake* **Georgina Heath**
	1700 – 1715	*Impact of sleep deprivation and extended duration recovery sleep opportunity on neurobehavioural performance* **Jade Murray**
1715 – 1745		**ACS Business Meeting and Award Presentation**
1745 – 1930		**Pre-dinner Drinks** *Appleton Institute*
2000		**Conference Dinner** *Suzie Wong's Room - 120 Port Road, Hindmarsh*