FINAL REPORT

SLEEP AND MOOD
IN ADOLESCENT MALES

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MAIN MESSAGES

During adolescence, physiological and psychosocial factors delay sleep patterns so bedtimes are later, but wake times remain the same due to school attendance. Lost sleep is often recuperated on weekend and holidays (called yo-yo sleeping) but it is unclear if this sleep loss is recuperated enough or if it accumulates over the term. With a simultaneous increase of mood problems during adolescents, we wanted to assess if sleep loss increased over an entire school term and if this sleep loss was associated with changes to mood status. So we recruited 48 healthy adolescent males, aged of 15.57 (SD = .86y) and objectively measured their sleep every night for 80 days and gathered self-report mood data every week.

The main messages arising from the study are as follows:

- Adolescents sleep significantly less during the school week compared to school holidays and weekends and a lot less than sleep guidelines. Despite this, sleep loss did not accumulate over the school term seemingly prevented by weekend catch-up sleep.
- How much they slept DID NOT impact depression, anxiety or stress. However, the degree of variability from night to night, or from school day to non-school day WAS significantly related to depression and stress.
- So adolescents appear to cope with less than recommended sleep but sleep variability, which is the VERY common in adolescents, is the main contributor to mood.
- Managing these variable sleep schedules and thus their mood could be minimised by:
  - Increasing awareness, through sleep education in schools, of the negative impact on mood of variable sleep
  - Teaching adolescents methods of minimising these variations, for example, by keeping weekend wake times similar to those in the week or by
  - Selectively delaying school start times for adolescents at risk
- This snapshot of adolescent male sleep helps us understand the relationship between sleep and mood. As sleep is modifiable, so too is its contribution to mood giving another avenues to improve mood status in young males.
EXECUTIVE SUMMARY

Background

During adolescence sleep changes due to both physiological changes in sleep wake patterns and social and academic influences that put sleep at the bottom of the list of priorities[1]. As a result, sleep patterns during adolescence are characterised by going to bed later compared to when younger. With school times restrictive, this means that adolescents cannot sleep in the next day and so are often sleep deprived during the week, when they need it most. They often sleep in on the weekend, recovering their ‘sleep debt’, making their sleep very different between week and weekends[1]. If they sleep later on a weekend morning they will go to bed later on weekend nights. This will push their sleep patterns further forward. By Sunday night, they are not likely to be tired by their required bedtime (e.g. 10.30 pm), so they take a long time to get to sleep, can’t sleep in on Monday morning and the cycle continues[2]. These patterns are well known but most previous studies that have studied this have either concentrated on sleep duration alone or studies sleep schedule changes between weekend and weekdays over short periods of time. Sleeping in on the weekend seems to be helpful but it is not known if sleep debt is actually fully caught up by sleeping in on weekends. Studies conducted over extended periods of unconstrained sleeping are important as they may help answer questions regarding the time taken to recover from presumed sleep debt and how that sleep debt may impact adolescent health.

So why is this important? Strong relationships have been reported between sleep and a range of mental, physical and performance deficits, including memory, learning and attention deficits [3, 4], , problematic behaviours [5, 6], and decreased school performance in non-clinical studies [1, 7]. Children with reduced sleep quantity are more likely than other children to be overweight or obese, [8], to have changes in appetite regulation, and insulin
and glucose utilisation which are associated with metabolic syndrome [9]. One of the main areas of concern is the impact of poor sleep on mood, particularly depression. There is much evidence to show that when adolescents sleep less, they are more likely to show and report signs of depression. However, in adolescent males the story is even more complicated. This particular group are less likely to report depression yet have higher rates of undiagnosed depression [10] and have a four-fold rate of suicide [11].

What happens to adolescent mood, particularly in males, over an entire school term, when they are at risk of deteriorating sleep, increasing variability across the term, potential accumulated sleep loss and academic pressures? We do not know. So we sought to investigate the answer to these questions in order to better know how to tackle mood problems in this at risk group.

**What did we do?**

We tracked the sleep and mood of 48 healthy adolescent males, (average age of 15.5) years, over an entire school term including a school holiday week prior and post term. We tested health, sleep and mood during the last week of the school holidays and then sleep, mood and quality of life every day for 80 days. Participants wore a sleep monitoring device on their wrists at all times and completed sleep diaries daily. The Depression Anxiety and Stress Scale (DASS-21) and Satisfaction with Life Scale were completed weekly.

**What did we find?**

Sleep patterns were, as expected, showing 45 minutes less sleep per night on average during school week compared to the weekend and the school holidays. They were also sleeping significantly less than current sleep guidelines. However, they seemed to catch up their sleep on weekends by sleeping in, on average, an extra 32 minutes. So although they did not catch up their sleep completely, they did not report any changes to sleepiness so this suggests they were catching up enough. Surprisingly, there was no significant relationship between any
mood scores and sleep duration at any one time or across time. That is, how much they slept did not change how they felt. It is possible that this finding is because the boys in this study didn’t report their levels of mood and sleepiness honestly, and this is very common in this age group. It is also possible that they don’t know how to identify feelings of depression or indeed that the scale we used (even though it is a validated and commonly used scale) is not sensitive enough to small variations in mood. However, when we explored the relationship between night to night variability in sleep patterns, and/or differences between sleep on days off compared to school days we DID see a relationship. That is, the more variable the sleep wake patterns, the worse their depression and stress levels.

This data changes the story that we have been told about adolescent sleep. In general, the story has been that reduced sleep duration is the main contributor to mental health issues in adolescents. But in this study, sleep, at least in these boys, does not get worse over the school term and the amount of sleep they get seems to have little impact on their mental health. And this is the first time these variables have been studied over such a long period of time.

However what is new here is that it is clear that the sleep quality, the variability from day to day and week to weekend has the most detrimental impact. Only three studies [12-14] have reported the impact of variability in this age group and they all report detrimental effects but none have studied them in so much detail.

Conclusion

Sleep variability is the most common characteristic of adolescent sleep. This data could and should therefore inform health policy and health and sleep guidelines. If we are to better tackle depression in young males, adolescents must understand the consequences of varying their sleep patterns so dramatically and be given strategies (which exist) to counteract this tendency in this age group.
MAIN REPORT

Introduction

Little doubt exists amongst health and education professionals about the importance of sufficient sleep in maintaining adolescent physical and mental health. Of the many changes that occur during adolescence, sleep changes are among the most dramatic. Adolescents get less sleep per night than younger children [1]. Shortened nightly sleep can be associated with a higher incidence of mood symptoms [15] (defined here as symptoms of depression, anxiety and/or mood). Given that sleep behaviour is modifiable, adolescent sleeping patterns provide a potential avenue for effecting improvement in mental health outcomes. This study assesses associations between sleep and mood across an entire school term in a sample of adolescent males.

Adolescent sleep

The reduction in sleep duration from childhood through to adolescence has been widely documented [16, 17]. Total sleep duration decreases from an average of 10.3 hours at age 10 to 9.2 hours at age 16 [18]. Sleep duration decreases because bed times are delayed without a concomitant delay in wake-up times [19]. These changes in adolescent sleep are the product of developmental changes in sleep physiology together with competing psychosocial demands.

Adolescent maturation yields a delay in the phase of circadian rhythms that have a regulatory role in sleep/wake timing. The circadian rhythm of melatonin secretion, for instance, is responsible for the night-time rise in sleepiness. In adolescents, the phase of melatonin onset is delayed by 37 minutes in comparison to 9-12 year olds [7]. Thus, in the absence of early melatonin onset, the desire to sleep is delayed at night time, and alertness is
sustained until later in the evening [1] so sleep onset is delayed. This makes for later bedtimes. Extensive social influences also interfere with adolescent sleeping habits and may exacerbate these later bedtimes. Adolescents develop a strong desire to assert independence from their parents and have greater control in how they schedule their time [20]. This is evident in later parental-set bed times, increased access to technology, more social opportunities and vocational responsibilities [21]. In addition, academic demands increase substantially across the adolescent years. Thus, greater time dedicated to waking activities together with a biological preference to remain alert at night, perpetuates a delay in bedtime.

The tendency for adolescents to go to bed late leads to sleep restriction on school days because school start times remain the same [20, 21]. The school schedule is the most salient social factor that affects wake-up times during the week [15]. In Australian samples, sleep duration is 30-45 minutes longer on weekends than on weekdays [18]. This may reflect a catch up process whereby adolescents try to compensate for an accumulated sleep loss across consecutive school days. It is currently unknown whether adolescents recover sufficient sleep on the weekends in order to function efficiently, or whether insufficient sleep recovery results in an accumulation of sleep debt over the entire school term. If it does accumulate, this could be a cause for major concern. This is a particularly important issue given that in many South Australian schools, examinations and assessments happen in the final weeks of school term.

**Sleep and mood in adolescents**

As noted, mood discussed here includes symptoms of depression, anxiety and stress [22]. In adolescence, the occurrence of disturbed sleep is frequently accompanied by a higher prevalence of depressed mood [15, 23, 24]. It is also known that mood problems such as anxiety and stress in adolescents also increase as the school term progresses, due to academic pressures [25]. Not only does stress impact sleep [26] but adolescents who are tired cope
less well with stress [27]. However, the question that we do not know the answer to is: Do changes in mood symptoms mirror or reflect changes in sleep duration? Given the importance of end of term examinations and performance needs in this age group, changes to symptoms of depression, anxiety and stress and sleep over the school term shown in other studies [28], need to be better understood. Sleep behaviour is modifiable, so adolescent sleeping patterns provide a potential avenue for effecting improvement in mental health outcomes. The association between short sleep and self-reported symptoms of mental health problems in non-clinical adolescent populations has been limited to short duration or cross-sectional studies [1, 28, 29]. In order to address this question better we decided to study sleep behaviour and mood symptoms in adolescent males longitudinally over an entire school term of between 9-11 weeks to answer the questions above.

In this study we have focussed on adolescent males. Why? Because, in comparison to adolescent females, adolescent males are less likely to seek help for depression [30], have higher rates of undiagnosed depression [31] and have a four-fold rate of suicide [32]. In addition, males are more likely than females to give up sleep so they can spend more time engaged with electronic media (e.g. television, videogames and computers) [33]. Light emitted by these devices further contributes to delayed bed-times and sleep loss by triggering phase shifts of the light-sensitive circadian system [34, 35].

So our research questions were: Do depression, anxiety and stress and sleep change over a school term? Do they change individually, or do they change simultaneously? Does sleep loss become chronic over an entire school term and if so, how does this impact mood in young males?
Methods

Participants

Adolescent males who were attending years 10-11 (which in South Australia represent the third and fourth years of a five year high school program), were targeted for recruitment. Participants were from both private (n=2) and public (n=3) co-educational schools in Adelaide, South Australia. The sample was selective, that is, schools who had a previous relationship (schools from western, northern and metropolitan school districts) were invited to participate. Of the 295 students who attended information sessions at their school, 192 left contact details as an expression of interest. From 192, final participant response rates varied from 10-50% by school. Specifically, these were Eastern suburbs public school 1, 38% (7 from 18), Metropolitan public 10% (6 from 57), Eastern suburbs public 2, 50% (14 from 28), Western suburbs private, 25% (15 from 60), and Northern suburbs private, 46% (20 from 43) totalling 62. Eight participants withdrew before the beginning of the study and five participants began the study but withdrew (personal reasons, health, or waning interest). The final dataset comprised of data from 48 participants aged between 14 and 17y (M = 15.57y, SD = 0.86y). The number and average age from each school is shown in Table 1. There were no exclusion criteria.

Table 1. Demographic characteristics of participants

<table>
<thead>
<tr>
<th>School</th>
<th>n</th>
<th>Age M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western suburbs private</td>
<td>13</td>
<td>15.17 (0.83)</td>
</tr>
<tr>
<td>Metropolitan public</td>
<td>6</td>
<td>15.50 (1.22)</td>
</tr>
<tr>
<td>Eastern suburbs public 1</td>
<td>10</td>
<td>16.40 (0.52)</td>
</tr>
<tr>
<td>Eastern suburbs public 2</td>
<td>6</td>
<td>14.75 (0.50)</td>
</tr>
<tr>
<td>Northern suburbs private</td>
<td>13</td>
<td>15.6 (0.63)</td>
</tr>
</tbody>
</table>
Data collection

The study began during the second and final week of school holidays which was used as a baseline. Given that previous studies have reported significant catch-up sleep during the first week of the school holidays [36], we decided to start in the second week in the hope that sleep would have stabilised somewhat, sleep debt would be minimised and therefore we would have a more logical baseline sleep duration for use in comparison across the school term. Data were therefore collected across the last week prior to school term, the entire school term and one week after school term in the subsequent school holidays. Depending on the school (private schools have shorter academic terms) the data gathered ranged from 10-12 weeks. Specifically, two schools (the private schools) had shorter school terms (of 9 weeks duration), but all participants had at least 10 weeks of complete data (baseline, school term and one week post school term). Only one school participated per school term, so data collection continued over two years for five consecutive school terms. Consequently data was collected over both summer and winter months.

Materials

Activity monitor: To objectively measure sleep, participants wore actiwatches (Actiwatch 2, Philips-Respironics, Oregon, USA) for the entire study. These watch-like devices, which are continuously worn on the non-dominant wrist and provide an objective measure of sleep through the detection of movement. Estimates of sleep timing and duration were calculated from the actiwatches based on the fact that activity data can be used to study sleep/wake patterns in adolescents [37]. Due to battery life, these were changed every four weeks, with a maximum of three changeovers during the study period.
Sleep diary: Subjective sleep was measured using a sleep diary to compliment activity monitor data. They recorded bedtimes, what time they went to sleep times (which is different to bedtimes), wake-up times, and sleep locations.

Mood: The Depression Anxiety Stress Scale-21 (DASS-21). Self-reported depressive symptoms were assessed using the DASS-21 [38]. The DASS-21 is a 21-item, self-report inventory comprised of three subscales (7 questions each) that measure depression, anxiety, and stress over the last week. 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. All subscales have a range of 0-21 with moderate symptoms of depression above 7, moderate anxiety above 6 and moderate stress above 10. The DASS-21 has excellent internal consistency and stability over short periods [39], and has been used in longitudinal studies with adolescents [7, 40].

Procedure

Interested students and their parents were invited to an information night at which participants completed consent forms, a general health questionnaire, the DASS-21 and sleep baseline assessment. Participants were asked to wear their activity monitor on their non-dominant wrist for the entire study period and were instructed to remove the device only to avoid damage (e.g. when playing sport or swimming). In addition, participants were asked to complete sleep diary entries as soon as practicable upon waking each morning and to complete the DASS-21 and Quality of Life Scale once a week on Thursday evenings. Thursday evening was chosen to maximise the amount of potential sleep loss accrued over the school week while minimising the impact of weekend social or sporting activities that occur on Friday night and may impact sleep. Reminder text messages were sent to participants every morning to prompt them to complete the questionnaires and sleep diaries. Activity monitors and questionnaires were collected from participants and exchanged every
four weeks. To encourage compliance with the protocol, participants were offered a $25 gift card for signing on to the study, and an honorarium $75 gift card upon completion and were also entered into an iPad raffle for diligent completion of the study protocol.

Data analysis

We measured sleep over the entire period and then analysed the data to assess if there were any changes to our outcome variables using mixed-effects ANOVA. We wanted to see differences in total sleep time between week and weekdays and between holidays and school term. When considering school term sleep patterns overall, calculations took into account the differences in school term lengths (9 or 10 weeks). Changes in total mood scores as well as separately for depression, anxiety and stress were equally assessed. Mixed-model regressions were utilised to investigate any relationships between weekly total sleep time and mood scores.

We also measured variability to see whether differences between week and weekend sleep patterns, or school holiday/school term sleep patterns impacted mood. This is because stable and non-varied sleep wake patterns have in the last few years, emerged as a major component of what is considered good sleep. We collected this in two ways. First, by calculating the absolute difference between each bedtime with the bedtime immediately preceding it. An average score was then created for each school night across the study period (Sunday to Monday bedtime), each non-school night across the study period (holiday and Friday and Saturday night bedtimes during term), and an overall average. Second, by simple correlation with the standard deviation scores of bedtimes and wake times. Correlations were then run between both the variability scores and mood scores. All procedures were approved by The Central Queensland University Human Research Ethics Committee and the Department of Education and Child Development.
Results

General health

Overall, all participants reported good general health, with healthy Body Mass Indices (BMI; $M = 21.97$, $SD = 4.27$), no smoking or chronic illness. Participants obtained an average of 6.12 hours ($SD = 4.53$) of exercise per week. This is on average less than the recommended guidelines of 60 minutes per day (Australian Government Department of Health).

Sleep

Sleep periods were classified as either weekday (Sunday to Thursday) or weekend sleeps (Friday and Saturday) depending on the day of wake-up. Thus, sleep periods initiated on Sunday night were classified as weekday sleeps due to going to school the next morning. Similarly, sleep periods initiated on Friday night were classified as weekend sleeps. At baseline, that is, during the last week of school holidays, participants spent on average 8.49 ($SD = 1.74$) hours in bed and obtained 7.28 ($SD = 1.65$) hours of sleep per night. In comparison, they spent a lot less time in bed during school term with 7h 59m ($SD = 88m$) time in bed and 6h 55m ($SD = 83m$) of total sleep time per night during the school term. This is a lot less than recommended guidelines which suggest at least 8 hours of sleep per night [14].

Yo–yo sleeping was evident in these participants. That is, their sleep was less during the week and more during the weekend (See Figure 1). There were significant differences in how much time they spent in bed between school holidays and school term each week and weekend. Apart from the difference from school holidays, no other weeks were different from one another. Time in bed did not really change overall across the school term. The same pattern emerged for actual total sleep time, (rather than just how much time they were in bed)
with weekend sleep significantly longer than weekday sleep for all weeks except the pre-term holiday and weeks 7, 9 and 10. Weeks 4, week 9, and week 10 were all significantly less than baseline. No other weeks were different from one another (See Table 2 and Figure 1).

Figure 1. Mean total sleep time presented by weekday and weekend across 11 weeks.

However, it was clear that the participants caught up sleep on the weekends. In Figure 2, we see that the blue bars show how much sleep they missed compared to the school holidays. For example, we see that in school week 1, they lost about 40 minutes per night compared to school holidays. However, on weekend 1, they only lost about 8 minutes. So they seemed to ‘catch up’ about 32 minutes on the weekend. Only once did they actually sleep more than school holidays (see week 5). This is why, over all, there was no difference in total sleep time or time in bed, although their yo-yo sleeping was clear.
Figure 2. Differences in total sleep time from week to weekends across the school term: evidence of yo-yo sleeping.

Bed time and wake times

Participants went to bed significantly later on weekends and woke up later than on weeknights across each week in the study period, except for week 10. Week 10 was exam time. During the school term, bed times were earlier on weeknights than on weekends [23:41 (64min) compared to 00:32 (86min)]. This also corresponded to later wake times on the weekend than during the week across the entire study period (all p < .05).

Table 2. Means (in Hrs: mins) SD (in mins) for pre-term and term sleep split by school and non-school days.

<table>
<thead>
<tr>
<th></th>
<th>Pre-term</th>
<th>Term</th>
<th>Post-term</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weekdays</td>
<td>Weekends</td>
<td>Weekdays</td>
</tr>
<tr>
<td>TIB*</td>
<td>8h 14m (97)</td>
<td>8h 5m (118)</td>
<td>7h 43m (83)</td>
</tr>
<tr>
<td>TST*</td>
<td>7h 20m (65)</td>
<td>7h 5m (89)</td>
<td>6h 39m (40)</td>
</tr>
<tr>
<td>Bedtime</td>
<td>01:08 (109)</td>
<td>00:52 (100)</td>
<td>23:41 (32)</td>
</tr>
<tr>
<td>Wake-time</td>
<td>09:24 (108)</td>
<td>09:32 (97)</td>
<td>07:09 (33)</td>
</tr>
</tbody>
</table>

NB* TIB = Time in Bed; TST = Total Sleep Time

Weekly mood

For depression, anxiety and stress, all scores were highest for the first week of school term and then gradually reduced. Stress and anxiety rose slightly during the exam periods and at the end of term but these were not statistically different across the term because they only changed at the most by one point on the scale. In fact there was a gradual and gentle decline in mood scores, suggesting better mood over the school term. Figure 3 shows the DASS21 subscales across the study period. For depression overall, scores were in the non-clinical range (i.e. ≤4 for the DASS21). However, 30% of participants had scores indicating mild
probable depression at some time during the trial period (> 4), with 22% having scores for mild depression, with 4% having scores indicative of moderate depression and 4% severe depression. For anxiety overall, scores ($M = $ were also in the non-clinical range ($\leq$ for the DASS21), although 22% of the sample met the criteria for probable mild anxiety at least some point in the study period. Overall, 10% had scores indicative of probable mild anxiety (>3), 6% for moderate anxiety, 4% for extreme anxiety and 2% for extremely severe anxiety.

Finally for stress overall, scores were within the non-clinical range (<7 for the DASS21). Overall, 10% of the sample had scores indicative of mild stress at some point during the study period particularly around school examinations.

**Figure 3. DASS21 scores across the school term**

*The relationship between sleep and mood*

One main research question was whether sleep and mood were related and whether any changes to one was related to changes in another. The results suggest that the trajectory of sleep patterns and mood were not overall related in terms of sleep duration or time in bed ($p > 0.05$). However, sleep variability, that is, how different bed and wake times were over the
week or between school and non-school days were significantly related to depression scores and stress scores. When evaluated through the first method of calculating variability described above, there was a significant relationship between overall wake time variability and stress ($r (46) = .32, p = .031$) and quality of life and also $r (45) = -.34, p = .024$. Quality of life was also significantly related to bedtime variability ($r (45) = -.30, p = .044$). When tested with the standard deviation scores, (that is, the range of responses) higher depression and stress scores were related to higher standard deviation scores. That is, the greater the amount of variability the worse the depression and stress scores ($p<0.05$). Therefore these data show that sleep variability, in other words yo-yo sleeping, is related to depression, stress and self-reported quality of life, rather than sleep duration.

**Discussion**

This was the first study to examine sleep and depression, anxiety and stress symptoms across an entire school term, presenting important information from a sample of Australian adolescent males aged 14-17 years, collected in their naturalistic home and school environments. Findings concur with previous studies suggesting, adolescents obtain less sleep per week during the school week than at any other time [36]. Across the first week of the school term, participants incurred an average sleep deficit of 5.5 hours compared to the pre-term period. This equates to 47 minutes per night. However, sleep loss did not accumulate from the beginning to the end of the school term presumably due to ‘catch up’ recovery sleep on weekends but did accumulate relative to pre-term. Depression, stress and anxiety did not significantly increase across the term nor was it related to sleep. BUT it seems that sleep duration was not the main contributor to worse mood, but rather sleep quality with increased variability significantly related to depression, stress and quality of life.
One of the main findings of this study was that sleep duration and sleep timing differed depending on the day of the week and whether it was during holidays or the school term. Yo-yo sleeping was clearly evident in this group. This was observed in earlier bedtimes on weekdays and 20-30 minutes longer sleep duration on weekends. Presumably, earlier bed times were a strategy taken by adolescents (or perhaps parents) to compensate for the early school starts. Weekend sleeps were longer because students slept in until later on these days and this would suggest some recovery of sleep loss accrued during the week and would also account for the fact that overall, sleep duration did not significantly change across the school term. Baseline measures were obtained during holidays and thus the sleep data recorded here were used as reference for any changes. On the assumption that sleep taken in school holidays is relatively unconstrained and that any accrued sleep debt from the previous school term would have been recovered by the second week we believe this provides the best available measure of individual sleep need in the absence of any other definitive method for determining sleep need in adolescents. We have interpreted our findings to suggest that these young men are not receiving the sleep they need throughout the entire school term.

The behaviour of sleeping more on weekends to recover lost sleep is not a new phenomenon [1, 2, 41] but few studies have been able to evaluate accumulation of sleep loss over several weeks. Our data would suggest that sleep in this cohort is sufficiently recovered on weekends so sleep loss does not accumulate over 11 weeks. Bedtimes and total sleep time varied significantly across the term, with later bedtimes and wake times on weekends compared to weekdays. This information affirms the irregular adolescent "yo-yo" sleeping habits that are demonstrated in Australia and worldwide [42]. The time participants went to bed, when constrained by school, is fairly consistent. The bedtimes across the ten week term were significantly earlier than the pre-term holiday sleep.
There was a small consistent advance of bedtimes that occurred from week one to five perhaps this demonstrates a possible adaptation to the school schedule suggesting that adolescents are responding to their sleepiness from the weekends thus altering their bedtimes during the school week. A strategy that seemed to be successful in keeping their sleepiness levels stable. Furthermore, given that school principals confirmed that weeks 7 and 8 were examination weeks, the change in sleep during those weeks may suggest that adolescents are also adapting and responding to their examinations schedules. Interestingly, at that time, adolescents did not recover their sleep but remained at a significantly reduced sleep duration during the course of their examination weeks compared to baseline. As we did not gather data on school performance, it is unclear if and how this sleep pattern may have impacted on student performance during that time but there is previous evidence of a well-known dose response relationship between sleep and academic performance in adolescents [21, 22]. That is, the less sleep the worse the school performance.

A final comment about sleep patterns between school holidays and school term relates to the fact that Time in Bed is similar between school holidays and school term. Whilst this is not surprising and concurs with the literature, it may be an indicator that even when given the opportunity to sleep more, adolescents either choose other activities in their room apart from sleep (perhaps screen time) or that they have similar sleep onset times during school terms and school holidays. It may also further suggest that these students are coping well with less sleep than recommended. It may be the strongest indicator yet that adolescent sleep guidelines are inflated.

The second important finding in this study was that mood scores increased from school holidays to school term. This would be a plausible psychological adjustment to school life after a school break, but it did not reach statistical significance. This in itself is not necessarily a reason to completely dismiss the change in mood form holidays to school term,
but it disallows statistical scrutiny. More importantly, mood scores did not radically change across the school term, except for minor adjustments to school pressures and furthermore, they did not reflect changes to sleep duration. That is, this sustained sleep loss, particularly at weeks 7 and 8 was not reflected in a change or increase in depression, anxiety or stress scores. Nor were there any parallels between sleep duration and self-rated mood symptoms or quality of life scores across the study period which has been reported in a previous study [22]. Interestingly, in another Australian study of mood and sleep in South Australian adolescents who self-reported their normal sleep patterns and completed the DASS21, similarly reported no significant relationships between sleep variables and DASS scores, despite similar mood scores overall and similar sleep patterns [43]. Our observed distributions of sleep loss and mood symptoms were not consistent with the expectation that sleep loss and mood symptoms would be related, and both would become worse over an extended school term. Not only did sleep loss not accumulate over the term. Indeed mood scores showed slight decreases. These unexpected results may be due to several factors.

Firstly this may be reflective of a potential bias due to the self-selected small convenience sample or that there was an overrepresentation of private school students of higher socio-economic status. Investigations into differences between private and public schools reveal that students with higher socioeconomic status have lower rates of depression and trait anxiety [44] and better sleep. But this does not account for the higher mood scores on all scales during the first week of school term. Potentially the first week of school term reflects increased worry about the upcoming school term. Secondly the DASS-21 may have lacked sensitivity to detect small changes in mood symptoms in this non-clinical sample, particularly as the other South Australian study found similar results with the DASS21. The majority of the existing literature on adolescent sleep and depression has used populations with diagnosed affective disorders, particularly Major Depression Disorder [45]. Thus, the
hypothesised links between sleep and mood problems may only present if the severity of mood problems is in the clinical range or in at risk adolescent males or alternatively in adolescents with severely reduced sleep duration, neither of which was the case in this study. The rate of clinical depression each year in young Australian males is 4.3% [46]. Thus, the chance of gathering community data from adolescent males with clinical depression in this small sample in the clinical range is small and only 3-4% of our participants reported clinical symptoms. Thirdly, there was the potential for a response bias. Adolescent males are less likely to identify depressive symptoms [30] and given the shame, guilt and incompetence that some males associate with depression [32], may subsequently either consciously or unconsciously respond in a manner that is expected.

In addition, why depression symptoms did not increase at week 7 and 8, in parallel to sleep changes and academic pressures is also unclear particularly as in a previous study in Australian adolescents, stress increased at during the examination period [43]. Perhaps and likely, the relative stability of the depression scores reflect a practice effect with weekly completion of the DASS. That is, perhaps the participants simply got sick of completing the scale and just ticked whatever boxes they wanted without it being truly indicative. However, this was not the case when the researchers asked the participants if they were tired of completing the scales during the study. Mood scores over time have not been used for this length of time in this population to our knowledge. But one previous study utilised DASS in medical students over five consecutive weeks with no reports of a practice effect in that study [47]. In addition, perhaps the DASS-21 which assesses specific symptoms of psychological distress (e.g., “I was aware of the action of my heart in the absence of physical exertion”) may not be applicable, or understood in adolescent males who are not reporting clinically significant symptoms.
However, all the above discussions centred on sleep duration. This study, and others before it [12, 13, 15] have shown that variability is a key factor. This study confirms these findings and adds significantly to our understanding of adolescent sleep and mood. We found that the only factor that reflected changes in mood were inconsistent and variable sleep patterns between school and non-school days. So irrespective of whether the participants recuperated their sleep on the weekend or during the holidays, and similarly irrespective of how well they seemed to cope with that, these findings suggest that the most common feature of adolescent sleep - yo-yo sleeping is predictive of worse mood.

Indeed, in two previous studies in adolescents, Fuligni and Hardway found that poor sleep schedules in adolescents was associated with increased anxiety and depression, while Wolfson and Carskadon (1998) found correlations between poor performance at school and bedtime variability in adolescents. Similar findings have been fund in Australian junior school children. Interestingly, quality of life, that is, the participants own perception of how they perceive their life to be, was the scale the most impacted by variability. This may suggest that quality of life scales are more effective in understanding the subtleties of adolescent male mood. It may also reflect the fact that, if males are less likely to report symptoms of depression or anxiety as has been reported, they are perhaps less guarded when reporting quality of life. Further studies in this area, should utilise different mood scales to test this hypothesis.

**Conclusion and impact for adolescents**

The impact of the school schedule on adolescent sleep and their coping mechanisms for sleep loss may be more complex than suggested by existing sleep literature which currently is generally focussed on sleep duration. Our findings suggest that some adaption to the school schedule is occurring despite the fact that adolescents are getting a lot less sleep
than even the broadest and most generous sleep guidelines. But this in itself, according to this sample, appears to be well tolerated, with sufficient catch up sleep across the term. But paradoxically, this catch up sleep is the factor that drives yo-yo sleeping and has the most impact on mood. These findings have implications for:

1. Increasing awareness of how to reduce yo-yo-sleeping in adolescents. Sleep education programs that improve sleep hygiene and promote the use of napping to recuperate sleep rather than excessive “sleep-ins” on the weekend would be beneficial

2. Sleep education needs to increase awareness at the student level, the school level, and it should include the families and community level.

3. Sleep health should be included in all conversations about wellbeing in adolescents and be partnered with conversation about diet and physical activity.

The future requires studies of the relationship between sleep loss over time and mood scores would benefit from larger samples. A wider survey, with different mood scales, could be used to see whether the results we observed in our narrow sample of students generalise to the wider population of adolescents from a range of socio-economic backgrounds in Australia and overseas.

Sleep is modifiable. Reducing variability in sleep patterns could plausibly improve mental health of our young people.
References


Outputs from the research

Presentations

This data has already been presented at six conferences to date, presented by the Honours student working, and the chief investigator on the project. One paper has been published with two in preparation.


