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The challenges of adolescent sleep

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Review

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Sleep is vital for our physical, emotional and cognitive health. However, adolescents face many challenges where their sleep is concerned. This is reflected in their sleep patterns including the timing of their sleep and how much sleep they achieve on a regular basis: their sleep is characteristically delayed and short. Notably, insufficient sleep is associated with impairments in adolescent functioning. Endogenous and exogenous factors are known to affect sleep at this age. Alterations in the bioregulation of sleep, comprising the circadian timing system and the sleep/wake homeostatic system, represent the intrinsic mechanisms at work. Compounding this, environmental, psychosocial and lifestyle factors may contribute to shortened sleep. This review discusses the amount of sleep gained by adolescents and its implications, the challenges to adolescent sleep and the interventions introduced in an effort to prioritize sleep health in this important developmental period.

1. Introduction

Adolescence is the stage of life that begins with the onset of puberty and ends with adulthood, although the ages at which these transitions occur differ across the world, and conceptions of adolescence vary by culture [1]. While acknowledging that other sleep parameters are important, for example, sleep quality, timing and schedule regularity, for the purposes of this review, sleep duration will be the primary focus. The amount of sleep gained per night diminishes from childhood to late adolescence; however, it has been suggested that sleep need does not change across adolescence [2,3]. A meta-analysis of studies that used an actigraphic assessment of sleep (where sleep/wake is inferred from the absence/presence of movement) revealed a developmental trend of reduced sleep and later sleep onset from childhood through adolescence [4]. There are suggestions that today's adolescents are sleeping less than those of previous generations, with an historical decline over 20 years identified in the sleep duration of US adolescents [5], as well as a decrease of over an hour per night over the previous 100 years using data from 20 countries [6].

It is salient to establish how much sleep an individual is likely to require for optimal functioning, while acknowledging that sleep need will vary by individual as will vulnerability to sleep loss [7]. The National Sleep Foundation convened a multi-disciplinary expert panel to investigate sufficient sleep durations across age categories, resulting in a recommended guideline for sleep length of 8–10 h for teenagers (aged 14–17 years) [8]. The American Academy of Sleep Medicine, again based on expert judgement, similarly concluded that 13- to 18-year-olds should regularly sleep 8–10 h [9]. According to these recommendations, survey data in Canada [10] and China [11] suggest that adolescents are a chronically sleep-deprived population. Furthermore, a meta-analysis of 41 surveys worldwide concluded that adolescents were typically experiencing insufficient sleep (less than 8 h) on school nights and extended sleep at weekends [12]. It is important to acknowledge, however, that determining what constitutes sufficient sleep is not without complexity. Indeed, much empirical evidence suggests that sleep need does not decline from late childhood through the second decade of life [13], and sleep need estimates of approximately 9 h have emerged from investigations into sleep duration and behavioural outcomes [14,15].

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This review outlines, firstly, why it is important to address insufficient sleep in adolescence, before considering how adolescent sleep is challenged. Secondly, it identifies the endogenous factors known to affect sleep at this age (specifically, alterations in the bioregulation of sleep, comprising the circadian timing system and the sleep/wake homeostatic system). Thirdly, it discusses the exogenous factors that may contribute to shortened sleep: environmental, psychosocial and lifestyle factors. Lastly, this review ends with a summary of the role of school-based interventions introduced in an effort to prioritize sleep health, as well as home-based interventions aimed at manipulating sleep.

2. The implications of insufficient sleep

The chronic experience of insufficient sleep in adolescence has been identified as a public health epidemic in the USA [16], while the reduction of sleep deprivation is viewed as a public health priority in the UK [17]. Sleep is essential for our physical and emotional health as well as our behavioural, cognitive and—fundamental to adolescence—academic performance. A wealth of cross-sectional and experimental studies support the important role that sleep plays across many domains of adolescent functioning and as such, it is vital to understand the implications of insufficient sleep. In a systematic review, largely based on self-reported sleep in 40 countries, shorter sleep duration was associated with adverse physical and mental health outcomes [18]. While peak levels of mental health were found for adolescents with Mexican American backgrounds who experienced the recommended amount of sleep on a school night [19], shorter than recommended sleep duration was associated with psychological complaints in a Swedish sample [20]. However, it is important to recognize the potential bi-directional relationship between mental health and sleep loss in teenagers. Indeed, the authors of a review that focused on sleep and emotional and behavioural difficulties in childhood and adolescence concluded that links between sleep and psychopathology are complex and likely to be bi-directional [21].

In a large survey of risk behaviour in the USA, less than 8 h sleep on a school night was associated with a variety of health-risk behaviours [22]. A number of systematic reviews and meta-analyses have found an association between short sleep duration and an increased risk of obesity in the pediatric population [23–25], and experimental and epidemiological research over the last 30 years has linked short sleep duration with obesity [26]. Given that obesity [27] and chronic sleep deprivation are considered public health issues, this link between short sleep and obesity is particularly noteworthy. Duraccio *et al.* [28] developed a mechanistic model to explain this relationship in an adolescent population. The authors proposed that increases in food reward processes, decreases in insulin sensitivity, disrupted meal timing and increases in sedentary behaviour represented the most compelling mechanisms. When considering glucose metabolism, poor sleep may increase the risk of insulin resistance, when cells become less responsive to insulin and the regulation of blood glucose is compromised [28]. For example, in a sample of adolescents participating in the Brazilian Metabolic Syndrome Study, sleep deprivation—defined in the study as having less than 8 h sleep per night—was associated with decreased insulin sensitivity [29]. Therefore, it has been suggested that it is important to consider sleep in the prevention and treatment of obesity [30].

Shorter sleep duration has consistently been found to correlate with poorer academic and school performance in cross-sectional studies [31]. A population-based study in Norway comprising 16- to 19-year-old adolescents, found a dose–response relationship between sleep and academic performance. Adolescents sleeping between 7 and 9 h had the highest grade point average compared with those sleeping less than 5 h. Notably, this study included a large sample size of 7798 adolescents and used official, register-based academic grades [32]. A study that instead sought to investigate cause and effect used a sleep manipulation protocol so that adolescents experienced short sleep (6.5 h in bed) and healthy sleep (10 h in bed). Participants also viewed lecture-based videos and completed quizzes on the content in a simulated classroom. After five nights of short sleep, adolescents demonstrated diminished learning by scoring lower on the quiz compared with when they were well-rested [33]. Furthermore, adolescents themselves have recognized that getting insufficient sleep impacts on daily life through their mood, concentration and decision-making [34].

3. Endogenous factors: alterations in the biological regulation of sleep

The two-process model of sleep, first proposed by Borbély [35], informs our understanding of the biological regulation of sleep and our sleep/wake behaviour, and serves as a framework for understanding the changes that occur in adolescence. The model comprises a circadian timing system (Process C) and a sleep/wake homeostatic system (Process S) that interact to regulate sleep timing and duration. The circadian system guides the timing of sleep, independent of prior wake and sleep. Circadian rhythms are an approximately 24 h cycle of oscillations in physiology and behaviour. The genetically regulated circadian pacemaker, situated in the suprachiasmatic nucleus of the hypothalamus, requires a daily adjustment to the external 24 h day. This entrainment is achieved through environmental time cues. The light–dark cycle is the principal zeitgeber (time-giver) [36] with early light exposure advancing (an individual will wake up earlier the next day) and late light exposure delaying (an individual will wake up later the next day) an individual's circadian phase [37]. By contrast, the homeostatic process is responsible for the increase in the drive to sleep (called sleep pressure) in proportion to the amount of time an individual has been awake and a corresponding dissipation of this pressure during sleep.

Adolescence is characterized by a delayed sleep–wake cycle that can, in part, be explained by modifications to the two systems described above. The circadian pacemaker shifts later with the progression of puberty [38], with a 'phase delay' in circadian timing occurring in humans as well as nonhuman mammals [39,40]. The delay is observable at a behavioural level through an individual's 'chronotype', referring to their preferred sleep/wake timing. Adolescents, with a tendency to sleep late and to wake late, are described as having an 'evening chronotype' with maximum lateness being reached at around 19.5 years for women and 21 years for men [41]. The delay has been demonstrated around the world through adolescent school-night and weekend bedtimes progressively getting later with age [12]. Bedtimes at the weekend were found to be consistently later than those on school nights, and it has been suggested that because an adolescent is more likely to be able to choose their bedtime on weekend nights, this timing may be more representative of their circadian preference [12]. On the other hand, it should also be considered that adolescents may stay up late at the weekend to use this additional time awake for social reasons and for activities that could be restricted on school nights: for example, spending time with friends or video gaming. The proposed mechanisms for the circadian delay with puberty include a lengthening of the endogenous circadian period (longer internal day length is associated with more 'night owl'/evening type tendencies) and an altered sensitivity of the circadian system to light (light in the evening/early night delays while light in the late night/early morning advances the clock) [38,42]. However, recent studies suggest that alterations to circadian physiology may occur earlier in pubertal development and that older adolescents have a similar circadian period and response to light as adults [3,43,44].

Moving on to the homeostatic system, slow-wave activity (SWA) of the sleep electroencephalogram, and the time it takes for an individual to fall asleep, have been proposed as markers of the accumulation of sleep pressure [45,46]. Cross-sectional studies, using these measures, have provided evidence to support an altered sleep drive. Mature adolescents were found to have a slower build-up of homeostatic sleep pressure than pre- or early pubertal children using a sleep deprivation paradigm [45]. This finding, based on the adolescent brain's response to sleep loss as measured by SWA, indicates that more mature adolescents may be able to stay awake longer. This hypothesis is supported by a study that instead measured the speed of falling asleep after a period of prolonged wakefulness (14.5, 16.5, and 18.5 h awake). Pre-pubertal adolescents demonstrated greater sleep pressure by falling asleep faster than mature adolescents after extended waking [46]. Therefore, changes to the bioregulation of sleep enable an adolescent to feel awake later into the evening than before and so less likely to be in favour of a bedtime that would be beneficial for sleep duration.

4. Exogenous factors: the influence of environmental, lifestyle and psychosocial factors

The alterations to the biological regulation of sleep that contribute to insufficient sleep do not act in isolation but instead may be influenced by environmental, lifestyle and psychosocial factors, some of which are considered below.

4.1. School start times

After discussing the adolescent propensity to go to sleep late, it may come as little surprise that schools' designated start times restrict the window of opportunity for sleep. School start times were identified as a major environmental barrier to sleep duration in the late 1990s [47]. In general, it is not common practice for schools to take the adolescent phase delay into account when setting the timing of their day; therefore, it could be said that adolescent sleep timing faces pressures both at the onset and the end of sleep. The late bedtimes set by the endogenous clock can hinder an adolescent's ability to gain sufficient sleep during the school week due to the requirement to wake early for lessons. In order to be at school when expected, if an adolescent is forced to wake up earlier than their biologically appropriate time, they may also have to attend school when they are not yet feeling mentally alert. This misalignment of biological and social timing is known as 'social jetlag' [48] and is the disparity between sleeping in accordance with chronotype (weekend sleep) and sleeping to meet social commitments (school-day sleep). Adolescents who accumulate a 'sleep debt' over the school week are then prone to 'catch up' sleep at the weekends which may exacerbate delayed sleep. Sleep duration may be shortened during subsequent school days as the clock shifts later and sleep onset takes longer [49,50]. Evening chronotypes are more likely to experience a disparate weekday/weekend sleep pattern and greater social jetlag. Early school start times intuitively align with the sleep timing of a morning chronotype rather than an evening chronotype; for example, a morning chronotype has been found to associate with better academic performance and higher attention [51].

Even though a maximum lateness of chronotype is proposed to be reached after the school years have ended [41], institutional interventions with older adolescents have not been prioritized. Importantly, wake times have been shown to be less constrained after adolescents have left school [52] and are at university [53], and their sleep timing is no longer influenced by school schedules. Adolescents have a greater autonomy to plan their own timetables and class attendance when university students compared with the compulsory attendance and fixed timetables experienced by those at school [54].

4.2. Electronic media use

A primary concern in recent years has been the potential challenge to sleep arising from the widespread, habitual and growing use of electronic devices among adolescents. It could be proposed that research into the effects of electronic media use on sleep has been limited by the tendency to use self-report measures and cross-sectional data, as well as challenged by the constant evolution of technology and the ways in which these technologies are used. Several mechanisms were implicated in a model developed to potentially explain the detrimental impact of electronic media on sleep [55]. Firstly, electronic media use may directly replace sleep or other activities that may be beneficial for sleep. Secondly, physiological, cognitive and emotional arousal may increase, so that adolescents are less likely to feel relaxed and ready for sleep. Thirdly, evening exposure to bright light may disrupt circadian rhythms by suppressing melatonin release. The rhythm of the hormone melatonin is closely associated with the timing of sleep and sleep propensity [56]. Exposure to artificial light in the evening has the capacity to modify rhythms and therefore sleep [57]. Bedtimes and sleep onset may then occur later through a shift in the circadian timing system. Furthermore, electronic devices emit light with a short wavelength (i.e. blue light) and the circadian system and alertness levels have been found to be particularly sensitive to light in this range [57].

A much-cited 2010 review of 36 studies concluded that excessive media use was associated with delayed bedtimes and shorter sleep duration in school-aged children and adolescents [55]. A large US survey investigated whether the trend towards shorter sleep had continued between 2009 and 2015, and the factors that might be responsible for this reduction. By 2015, more than 40% of adolescents regularly slept less than 7 h a night and were 16–17% more likely to do so than in 2009. During the period under review, new media screen time increased (including electronic device use, social media use and reading news online) and screen time was related to a greater likelihood of short sleep duration. Notably, other activities that could be proposed to interfere with sleep (television watching, working for pay, homework) did not increase over these years [58]. Another large-scale study used cross-sectional data from the Millennium Cohort Study in the UK [59]. The authors investigated the social media use of 11 872 adolescents, aged 13–15 years, and associations with sleep outcomes using data from 2014. Social media use was measured using a single item: the amount of time spent using social media on a typical weekday. Heavier social media use was associated with poorer sleep outcomes after controlling for covariates. In particular, very high social media users (who used social media more than 5 h a day; 20.8%), compared with typical users (who used social media 1–3 h a day; 31.6%), were more likely to report late sleep onset during the school week.

As well as a focus on general screen time, researchers have also looked at particular technologies and their relationship with sleep. A meta-analysis investigating protective and risk factors for adolescent sleep on 41 studies from 2003 to 2014 found that video gaming, mobile phone, computer and Internet use were related to delayed bedtimes for 12- to 18-year-olds, albeit with small effects. However, of these, only computer use was associated with sleep duration so that greater computer use related to shortened sleep [60]. While acknowledging the mixed results, the authors noted that the meta-analysis was not able to take into account whether adolescents were multi-tasking (using more than one device at a time) or the device content (whether devices were used for passive or interactive activities). Mobile phones are ubiquitous, part of everyday life, and viewed by adolescents as an essential tool for social interaction. A survey-based, longitudinal study investigated the effect of mobile phone use in the night over four years in Western Australia from 2010 to 2013. Individuals were asked what time they usually sent or received text messages or made phone calls at night and whether this continued after lights out. Night-time mobile phone use was found to increase over these years, with a corresponding increase in poor sleep behaviours [61]. Studies have primarily used survey data and correlational analysis; however, a recent experimental study asked adolescents to stop using their phone an hour before their average weekday bedtime and to complete a sleep diary. During the intervention week, adolescents stopped using their phone 80 min earlier, put their lights out 17 min earlier and had a 21 min increase in school-night sleep duration [62].

The timing of electronic media use is pertinent given the mechanistic pathways mentioned previously [55]. Orzech *et al.* [63] investigated digital media use near bedtime and relations with sleep timing and quality. A sample of first-year university students tracked their sleep through daily online diaries and completed a digital media survey in 15 min blocks for 2 h before bedtime on nine occasions. More time spent using digital media was associated with later bedtime and reduced total sleep time. The researchers proposed this provided support for the suggestion that digital media use may directly displace sleep. In addition, the type of activity in the hour before bedtime played a role, with computer work, surfing the Internet, and listening to music showing the strongest relationship to sleep measures. The authors concluded that using digital media, especially in the hour before sleep, contributes to poorer sleep [63].

An experimental paradigm is now also being used to provide more information about when adolescents use electronic media and sleep outcomes. A recent study in Switzerland, including 183 adolescents, aged 12 to 19 years old, investigated the timing of sleep and electronic device use [64]. Participants received a 40 min sleep education workshop and instructions to stop using screen devices after 21.00 on school nights for two weeks. Sleep was measured using actigraphy and daily diaries, with a baseline finding that screen use time after 21.00 was negatively correlated with sleep duration on school nights. Importantly, experimental support was found for screen use in the evening affecting sleep as decreasing screen time after 21.00 was associated with earlier sleep onset time and increased sleep duration. Regarding potential mechanisms, when participants spent a substantial amount of time on off-screen activities, this did not correlate with sleep, indicating that screen time use did not merely replace sleep time. Instead, sleep may have been influenced by screen use activities that increased emotional arousal levels and from exposure to blue light [64].

4.3. Caffeine

Caffeine is a commonly consumed, psychoactive substance, working primarily as an adenosine antagonist, blocking adenosine receptors [65]. Caffeine is considered a challenge to sleep as adenosine is a neurochemical, the level of which increases in the brain in relation to wakefulness; adenosine is proposed to promote sleep and to play a role in sleep homeostasis [66]. Compounding this, consuming caffeine in the afternoon or evening can be problematic as a single dose has a half-life between 3 and 7 h and so may inhibit the ability to fall asleep [65]. Energy drinks have received attention in recent years, in particular the trend for adolescent consumption. Caffeine is a major ingredient in energy drink products with between 70 and 240 mg in a 16 ounce drink and 113–200 mg in an energy shot [67]. More than two-thirds of 10- to 17-year-olds in the UK have been reported to consume energy drinks [68], while almost one-third of 12- to 17-year-olds in the USA regularly consume energy drinks [67]. Adolescents may consume caffeine to increase alertness, get through the day, and combat sleepiness [69]. A meta-analysis of 11 studies found that general caffeine consumption in adolescence had a small negative correlation with sleep duration but was not associated with bedtime or sleep onset latency [60]. To explain these findings, the authors proposed that adolescents who sleep less may be more likely to consume caffeine, but additionally have a higher sleep pressure that could counteract the alerting effects; therefore, bedtimes and the time it takes to fall asleep would not be affected.

4.4. What do adolescents say themselves?

Much research into adolescent sleep has used solely quantitative methods. However, adolescents were asked what they thought impeded their sleep in a number of recently published studies that included a qualitative approach [34,70]. A study in three US high schools used semi-structured interviews and surveys with 14- to 19-year-olds to investigate self-reported barriers to sleep [70]. The adolescents who took part reported an average weekday sleep duration of 7 h, 18 min and multiple contextual barriers to sleep. Regarding school, the most commonly reported barrier in the interviews related to homework (cited by 47%), while 67% reported that too much homework was 'sometimes' a barrier to sleep in the survey. Socializing with peers as a barrier emerged as a major theme in the interviews (19%), while 53% of students reported that 'socializing' was a barrier at least 'sometimes'. Extracurricular activities were said to be a priority and to regularly take up time after school (33%), and to be a barrier by 44% of participants in the survey. Also, 31% of those interviewed stated that watching television or online videos meant they went to bed later. Additionally, family influences and neighbourhood factors were reported to affect sleep.

A study in the UK included 33 students aged from 13 to 14 years, from two schools, in focus group discussions about sleep; one of the themes that emerged from the data was inhibitors to sleep [34]. The bedroom environment could be problematic due to temperature, noise and sharing a bedroom with a sibling. Light was a common inhibitor: for example, landing lights left on for younger siblings as well as technology-related lights (such as a laptop's standby light). Distractions delayed sleep onset and prevented sleep. Although all participants mentioned distractions related to electronic devices, gender differences were revealed. Girls were distracted by mobile phones, particularly through messaging on social media sites, whereas boys reported watching 'Netflix' on computers and participating in online gaming. Lastly, social pressures inhibited sleep. Mobile phone use at night involved social expectation and pressure according to girls, who also described how concerns about looking attractive might keep them awake or mean that they got up extra early to get ready.

5. School-based interventions

In recognition of the insufficient sleep experienced by adolescents and the importance of sleep for functioning and health, school-based initiatives at the organizational and classroom level need implementing. Our Teensleep research group has developed and evaluated such an initiative in an effort to improve adolescent sleep in the UK [71,72]. This work follows in the footsteps of sleep education interventions introduced worldwide: for example, in the USA [73], Australia [74,75] and Asia [76].

5.1. School start time change

Delaying the start time of a school aims to address the biological factors contributing to insufficient sleep and social jetlag, or in other words, the mismatch between adolescent sleep timing and early starts. The movement towards later school start times has received the greatest momentum in the USA, with work done by advocacy groups such as Start School Later and recommendations that middle and high schools should not start earlier than 08.30 [77]. The findings from three articles that have evaluated the body of evidence on delayed school start times are summarized here [78–80]. In a systematic review by Minges & Redeker [78], school start times were delayed by 25–60 min, while weeknight sleep duration correspondingly increased by 25–77 min in the six studies included. Additionally, some studies reported reduced daytime sleepiness, depression, caffeine use and tardiness to class. Bowers & Moyer [79] used a meta-analytic approach with five longitudinal and 15 cross-sectional comparison group studies and found that later school start times were associated with longer sleep durations, and in some studies, with less daytime sleepiness and tardiness to school. Wheaton *et al.* [80] reviewed 38 studies and concluded that most reported that delaying school start times increased weeknight sleep duration, primarily though the delay of rise times, as well as generally corresponding with improved attendance and grades, less tardiness and falling asleep in class, and fewer motor vehicle crashes.

5.2. Sleep education

Sleep education is an intervention that aims to address the psychosocial and lifestyle factors that may reinforce an evening chronotype and further delay sleep. Adolescents might be engaging in behaviours that are not conducive to sleep, whereas the adoption of good 'sleep hygiene' practices, such as maintaining a regular sleep schedule and a sleep-friendly bedtime routine, could be beneficial. Schools provide an environment where adolescents can receive information about sleep in the same way that they currently receive other important health and wellbeing information in the classroom. Sleep education programmes have focused on a variety and combination of goals, but in general, programmes aim to increase adolescents' understanding of the importance of sleep and to improve sleep health and related outcomes. According to reviews on the success of these programmes, sleep knowledge has largely been enhanced whereas sleep behaviour change has been limited [81–83]. Examples of sleep behaviour change have included improvements in sleep hygiene immediately following an intervention, although not at follow-up [73], and increases in sleep duration and a reduction in sleep onset latency [74]. The challenge faced in asking adolescents to change behaviours that might impact sleep was highlighted by a study that requested 14- to 18-year-olds to alter their mobile phone use for a week. Of the 240 adolescents approached, 40% volunteered to participate and only 26% provided data [62]. This reluctance to take part may be explained by adolescents' emotional attachment to their phones and suggests that increasing the motivation to change behaviour should be considered when working with adolescents. Recommendations to enhance the effectiveness of sleep education programmes have included adapting the programme for local use, assessing and addressing barriers and facilitators for programme implementation, tailoring it to developmental needs and improving sustainability by engaging multiple stakeholders [83].

6. Home-based sleep manipulation interventions

Experimental work utilizing protocols to increase adolescent sleep duration and manipulate sleep timing have shown promise outside the school environment [84,85]. Although adolescents have a propensity for late sleep, the ability to extend sleep through the introduction of earlier bedtimes is an interesting possibility that should not be overlooked. Van Dyk *et al.* [84] assessed a home-based, sleep manipulation protocol with habitually short-sleeping adolescents, defined as those sleeping 5–7 h on school nights. The research team took an individualized, problem-solving approach to extend participants' sleep. After it emerged that adolescents woke as late as they were able to get to school on time, shifting bedtimes earlier was prioritized. Following a baseline week of sleep measured using actigraphy, participants experienced two counter-balanced experimental conditions each for two weeks: habitual sleep, when sleep times were set to match baseline, and sleep extension, when time in bed on school nights was increased by 1.5 h from baseline. This study demonstrated that it was feasible to experimentally extend sleep for habitually short sleepers as the teenagers gained an average additional 72.6 min of sleep per night compared with their habitual sleep [84]. While this represents an encouraging finding, whether short sleepers are able to maintain this sleep improvement long term is still to be established.

As previously mentioned, school start times align better with the sleep/wake timing of a morning chronotype than an evening chronotype. Therefore, an intervention that successfully phase advances, in other words that shifts late timing to an earlier time, could be beneficial. Facer-Childs *et al.* [85] conducted a field study that aimed to phase advance the sleep/wake timings of an older adolescent sample (average age of 21.3 years) of late chronotypes, classified using the Munich Chronotype Questionnaire. The experimental group in this randomized controlled trial received an intervention schedule to follow for three weeks. This provided sleep hygiene instructions and targeted appropriately timed light exposure through earlier wake/sleep times, fixed meal times, caffeine intake and exercise. These participants demonstrated a phase advance of around two hours in sleep/wake timing post-intervention: a positive finding that suggests timing can be shifted in a real-world setting to align more closely to societal demands [85].

7. Future research and conclusion

Adolescents today face challenges that limit the amount of sleep they regularly get. Arguably, the influence of societal factors is pervasive, with the proliferation and habitual use of electronic media playing a significant role. More work is needed to assess the mechanistic pathways of the impact of electronic media use on sleep. Chronic short sleep is a key health issue to address due to the important role that sleep plays in so many aspects of our lives. However, it should be noted that other sleep and circadian variables are also being investigated as potentially influential factors: for example, sleep quality, sleep timing and regularity, and chronotype. Encouragingly, a movement towards identifying and introducing interventions to improve the sleep health of adolescents has been gaining momentum. Although evidence is mixed regarding the impact of these interventions, educating adolescents about how to sleep better seems intuitively an improvement over not facilitating their increased understanding. Sleep education programmes need to be developed and disseminated that are capable of inducing sufficient motivation in adolescents to alter the behaviours that may compromise sleep and to promote behaviours that may facilitate sleep. Furthermore, longitudinal studies would enable an evaluation into whether improvements following sleep education are maintained over time and whether those already sleeping well may be protected from developing poor sleep.

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