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Normal Sleep in Children and Adolescence

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Key points:

- Sleep plays an integral role in the health and wellbeing of children and adolescence, including physical health, immune function, mental health, and academic performance
- Sleep duration, architecture, and timing change significantly over the course of child development
- Several biological and psychosocial factors combine to result in a preference for later bedtimes across adolescence
- It's imperative that sleep is considered in the treatment of mental health concerns in children and adolescence

Synopsis:

Adequate sleep is essential for healthy development in childhood and adolescence. Healthy sleep contributes to good physical health, immune function, mental health, and academic performance. The regulation and architecture of sleep changes greatly across childhood and adolescence and the ability to obtain sufficient sleep is impacted by a range of factors that change with maturation. This paper describes normal sleep across childhood and adolescence and discusses some of the most common barriers to adequate sleep, including early school start times, technology use, and changes to circadian rhythms and sleep homeostasis across puberty.

Introduction/ Background

Sleep is imperative for the healthy development of children and teenagers. Compared to adulthood, childhood and adolescence are times of peak creativity, optimism,[2] and growth,[3] increased opportunities for extra-curricular activities, and greater social support.[4] However, adolescence has also been referred to as "the great and terrifying transition from childhood to adulthood"[5] and is an extremely important and complex period of development. A multitude of changes occur during adolescence, including puberty, hormonal changes, and social changes such as forging independence from parents and greater reliance on peers for social support.[6,7] It is a vulnerable period for mood disorders such as anxiety and depression[8,9] and is also a time during which children are likely to experience emotional pressure or bullying.[10] The teenage years are also important for physical health, especially weight status,[11] but also growth.[3] During adolescence, risk-taking increases, as does the importance of school performance.[12]

These factors are all intricately linked to sleep, which means it is imperative that healthcare practitioners are aware of the impact that sleep has on the physical and mental health of children and teenagers.

Impact of Sleep on Youth Health and Wellbeing

Insufficient sleep may result in poorer school performance and impaired safety

Sleep is imperative for several functions, including maintaining attention, learning, and academic achievement.[13-15] Being able to maintain attention and learn is extremely important during childhood and adolescence for many reasons including school achievement.

Many studies have found relationships between sleep duration and school achievement. Obtaining less than 8h sleep per night has been associated with a decrease in mathematics and language skills.[16] Wolfson and Carskadon[17] also found that those receiving C, D, or F grades at school reported on average obtaining 25 minutes less sleep on school nights and going to bed 40 minutes later than those getting A or B grades. While studies suggest a direct relationship between sleep and academic achievement, there may be indirect influences too. For example, previous research has suggested that eveningness preference,[18,19] lower learning motivation,[19,20] and lower socioeconomic status[21] may decrease the strength of the relationship between sleep and academic performance, and many studies do not take these potential effects into account. Regardless, most studies suggest that sleep restriction is likely to be associated with poorer school performance.[22]

Sleep is also imperative from a safety perspective, as adolescence is a time at which many learn to drive. When learning to drive, adolescents are at increased risk of accidents due to their relative inexperience with driving,[23] which when teamed with sleep loss-related attentional lapses, may result in an even greater risk of accident.[24]

Sleep may be related to physical health

Studies in both humans and animals suggest that the sleep-wake system and the immune system are linked,[25] with sleep helping to restore immune system functioning.[26] Perhaps unsurprisingly, insufficient sleep may result in decreased immune system function, including a weakened response to vaccinations and increased infection.[27] Dickstein and Moldofsky[28], in their review, concluded that sleep deprivation may result in changes in levels of hormones necessary for healthy immune function.

While there is a paucity of research conducted on the associations between health outcomes and sleep duration in healthy child populations, a few studies have investigated the immediate or possible

long-term associations between short sleep and health. For example, Orzech and colleagues[29] found that adolescents who obtained more sleep reported fewer illnesses than those who obtained less sleep across a 16 week period. Matthews and colleagues[30] found that there may also be longer term consequences, with shorter sleepers having higher levels of insulin resistance, which is associated with increased risk of cardiovascular disease[31] and diabetes.[32] Similarly, Klingenberg and colleagues[33] found a reduction in insulin sensitivity, which has been linked to increased risk of type 2 diabetes, in healthy adolescent males after only three nights of sleep restriction. Further, sleeping less than eight hours per night has been associated with decreased physical activity,[34] which is important for several reasons, from increasing resting metabolic rate, to improving blood glucose levels and protecting against chronic illnesses.[35]

Insufficient sleep has also been associated with greater risk of injuries and increased sedentary behavior. In a study of adolescent athletes, Milewski and colleagues[36] found that insufficient sleep increases the risk of sports injuries. Together, these results suggest that poor sleep in childhood and adolescence could be associated with increased risk of both acute and chronic illness. However, a large-scale study of sleep and health in children and adolescents is yet to be conducted.

Poor sleep is associated with mental health concerns

Childhood, and adolescence in particular, is a vulnerable time for mental health disorders.[8,9] Early intervention for sleep problems is key, with evidence showing that sleep problems as a toddler can predict anxiety and depression in adolescence.[37] Several environmental changes occur during adolescence, as teens forge independence from their parents and rely more on social interaction with their peers.[6] This greater reliance on social interactions may make teens vulnerable to the impact of bullying,[10] which can affect an adolescent's mood and sleep.[38,39] This is a time of life when there is increased pressure to perform well at school, be involved in many extracurricular and social activities, and gain employment,[40] which can lead to increased risk of mental disorders, as can changes in hormonal levels during adolescence.[8,41]

Sleep is a factor which has been consistently related to mood and mental health in adolescence. Several studies have found associations between short sleep and depressed mood. Ojio and colleagues found that the lowest risk of depression and anxiety was in males who slept 8.5 hours or more and in females who slept 7.5 hours or more on school nights.[42] In a longitudinal study assessing sleep and mental health, Fredriksen and colleagues[43] found that adolescents who slept less had higher levels of depressive symptoms. Similarly, positive correlations have been found between sleep problems and

depressive mood and anxiety.[44] Insufficient sleep has also been found to influence adolescents' ability to deal with stressors, such as bullying, further impacting mental health.[39]

Studies have also found associations between sleep duration and suicidal thoughts and self-harm behaviours.[45] McKnight-Eily and colleagues[34] found that obtaining less than eight hours of sleep per night was associated with greater odds of feeling sad or hopeless and seriously considering attempting suicide. Similarly, voluntary sleep curtailment has been correlated with increased suicidality, even after controlling for depression scores.[46] Poor sleep quality and duration has also been related to emotional and peer related problems, anxiety, conduct issues, and suicide ideation.[47] Using sleep extension and restriction protocols, experimental studies have supported the findings of these naturalistic studies, showing that adolescents suffer from reduced mood and greater emotion regulation problems during periods of sleep restriction.[48,49]

Insufficient sleep can also impact physical and mental health indirectly, via behavioral factors. A study by Owens and colleagues[50] found that decreasing amounts of sleep were associated with increasing odds of risk behaviors, such as antisocial behaviors, drug use, and gang involvement. Further, Weaver and colleagues[51] found that, compared to adolescents who obtained more than 8 hours of sleep, those who obtained less than 6 hours of sleep were approximately twice as likely to engage in risky driving, marijuana, alcohol, and tobacco use, risky sexual behavior, and aggressive behaviors. Alarmingly, this likelihood increased to over three times for considering or attempting suicide and making a suicide attempt plan. These findings suggest that both direct and indirect impacts of poor sleep may have negative consequences for children and adolescents.

In sum, the existing research strongly suggests that sleep is crucial for academic performance, and physical and mental health. The following section will describe what can be considered 'normal' sleep, how this differs across childhood and adolescence, and the common barriers to healthy sleep.

Sleep Changes across Child Development

Sleep Architecture

Differences occur in the structure of sleep with age. For the first 16 weeks of life, sleep has little to no structure, with infants sleeping around the clock.[52] From 16 weeks, sleep begins to adhere to a more diurnal, consolidated nighttime pattern, but with frequent naps throughout the day.

The two main stages of sleep for infants are referred to as quiet sleep and active sleep. Quiet sleep is characterized by even respiration and discontinuous electroencephalography (EEG) pattern in infants and

turns into non-Rapid Eye Movement (NREM) stages of sleep as the infant matures. By 6 to 9 weeks of age, NREM begins to differentiate into light (stage 1 and 2) and deep (slow wave sleep; SWS) sleep, and by 2 to 3 months of age, the sleep spindles characteristic of stage 2 sleep appear. Active sleep is characterized by uneven respiration, muscle atonia, continuous EEG pattern, rapid eye movements, sucking movements, and twitches. This stage of sleep matures into Rapid Eye Movement (REM) sleep.

Figure 1 displays a typical sleep period in childhood (A) compared to adulthood (B). In adulthood, a sleep cycle typically lasts 90 minutes and includes a period in each stage of sleep. During early childhood, the percentage of REM sleep is often higher than during adulthood, at roughly 30% compared to 20-25% in adulthood, and sleep cycles are often shorter, at approximately 60 minutes compared to 90 minutes in adulthood.[53] Further, during early childhood, the amount of time spent in slow wave sleep (SWS) is often longer compared to during adulthood.[53] Throughout childhood, changes in sleep staging and cycles occur, predominantly in reductions in percentages of REM sleep and SWS. This reduction of REM sleep and SWS makes way for the increase in stage 1 and 2 sleep characteristic of adult sleep. Some suggest that by early adolescence sleep patterns often mirror those of mature adults.[53] However, others show continuing alterations in amount of time spent in SWS, across development from preadolescence through adulthood.[54] Higher amounts of REM sleep and SWS across childhood and adolescence may reflect higher rates of growth, development, and learning during these periods.[53]

Sleep Duration

Sleep duration also changes across the course of childhood. In infancy, children sleep approximately 12 hours to 16 hours across the 24-hour period, including 1 nap to 2 naps per day. The daytime nap(s) are lost for most Western children between the ages of 3 years and 5 years, which corresponds with children beginning kindergarten and school. With the loss of this nap, total sleep duration decreases, as nighttime sleep duration remains stable. During the school years and across adolescence, sleep duration continues to decline (see table 1 for sleep duration recommendations).

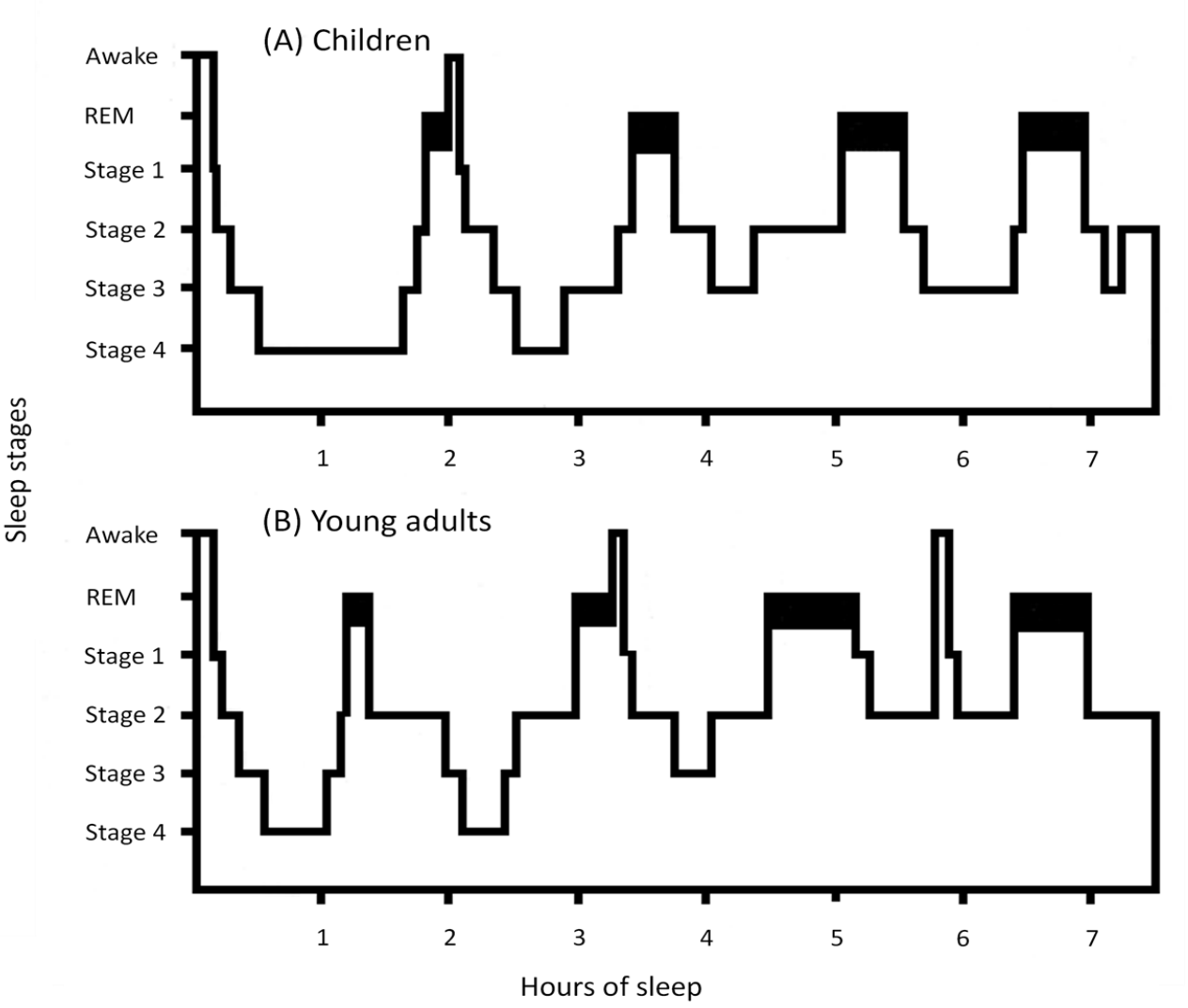


Figure 1. A typical nocturnal sleep period for children (A) and young adults (B). Adapted from[1]

Table 1. Sleep duration recommendations.[55]

Age	**Recommendation per 24h**
Infants (4-12 months)	12-16h
1-2 years	11-14h
3-5 years	10-13h
6-12 years	9-12h
13-18 years	8-10h

The Two Process Model of Sleep: Biological and Behavioural Changes in Adolescence

While some changes to sleep timing and duration occur from infancy to early childhood, arguably the most meaningful changes occur during puberty. The processes controlling sleep regulation change drastically in adolescence. Sleep is regulated by both homeostatic and circadian factors. The circadian rhythm interacts with homeostatic sleep pressure to regulate the sleep/wake cycle in humans.[56] While homeostatic sleep pressure increases throughout the day (with increased time awake), the circadian rhythm works to keep one active and alert until the night, helping humans to maintain optimal sleep/wake alignment with the environmental patterns of dark/light.[56]

Sleep homeostasis

Homeostasis refers to an organism's tendency to maintain stability and equilibrium.[57] Sleep homeostasis – or the drive for sleep - is dependent on sleep/wake processes, as homeostatic sleep pressure rises during wake and declines during sleep.[56] This pressure increases the propensity for sleep, increasing the likelihood that a person will fall asleep.[56] When sleep is delayed, there is a continued increase in the propensity for sleep until sleep occurs, at which point the homeostatic sleep pressure declines until waking. When deprived of sleep, the subsequent sleep is often longer and deeper than typical in order to dissipate sleep propensity.[58] SWS (i.e., deep sleep) is considered a measure of homeostatic sleep pressure, as SWS declines throughout a sleep period, regardless of the timing of sleep onset,[59] suggesting a homeostatic, rather than circadian, process. SWS also increases during recovery sleep after periods of sleep deprivation.[60]

Several cross-sectional studies have shown that there is a decline in SWS as teenagers mature[61] and that the accumulation of sleep drive across the day becomes slower with maturation.[62,63] This suggests that more mature adolescents may take longer to accumulate a sufficient sleep drive over the day than younger adolescents, meaning that older adolescents are less likely to want or need to fall asleep until later in the evening. The reduction in the rate of build-up of sleep drive across the day may encourage later bedtimes in more mature teens.[63] While the later drive for sleep can impact bedtimes, the dissipation of this drive for sleep across the sleep period remains stable across adolescence.[64] This suggests that although adolescent sleep is pushed later, the need for sleep is unchanged. However, it is not only the changing homeostat that promotes later bedtimes during adolescence; the primary factor that pushes bedtimes later is the changing circadian system.

Circadian rhythms

Many of the body's biological processes, including sleep and wakefulness, body temperature, and hormone levels, fluctuate according to a circadian rhythm, [65] that is, over roughly 24 hours.[66] Because

circadian rhythms often run on a slightly longer than 24-hour period, with adolescent studies finding them to be approximately 24.3 hours,[67] they need to be externally reset each day. This is predominantly achieved by exposure to light, which is a major 'zeitgeber', or time giver, for the body's circadian rhythms.[53] Melatonin is a hormone with a strong 24-hour rhythm and provides an indication of circadian timing. Melatonin secretion begins just prior to the onset of sleep and ceases around wake up time.[68] As such, melatonin is often considered to be a sleep promoting hormone[69] and changes in the timing of melatonin onset are considered effective markers of circadian phase[70,71], which is known to shift during puberty (see Figure 2).

Several studies have found that melatonin secretion delays across adolescence. For example, using Dim Light Melatonin Onset (DLMO) as a measure of circadian phase, Crowley and colleagues[72] found that older adolescents had a later DLMO than younger adolescents. In addition to the slower build-up of homeostatic sleep drive, this later melatonin onset time in more mature teenagers facilitates later sleep onset times and makes it difficult to fall asleep early in the evening and rise in the mornings.

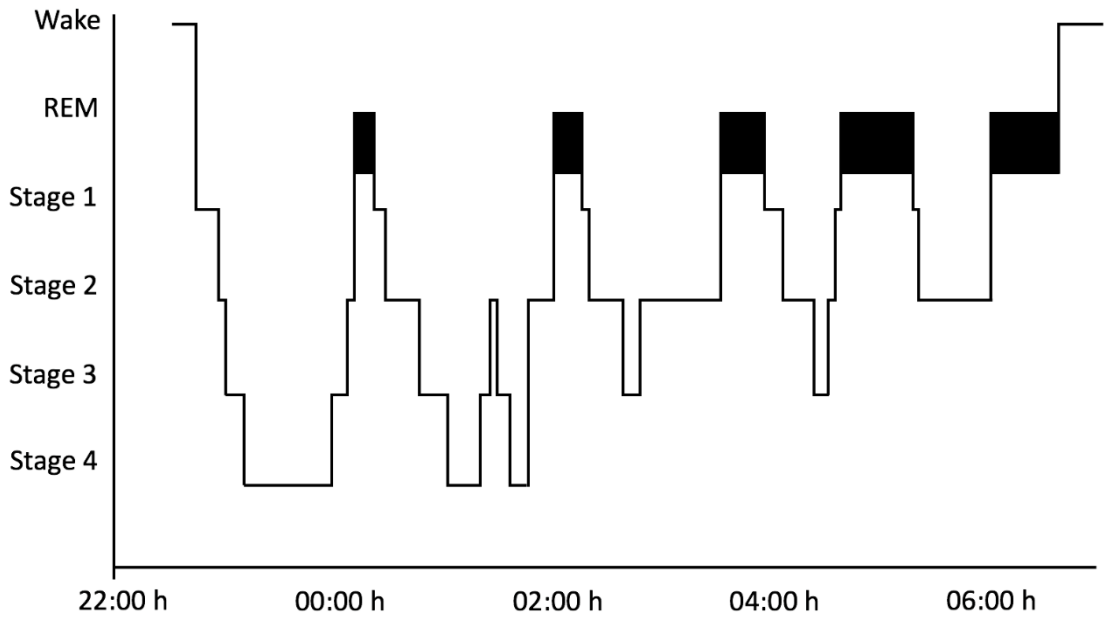


Figure 2. Schematic displaying timing and patterns of sleep stages across a nocturnal sleep period. Y-axis shows each stage: Wake = wakefulness, REM = Rapid Eye Movement, X-axis shows time (24h clock) across the night. The line shows a typical adult sleep period, with five successive cycles of sleep consisting of four non-REM stages and REM sleep.

Psychosocial Barriers to Sleep Across Childhood and Adolescence

There are many psychosocial factors that may prevent good sleep among youth and lead to abnormal sleep patterns in the long-term. In younger children, the major factor contributing to changes in sleep patterns is starting school. As mentioned, the start of schooling usually results in the end of daytime napping, which can be problematic if nighttime sleep duration doesn't increase. Normal sleep routines may also be more difficult to achieve for children in chaotic households[73] and those whose guardians have less parental control.[74] Despite these barriers to normal sleep in children, the most significant changes and barriers to normal sleep manifest during the transition into adolescence.

Social barriers

In conjunction with biological changes, social factors, such as increased freedom from parents and after school employment also contribute to later bedtimes during adolescence.[43,75,76] Adolescents also face an increase in demands across multiple life domains. For example, after school, teenagers need to complete increasingly complex homework, as well as being involved in extracurricular activities[77], spending time with friends, and potentially gaining part time employment.[75] These factors can push bedtimes later and contribute to difficulties obtaining adequate sleep before attending school early in the morning.

School Schedules

Later bedtimes alone may not necessarily be a problem, especially given the later circadian rhythms of teens. It seems there are physiological allowances for later bedtimes during adolescence, so later bedtimes may be beneficial rather than detrimental, especially for sleep quality.[78] However, later bedtimes may become a problem when we consider school schedules. In the US especially, when the average school start time is before 08:00 AM[79], adolescents' sleep is truncated by the need to wake early in the morning for school attendance.[80] Studies frequently find sleep durations that are below the recommendations[17], and highlight that sleep restriction may begin in early adolescence and increase over time.

Social jet lag refers to a phenomenon whereby a person's internal clock (one's circadian rhythm of sleep and wake) is not in alignment with his or her external clock (the external light/dark cycle).[81] In adolescents this means that circadian pressure to stay awake later in the evening is not synchronised with factors that typically forces them to rise early for school.[81] Compared to school days, on weekends and school holidays adolescents both delay and lengthen their sleep to catch up on their restricted sleep across the school week.[82] This social jet lag can make falling asleep on Sunday nights more difficult when teens opt to sleep later on Sunday mornings, leading to them not being awake for long enough to build

up a sufficient sleep drive by Sunday night. This means that teenagers are unlikely to be able to obtain enough sleep on Sunday night to be well rested for school on Monday.[83] Combined with potentially restricted sleep throughout the week as a result of school start times, many adolescents are facing Monday mornings at school in a significantly sleep deprived state.

There are also safety implications for adolescents who drive to school, with studies having found that areas of the United States with later school start times have fewer teen motor vehicle accidents.[84-86]

Technology Use

The biggest threat to adequate sleep today is overuse of technology. Greater access to technology can also result in later bedtimes, with children choosing to be in contact with friends, watch television or movies, or play computer games until later in the evening.[77] In America, 75% of children have at least one electronic device in the bedroom, and 16% report reading or sending messages after initially going to sleep.[87] Several studies have found that access to digital devices in the bedroom leads to significant reductions in sleep quantity and quality in children.[88-91]

Nighttime technology use disrupts sleep through two pathways. Firstly, the bright, blue-wavelength light emitted from mobile phones, laptops, and tablets can delay sleep onset by suppressing the release of melatonin.[92] This is especially problematic for adolescents, who already have a biological tendency towards delayed circadian rhythms.[93] Secondly, technology use can increase physiological arousal.[94] When this occurs in the evening, the hormonal processes involved in the onset of sleep, for example a decrease in cortisol and an increase in melatonin, can be altered, leading to a state of hyperarousal which makes it difficult to 'wind down'.[95] Social media use at night has also been related to shorter sleep duration, reduced sleep quality and mental health[96], as well as poorer academic outcomes.[97]

Setting boundaries surrounding technology use in the evening and limiting technology in the bedroom can be beneficial, with a recent study finding that children who reported having rules at home about restricting technology use at certain times were more likely to report earlier weekday bedtimes.[98] Refraining from using devices for even one hour before bed may improve sleep duration.[99] However, further interventions on nighttime technology use and sleep are needed to assist parents with providing clear guidelines on technology use in the evenings.

Summary

This paper has identified some of the common effects of disturbed sleep and some of the barriers to healthy sleep across childhood and adolescence. Several factors combine to influence adolescent

sleep patterns. Biological changes, environmental and social factors interact to result in the facilitation of later bedtimes, while school start times force early awakenings. This truncation of sleep can result in sleep deprivation? in this age group, as studies show that although sleep duration is reduced, the *need* for sleep does not decrease throughout adolescence. Sleep restriction can have many negative consequences for daytime functioning and health, including poor performance, increased sleepiness and weight gain, as well as changes in mental and physical health. Further research must be conducted in younger children, especially with an increase in technology use in primary school aged children.

Clinical Care Points

- Psychoeducation on sleep health (e.g., recommended sleep duration) is important for maintaining normal sleep across childhood, especially in primary years
- Sleep and mental health are intrinsically linked; greater patient care could be provided by practitioners including questions about sleep when children and adolescents present with mental health symptoms. Improvements to sleep behaviors/patterns may result in lessened mental health concerns.
- Reduced academic outcomes and poorer mental health during adolescence may impact quality of life across adulthood, so early intervention in these areas is imperative to promote outcomes across the lifespan
- Technology use should be limited in the evening hours; guidelines should be set by parents to minimize technology use in the hours before bed and in the bedroom

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