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Adolescent sleep and school performance — the problem of sleepy teenagers

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It is recommended that adolescents achieve 8–10 hours of sleep per night but a large proportion of adolescents worldwide are not achieving that amount. Adolescence is a time when the circadian clock drifts later, there are changes to the sleep homeostatic mechanisms, and individuals experience growing autonomy where poorer sleep hygiene behaviours can take hold. These changes to adolescent sleep drive bedtimes later and, with a consistent school start time, condense the opportunity for sleep. Sleep is essential for memory and learning and the shortening of sleep and subsequent sleepiness may impair an adolescent's opportunity to perform to the best of their ability in class. Numerous research groups and organisations are now striving to find ways to improve adolescent sleep including delaying school start times, providing sleep education, and utilising light therapy as a means to improve the health, wellbeing and academic performance of sleepy teenagers.

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A global problem of sleepy teenagers

Current guidelines suggest that adolescents require a sleep duration of 8–10 hours for optimal functioning with a recent dose-response modelling study suggesting 9.35 hours of sleep was required by adolescents, aged 15–17 years, to keep sustained attention in a psychometric performance task [1,2••]. A large scale monitoring of adolescent sleep from 1991 to 2012 in the USA has indicated a historical shortening of adolescent sleep, with today's adolescents more likely to experience insufficient sleep (<7 hours) than they did 20 years ago [3]. Sleep is fundamental for educational performance to be at its best and this review will discuss the challenges to adolescent sleep, the impact of this on academic performance, and current strategies being utilised by schools to try to help reduce the number of sleepy teenagers in the classroom.

The challenges to sleep in adolescents

Sleep regulation is proposed to be governed by two processes, a sleep homeostatic process (sleep-dependent) and a circadian process (sleep-independent), both working in tandem to promote stable sleep [4]. The sleep-independent biological clock regulates all of our biological processes and alertness levels through internally generated, approximately 24-hours oscillations in physiology and behaviour. Core body temperature, rest-activity and alertness, as examples, all follow a predictable pattern over the day [5]. The sleep-dependent process, the sleep homeostat, tracks sleep need (pressure) through the changing levels of adenosine [6–8]. The longer the duration of wakefulness, the greater the intensity of deep sleep, specifically an increase in slow waves (0.5–4 hz) required to clear adenosine in the sleep-deprived brain.

Physiological changes

During adolescence, there is a gradual shift in sleep/wake timing, with bedtimes being significantly later on non-school days compared to school days, reflecting changes in the circadian sleep drive [9,10]. A meta-analysis conducted on adolescent bedtimes indicated that this disparity between school night and free night bedtimes grows with age [11]. Further, this disparity appears to be related to pubertal development [12]. Indeed, self-reported 'eveningness', a later chronotype (preferred sleep/wake timing), appears to rise from 10 years of age, resulting in a discrepancy of 1–3 hours between fixed schedule (school) days and free days [13]. Early studies indicated that the oscillation period of the intrinsic circadian rhythm lengthens during puberty [14,15]. As the oscillation period lengthens, there is a delay in the circadian clock, which may explain an adolescent's drive to go to bed later. However, a more recent evaluation compared the free running period, the natural frequency of the oscillation without external influence, of the circadian clock of adolescents (aged 14–17 years) to adults (aged 30–45 years). This study found no significant difference between the two groups, suggesting that the delay in preference may be driven by other factors such as the influence of external zeitgebers (see Section 'Psychosocial influences on sleep') [16•].

Adolescents experience alterations in the sleep homeostatic system. Evaluations of sleep pressure, as measured by slow wave sleep during multiple nap opportunities, is slower to accumulate in older adolescents compared to younger adolescents [12,17]. As sleep pressure is a measure of sleep debt, one could then assume that perhaps older adolescents are more resilient to sleep deprivation, accruing less sleep debt than younger adolescents during the same duration of wakefulness. However, the rate of dissipation of sleep pressure accrued after extended wakefulness was found to be similar for both younger and older adolescents, thus suggesting no difference in their sleep homeostatic drive [17,18].

Psychosocial influences on sleep

Alongside the changes to both the circadian and homeostatic sleep processes influencing sleep timing, adolescents face psychosocial challenges to sleeping at an appropriate time, such as peer influence and electronic media use. A number of recent studies have focused on gathering qualitative data concerning adolescents' perceptions of sleep barriers and targets for therapeutic interventions [19,20]. A qualitative study in the US conducted three focus groups with adolescents aged 14–18 years [19]. Thematic analysis was used to identify that despite recognising the importance of sleep, these thoughts did not translate into behaviour practices. Adolescents cited overuse of electronic media, particularly mobile phone use, and overuse of caffeinated drinks during the day as factors perceived to delay bedtimes or disrupt sleep. A similar study in the UK with 33 adolescents (13–14 years) found that electronic media were the greatest reported barrier to sleep [20]. This study identified an effect of gender, with males reporting gaming/watching videos as the greatest obstacle to sleep whereas females reported being disturbed by mobile communications, with some females reporting fear/anxiety if phones were removed from their bedrooms in the evenings. Night-time electronic media use in this age group has been shown to significantly associate with later bedtimes, shorter sleep durations, increased self-reported feelings of being 'stressed' at school and higher self-reported sleepiness in the classroom [21,22,23•,24]. Evaluations of the USA 2017 Youth Survey ($n = 14\,603$) found that adolescents who engaged in excessive screen time, defined as over three hours of usage per day, were 1.34 times more likely to also report an inadequate sleep duration, defined as less than 8 hours' sleep on a school night [25]. In a study where screen time was reduced after 9 p.m., time taken to fall asleep was reduced, total sleep time increased and daytime attention improved [26]. Poor sleep environments, negative family relationships, extracurricular clubs/activities, and homework were other cited barriers to sleep [20,27,28].

A global pattern of insufficient adolescent sleep

Both the physiological and psychosocial factors push bedtimes later and, when combined with a fixed school start time, the sleep opportunity window shortens [29]. This invariably leads to catch-up sleep on days without school, as adolescents try to relieve the accrued sleep debt and sleep timing mimics that of their delayed internal clock: a state known as social jet lag [13]. A recent modelling paper has indicated that this progressive shortening of sleep and increasing degree of social jet leg begins around the age of five years and plateaus, but does not reverse, at the age of 16–17 years [30]. However, this study utilised self-report measures in a single country, Germany, whereas a much larger, worldwide study ($n = 17\,355$) utilising commercial tracker users identified a significant delay in bedtimes throughout adolescence, stabilising in participants over 30 years old [31•]. Regardless of when these challenges are at their peak, sleep is under pressure during the ages a child is at school and expected to perform well in exams.

Sleep and school performance

The role of sleep in memory and attention

Learned information needs to be encoded and consolidated for later retrieval. Many studies have highlighted that sleep is an active, rather than passive state, that is optimised for the processing of acquired information into long-term easily accessible memories [32]. Importantly, current thought is that sleep, and in particular the cycling between sleep stages, promotes the replay and integration of memories into long-term stores and the optimisation of synapse connections between these memories through synaptic pruning [32–34]. Therefore, shortened sleep has the potential to limit the ability of adolescents to encode and retain learnt information. Similarly, sleep deprivation can impair the ability to hold sustained attention: the shorter the sleep opportunity, the poorer an adolescent is likely to be at holding attention throughout the day [2••].

The direct impact of sleep loss in the classroom

Shortened sleep opportunities can have a direct impact on an adolescent's performance in the classroom. A novel experimental study utilised an in-laboratory, simulated school week whereby, following a baseline sleep, adolescents (twelve 15–17-year-olds) underwent five days of sleep restriction (five hours' sleep) followed by a simulated weekend of recovery sleep [35]. Importantly, this study not only showed impaired performance and lapses in sustained attention during three-hourly reaction time tasks during the day but also a cumulative impact of sleep restriction as performance became worse over the week. Notably, although self-reported sleepiness returned to baseline following the simulated weekend recovery sleep, sustained attention did not. This is a replication of findings from similar studies which identified sustained and cumulative performance deficits following simulated sleep restrictions and performance that did not return to baseline levels following recovery sleep [36,37].

The above studies utilised a simulated sleep restriction protocol and psychometric testing platforms as their performance measures. A more ecologically valid study was conducted on 7798 older adolescents (16–19 years) measuring self-reported sleep variables including weekday/weekend bedtimes and sleep duration alongside links to school academic grades [38]. When researchers controlled for socioeconomic factors and school absences, all sleep variables, including shorter sleep duration, associated with poorer academic outcomes. However, these findings do need to be interpreted with caution as a number of other studies have not found a link between sleep duration and academic outcomes, instead finding that sleep efficiency, a measure of sleep quality, associated with school performance [39,40]. A recent study evaluated sleep in 257 adolescents using wrist-based sleep trackers and a validated sleep quality questionnaire [41]. When controlling for pubertal status and sociodemographic factors, only subjective sleep quality, not objective sleep measures or subjective sleep duration, associated with academic performance.

A simulated classroom study sought to combine the rigour of the sleep laboratory and the ecological validity of real world classroom performance [42]. During this study, 87 adolescents (14–17 years) spent three weeks in a crossover design comprising a week's baseline sleep, an ideal sleep duration week or a shortened sleep week. Testing occurred in a simulated classroom, timed to mimic a school day, where participants were required to watch lectures, complete quizzes, and were monitored remotely for signs of sleepiness or inattention. When the testing followed the week of short sleep, adolescents displayed more behaviours associated with lapses of attention and sleepiness. However, despite parental and adolescent reports of impairment during the week of sleep restriction, no significant associations were drawn between sleepiness and quiz scores in the sleep restriction or extension weeks.

Importantly, with technological advances, studies are now highlighting a link between delayed sleep timing, insufficient sleep, and changes in brain structure. A number of studies have indicated associations between later weekend sleep timing, poorer academic performance and reduced grey matter volume in the pre-frontal cortex and the amygdala, areas of the brain related to emotional control and executive function [43,44]. These studies highlight the importance of monitoring sleep, including both duration and timing, as part of the pastoral care in school for adolescents who may be underachieving, specifically concerning the cumulative impacts of sustained sleep impairment and potential neuro-structural changes.

Chronotype

In contrast to the conflicting evidence surrounding the impact of sleep restriction and academic performance, the evidence surrounding chronotype and academic performance is more congruent. It is well known that performance has a circadian variability [5]. Therefore, it is unsurprising that the timing of school exams, in particular the tendency for morning assessments, favours the earlier chronotypes. This has led to the suggestion that examinations should occur in the mid-afternoon where the effect of chronotype is lessened [45]. A large meta-analysis identified that having a later chronotype associates with poorer academic performance in both those in compulsory education and those at university/college [46]. Alongside the circadian influence on performance, adolescents who identify as moderate to extreme evening types appear to report more sleep disturbances and inattentiveness in class than earlier chronotypes independent of sleep duration [47,48]. Although it is likely that adolescents with evening tendencies will have a later sleep onset and a shorter sleep window, the evidence above demonstrates how the academic system unintentionally favours the early chronotypes and, given that all adolescents will experience a drift to more evening tendencies, it is unsurprising that researchers are evaluating sleep interventions at an organisational level.

Emerging interventions for improved sleep in adolescents

One of the more obvious targets for intervention is to realign the school day to the adolescent biological clock through delaying school start times. In light of the supporting evidence, the American Academy of Sleep Medicine released a position statement detailing that no school should start before 08:30 and that delaying school start times has a positive impact on adolescent health and academic performance [49]. Numerous studies have indicated the positive benefit of delaying school start times with students reporting longer time in bed, less daytime sleepiness and fewer incidences of lateness to school [50,51]. An important study recently evaluated adolescent sleep using an objective measure, actigraphy, across a number of US schools with varying start times [52•]. This study demonstrated that students at schools starting after 08:30 slept significantly longer than students at schools which started earlier, with students using the extra time in the morning to sleep.

Considering these findings, it could appear clear that delaying start times is an ideal intervention, however most studies involve assessments of adolescent sleep either cross-sectionally or immediately pre/post timetable change. Longitudinal evaluations of delaying schools start times have demonstrated mixed findings: for example, one study reported a weakening but sustained increase in sleep duration at follow-up whereas another reported a gradual delay of bedtimes [53,54]. However, both studies showed a sustained improvement in daytime sleepiness and a reduction in lateness to school suggesting that further studies are required to evaluate the long-term impact of delaying school timetables.

An alternative intervention is to improve adolescent sleep through sleep education, providing tools and knowledge to enable adolescents to engage in more sleep-friendly behaviour before sleep. However, again, findings have been mixed with most studies showing increases in sleep knowledge but limited changes in objective/subjective sleep parameters, or changes that are not maintained at follow up [55,56]. To our knowledge, studies have not evaluated whether sleep education can improve academic outcomes in older adolescents. However, a small study of 71 younger children (7–11 years) found that not only did a classroom-based sleep education programme improve sleep but this associated with improvements in educational outcomes [57].

There are a number of emerging novel interventions that were developed to improve adolescent sleep. One study aimed to evaluate if supplementing a restricted nocturnal sleep with a nap can ameliorate the impact of sleep deprivation on memory [58]. In this study, 58 adolescents either experienced a shortened sleep opportunity (6.5 hours) or a shortened sleep (five hours) plus a daytime nap (1.5 hours). Upon morning testing, there was no difference between groups in performance; however, performance during afternoon testing appeared to improve following a nap. Although not ideal, this intervention provides evidence that if extension of nocturnal sleep is not possible, then an afternoon nap could boost performance in chronically sleep-restricted adolescents. An alternative to delaying school start times, to better fit the adolescent biological clock, is to use chronotherapy to move the adolescent clock to the school. An extremely novel study utilised passive light flash therapy to attempt to ameliorate the circadian delay in the adolescent biological clock [59••]. The study was split into two phases. In phase 1, light flashes or sham therapy were administered during the final three hours before wake to 72 adolescents for three weeks. In phase 2, 30 adolescents were either given light therapy or sham therapy during the final two hours before wake plus cognitive behavioural therapy (CBT) for four weeks. Light therapy alone was found to be ineffective at advancing sleep onset. However, light therapy plus CBT advanced sleep onset and increased total sleep time compared with sham therapy plus CBT. Importantly, as this was passive therapy, this intervention highlights how emerging technologies could be utilised alongside sleep education/CBT to promote physiological change in adolescents.

Conclusion

Worldwide, adolescents are not getting enough sleep. As sleep is essential for learning and memory, it is unsurprising that sleep complaints associate with poorer academic outcomes. There is now a growing movement supported by an increasing number of research studies seeking to improve sleep in adolescents. With the emerging novel light therapies and a number of qualitative studies demonstrating an emerging addiction to technology, more studies are needed to combine both physiological and educational interventions to better support sleepy teenagers in the classroom.

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Conflict of interest statement

Nothing declared.

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- • of special interest
- •• of outstanding interest

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This study uses a novel treatment intervention to ameliorate the impact of the circadian delay in adolescents. Passive light therapy was administered whilst the adolescents were asleep to augment the impact of cognitive behavioural therapy on sleep. This study demonstrates how emerging technologies could be utilised in the home to improve the effectiveness of other sleep interventions.