

Sleep, & Performance & Well-being

in Adults & Adolescents

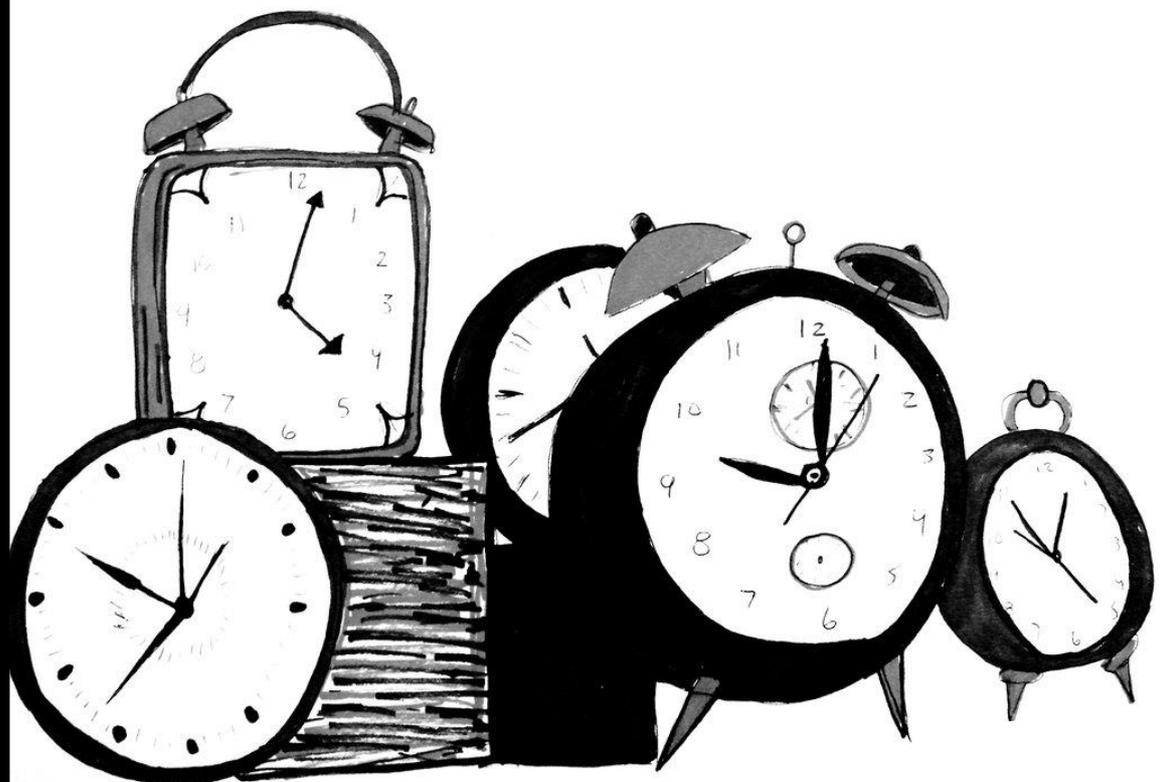
Full Papers

The Clock Strikes Ten

10th Annual Meeting

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Sleep, Performance & Well-being in Adults and Adolescents

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Chapter 1

Neurobehavioural Performance during a Split 28-h Forced Desynchrony Schedule

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Aims: Neurobehavioural performance is typically worse during night shifts than day shifts because the sleep/wake cycle and circadian rhythm are misaligned. Working multiple shorter shifts per day, to allow some sleep at night and some work during the daytime, may improve night-time performance. However, the effect of splitting the work-rest schedule on night-time performance is not currently clear. Therefore, the aim of this study was to compare performance during split and consolidated work-rest schedules at different times of the day.

Methods: Twenty-nine male participants lived in a time-isolation laboratory for 12 days. Participants were scheduled to one of two 28-h forced desynchrony (FD) protocols. Each provided the same total time in bed (TIB), either consolidated (9.3h TIB/28h) or split (2 x 4.7h TIB/28h). Neurobehavioural performance was assessed with a psychomotor vigilance task (PVT), 2h following waking and every 2.5h thereafter. Response time (RT) relative to baseline was the measure of performance. A nadir at 0500h on the first day and a period of 24.2h were assumed to estimate circadian phase.

Results: Participants in the consolidated (n=13) and split (n=16) conditions were similar in terms of age and BMI. Mixed effects model analyses indicated no overall difference between conditions in relative RT. However, there was a main effect of circadian phase and a circadian phase x condition interaction. Relative RT was fastest at the circadian acrophase and slowest around the circadian nadir. Relative RT during the split schedule was faster than the consolidated schedule around the circadian nadir.

Discussion: Overall performance did not differ by splitting the work-rest schedule. However, in shortening the duration of wakefulness between sleep periods, performance during the night was maintained at a higher level than for the consolidated schedule. Therefore, this schedule may be beneficial to industries that require a high standard of performance sustained around the clock.

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Introduction

In an increasingly 24-h society, services available around the clock are in demand more than ever. However, shiftwork is associated with suboptimum performance and the risk of errors and accidents, particularly at night, is much higher than for those working 9am-5pm office hours

[6]. The increases in fatigue, accidents and injuries are largely due to circadian misalignment and getting insufficient sleep associated with these shifts [6].

Sleep and wake are regulated by two interacting physiological processes [1]. The first is a homeostatic process that

follows the sleep-wake cycle, progressively increasing the drive for sleep across durations of wakefulness and rapidly decreasing this drive for sleep after sleep onset. The second is a circadian process, regulated in the suprachiasmatic nucleus, that is entrained to the 24-h light/dark cycle and increases the biological propensity for sleep during the night and wake during the day [9]. In a normal sleep/wake cycle, these two processes align such that the accumulated drive for sleep occurs at the end of the day, at which point the circadian process would maintain and promote sleep over the course of the night. However, for those working shifts at different times of the day, these processes are often in conflict; many shiftworkers are required to work when primed for sleep, with rostered sleep opportunities when primed for wake. As a consequence, neurobehavioral functioning is diminished and the associated risk of error is increased [8].

Working a split schedule of multiple short shifts per day (e.g. 2x 6h on, 6h off), instead of fewer longer shifts (e.g. 12h on, 12h off), may be useful in industries that require their workforce to sustain a high level of functioning around the clock. There is evidence to support splitting work/rest schedules for sustaining performance capacity. First, the faster shift rotations ensure that all personnel are scheduled to do some work during the day, and have some opportunity to sleep at night. Second, it is well known that performance declines with increasing sleep pressure [5]; a split work/rest schedule reduces the duration of work required of personnel between sleep periods. Additional support for this work/rest schedule is a finding that dividing sleep into multiple short periods may not disrupt daytime function, provided the total amount of sleep obtained per day is sufficient [10]. However, the findings from these studies are limited as they confound time-of-day with wake duration, and the latter study

only compared the effect of consolidated night-time sleeps with shorter night-time sleeps supplemented by daytime naps, on daytime functioning. Therefore, it is not clear how functioning would differ in a split work/rest schedule during the night.

A forced desynchrony (FD) laboratory protocol may be the most efficient method of identifying the effects of time of day on neurobehavioural functioning during a split work/rest schedule. FD protocols impose a sleep/wake cycle that is significantly longer or shorter than the 24-h chronological day [7]. As the near-24-h period of the endogenous circadian rhythm is so different from the period of the imposed schedule, it cannot entrain to it. Thus, the circadian rhythm is desynchronised from the sleep/wake cycle, and the effect of biological time-of-day on performance can be assessed separately. So far, neurobehavioural function has been evaluated in FD protocols employing consolidated sleep/wake schedules, but none have employed a split schedule [4, 8, 12]. Therefore, the aim for this study was to determine whether there is any advantage of a split sleep/wake schedule for neurobehavioural functioning compared to a consolidated schedule at different times of the day.

Methods

Participants

Twenty-nine healthy males with a mean (\pm SD) age of 22.5 (\pm 2.6) yrs and body mass index (BMI) of 22.1 (\pm 2.0) kg/m² participated in this study. Participants were required to have habitual bedtimes between 22:00 and 00:00h, and sleep durations of between 7 and 9h per night, as determined by a week of wrist actigraphy. Volunteers who reported medical or sleep problems, smoking, excessive consumption of caffeine or alcohol, a BMI outside 20-25 kg/m², or transmeridian travel / shiftwork in the previous month were excluded.

Ethics

This study was approved by the CQUniversity Human Research Ethics Committee and met the guidelines of the National Health and Medical Research Council of Australia. Participants provided informed consent and were remunerated with an honorarium for their involvement.

Setting

Appleton Institute researchers conducted this study in the time-isolation laboratories of the Appleton Institute and the Centre for Sleep Research in Adelaide, South Australia. These laboratories were arranged to accommodate three or four participants at a time with a bedroom, living room, and bathroom facilities. The laboratories were windowless and sound-attenuated to minimise external time cues. Ambient temperature was maintained at $22\pm 1^\circ\text{C}$ throughout the study, and lighting during wake periods was maintained at 10-15 lux. During the study, participants had no access to clocks, live television, internet or mobile phones.

Protocol

Participants were randomly assigned to one of two conditions of forced desynchrony: a consolidated schedule or a split schedule (Fig. 1). Each condition began identically with 24-h adaptation and baseline days. On the adaptation days, participants were trained on tasks to minimize practise effects. On the baseline day, participants completed 5 testing sessions beginning 2h after waking. After the baseline day, participants assigned to each condition were scheduled to 7x28-h forced desynchrony (FD) periods with an enforced rest-to-wake ratio of 1:2. The FD periods for the consolidated schedule incorporated a single rest/wake cycle of 9.3h time in bed (TIB) per 18.7h awake. In contrast, the FD periods for the split schedule were subdivided into two 14-h rest/wake cycles of 4.7h TIB per 9.3h wake. Neurobehavioural testing in both

protocols was scheduled 2h after waking, and at 2.5-h intervals thereafter (Fig. 1). As FD periods were 4h longer than the 24-h solar day, each cycle of testing commenced approximately 4h later in participants' circadian rhythms.

Between testing sessions, participants were free to read books, listen to music, or watch DVDs in their own living areas.

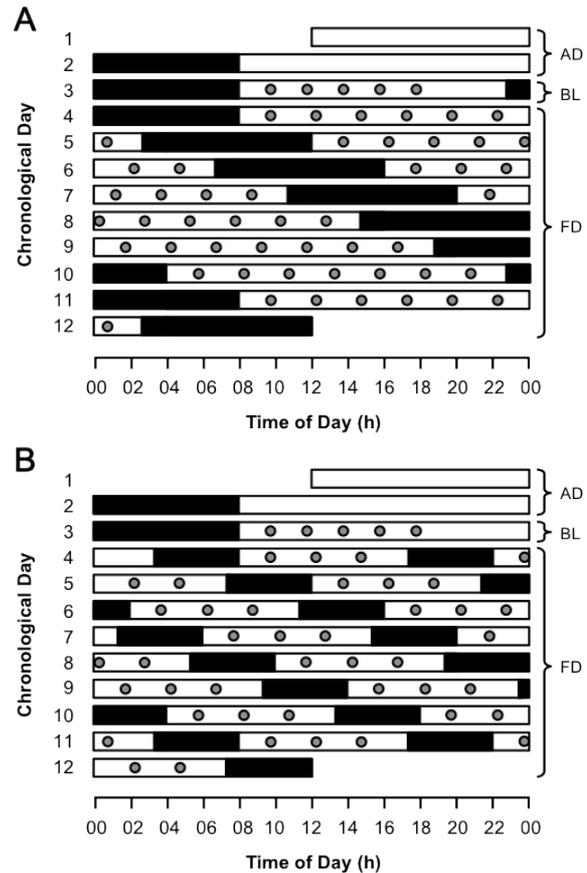


Fig.1. Forced desynchrony protocol diagrams. Fig. 1A depicts the consolidated schedule and Fig. 1B depicts the split schedule. The y-axis represents chronological days, and the x-axis represents time of day. Black rectangles represent sleep opportunities, and grey circles represent testing sessions. Both protocols begin with 2 adaptation (AD) and 1 baseline (BL) days, followed by a period of forced desynchrony (FD).

Materials and Measures

Neurobehavioural function was measured using a 10-min psychomotor vigilance task (PVT). This task required participants to respond to stimuli appearing at random intervals on an

electronic hand-held device by pressing a button as quickly as possible. Mean response time (RT), in milliseconds, was the measure of performance. Participants' RT at each testing session were expressed relative to their mean performance at baseline.

Estimated circadian phase was used as the measure of participants' biological time during the protocol. Based on the results of previous studies [3, 4], their circadian rhythms were assumed to have a nadir at 05:00h on the first day and a circadian period of 24.2h. Relative RT from each protocol (i.e., consolidated and split) were assigned to one of 6x60° bins of estimate circadian phase, with midpoints at 0°, 60°, 120°, 180°, 240°, 300°.

Results

Independent t-tests showed that participants in the consolidated (n=13) and split (n=16) conditions did not differ in terms of age [$t(27)=0.10$, $p=.92$] and BMI [$t(27)=0.19$, $p=.85$].

Data were analysed using a linear mixed-effect model to determine whether there were any main effects of sleep/wake schedule (2 levels) and circadian phase (6 levels), or an interaction. Relative RT was the dependent variable, and "Participant ID" (N=29) was entered as a random term to account for individual differences. Bonferroni post hoc comparisons were conducted for any significant main effects or interactions.

Linear mixed-effects model analyses indicated that there was no main effect of condition on performance [$F(1,27)=0.37$, $p=.55$], but there was a main effect of circadian phase [$F(5,793)=11.75$, $p<.01$] and an interaction of condition and circadian phase [$F(5,793)=2.54$, $p=.03$]. Bonferroni post hoc analyses of the main effects of circadian phase showed that relative RT at the circadian nadir (0°) was significantly ($p<.05$) slower than at the circadian acrophase (180°) (Fig. 2).

Post hoc analyses of the interaction revealed that performance during the split sleep/wake schedule was significantly ($p<.05$) faster than during the consolidated schedule around the circadian nadir (0°, 60°), but did not differ at other phases (Fig. 2). Analyses of the simple effects within each protocol revealed a significant effect of circadian phase for the consolidated protocol [$F(5,793)=17.70$, $p<.01$], but not for the split protocol [$F(5,793)=1.53$, $p=.18$].

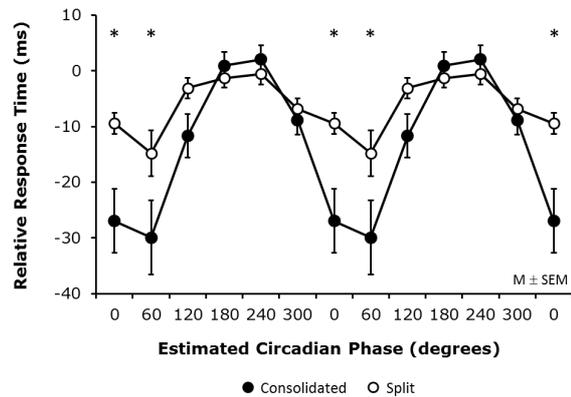


Fig. 2. Response time relative to baseline by circadian phase (M±SEM). Y-axis represents response times relative to baseline, with lower values indicate slower response times. X-axis represents estimated circadian phase. Black circles represent performance during the consolidated protocol, and white circles represent performance during the split protocol. Asterisks indicate significant differences between conditions.

Discussion

The results of this study suggest that splitting the sleep/wake schedule is not detrimental to neurobehavioural function and may be advantageous at certain times of the day. On the whole, performance during both consolidated and split schedules did not differ. However, declines coinciding with the circadian nadir were less severe during the split schedule than during the consolidated schedule.

The main effect of circadian phase on neurobehavioural performance found here is consistent with findings of other studies employing forced desynchrony

protocols [12]. Performance around the circadian acrophase was similar to baseline performance, and deficits occurred around the circadian nadir. Previous findings that splitting sleep does not impair daytime function are supported in the current study, as no differences between schedules were found. Consistent with the state instability conclusions of Zhou et al. [11], the differences in wake duration imposed by each protocol appear to be the primary factor affecting performance around the circadian nadir. Participants in the consolidated schedule had to maintain wakefulness for a period of 18.7h, a duration known to impair neurobehavioral performance equivalent to a blood alcohol concentration of 0.05% [5], at times when they were most strongly primed for sleep. In contrast, participants in the split schedule who maintained wakefulness during the circadian nadir had only accumulated a sleep pressure of 9.3h by bedtime.

The findings of this study have practical importance as they suggest split work/rest schedules have the potential to improve productivity and sustain alertness in the workplace day and night. A schedule of continuously alternating short rest and work periods may not be conducive to all shiftworkers in all industries, due to the disruptions it would have on social and family life; additionally, in instances where employees commute between work and home, regular split schedules would reduce the time available for sleep. However, in circumstances where the task is important enough (e.g., a multi-day firefighter response) or where disruption to social or family life would be minimal and employees live on or near the site (e.g. fly in, fly out industries), split work schedules may be more effective than current shift schedules in sustaining a high level of operational performance.

There are a few caveats regarding the application of findings from this study. First, splitting the schedule increases the number of hand-overs between employees of contiguous shifts. While neurobehavioural function may be maintained during these shorter shifts, it is possible the increase in hand-overs may facilitate opportunities for miscommunication and errors as a consequence. Second, the participant sample of healthy young adult males is not representative of the broader shiftworking population [2]. The recruitment of healthy males to minimise individual variability is normal practice, but the characteristics of the target population should be carefully considered when extrapolating the findings. The other caveat is that the laboratory facilitated “best case scenario” sleeping conditions, which shiftworkers are not always able to achieve for a variety of social, physiological, or work-related reasons. Future research should investigate the effect of split work/rest schedules on neurobehavioural performance under conditions of sleep restriction.

In conclusion, while split and consolidated sleep/wake schedules did not differ substantially on average, splitting the schedule reduced the declines in performance associated with the circadian nadir. This supports the introduction of shorter work-rest cycles to sustain performance, particularly in industries where a high level of functioning at all times of the day is critical.

Acknowledgements

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Chapter 2

The Efficacy of Subjective Ratings is Limited during the Biological Night

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Aims: Disturbed sleep is associated with sleepiness and impaired neurobehavioral performance. It is important to implement strategies to minimise the impact of performance impairment. It can be difficult for an individual to know when their performance is impaired by sleepiness. The aim of the present study was to examine whether the efficacy of subjective ratings varies as a function of circadian phase.

Methods: Sixteen healthy males volunteered for a 12-day 28-h forced desynchrony protocol. Subjective sleepiness was measured using the Karolinska Sleepiness Scale (KSS). Reaction time (the metric was reciprocal reaction time (RRT)) was assessed using the Psychomotor Vigilance Task (PVT). Self-perceived performance capacity was measured using a Visual Analogue Scale (VAS); all measures were given at various combinations of circadian phase.

Results: Pearson's correlations revealed a weak negative association between KSS and RRT and a weak positive association between VAS and RRT during all circadian phases. The association of subjective measures and RRT was strongest during the estimated circadian phases associated with the biological night. Overall, KSS had the strongest negative association with RRT.

Discussion: The findings suggest that the efficacy of subjective ratings is limited during the biological night and therefore should not be relied upon to determine whether an individual will engage in unsafe behaviour. The results of this study may be helpful when developing ways to determine when it would be necessary to employ strategies to mitigate performance impairments resulting from nightshift rosters.

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Introduction

Sleep research has shown how performance can be adversely affected by factors such as sleep duration, period of prior wakefulness and time-of-day. Total sleep deprivation studies (TSD) can be used to examine the relationship between performance and a period of sustained wakefulness typically between 24 to ~90-h [1]. TSD studies have shown how periods of wakefulness can produce increasing performance variability [2]. Sleep restriction protocols highlight the changes in performance reliant on sleep dose [3]. A sleep dose between 3 and 7-h

can result in slower reaction times and an increase in the incidence of lapses of attention [4]. The contributions of time-of-day dependent changes in performance have been examined using a forced-desynchrony paradigms. These studies involve either extending (28-h; 3) or shortening (20-h; 5) the period of sleep-wake beyond the normal 24-h entrainment of the circadian system. Findings have illustrated the main effect circadian phase has on sleepiness and performance. Studies have shown that performance is better during the biological daytime versus during the

night and that people are sleepier during the night [6].

Performance impairments can occur as a result of people performing when they are sleepy [7]. When organisations identify employees as being at risk of fatigue-related incidents or accidents risk mitigation strategies such as napping and/or caffeine consumption can be employed to reduce fatigue-related performance impairments [6]. Napping is one method that has been found to compensate for sleep loss caused by temporal displacement of sleep [8]. Caffeine consumption at appropriate times can reduce sleepiness and performance deficits during night time work [9]. In circumstances where employees have an onus of responsibility to report themselves as unfit for duty, it is assumed that they (1) have the ability to accurately assess their performance and that (2) this ability remains constant across different times of the day. Accurate assessment of sleepiness may enable some of the adverse effects of sleep disruption to be minimised.

Insight into performance capacity is important in determining when the application of risk mitigation strategies is most effective and appropriate [9]. Research has indicated that people have some insight into performance capacity when fatigued. For example, a sleep deprivation study consisting of 28-h sustained wakefulness, found a moderate correlation between actual performance and predicted performance [10]. The authors concluded that for performance parameters affected by fatigue (grammatical reasoning, vigilance, simple sensory comparison and tracking), predicted performance and subjective alertness closely tracked actual performance [10]. However, there is evidence to suggest that some people may not know when their performance capacity has reached a safety-critical level. Drivers falling asleep do not always

recall having done so, even if they are aware of their state of increasing feelings of sleepiness [10]. The association between sleepiness and the high likelihood of falling asleep is not always fully appreciated by drivers. However it still remains that one's own personal knowledge of level of sleepiness and capability are the most valid and reliable forms of assessment [10].

Employees who work in safety-critical industries such as mining and transportation have to work at all times of day. They experience a misalignment between their sleep/wake pattern and circadian timing system [11] because their schedule, particularly for night work, requires them to sleep during the day when their circadian system is promoting wakefulness. Therefore, the employees within these industries are vulnerable to the adverse effects of sleep disruption on performance [7]. It has been suggested that to combat the effects a disruption to the sleep/wake schedule has on performance, individuals can assess their functionality and determine whether they are capable of performing safely. One such method of assessment is subjective-ratings.

The aim of the current study was to examine whether the efficacy of subjective ratings vary as a function of circadian phase. Specifically, the investigation was centred on whether subjective feelings of sleepiness and subjective ratings of performance capacity could provide a reasonable marker of actual performance during all circadian phases.

Methods

Participants

Sixteen healthy males (age, $M = 22.6 \pm 2.9$ yr; body mass index 22 ± 1.9 kg/m²) gave written consent to participate in the study. Volunteers were all non-smokers and did not use recreational drugs. Volunteers who reported excessive consumption of alcohol or caffeine,

medical or psychiatric conditions, or sleep problems were excluded. Volunteers who had engaged in shift work or transmeridian travel (i.e., crossing different time zones) in the previous months were also excluded. This study was approved by the CQUniversity Human Research Ethics Committee

Setting

The study was conducted at a time-isolation sleep laboratory. The sleep laboratory has living quarters that comprise of four bedrooms. During wake periods the light intensity was 10-15 lux (i.e. dim light) and during sleep periods <0.03 lux (i.e. darkness). Ambient temperature remained at 22(±1) °C. Participants were isolated from all external time cues through-out the study.

Materials and Equipment

Neurobehavioural function was measured using the psychomotor vigilance task (PVT; 12). The PVT is a 10-min reaction time task measuring sustained attention. The task required participants to respond as quickly as possible to the presentation of a visual stimulus, at random intervals, by pressing a button with the thumb of their dominant hand. The reciprocal reaction time (RRT; $RT \text{ in } ms^{-1} \times 10^{-3}$) was selected as the dependent measure.

A visual analogue scale (VAS) was used to measure the assessment of pre-performance capacity [4]. The scale required participants to rate ‘how well do you think you will perform?’ by placing a mark on a 100 mm non-numeric line, anchored with ‘Extremely poorly’ on one end (0mm) and ‘Extremely well’ on the other (100mm). The position of the marking determined a score between 0 and 100 of the participant’s assessment of their performance capacity. A higher score indicated a greater level of belief in their performance capacity.

Subjective sleepiness was assessed using the 9-point Karolinska Sleepiness Scale

(KSS; 7). The KSS required participants to circle a number from 1 ‘Extremely alert’ to 9 ‘Very sleepy, great effort to keep awake, fighting sleep’.

Procedures

Participants undertook two training days and one baseline day, each separated by 8-h sleep periods from 00:00 to 08:00h. This was followed by a 28-h forced-desynchrony protocol consisting of two 14-h sleep/wake cycles with a sleep:wake ratio of 1:2 (see Fig.1). The imposed sleep/wake schedules during the study are summarised in Fig 1. After two training days and a baseline day, participants were scheduled to nine 28-h days. There was a recovery day following the 28-h protocol.

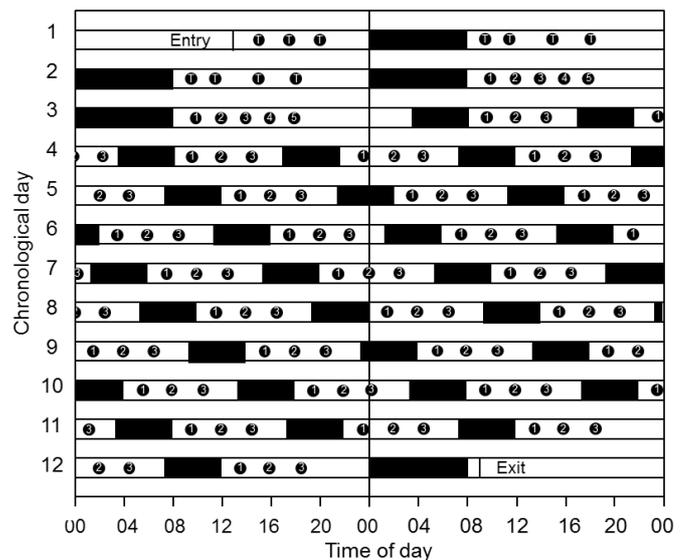


Fig.1. Forced desynchrony protocol. Solid black bars represent time in bed periods; white bars represent scheduled wake periods and black dots represent scheduled test batteries.

During the forced-desynchrony schedule a test battery was administered 1.5-h following waking and at 2.5-h intervals thereafter. The test batteries were completed in each participant’s lounge room to minimise the risk of distractions. During free periods participants were permitted to engage in any non-vigorous activities, except watching television and

using the internet or mobile phone. Participants were monitored by researchers, either in person or via a television system, to ensure they did not nap during wake periods.

Results

Data Analysis

Based on previous literature [13] circadian rhythms were assumed to have a nadir at 05:00h on the first day, and a period of 24.2h. RRT, VAS and KSS were assigned to one of six 60° estimated circadian phase bins. The starting point of each bin were 0°, 60°, 120°, 180°, 240° and 300°. The individual scores on each test battery were assumed to be independent and categorised according to the estimated circadian phase. Data were analysed using Pearson's correlation to measure the linear relationship between the KSS and RRT and the VAS and RRT as a function of circadian phase.

Participants reported higher levels of sleepiness around the circadian nadir, or biological night (270°-90°) and reduced levels of sleepiness at the circadian phases associated with the biological day (90°-270°) (Fig 2). Figure 2 illustrates a belief in higher performance capacity at the biological day, and lower scores on the visual analogue scale at the biological night indicating a reduced expectation of performance capacity.

Pearson's correlation was used to measure the strength of the relationship between the KSS and RRT. Figure 3 illustrates a negative relationship between KSS and RRT ($r = -.13 \pm .08$). A significant correlation between KSS and RRT during the circadian phase 180° and 240° ($p < .05$) was observed (Fig 3). Pearson's correlations indicated a significant relationship for VAS and RRT during the same circadian phases (180°-240°; $p < .05$). The relationship between the RRT and the two dependent variables

(KSS and VAS) was weak at all circadian phases but strongest during the biological day. Fig 3 indicates a stronger correlation between KSS and RRT than VAS and RRT, at all circadian phase estimates.

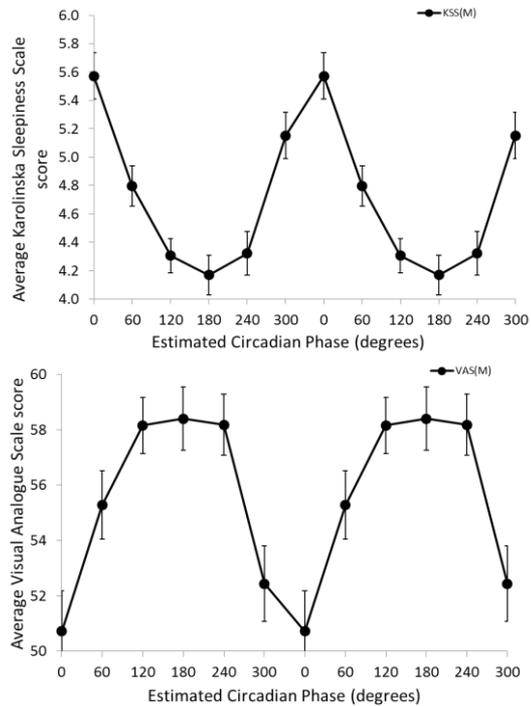


Fig.2. The scores ($M \pm SEM$) for each subjective measure (KSS and VAS) as a function of estimated circadian phase

Discussion

The relationship between KSS and RRT was stronger than VAS and RRT. The structure of the test batteries may have played a role in contributing to the different strength of relationship between the subjective ratings and actual performance. The test batteries included a range of neurobehavioural performance tasks. Subjective ratings of performance capacity were measured prior to these. It is possible that participants rated their performance capacity based on global estimates, rather than making test-specific predictions concerning the PVT [13].

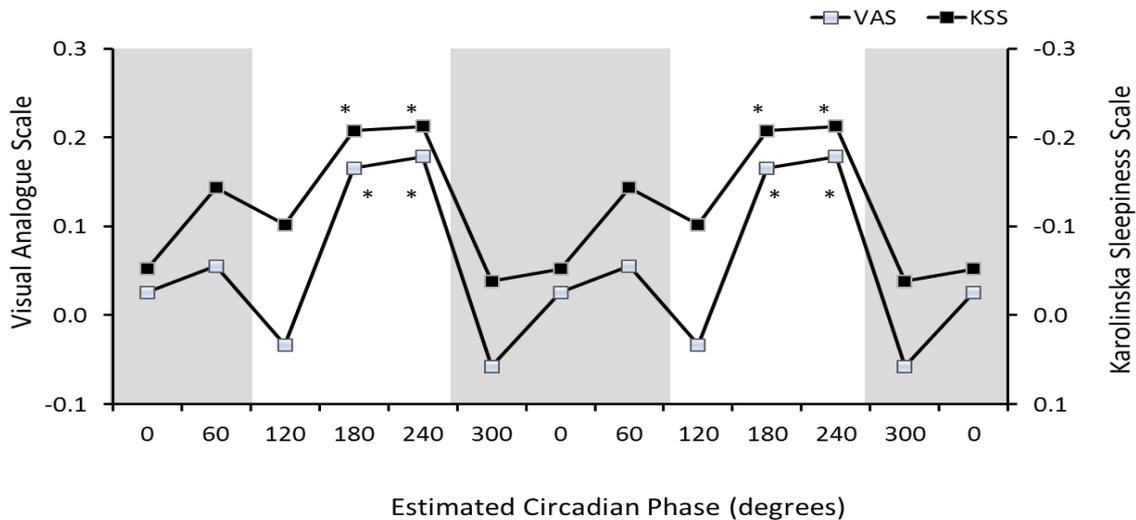


Fig.3. The correlation coefficients of subjective measures, KSS and VAS with RRT as a function of circadian phase estimates.

Future research should administer subjective ratings of performance capacity immediately prior the specific performance task being assessed or develop the subjective rating question to relate specifically to the task. An additional consideration is the small range of responses for the KSS and VAS. The VAS and KSS ratings typically did not distribute beyond the middle of the scales. These participants may simply be conservative in their self-ratings or metric-related factors such as a ceiling effect may contribute to the lack of predictive efficiency in so much as fluctuations in experience may not be reflected in the ratings [15]. Nevertheless the small variation illustrates the influence of circadian variation on the ability to self-assess, indicating that the efficacy of subjective ratings vary as a function of circadian phase. More research is necessary to identify factors that influence individuals' perception of their sleepiness and performance capacity.

In summary, the results indicate that comparatively subjective feelings of sleepiness may act as a more appropriate indicator of actual performance than ratings of how well individuals think they may perform. Future research should address the issue of test administration to achieve a

more valid examination of the efficacy of subjective ratings and the relationship between measures.

Acknowledgements

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Chapter 3

The Effect of Sleep Restriction and Exposure to Physical Activity on the Cognitive Ability of Volunteer Firefighters across a 3-day Simulated Fire-ground Tour

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Aims: To determine the combined effects of concurrent days of physical work and sleep restriction on attention in a group of volunteer fire-fighters.

Methods: Twenty-four volunteer fire fighters (Males, $N=20$, Females; $N=4$) were required to live in a simulated fire ground environment for four nights/five days. On the first night (adaption) participants were given 8 hours sleep opportunity, whereas on nights 2 and 3 sleep opportunity was restricted to 4 hours. On the last night (recovery) they were given 8 hours sleep opportunity. Physical activity circuits lasted 1 hour followed by a cognitive battery that included the measurement of vigilant attention using a 5-minute version of the Psychomotor Vigilance Task (PVT). The dependent variables were reciprocal reaction time and lapses as measured by PVT.

Results: There was a significant main effect of day on reciprocal reaction time on the PVT, ($F(2.65, 60.95)=9.69, p<.001$), with significantly lower reciprocal reaction times on day 2 compared to day 1 ($p<.001$), and day 3 compared to recovery day, ($p<.01$). There was a significant main effect of day on lapses, ($F(2.26, 52.05)=3.67, p<.05$). Lapses were significantly lower on recovery than day 3 ($p<.05$).

Discussion: Multiple nights of partial sleep restriction in combination with physical work leads to a reduction in attention. Further nights of similar sleep restriction is expected to lead to more dangerous declines in performance. Thus, it is imperative that firefighting agencies acknowledge that even one night of little sleep may lead to a decline in their ability to remain vigilant and respond rapidly to threatening situations. Unfortunately it is difficult to determine whether physical activity during the day adds to the effect of fatigue, or counteracts the influence of fatigue.

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Introduction

Every year in Australia bushfires threaten communities, civilians and infrastructure [9]. A population of around 220,000 volunteers is relied upon for the suppression of these fires [13]. Firefighting is considered a dangerous occupation as it often involves working in remote areas over multiple days [1] whilst exposed to multiple occupational stressors [3]. These stressors include intense physical work in environments

that are often noisy, smoky, and hot [1]. Depending on the severity of the fire, a suppression campaign can last for days or even weeks, resulting in fire-fighters working shifts of approximately 12-18h duration across the day and night. Such working conditions can lead to additional stressors such as sleep restriction [4]. Adequate sleep during suppression campaigns is difficult to obtain for a number of reasons. Firstly, sleep opportunities can be limited to less than

4h per night due to lengthy shifts and lack of replacement teams [3]. Secondly, environmental conditions such as noise, heat and light exposure make it difficult for fire fighters to fall and remain asleep [10]. Combined with intense physical activity, fire fighters often report aching muscles and joints, feelings of sleepiness and lethargy, and difficulties concentrating [1]. Evidence has shown that increasing fatigue levels results in decreases in cognitive functioning that seriously threaten the safety of fire-fighters and their crew [1].

Cognition can be defined as the mental processes involved in everyday functioning. It is the acquisition and understanding of knowledge through thought, senses and experiences [7]. Fire fighters are highly dependent on a range of cognitive abilities to complete fire-fighter specific tasks and remain safe on the field. For example, they must be able to make safety critical decisions, remain vigilant, and co-ordinate and recall numerous geographical points to be able to navigate their way out of dangerous fire zones. Vigilant attention underpins the majority of these abilities. Vigilant attention is characterized by one's readiness to detect unpredictable stimulus over an extended period of time [15]. This cognitive ability can be measured using a Psychomotor Vigilance Task (PVT), which is known to be sensitive to sleep loss [11].

When on the fire-ground, firefighters often experience chronic partial sleep restriction (that is <5h sleep in a 24h period [14]). The majority of studies investigating sleep restriction report that the ability to respond to a stimulus in a timely manner is severely compromised when subjects are sleep deprived [11]. More specifically, sleep restriction causes an overall slowing of reaction times [2], and an increase in the number of response lapses (a response time ≥ 500 ms) [5]. However, studies have shown that there is a different effect depending on

the form of sleep restriction. Partial sleep restriction appears to have a greater effect on cognitive performance than short term or long term sleep deprivation [14]. The decrements in vigilant attention that are present due to sleep restriction are of great concern to fire fighters. Given the dangerous environments in which they work, fire-fighters require a high level of concentration and must be ready to respond to unanticipated threats such as the rapid change in fire direction or falling tree limbs which they must avoid in order to prevent injury [1].

Current research on sleep restriction and cognition has found significant results however, it is difficult to generalize the results to fire fighters. This is because studies do not incorporate multiple stressors such as physical work or activity over multiple days. Therefore, the aim of the present study was to investigate the effect of physical work in conjunction with sleep restriction on the cognitive performance of volunteer fire fighters during a simulated fire ground tour.

Methods

Participants

Twenty-four healthy volunteer fire fighters (Males, $N=20$, Females; $N=4$) were recruited to take part in the 'Awake, Smoky and Hot Project' funded by the Bushfire Cooperative Research Centre. The participants had a mean (\pm SD) age of 38.1, (± 13.3), and an average (\pm SD) body mass index (BMI) of 29.4 (± 5.1) kg/m². Participants were recruited from state fire agencies including the Country Fire Authority (CFA), Tasmania Fire Service and New South Wales Fire Service. To gain a representative sample of volunteer fire fighters potential candidates were excluded from the study if they had any injury or medical condition preventing them from firefighting activity, previous cardiovascular disease or a sleep disorder, or were pregnant. Participants were

Results

A repeated-measures ANOVA was run using planned contrasts to compare each day to the previous. The independent variable was day and the dependent variables were reciprocal reaction time and lapses.

The assumption of sphericity had been violated for PVT reciprocal reaction time, $\chi^2(9)$, =28.29, p =.001, η_p^2 =.30, therefore multivariate tests are reported (ϵ =.66). There was a significant main effect of day on PVT reciprocal reaction time, ($F(2.65, 60.95)$)=9.69, p <.001). Reciprocal reaction times (RRT) were significantly lower on day 2 than day 1

(p <.001). Reciprocal reaction times were also significantly lower on day 3 than recovery, (p <.01). No significant difference was found between baseline and recovery (p =.302) or day 2 and day 3 (p =.08) (Fig.2A.).

The assumption of sphericity had also been violated for minor lapses on the PVT, $\chi^2(9)$, =34.87, p <.001, η_p^2 =.14, therefore multivariate tests are reported (ϵ =.57). A significant main effect of day on lapses was found, ($F(2.26, 52.05)$)=3.67, p <.05) (Fig.2B.). Lapses were significantly lower on recovery than day 3 (p <.05).

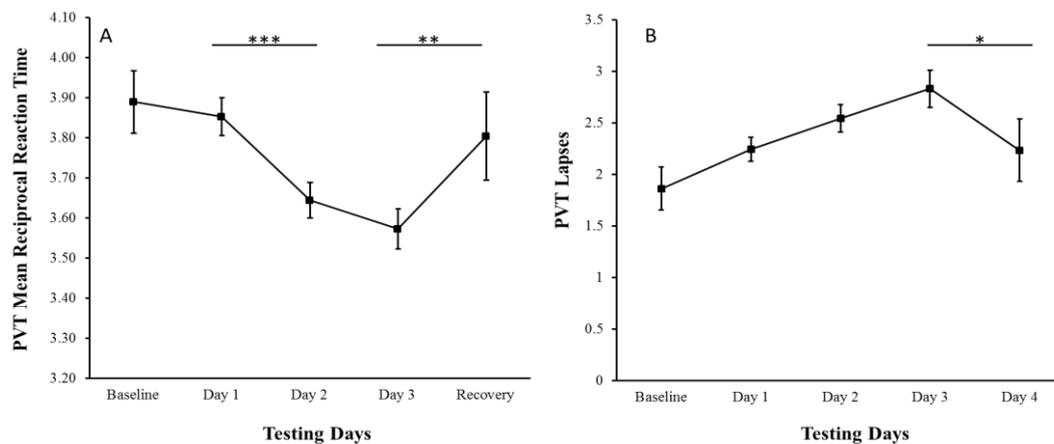


Fig.2. Effect of sleep restriction on PVT performance across each day of the study. Panel **A** shows group means (\pm SEM) across days for PVT reciprocal reaction time and panel **B** shows group means (\pm SEM) across days for PVT lapses. * p <.05 ** p <.01 *** p <.001.

Discussion

Similar to previously reported findings [2, 11, 14], sleep restriction resulted in a decline in reciprocal reaction time. Results showed that RRT decreased after only one night of 4 hours sleep opportunity. The reduction in performance (RRT and lapses) was even greater after two nights of 4 hours sleep opportunity.

These results are of particular relevance to volunteer fire fighters who are exposed to sleep restriction during suppression campaigns. Fire fighters need to maintain vigilance to safely conduct work in hazardous environments. For example, they need

to be able to quickly respond to the changing direction of the fire or the constant movement of trees and objects. The findings suggest that fire fighters may be susceptible to the effects that sleep restriction has on reaction time as early as the first day after sleep has been restricted (to 4 hours). However, the change in the number of lapses in attention was only significant when comparing day 3 to day 4, indicating that 8 hours of recovery sleep can positively impact the amount of lapses in concentration. It is unknown whether the physical tasks conducted during the day counteract the effect of sleep restriction or fatigue, or whether it adds to the cumulative effect of sleep

restriction and fatigue. Further studies should investigate the impact of fire fighter specific physical activity alone on cognitive performance.

This study simulated a 3-day campaign which restricted sleep to two nights of four hours. Thus, the results are not generalizable to fire-fighters that are exposed to more than 2 days of sleep restriction on the field. Based on these results, it is expected that the decrements in attention will increase after each additional night of only four hours sleep. The findings from this study warrant further investigation into the effects of sleep restriction in conjunction with physical work has on cognitive abilities.

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Chapter 4

Can Australian Bush Fire Fighters Accurately Self-monitor Their Cognitive Performance during a 3-day Simulated Fire-ground Campaign?

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Aims: To understand the extent to which bush fire fighters can reliably and accurately monitor their cognitive performance following sleep restriction over a 3-day simulated fire-ground campaign.

Methods: Twenty-five participants performed a total of 14 circuits over three days that involved intense physical work. Participants received an 8-h sleep opportunity for the first night, and were restricted to 4-h sleep opportunities on nights two and three. Reciprocal reaction time on the Psychomotor Vigilance Task (PVT) was assessed at the end of each circuit, with self-reported measures of performance being attained before and after each cognitive battery.

Results: A main effect of day was discovered for reciprocal reaction time $F(2.75, 65.92) = 10.86, p < .001, \eta_p^2 = .31$; pre-performance ratings, $F(3.03, 64.06) = 6.53, p = .001, \eta_p^2 = .21$; and post-performance ratings $F(2.74, 57.58) = 9.31, p < .001, \eta_p^2 = .31$. Standard contrasts revealed that despite no significant difference between reciprocal reaction time on day 2 and day 3 ($p = .077$), significant differences were found for both pre ($p < .05$) and post ($p < .05$) subjective ratings of performance. Pre and post ratings of performance were found to have no significant relationship with objective performance.

Discussion: Results indicate that fire fighters can accurately identify performance decrements after experiencing partial sleep restriction, despite being unable to identify the degree to which their performance would be impaired. The use of subjective judgments of fatigue and performance appear to offer an effective, efficient and cost effective tool in fatigue management strategies. Some caution must be taken however, as it is possible that fire fighters may over or underestimate the degree to which their performance will be affected.

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Introduction

In Australia, volunteer fire fighters are responsible for the suppression of bush fires. This involves protecting against threats to public and private infrastructure, communities, and human and animal lives [7]. Fire fighters are frequently exposed to a vast array of occupational and environmental stressors such as intense physical work

in hot, noisy and smoky conditions [4]. During multiple day campaigns it is not uncommon for fire fighters to work long consecutive shifts that range from 12 to 18h following a full or partial day of usual employment [4]. Sleep opportunities are often limited due to a lack of replacement crews, fires that are burning out of control and need urgent attention, and suboptimal sleeping

conditions [1]. As such, fire fighters may experience as little as 3-6h sleep per opportunity between shifts [1,4]. The combinations of inadequate sleep, long periods of wakefulness, intense physical work and extreme environmental conditions makes fire fighters highly vulnerable to fatigue and fatigue related injuries [1,9].

The work that fire fighters undertake requires a high level of vigilance, as well as the ability to make sound judgments in response to their surrounding environment [9]. Sleep deprivation is believed to severely compromise many neurological processes that are vital for processing information and responding to spontaneous stimuli [6]. Fatigue on the fire-ground can therefore have severe consequences as individuals become less aware of small obstacles or threats that can result in injury or even death [1,10]. Simple tasks such as walking through rocky terrain, using appropriate lifting techniques or paying attention whilst driving can result in unnecessary and avoidable accidents [10].

Dawson and McCulloch [5] suggest that fatigue management strategies should target the specific events that occur prior to a fatigue related accident because there are many 'tell tale' signs of fatigue. The New South Wales Rural Fire Service has incorporated this theory into their fatigue management policy by placing a heavy responsibility on the fire fighters to monitor their own performance and ascertain whether or not they are fit for duty [11]. Given the conditions in which fire fighters must work, it is rarely possible or practical to rely on external feedback given from crew members or superior officers. Therefore, the ability to self-monitor performance, if done accurately, offers a quick and cost effective way to minimise accidents and protect the safety of both the individual and their crew.

The capacity to self-monitor performance following sleep deprivation has been well documented in laboratory-based studies. Results suggest that in most cases, subjects are accurate in their perceptions of performance even after being sleep deprived [2,3,6]. In one notable study, Dorrian and colleagues found that even after acute sleep loss (28 hours), subjects could still accurately rate the deterioration of their performance on multiple cognitive tasks [6]. While subject's ability to predict significant declines in performance were questionable, the declines were fully appreciated in the performance evaluations [2,6]. The ability to self-monitor performance begins to deteriorate after pro-longed periods of wakefulness of around 54 hours [2].

To date, studies investigating performance monitoring have used laboratory-based methodologies that do not reflect the environments bush fire fighters are exposed to. In addition, samples used are not representative of this particular population. Therefore, there is a need to gain an understanding using field-based approaches as to the ability of bush fire fighters to monitor their performance under conditions that reflect their working environment. The aim of this study was to investigate how well fire fighters could self-monitor performance following sleep deprivation and physical exertion during a 3-day simulated fire-ground campaign. This information will be vital for the validation of existing fatigue management policies, and educating individuals to be better able to monitor and manage fatigue. It is predicted that fire fighters will be able to predict and identify decrements in their performance. That is, over the course of a three-day fire-ground simulation, as cognitive performance deteriorates, individual's pre and post subjective performance ratings will decline.

Methods

Participants

Twenty-five volunteer fire fighters ranging from 18 to 63 years of age ($M=38.4$) completed the study. Participants were recruited from agencies Australia-wide, and were a mixture of volunteer and salaried rural fire fighters. Ethics approval was obtained by the Central Queensland University (H12/01-016) and the Deakin University Human Research Ethics Committees (210-170) and conformed to the guidelines established by the National Health and Medical Research Council of Australia. Participants were required to complete a consent form, and a general medical questionnaire that included questions relating to their demographics, health, sleep behaviour, and fire fighting experience. Plain language statements were also provided prior to the study.

Protocol

The study required participants to stay on site at the training facility for 4

consecutive nights. The protocol was completed in groups of 4 or 5. On the evening prior to testing, the participants were briefed about the study and were provided with training on physical and cognitive tasks to limit/eliminate practice effects. During the testing phase a total of 14 circuits were completed. Participants received an 8-h sleep opportunity on the first night followed by two consecutive nights restricted to 4h sleep, after which they received an 8-h recovery sleep. Circuits consisted of 1-h of physical work (55min) followed by physiological testing (20min) and a cognitive battery (20min). On day 1, baseline cognitive measures were taken and participants completed 3 circuits following lunch. On days 2 and 3, subjects were required to complete 5 circuits, 2 before and 3 following lunch. Day 4 consisted of only one morning circuit following the 8h restoration sleep opportunity. See Figure 1 for study protocol schedule.

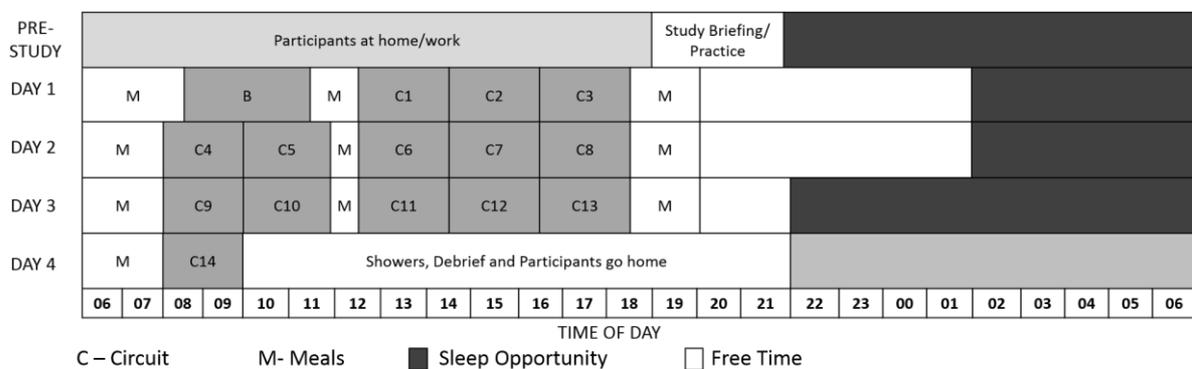


Fig. 1. Study protocol.

Materials

In the cognitive battery, participants completed five cognitive tasks, and completed subjective measures before and after each cognitive battery. Subjective performance ratings were attained using a Visual Analogue Scale (VAS) [12]. Participants were required to mark a single stroke along a 100mm line that best represents their response to the particular question. For pre-test performance ratings, participants were

asked, “how well do you think you will perform?” ranging from “very poorly” on the left to “very well” on the right of the line. Post-test performance ratings required participants to answer the question, “How well do you think you performed?” with response ranging from “very poorly” on the left and “very well” on the right. The higher the score on the VAS, the better the subject believed they would or had performed on the cognitive battery. Cognitive performance

was measured with a 5min version of the Psychomotor Vigilance Task (PVT) using a hand held palm pilot [8]. For the duration of the task, participants were required to attend to the screen. Immediately following the appearance of the target stimulus, participants were to press the response button with their dominant thumb as quickly as possible. The interstimulus interval varied between 2000 to 10,000 ms. After responding, reaction time was displayed on the screen for 1 second.

Results

A series of repeated measure ANOVAs was used to assess change in cognitive performance, as well as pre and post-performance ratings over the duration of the study. Pearson's correlations were used to determine the degree of the relationship between subjective and objective measures of performance. The dependent variables were PVT performance measured by reciprocal reaction time, and pre and post-performance ratings. The independent variable was study day, which consisted of 5 levels; baseline, day 1, day 2, day 3 and recovery. Data was reduced for days 1, 2 and 3 by calculating the average of participant's scores from each circuit to provide a mean score for each day. Baseline and recovery consisted of participant's scores from 1 test battery. For significant main effects, repeated planned comparisons were conducted comparing each day to the previous day. In addition, baseline was compared to recovery.

Reciprocal Reaction Time

Mauchley's test indicated that the assumption of sphericity had been violated for performance on the PVT ($X^2(9) = 28.38, p=.001$) therefore multivariate tests are reported ($\epsilon = .69$). There was a significant main effect of day on reciprocal reaction time on the PVT $F(2.75, 65.92) = 10.86, p<.001, \eta_p^2 = .31$. Repeated standard contrasts showed that subject's performed

significantly poorer on day 2 than day 1 ($p<.001$) and day 3 than recovery ($p<.01$). There was no significant difference between baseline and day 1 ($p=.235$), and day 2 and day 3 ($p=.077$). Pairwise comparisons revealed no significant difference between baseline and recovery ($p=.248$). See Fig. 2.

For pre-performance ratings, Mauchley's test indicated the assumption of sphericity had been violated ($X^2(9) = 21.62, p = .01$) therefore multivariate tests are reported ($\epsilon = .67$). There was a significant main effect of day on pre-performance ratings, $F(3.03, 64.06) = 6.53, p=.001, \eta_p^2 = .21$. Repeated standard contrasts revealed that subjective estimates of pre-performance were significantly lower on day 2 than day 1 ($p<.01$) and day 3 than day 2 ($p<.05$). Ratings were significantly higher at recovery than on day 3 ($p<.05$). There was no significant difference between pre-performance ratings at baseline and on day 1 ($p=.367$). Furthermore, pairwise comparisons showed no significant difference between baseline and recovery pre-performance ratings ($p=.204$). See Fig. 2. Correlations showed that while there was a weak negative correlation between pre-performance and reciprocal reaction time, the relationship was not significant, $r(23) = -.23, p = .137$ (one-tailed). The relationship accounted for 52% of the variance.

Post-performance Subjective Ratings

For post-test performance ratings, Mauchley's test indicated the assumption of sphericity had been violated ($X^2(9) = 17.45, p<.05$) and therefore multivariate tests are reported ($\epsilon = .68$). There was a significant main effect of day on post-performance ratings, $F(2.74, 57.58) = 9.31, p<.001, \eta_p^2 = .31$. Repeated standard contrasts revealed that subject's estimates of post-performance were significantly lower on day 2 than day 1 ($p<.05$), day 3 than day 2 ($p<.05$) and were significantly higher

at recovery than day 3 ($p<.001$). There was no significant difference between baseline and day 1 ($p=.059$). Pairwise comparisons showed no significant difference between baseline and recovery ($p=.142$). See Fig. 2. While there was a weak negative correlation between post-performance and reciprocal reaction time, the relationship

was not significant, $r(23)= -.25, p= .117$ (one-tailed). The relationship accounted for 62% of the variance. In addition, correlations showed that post-performance ratings had a significantly strong relationship with pre-performance ratings, $r(23)= .89, p<.001$. The relationship accounted for 79% of the variance.

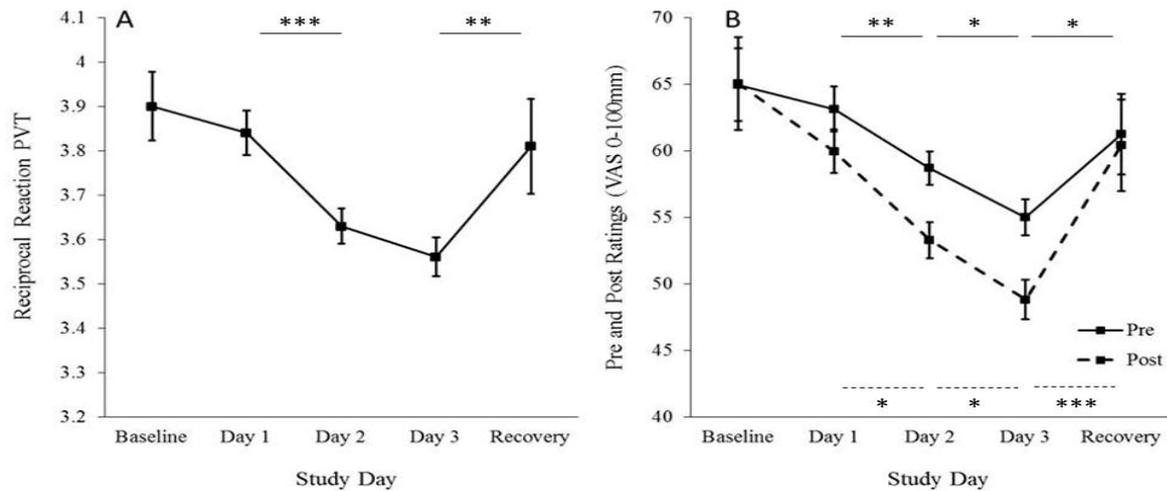


Fig. 2. Means, standard errors and results of follow up tests for PVT performance, and subjective ratings of performance (pre and post). A) Reciprocal reaction time on the PVT. B) Pre and post-performance ratings on the VAS (0-100). Note: * = $p<.05$, ** = $p<.01$, *** = $p<.001$.

Discussion

Results indicate that fire fighters are able to identify performance declines however, are not adept at perceiving the degree to which their performance declines. That is, they were unable to anticipate and evaluate how much their performance was declining, despite being able to identify performance decrements.

Previous research suggests that post performance ratings are a more accurate indicator of actual performance than pre performance ratings [2,6]. While neither was found to be significant when compared with objective performance, post evaluations had a stronger correlation than pre-performance ratings. Mean comparisons suggest that as sleep restriction accumulated, the difference between pre and post-performance ratings became more

pronounced. However, there were strong correlations found between the two measures suggesting that ratings were too similar to identify whether one was better indicator of objective performance than the other. Given the PVT provides feedback for each response; participants may have based their post-performance evaluations on actual feedback which they then compared to previous superior performances, explaining the slight difference between pre and post ratings.

It has been proposed that as sleep debt accumulates, fatigue levels may increase and motivation levels decrease [6]. This can result in participants developing a negative attitude and/or lower confidence in their ability to perform, and in their evaluations of their actual performance. As indicated by this study, obtaining an appropriate amount of sleep (e.g., 8 hours) is likely to decrease feelings of fatigue and increase

motivation, and thus lead to a greater confidence in their performance ability. It must be noted that as subjective ratings were assessed before and after a battery of 5 cognitive measures, results on subjective measures cannot be attributed solely to their perception of PVT performance. In addition, when subjects performed the PVT, they were required to hold information for a memory recall task, which may have hindered their ability to focus all attention on the PVT itself. Further, information relating to general fitness and habitual sleep patterns of the participants was not considered in this paper, which may have influenced the onset of fatigue.

Given that fire fighters can work for successive days, are exposed to multiple stressors, and can quickly accumulate sleep debt, it seems imperative that future studies investigate how subjective measures of performance vary over the course of the day, as well as when exposed to higher accumulation of sleep debt. From the findings of this study, it is suggested that in order to minimise the likelihood of accidents on the fire-ground, individuals should report to supervisors if they have accrued a sleep debt, and whether or not they believe that their performance will be/or is significantly impaired.

Acknowledgements

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Chapter 5

Sleepy Schoolboy Blues? Sleep and Depression across the School Term

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Aims: Adolescents experience a change in sleep patterns, together with a later sleep onset time compared to children in younger age groups. This, in combination with early school starting times can restrict the time available for sleep. As a consequence, sleep loss can accumulate across the school week. If sleep loss is not recovered on weekends, a cumulative sleep debt may develop across weeks of the school term. Cumulative sleep loss has been linked to depression. We sought to determine whether adolescent males accumulated a sleep debt across the term, and if so, whether the loss was associated with the onset of depressive symptoms.

Methods: Eleven healthy adolescent males, with a mean age of 15.29 (± 0.83) years, participated in an 11-week field study. Baseline testing occurred in the pre-term holiday, prior to the term commencement. Participants wore an activity-monitoring device (Actiwatch) at all times and completed sleep diaries daily. The Depression Anxiety and Stress Scale (DASS-21) was completed weekly. Mixed-effects models examined differences in weekly sleep across the term and any associations with depressive symptoms.

Results: On average, daily sleep was 18 minutes longer in the pre-term period than during the term period. Participants spent less time in bed on school nights than on weekends during the school term ($p < .05$), but to some extent minimized sleep loss by going to bed earlier ($p < .05$). Thus, the hypothesised progressive weekly reduction in term sleep amount did not occur ($p > .05$) because participants advanced weekly bed times and increased sleep duration on the weekends. The changes observed in sleep were not associated with depressive symptoms.

Discussion: This pilot study provides insight into sleeping habits during a school term. Whilst a relationship with depression was not significant, future studies could investigate a clinical population rather than the normal population of adolescents sampled here.

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Introduction

Adolescence is defined as the period between the onset of puberty and the acquisition of sexual maturity and adulthood [1]. Of the many changes that occur during this time, sleep changes are among the most dramatic. Adolescents, in relation to younger children, experience shorter sleep duration. This shortened

nightly sleep has been associated with higher rates of depressed mood [2]. Given that sleep behaviour is modifiable, adolescent sleeping patterns provide a potential avenue for affecting improvement in mental health outcomes.

A reduction in sleep duration from childhood through to adolescence is

widely documented. Total sleep duration decreases from an average of 10.25 hours at age 10 to 9.18 hours at age 16 [3]. These decreases in sleep duration are because bed times are delayed until later in the evening, without a concomitant delay of wake-up time. Two main factors contribute to these specific adolescent sleeping habits: biological and psychosocial.

In adolescence, biological factors change the phase of circadian rhythms such that the body is not primed for sleep until later in the evening [4]. Melatonin, a hormone secreted by the pineal gland, maintains this sleep wake/cycle by inducing drowsiness in the evening [4]. An association between adolescent sleep, puberty and a delayed secretion of melatonin has been established [5].

In addition to these biological changes leading toward later night schedules, there are extensive social influences that interfere with sleeping habits of adolescents and exacerbate later bedtimes. Adolescents acquire a strong desire to increase their independence separate from their parents in the form of exerting greater control in how they schedule their time [6]. This is manifested in fewer parental-set bed times, increased accessibility to technology, extended social occasions and greater requirements academically and vocationally [7]. These aforementioned processes all interact so that additional waking activities and a biological preference to remain alert perpetuates a delay in bedtime.

The school schedule is the most significant environmental factor that affects wake-up times during the week in adolescents [1]. Subsequently, adolescents are going to bed late and their sleep is restricted by when school starts [6, 7]. Sleep duration is subsequently extended on weekends, to the extent of 30-45 minutes in Australian samples [3]. This may reflect a “recovery”

process as adolescents try to compensate for an accumulated school-week sleep debt [7]. However, this catch up sleep still may not be enough [8].

Evidence has shown that the accumulation of sleep loss plays a role in the etiology of depression [8]. Sleep problems are one of the nine key criteria for depression [9] and numerous factors have been proposed as influencing the association between insufficient sleep and depressed mood [10]. Whilst it is clear that sleep problems commonly co-occur with depression, it is not clear whether these problems occur simultaneously and independently change over time.

The role of sleep in the genesis of mental health disorders in non-clinical adolescent populations has been limited to short duration or retrospective studies [2]. This gap in the literature highlights a need for sleep duration to be tracked longitudinally to observe if any changes are mirrored by depression. The aims of this pilot study were to: (1) determine whether there was a difference in weekly sleep duration between the holidays and across an entire school term; and (2) determine whether differences were related to self-ratings of depression across the school term.

Methods

Participants

Adolescent males between the ages of 14 and 16 were targeted for recruitment because of their high rates of sleepiness and depression [11]. Participants were sampled from an Adelaide private co-educational school. Of the 46 potential recruits that attended an information session, 14 elected to participate in the study. One withdrew partway through the study while two others were excluded because more than 20% of their sleep information could not be validated due to poor compliance. Data analyses were therefore based on 11 participants, with an average age of 15.3 (± 0.8) years and enrolled in Grades 9 to 11.

Ethics

Ethics approval was granted by The Central Queensland University Human Research Ethics Committee and the Department of Education and Child Development following guidelines of the National Health and Medical Research Council of Australia.

Materials

Sleep Diary. The sleep diary included fields for participants to record for each sleep the bedtime and wake-up time, and sleep location.

Activity Monitor. Participants wore a watch-like monitor (Actiwatch 2, Respironics) worn on the non-dominant wrist that provided an objective measure of sleep through the detection of movement. Devices were configured to record activity in 1-minute epochs. Activity records were cross-referenced with sleep diaries to verify bed times. Estimates of sleep timing and duration were calculated with ActiWare software (Version 5.57). This method of cross-referencing sleep diaries and activity monitor data has been validated for use with children [12].

The Depression Anxiety Stress Scale-21. A 21-item, self-report inventory comprised of three scales (7 questions each) that measure depression, anxiety, and stress. Participants respond using a 4-point Likert scale, where 0 = *did not apply to me at all* to 3 = *applied to me very much or most of the time*. Only depression scores are reported here, with a score range from 0-21 (normal range of clinical cut off points= 0-4). Higher scores are indicative of higher levels of depressive symptoms. DASS-21 has demonstrated excellent psychometric properties, and has been used in longitudinal studies and in adolescents [5].

Procedure

Participants completed a baseline measure of the DASS-21. During the 10-week study period (1 week pre-term

holiday and 9 week term), participants were instructed to wear the activity monitor on their non-dominant wrist. Sleep diary entries were made as soon as practicable upon waking to increase accurate recall. The DASS-21 was completed on Thursday evenings, with reminder text messages sent out. Activity monitors and questionnaires were interchanged and downloaded every 4 weeks. Participants were given a \$25 gift card for signing on to the study and an honorarium \$75 gift card upon completion. To encourage compliance, participants were entered into an iPad raffle for diligent completion of the study protocol.

Data Analysis

Statistical analyses were analyzed with SPSS Version 21 (IBM). Alpha was set at .05. Mixed-effects ANOVA were used to test for differences in sleep and depression using calendar (pre-term *vs.* term) and day (weekday *vs.* weekend) as fixed effects. This procedure accounts for systematic correlation between repeated measures sampled over time and does not require the assumption of normality.

Standard power analysis methods mixed-effects ANOVA are not available, so a heuristic guideline was used. Assuming a correlation of 0.5, an alpha of 0.05 and a power of 80%, a repeated measures within-factors design requires 10 participants to give sufficient power ($d=1.1$).

Occasionally, participants neglected to wear sleep activity monitors during sleep (frequency percent= 6.7). When this occurred sleep diary records were used in isolation. Where missing data points could not be estimated, these were treated as missing values in analyses and replaced with the mean.

Results

Sleep Amount

Sleep periods were classified as either weekday or weekend sleeps depending on

the day of wake-up. Thus, sleep periods initiated on Sunday night were classified as weekday sleeps because wake-up occurred on Monday morning. Similarly, sleep periods initiated on Friday night were classified as weekend sleeps. Participants spent 8.8 (± 1.5) hours in bed and obtained 7.7 (± 1.3) hours of sleep per night in the pre-term holiday period. In comparison, they spent 8.3 (± 1.2) hours in bed and obtained 7.4 (± 1.2) hours of sleep per night during the school term. On average, term sleep was associated with a 32-minute daily reduction in time spent

in bed and a sleep loss of 16 minutes compared to the holiday period.

Table 1 reports the amount of sleep for the pre-term and term periods divided into weekday and weekend nights. More sleep was obtained on weekends than on weekdays, but the mean difference was greater in the term period, i.e. 27 minutes, than in the pre-term period, i.e. 8 minutes.

Table 1. Means (\pm SD) for pre-term and term sleep split by weekday and weekend

	Pre-term			Term		
	Weekdays	Weekends	<i>p</i>	Weekday	Weekend	<i>p</i>
Time in bed	8.8 (± 1.6)	9.0 (± 1.3)	ns	8.2 (± 1.0)	8.7 (± 1.5)	<.001
Total sleep time	7.6 (± 1.4)	7.7 (± 1.2)	ns	7.3 (± 1.0)	7.7 (± 1.4)	<.001

Sleep Timing

Figure 1 illustrates the timing and length of sleep across the week for pre-term and term. During pre-term, participants went to bed between midnight and 2 am and woke up between 8 and 10 am. During school term, bed times were earlier on weeknights; occurring between 10 pm and midnight. Participants woke between 6 and 8 am on school days. Bedtimes became progressively later across Friday and Saturday night. Most notably, however, were the delayed weekend wake times, which extended past 8 am. Mixed-effects ANOVA using calendar (pre-term *vs.* term) and day (weekday *vs.* weekend) as fixed effects and bedtime as the dependent variable, revealed significant main effects for both. Similarly, wake times were also significantly different depending on calendar or day $p < .001$.

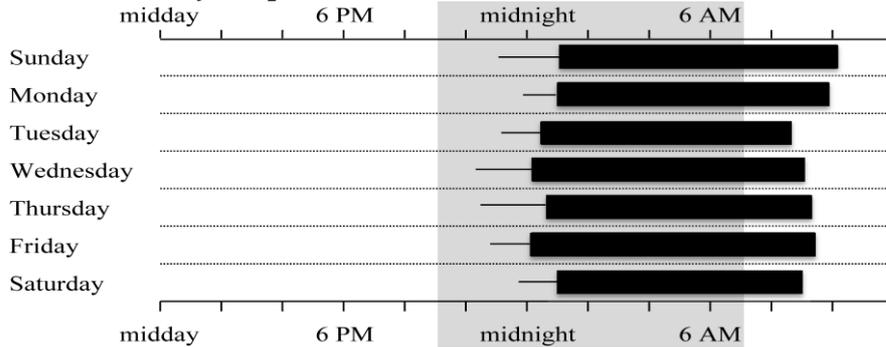
Weekly Sleep

Figure 2 shows the variation in weekly sleep across the term. A noticeable drop in sleep occurs in the first week of term, and again in week eight, however, mixed model ANOVA showed that these differences did not reach statistical significance, $F(9, 90) = .15, p = .24$.

Depression

In relation to the second aim, a mixed-effects ANOVA using depression as the dependent variable and term week as the fixed effect revealed no significant differences across the term, $F(9, 18) = .28, p = .97$. In addition, a mixed-effects regression analysis indicated no significant association between weekly sleep amount and depression $F(1, 67) = .15, p = .71$.

Pre-term holiday sleep



Term sleep

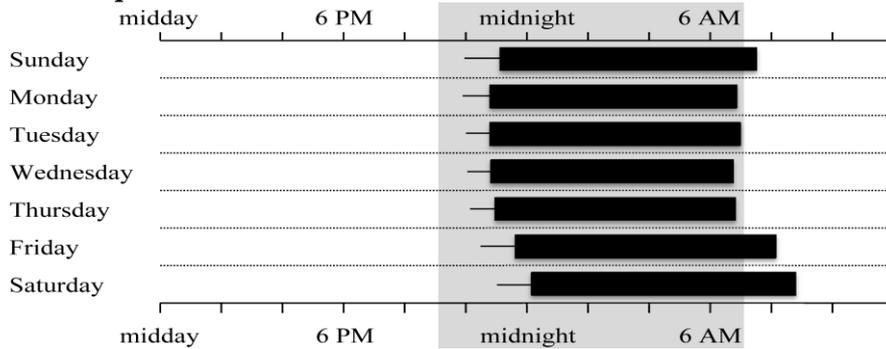


Fig.1. Timing and length of the average daily sleep across the term. The grey shaded bars represent nighttime between 9 pm and 7 am. Each 24-hour period shows midday on one day to midday the next. The weekday labels to the left (i.e. Sunday to Saturday) indicate the day of the week at the first midday clock time. The bars represent the standard deviations of participant bed times.

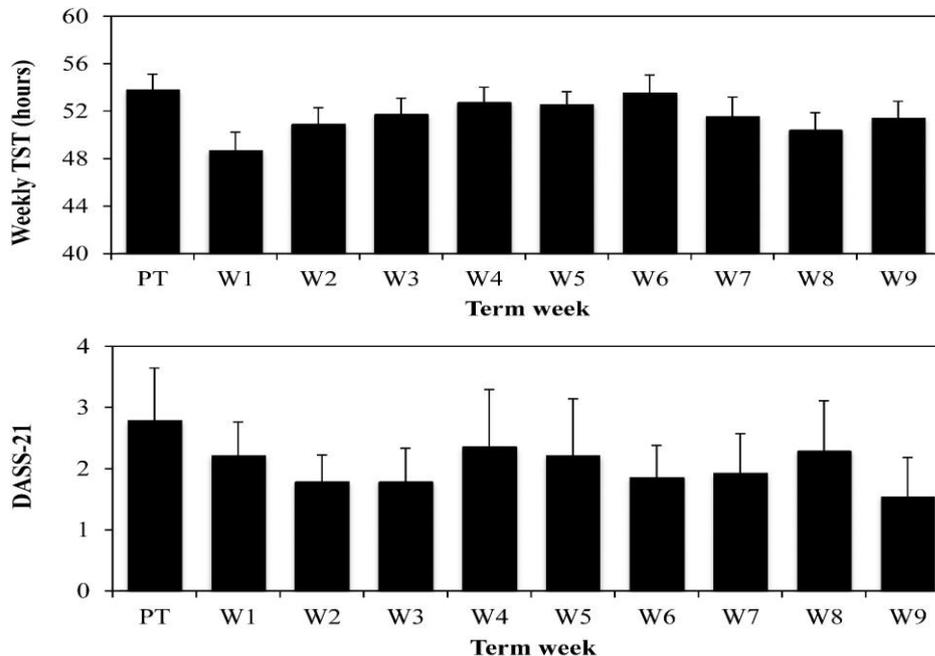


Fig. 2. Top panel: mean weekly total sleep time across the school term. Bottom panel: depression scores. (PT= Pre-term; W=Week). The bars represent the standard errors.

Discussion

Adolescents obtain more sleep on holidays than across the term.

Reduction of sleep was evident on day 1 of the school term. In the first week, participants incurred an average sleep

deficit of 5.8 hours compared to the pre-term period. Our finding is similar to the 7.5 hours of sleep loss reported in a previous study [13]. These data were based on a larger sample size (n=37) but sleep was measured using only sleep diaries. Beyond the first week, our findings demonstrate that the extent of sleep loss was not sustained. Across the term, sleep loss persisted but was attenuated in subsequent weeks. Sleep loss was to some extent mitigated because participants went to bed earlier after the first week. Presumably, earlier bed times were an attempt to compensate for the early school starts. Thus, while there was an overall reduction in sleep across the term, the difference was not significant.

We hypothesized that reductions in weekly sleep would parallel an increase in self-rated depression. The observed distributions of sleep loss and depression were not consistent with this hypothesis. Notably, there was no significant effect of week on the DASS-21. Perhaps the DASS-21 is not sensitive enough to detect small changes in depression. The DASS-21 is a clinical measure, and given none of the participants was clinically depressed; this scale may not have captured any decline in mood. The majority of the existing literature on adolescent sleep and depression has used populations with diagnosed affective disorders, particularly Major Depression Disorder [14]. Thus, the hypothesized links between sleep and depression may only present if the severity of depression is in the clinical range or in at risk adolescent males. It is possible that the current sample of 11 participants may not have been sufficiently large to detect significant differences of the order of magnitude observed here. Not only were the participants emotionally healthy but they also displayed healthy sleeping habits. This, in combination with a private support system provided by the school, is perhaps another reason why

no association between sleep and depressive symptoms was witnessed here.

The effects of the school schedule on adolescent sleep may be more complex than suggested by existing sleep literature. Our preliminary findings suggest that some adaptation to the school schedule may occur, however further investigation is warranted with a larger sample of students from schools in a wider range of socio-economic backgrounds.

Acknowledgements

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Chapter 6

Chronotherapy for Treatment of Severe Sleep Phase Delay in an Adolescent Girl

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Aims: Healthy, adequate sleep is integral to the process of growth and development during adolescence. At puberty, maturational changes in the underlying homeostatic and circadian sleep regulatory mechanisms influence the sleep-wake patterns of adolescents. These changes interact with psychosocial factors, such as increasing academic demands, hours spent in paid employment, electronic media use, and social opportunities, and constrict the time available for adolescents to sleep. As a result many adolescents have a delayed sleep phase, which makes falling asleep difficult and getting up for school even more difficult. This paper reports a severe case of delayed sleep phase disorder (DSPD) in an adolescent girl that was confounded by anxiety and school attendance issues.

Methods: A chronotherapeutic approach was taken using natural light exposure at specific time points and a forward moving sleep restriction schedule, advancing bedtime three hours every night, over one week.

Results: The sleep schedule was reprogrammed from a pre intervention mean sleep onset of 02.00h to a mean sleep onset of 22:30h. Secondary anxiety was alleviated and the sleep schedules were maintained 2 months later.

Discussion: This forward moving chronotherapeutic schedule was, successful in achieving a stabilised sleep p/wake pattern and a reduction of anxiety. This was achieved with simple sleep restriction and natural light exposure. Whilst compliance can be difficult for this intervention, this case suggests that it is a promising treatment for severe delayed sleep phase in adolescents.

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Introduction

Adequate sleep in adolescence is important for the regulation of behaviour, emotion, attention and learning which, in turn has implications for the development of social and academic competence and psychological health [1]. Whilst there is recent and significant debate on exactly how much sleep adolescents need [2], the overwhelming message from many studies is that the vast majority of adolescents report significant sleepiness [3] therefore suggesting that they are not getting 'enough sleep'. Several reasons have been proposed for this. At puberty, there is a marked delay in the timing of

sleep through changes to Process C, the sleep drive independent circadian regulator for the sleep wake cycle [4]. This circadian drive is marked by the release of melatonin, and during puberty, melatonin secretion is delayed [4]. As a result, adolescents tend to go to bed and sleep later than preadolescents but due to the rigours of school attendance cannot delay sleep offset. Delayed sleep phase difficulties however, are not entirely attributable to physiological factors. Psychosocial factors such as increased independence in sleep regulation, decreased parental control, increased social opportunities, greater academic

demands, extracurricular activities, participation in paid employment, and increased access to drugs, alcohol [5] and media also play a role. In fact, the increasing use of electronic media such as the internet, television, video games, and mobile phones much of which occurs in the bedroom, is a significant factor in delaying sleep phase in adolescents [6].

It is estimated that up to 80% [3] of adolescents experience some level of delayed sleep phase and the percentage of adolescents whose sleep/wake cycle is significantly delayed and who meet criteria for Delayed Sleep Phase Disorder (DSPD) [7] ranges from 1%-8% [14].

The International Classification of Sleep Disorders (ICSD) [7] – Revised, lists DSPD as (1) a persistent or recurrent pattern of sleep disturbances resulting from a misalignment of endogenous rhythm and external factors that affect the timing or duration of sleep (2) sleep disruption that leads to insomnia and/or excessive daytime sleepiness; and (3) impaired social, occupational, or other spheres of functioning related to the sleep disturbance.

An important characteristic of the disorder is that patients are able to initiate and maintain sleep on their normal delayed schedule but difficulties manifest only when they attempt to synchronize their sleep schedule with requirements of normal everyday schedules of society, particularly school.

Treatment for Delayed Sleep Phase Disorder

The first option, phototherapy, generally describes manipulation of light exposure. Morning phototherapy involves indirect exposure to bright light upon awakening which promotes the suppression of melatonin and increases alertness. This is usually coupled with significant reductions to light exposure in the evening to encourage the secretion of melatonin hence promoting sleepiness

[13]. Phototherapy is, when well structured, and in the cases of a mild sleep phase delay, effective when light is manipulated and bedtime can be incrementally advanced earlier and earlier so that the sleep /wake cycle undergoes a phase advance. Depending on the pre-treatment time of sleep onset and the time frame of each incremental sleep onset advance (e.g. a 15 minute advance every two or three days), phototherapeutic phase advance treatment can take more than 14 days [13].

However, when sleep phase delays are extreme, for example when sleep onset occurs after 02:00h, phototherapy as described above can be too slow and more focused chronotherapeutic techniques can be helpful [8]. Chronotherapy is intended to reset the circadian clock by manipulating bedtimes and wake times. The most common method of chronotherapy for sleep phase delays of this magnitude, consists of going to bed two or more hours *later* each day for several days until the desired bedtime is reached [8] which can be achieved within 7 days. Whilst compliance in chronotherapy can be problematic, it is faster than the traditional phototherapeutic methods. Within approximately 7 days, the sleep wake cycle can be advanced over the complete 24 hour clock.

Both phototherapy and chronotherapy must be coupled with behavioural treatments that target poor sleep hygiene and may also require some cognitive behavioural therapy techniques to address any psychological factors that may be contributing either as cause or effect, to the delayed sleep patterns.

This paper describes the use of chronotherapy for the treatment of DSPD. Consent was gained from IG and her parents to anonymously publish her data and the ethical and clinical guidelines of the Australian Psychological

Society were complied with.

Methods

Pre-treatment Assessment

IG was a 14 year old adolescent girl attending her third year of high school. She lived with her (very supportive) parents and her younger brother in Adelaide, South Australia. Her sleep patterns had changed around the onset of puberty when started to attend high school. Mood and behaviour were screened with the Child Behaviour Checklist [9]. IG had a history of high anxiety levels and at the time of presentation, her mood was within the clinical range for internalised behaviour (T score = 67, clinical range >60), particularly anxiety (T score = 66, clinical range >60). IG was increasingly worried about her sleep patterns and associated school performance and was withdrawing more and more into her bedroom, and engaging in poor sleep hygiene behaviours such as eating at irregular times and excessive media usage prior to sleep onset. This history was confirmed with the Sleep Hygiene Index [10]. School attendance was sporadic with her scholastic performance, usually in the top 10 percent of her class, suffering as a result.

Inspection of sleep was undertaken with two self report methods: Sleep Disturbance Scale for Children and Adolescents [11] and a 7 day sleep diary pre treatment and a 2 day sleep diary and evaluation post treatment. The sleep diary, previously used and published by the author [12] showed IG met criteria for DSPD with an average sleep onset after 02:00h and an average Total Sleep Time (TST) of over 9 hours. Sleep onset and offset were irregular and widely variable across the school week. The SDSC showed clinical scores for Difficulties Initiating and Maintaining Sleep (DIMS) and Excessive Daytime Sleepiness (EDS).

Chronotherapeutic Schedule Method

Given that the phase delay in this case

was significant [8], and IG's family chose to treat the DSPD with a forward moving chronotherapeutic schedule that systematically delayed IG's sleep onset time by three hours per night allowing for an 8h 30min sleep period. This was to be augmented with some phototherapeutic light manipulation. For example, on night 1, IG was to try and go to sleep at 02.00h and get up at 10:00h and this was to continue for 8 days until the target bedtime of 22:30h was reached.

Napping for 20 minutes, which has been shown to benefit performance and alertness without interfering with night time sleep [13], was permissible providing it was more than 6 hours before sleep onset. Light exposure was scheduled after sleep offset for at least 20 minutes and included eating breakfast outside in sunlight (weather permitting), and/or bright indoor lights, computer, iPod, and television. Light exposure, from all of those light sources was restricted for two hours prior to sleep onset. Exercise and meals were regularly scheduled in the 24 hour cycle so that they remained consistently timed within the structure of sleep/wake for each 24 hour period. The aim was to achieve a return to a sleep onset of 22:30h after 7 days. This information was documented and given to the family in the form of a spreadsheet, that was used for reference during the treatment week. Coupled with chronotherapy, although not the focus of this paper, were cognitive restructuring strategies to assist IG in reducing her anxiety. An evaluation of the sleep treatment with a reduced version (two days) of the sleep diary were sent to IG six weeks after the conclusion of the therapy and was returned seven weeks later.

Results

IG complied with the chronotherapeutic schedule. The clinical evaluation and two day sleep diary showed that IG had returned her sleep onset to 22:30h and reported that she had sustained a regular

sleep wake schedule program for a further seven weeks. IG reported that her DIMS and EDS had returned to non-clinical levels (See Table 1). The family found this to be excellent outcome and

reported that the program had reduced tension in the family home. Her anxiety due to sleep onset difficulties was significantly reduced.

Table 1. Mean (SD) sleep variables pre and post chronotherapeutic therapy

Variable	Pre	Range	Post	Range
Sleep Disturbance Sleep for Children T scores*				
DIMS**	86	n/a	<50	n/a
EDS***	77	n/a	<50	n/a
Mean sleep onset (SD)	02:30am (1h:15min)	11:00pm - 04:00am	10:27pm (0.04 min)	10:25pm - 10:30pm
Mean sleep offset (SD)	12h:18am (1h:55min)	11:00am - 03:00pm	07:00am (0.0min)	n/a
Mean total sleep time (SD)	9h:54 min (1h:42min)	7h:30min - 12h:00min	8h:30min (0.20min)	8h:30min – 8h:35min
Refreshment†	unreported		3	

*Clinical range ≥ 50 (1 SD = 20); **Disorders of Initiating and Maintaining Sleep; ***Excessive Daytime Sleepiness; †Refreshment scored 1= exhausted – 5 = most refreshed.

Discussion

This case study shows the use of chronotherapy treatment and manipulation of sleep hygiene in the treatment of DSPD in an adolescent girl who was suffering sleep loss, anxiety and school absenteeism. The treatment was successful in returning sleep to a regular and acceptable sleep wake rhythm and was sustained two months after treatment concluded.

Whilst there is significant literature on the use of synthetic exogenous application of melatonin in treating DSPD [14] the success of chronotherapeutic treatment in adolescents has been rarely reported and few studies have tested these treatments for DSPD in adolescents [14]. Chronotherapy was the first treatment identified as a successful non pharmacological treatment for adult DSPD [8] but still there is a paucity of literature even in the adult domain. Based on this case study, it would appear that under strict compliance conditions, this treatment is safe and efficacious.

One of the most interesting findings of this treatment study was that despite the difficulties known to exist in compliance with chronotherapeutic regimes due to their difficult and demanding nature, IG was able to successfully comply and as a result manipulate her sleep wake rhythm without the use of any pharmacological agent and within a short time frame. To a large extent this was due to the supportive family and perhaps the written schedule delivered to the family and to a large extent engineered by IG's father. It is known that changes in parent-child relationships during adolescence can also result in reductions of parental regulation of the adolescent's sleep schedules, particularly on school nights, and is likely a strong contributor to the development of unregulated sleep patterns and subsequent delayed sleep phase. For example, an early survey study examining the sleep patterns of 218 students at the childhood-to-adolescent transition [4] demonstrated a linear decline in parental influence over children's sleep patterns, with advancing age. Interestingly, in a recent Australian study that assessed the sleep

habits of 385 adolescents (aged 13-18 years), it was demonstrated that adolescents with parent-set bedtimes had earlier bedtimes, obtained more sleep, and experienced improved daytime wakefulness and less fatigue, compared to adolescents without parent-set bedtimes [15]. In the case of IG, given that four sleep periods were during the day and hence four wake periods were necessarily during the night when all other members of the family were asleep parental and family support was imperative. Not only did this entail logistical support but also emotional maturity. In addition, it was imperative that IG's parents entrusted her to comply with the schedule but also to not engage in activities that were not age appropriate, such as accessing inappropriate internet content.

This study is one of the first to report a successful case of chronotherapy for an adolescent. Given that this is a case study, more research is needed, with larger samples and diverse age groups over longer periods of follow up time in order to ascertain the apparent efficacy of this treatment in a population that is continually at risk of delayed sleep patterns.

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PROGRAM

Friday 13th September

0800 – 1000 Registration

1000 – 1010 Opening

1010 – 1205 **Plenary Speakers**

[Chair: Michael Boden]

- 1010 – 1035 **Professor David Kennaway** [University of Adelaide]
 1035 – 1050 **Professor Brendan Waddell** [University of Western Australia]
 1050 – 1105 **Associate Professor Sally Ferguson** [CQUniversity]
 1105 – 1120 **Dr Guy Warman** [The University of Auckland]
 1120 – 1135 **Professor Phillipa Gander** [Massey University]
 1135 – 1150 **Associate Professor Gerard Kennedy** [Victoria University]
 1150 – 1205 **Dr Greg Willis** [The Bronowski Institute of Behavioural Neuroscience]

1205 – 1250 **Lunch**

1250 – 1420 **Session 1: Circadian regulation in humans and animals**

[Chair: Tamara Varcoe]

- 1250 – 1305 *Using honey bees as a model to understand the effect of general anaesthesia on the circadian clock*
Nicola Ludin
- 1305 – 1320 *Maternal adaptation to pregnancy: changes in circadian expression of hepatic clock genes during mouse gestation*
Michaela Wharfe
- 1320 – 1335 *Obesity reduces maternal core body temperature and alters the normal thermoregulatory changes of late pregnancy in the rat*
Rachel Crew
- 1335 – 1350 *Circadian regulation of hypothalamic Kiss1 and Kiss1r during mouse pregnancy*
Cassandra Yap
- 1350 – 1405 *The subtlety of circadian involvement in the control of movement*
Dr Greg Willis
- 1405 – 1420 *A split sleep/wake schedule improves neurobehavioural performance at night*
Stas Kosmadopoulos

1420 – 1440 **Afternoon Tea**

1440 – 1640 **Session 2: Sleepiness and health**

[Chairs: Gerard Kennedy]

- 1440 – 1455 *Mood and sleep quality in intrinsic delayed sleep phase disorder*
Shaminka Gunaratnam
- 1455 – 1510 *Successful treatment of an adolescent with severe sleep phase delay using chronotherapy*
Dr Sarah Blunden
- 1510 – 1525 *Excessive daytime sleepiness and body composition: Examination of a population-based sample*
Amie Hayley
- 1525 – 1540 *Does change in sleep duration mirror change in mood in adolescent males across the school term?*
Breanna Drew

- 1540 – 1555 **Professor Leon Lack** [Flinders University]
1555 – 1610 *Self appraisal: The influence of sleepiness*
Natalie Muldoon (p.11)
1610 – 1625 *Circadian rhythmicity and sleep during the antarctic winter*
Oscar Murphy (p.7)

1625 – 1645 Break

1645 – 1715 Session 4: Data Blitz
[Chairs: Greg Roach]

- 1645 – 1650 *The effects of sleep deprivation on the ability of bush fire-fighters to monitor their cognitive performance, fatigue, and motivation during a 3-day fire-ground simulation*
Tess Armstrong
1650 – 1655 *The effect of physical work and sleep restriction on the cognitive performance of volunteer fire-fighters during a simulated 3-day fire-ground tour*
Tamika Christoforou
1700 – 1705 *Human and rat epithelial gene expression: a surrogate measure for circadian gene expression in other peripheral tissues?*
Dr Michael Boden
1705 – 1710 *Circadian clock gene expression in altered in an animal model of depression.*
Dr Tamara Varcoe

1720 – 1750 Annual General Meeting and Award Presentation

1830 Conference Dinner [Belgian Beer Café, Rundle Street]

