Optimal sleep and circadian habits in infants and children

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Glossary

Optimal sleep habits Optimal sleep habits are those that support infants and children in meeting their sleep need and maintaining wakefulness at appropriate times, in association with high quality concurrent and long-term health, developmental, and familial outcomes.

Sleep hygiene Good sleep hygiene practices include stable bedtime and wake times (including naps for infants and young children), avoidance of caffeine, no media sources in the bedroom, and a calm, consistent bedtime routine.

Two-process model of sleep regulation A theoretical model proposing that the interaction between a sleep/wake dependent homeostatic Process S and a 24-h intrinsically regulated circadian Process C determine sleep duration, sleep/wake timing, and sleep intensity.

Introduction

Sleep is a basic biological need and one of the most common problems reported by parents in children. Determining whether the sleep habits of infants and children are optimal is a complex undertaking. The most basic definitions of optimal are "most desirable" or "satisfactory." In young humans, we are compelled to ask for whom and for what reason are sleep habits desirable or satisfactory. Many possible answers to these questions exist, as the sleep habits of one child may not be ideal for another. Additionally, the functional relationships between sleep and different outcomes may vary based upon what dimension of sleep is measured, including its duration, timing, quality, and intensity.

The discussion of optimal sleep habits in infants and children is approached by taking the following theoretical, empirical, and ecological considerations into account. First, well-known individual differences in sleep exist (Iglowstein et al., 2006; Jenni et al., 2006). Second, sleep has many proposed functions, including a reduction in energy demands, facilitation of information processing and synaptic plasticity, and restoration of key cellular processes. Third, although daytime sleepiness is considered a hallmark feature of nonoptimal sleep in older children, adolescents, and adults, it is an appropriate behavior for infants and young children who meet part of their sleep need through a poly- or bi-phasic sleep schedule. Finally, because young humans have little-to-no control over their sleep environment and sleep schedule, their sleep habits both depend upon and affect their adult caregivers (e.g., parents, daycare workers, family members). From a transactional perspective, these complex interactions are central to determining a child's developmental standing in terms of physical health, growth, adaptability, psychological functioning, and learning. Thus, we define optimal sleep habits as those that support infants and children in meeting their sleep need and maintaining wakefulness at appropriate times, in association with high quality concurrent and long-term health, developmental, and familial outcomes.

Few studies have directly examined the benefits of optimal sleep habits in infants and children using well-controlled experimental protocols involving sleep restriction or sleep extension. Instead, the majority of studies have examined outcomes (e.g., emotional/behavioral problems, attentional disorders, and overweight/obesity) as a function of variations in sleep with the hypothesis that children who get less than normal amounts of sleep or those who get poor quality sleep will show decrements in comparison to those getting more or better sleep. Findings from a growing number of cross sectional and longitudinal reports shine some light

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on understanding the role of early sleep habits in the development and maintenance of poor physical and mental health outcomes at later ages. Another line of research informing our understanding of optimal sleep habits in the early years is intervention studies of children with clinical sleep problems such as sleep-onset delay, bedtime resistance, and prolonged nighttime awakenings. We draw upon a culmination of such research findings in the current review of optimal sleep habits in infants and children.

We first present two theoretical models central to conceptualizing and studying optimal sleep in infants and children. Second, we present data on developmental changes in sleep and rhythms in the first decade of life. Third, we address the question of "optimal sleep for whom?" including a review of individual differences in sleep, and the cultural context of sleep. We then focus on the question of "optimal sleep for what?" by discussing empirical findings linking sleep to health and development. Next we address the question "what environmental factors influence optimal sleep?" Finally, we provide a review of empirically supported treatments and recommendations for optimizing sleep in infants and children.

Models for conceptualizing and studying optimal sleep in infants and children

The goodness-of-fit perspective

Optimal sleep habits in infants and children may be conceptualized using the "goodness-of-fit" framework, which is an integrated application of the nature and dynamics of interactional/transactional processes. First proposed by Thomas and Chess in 1977, this model suggests that early behavioral attributes are best understood within the context of intrinsic child-related factors (i.e., biological capabilities and individual difference characteristics) in their interaction with extrinsic factors (i.e., environmental demands, opportunities, and stressors) (Chess and Thomas, 1991; Thomas and Chess, 1977). Consonance with the environment, or a good fit, occurs when the organism's capacities, motivations, and behavioral style are in agreement with the demands and expectations of the environment. Conversely, a poor fit results from dissonance between the organism's capacities/characteristics and the opportunities and demands of the environment. While consonance leads to optimal development, dissonance results in maladaptive outcomes. When applied to children's sleep behaviors, goodness-of-fit refers to the match between bioregulatory sleep capabilities (i.e., dynamics of sleep homeostasis and properties of the circadian system) and social/familial sleep-related expectations, opportunities, and demands; see Fig. 1: Goodness of Fit Model of Sleep Behavior in Development (Jenni and Lebourgeois, 2006).

The two-process model of sleep regulation

Current theoretical models suggest that sleep is regulated by two intrinsic physiological processes, a sleep–wake dependent homeostatic process (Process S) and a clock-like circadian process (Process C) (Borbély, 1982). Process S accounts for the accumulation of sleep pressure with prolonged wakefulness and for its dissipation during sleep. Process C contributes to sleep regulation via signals from the master clock (suprachiasmatic nuclei) of the anterior hypothalamus, which oscillates in a near 24-h cycle. Thus, Process C promotes arousal during the daytime and sleep during the night. The increase in homeostatic pressure during wakefulness is thus opposed by the increase in circadian alertness across the day, thereby allowing for maintenance of relatively constant levels of arousal throughout the waking episode. In the late evening, sleep propensity is facilitated by the combination of high homeostatic sleep pressure and an increase in circadian sleep tendency, thus producing a "sleep gate." During the night, an increase in circadian

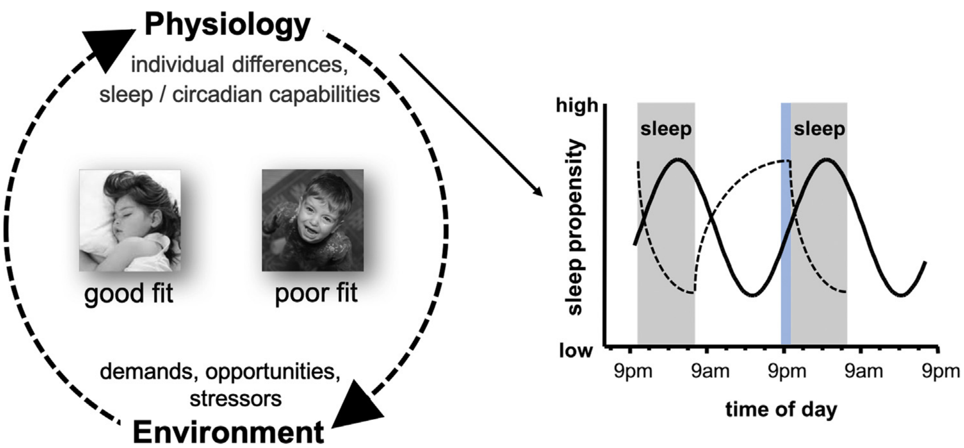

Fig. 1 Goodness of fit framework (left panel) and two-process model of sleep regulation (right panel). Sleep behavior is best understood as an interaction between physiology and environmental factors. The two-process model of sleep regulation guides the study and understanding of sleep and circadian capabilities The *dotted line* represents the sleep-wake dependent homeostatic Process S and the *solid line* represents the 24-h clock like circadian Process C. The "sleep gate" resulting from high homeostatic sleep propensity and an increase in circadian sleep tendency is shown as the *blue bar*.

sleep tendency counteracts the declining homeostatic sleep pressure to ensure sleep continuity. The interaction of both processes plays an important role in determining levels of alertness and sleep tendency across the 24-h day, although these processes are not fully developed in infancy and childhood.

What is known about the bioregulatory sleep capabilities of infants and children?

Studies of the bioregulatory sleep capabilities of adolescents, adults, and the elderly are growing; findings suggest that developmental changes and individual differences in the interaction of Process S and Process C influence optimal sleep, as well as behavioral and physiological processes. For example, misalignment between the timing of the circadian system and sleep impacts physical and psychiatric disorders in adults (Baron and Reid, 2014). Furthermore, across pubertal development, attenuation in the build-up of sleep pressure during the day and a delay in the timing of the circadian system lead to later bedtimes, increased difficulties falling asleep, problems waking in the morning, and daytime sleepiness (Crowley et al., 2018).

During the past few decades, research on the development of the homeostatic and circadian systems in infants has produced exciting findings. Following birth, infants have a poly-phasic sleep pattern, with random periods of wakefulness and sleep across a 24-h period. Longitudinal work following infants during the first 9 months shows sleep is homeostatically regulated in infancy, with an increase in sleep intensity and sleep time following periods of prolonged wakefulness (Iglowstein et al., 2003). The dynamics of sleep homeostasis are very fast in infants, thus accounting for their difficulty in sustaining wakefulness and the need for multiple sleep periods across a 24-h day (Jenni et al., 2004). With regard to the circadian system, the master biological clock begins developing in utero and receives biological time cues from the mother through the placenta. Post birth, the master clock continues to develop throughout the first two years of life (Swaab et al., 1990). During this sensitive period, the clock receives input from environmental time cues through light (Mirmiran et al., 2003) as well as maternal time cues via diurnally fluctuating hormones present in breast milk (Hahn-Holbrook et al., 2019). As the clock matures, overt biological rhythms begin to appear across the first year of life. The circadian rhythm of core body temperature emerges at 6 to 12 weeks of age and increases during the first few months of life. Day–night rhythms in melatonin can be detected by the age of 12 weeks, and circadian rhythms in cortisol appear between 8 and 12 weeks (McGraw et al., 1999). Interactions between brain maturational processes and social/environmental cues influence development of the circadian system in the first few months of life, thereby leading to greater organization of wakefulness and sleep. Currently, the internal circadian period and circadian phase measured by the dim-light melatonin onset (DLMO) of infants are unknown. Further research is needed to establish how such features of the circadian system change in the first year of life and how they are associated with individual differences in maturing sleep patterns and health and developmental outcomes.

Research on the homeostatic and circadian processes in children between 1 and 10 years of age is scant. Longitudinal and cross-sectional data, however, do provide evidence of differences in homeostatic control across early childhood. First, overall sleep duration declines, which is primarily attributed to a reduction in daytime sleep. Second, daytime naps drop out in frequency. Third, nap sleep-onset latencies increase. Finally, toward the end of the process of consolidating sleep into one nighttime period, children show a tendency to nap at later and later times in the day. If maturational changes in homeostatic control exist during early childhood, it is likely that younger children accumulate sleep pressure more rapidly than older children, thereby necessitating daily daytime naps and accounting for shorter nap sleep-onset latencies (LeBourgeois et al., 2012). The optimal stage of development for a child to drop their nap is variable and dependent on a complex interaction between endogenous homeostatic sleep processes and extrinsic factors such as parental and daycare/school schedules, and family demands. However, for most young children, the process of dropping naps results in inconsistent periods of prolonged wakefulness and acute sleep restriction that can influence their nighttime sleep. In toddlers who miss their daytime nap, nighttime sleep onset latency is decreased and nighttime sleep duration is increased compared to a night following a daytime nap, suggesting that the transition from a polyphasic to a monophasic sleep challenges the developing homeostatic system (Lassonde et al., 2016).

With regard to circadian rhythms, recent findings suggest that the circadian phase in toddlers, as assessed with salivary DLMO, occurs at about 19:30 (LeBourgeois et al., 2013a), which is approximately an hour before that of prepubertal children (Crowley et al., 2014). Additionally, 2–3-year-olds have a shorter interval between melatonin onset and parent-selected bedtimes (~30 min) than school-age children (~70 min). A shorter interval between DLMO and bedtime is associated with increased parent reports of bedtime battles and sleep-onset latency (LeBourgeois et al., 2013b). Napping may also play a role in the developing circadian system. Compared to non-napping toddlers, napping toddlers have later evening melatonin onsets, later bedtimes, and longer sleep onset latencies (Akacem et al., 2015). The delayed bedtime in napping toddlers likely results from an increase in evening light exposure, which leads to a delayed internal clock and evening rise in melatonin.

Fully understanding optimal sleep habits in infants and children will necessitate a more comprehensive picture of the interaction between Process S and Process C across the first decade of life. Many questions remain. For example, when is it optimal for infants to shift from a polyphasic sleep schedule to a two-nap-a-day schedule? How do maternal and environmental time cues influence the developing clock? When is it optimal for children to give up naps and consolidate sleep into one nighttime period? What is the best approach for the phasing out daytime naps? How do the homeostatic and circadian systems interact to influence sleep problems, such as bedtime resistance, sleep-onset delay, prolonged night wakings, and difficulties waking in the morning? In reality, the answers to such questions will always include an "it depends" clause, due to biologically based individual differences and the demands, opportunities, and stressors in a child's environment. Embracing a child-focused approach is crucial to identifying the most satisfactory sleep habits in infants and children.

Developmental changes in the sleep of infants and children

Remarkable changes in sleep exist across the first decade (Iglowstein et al., 2006). On average, newborns sleep for about 15–17 h every 24-h cycle with many phases and with no difference between nighttime and daytime sleep. At 3 weeks of age, the average longest sleep period is just over 2 h for most infants. As the infant matures, sleep is more consolidated; there is a distinct sleep–wake cycle, where sleep happens mainly at night allowing the infant to be awake for longer and longer periods during the day. At 6 months of age, the average longest sleeping period is almost 6 h. During the next few months, the polyphasic sleep pattern of infants becomes more stable, including a nighttime sleep period with a morning and an afternoon nap. By 12 months, an infant will sleep around 14 h, where 10–12 of these will be at night. By 22 months, most infants have dropped their morning nap. Between 2 and 5 years of age, afternoon naps gradually disappear such that sleep is consolidated into one single night-time period, with a total of 11–13 h of sleep in a 24-h duration. Average sleep duration is decreased to around 10 h by 8 years of age, which is maintained until the end of the first decade of life. At this time, children show adult-like sleep cycles due to increased maturation of their sleep and circadian systems.

"Optimal sleep for whom?" – individual differences, culture, and the family

Defining optimal sleep habits is best considered in the context of individual differences, culture, and the family (Jenni and O'Connor, 2005). Within the context of developmental trends previously discussed, sleep shows dramatic intra- and interindividual differences across childhood, with infancy being the period of most extreme variation. For example, one newborn may sleep as few as 10.5 h, while another sleeps for 22 h. Over the first 6 months of life, the average sleep duration per 24-h day decreases from 14.8 to 13.9 h; however, individual sleep durations range from 7 to 21 h. To some extent, older children also demonstrate variability in sleep duration. As with adult long and short sleepers, this variability suggests that individual differences in children's sleep need and bioregulatory sleep mechanisms influence their sleep patterns. Variability in the age at which children stop napping and consolidate their sleep into one nighttime period also exists. Some have proposed that the cessation of napping may be a marker of brain development associated with attenuation in the accumulation of homeostatic sleep pressure across early childhood.

In addition to sleep need and bioregulatory sleep mechanisms, research demonstrates that the variability in childhood sleep patterns can be partially explained by other individual differences, including race/ethnicity, socioeconomic status (SES), and culture. For example, findings indicate that in the United States White children stop napping earlier than Black children (Crosby et al., 2005), and a systematic review of the napping literature demonstrates that between the ages of 2 and 8, White children nap less and for significantly shorter durations than Black children (Smith et al., 2019). Alternatively, a review of the literature on nighttime sleep duration, demonstrates racial and ethnic sleep disparities in US such that White children tend to have longer sleep duration and earlier bedtimes than Black and Hispanic children (Guglielmo et al., 2018). With respect to SES, a systematic review examining the relationship between neighborhood SES and sleep in the United States and Australia found that poorer SES was associated with shorter sleep duration (Tomfohr-Madsen et al., 2020). These differences in napping and nighttime sleep are not fully understood, but researchers have suggested they could be due to a number of factors. Some examples include differences in awareness of the tendency for an afternoon nap in children and/or their caregivers cultural or family-related differences in attitudes about the importance of napping and consistent bedtimes, or differences in conditions of the physical sleep environment when examining SES (Bagley et al., 2015).

Because the sleep habits of infants and children are largely determined by their parents, culture is an important consideration in identifying what is optimal. For example, in some tribes, sleep schedules include both daytime and nighttime sleep with periods of night wakefulness including talking, playing, and other social interactions. In Mayan culture, there is no such thing as a "bedtime" for children or infants. Children and infants simply fall asleep when they are sleepy, usually in someone's arms or when they are taken to bed along with a parent (Morelli et al., 1992). Culturally guided sleeping habits are seen in Western countries as well, such as in Italy where it is common for children to participate in family evening life including late dinners (Giannotti et al., 2005), and fall asleep in a stroller or in someone's lap. In comparison, children raised in the Netherlands are much more likely to have rigorous sleep schedules, including relatively early bedtimes (Owens, 2004). It is important to remember that sleep habits determined by the family and culture may not be a good fit for an individual child. In other words, if culturally defined expectations of when and how infants and children are to sleep are not in harmony with their individual sleep and circadian physiology, it may be difficult for them to obtain optimal sleep (Jenni and O'Connor, 2005).

"Optimal sleep for what?" – health and developmental outcomes

Well-controlled experimental studies examining the consequences of not getting enough sleep or the benefits of getting more sleep in the first decade of life are growing but still scarce. Current protocols with infants and toddlers have utilized acute "nap deprivation" as a means to challenge the sleep system, making comparisons on a number of measures between nap and no-nap days. For example, findings in infants suggest that naps facilitate abstraction, which is important for the developing cognitive system (Gómez et al., 2006). Furthermore, these data indicate infants need to nap within 4 h of learning to obtain and recall information. Thus, infants appear to need frequent daytime sleep periods to encode and consolidate the steady stream of information they are presented with on a daily basis. Additionally, naps support declarative learning in preschool-aged children. Children demonstrate better recall of both visuospatial and episodic information following a nap compared with an equivalent wake period (Kurdziel et al., 2013; Lokhandwala and Spencer, 2020). Nap deprivation can also challenge children's emotion regulation. In toddlers, findings suggest that reduced sleep in the form of missing a nap produced a significant decline in the % time children facially expressed happiness, interest, and excitement when presented with a fun puzzle task compared to when they napped (Berger et al., 2012). Missing daytime sleep also significantly increased the % time children expressed negative emotion (primarily anxiety) and resulted in less-mature self-regulation strategies, such as self-soothing and negative self-appraisal, during a challenging unsolvable puzzle task (Miller et al., 2015).

In school-age children, a handful of experimental studies have used chronic (5–7 days) sleep restriction (delayed bedtime and/or early wake time) and/or sleep extension of about an hour to understand changes in health and behavior. For example, children assigned to decrease their time in bed by 1.5-h per night for 1 week had higher food intake, higher fasting leptin levels, and higher weight compared with children who increased their time in bed (Hart et al., 2013). Further, three nights of truncating sleep by 1 h produced not only more consolidated nighttime sleep, but also increased reports of tiredness and significantly poorer neurobehavioral functioning (Sadeh et al., 2003). Findings also show that after six nights of a 1-h bedtime delay, children, with and without attention deficit hyperactivity disorder (ADHD), had decrements in neurobehavioral functioning, with the ADHD group deteriorating from subclinical to clinical levels of attention (Gruber et al., 2011). Finally, in comparison to 1 week of optimized sleep duration, sleep restricted children of school going age were reported by their teachers to have poorer academic functioning and increased attentional problems (Fallone et al., 2005). Such findings provide strong evidence that optimal sleep duration plays an important role in how children attend to, learn from, and respond to their world, as well as how their bodies change physiologically.

Data are accumulating from cross-sectional and longitudinal research of health and developmental outcomes in infants and children who obtain insufficient sleep or have sleep disturbances. For example, a recent longitudinal study of 6- to 36-months over 5 time points found that sleep consolidation (daytime relative to nighttime sleep) was associated with language development, such that sleep partially mediated the association between SES and vocabulary skills (Knowland et al., 2021). Further, data from a longitudinal study of over 3500 toddlers showed that those who obtained the recommended sleep amount (11–14 h) scored higher than those obtaining less or more sleep on a standardized measure of cognitive development when assessed 4 years later (Kocevska et al., 2017). Also, in a sample of school entry students, 40% had reported sleep problems, which were associated with emotional, conduct, and peer-related problems (Quach et al., 2012). Just as in adolescents and adults, insufficient and disrupted sleep in childhood is a hallmark of childhood psychiatric disorders, such as ADHD, anxiety, autism, and depression (Asarnow and Mirchandaney, 2021; Crowe and Spiro-Levitt, 2021; Dimakos et al., 2021; Vasa et al., 2020).

In terms of physical health, findings from a number of publications suggest short sleep duration, high sleep variability, and poor sleep quality are associated with overweight and obesity in childhood (Fatima et al., 2016; Patel and Hu, 2008; Wu et al., 2017). This trend is even observed in infants – those who sleep <12 h per day are more likely to be overweight by the age of 3 years (Taveras et al., 2008). Whether or not sleep-related increases in weight and obesity in the first decade of life are due to alterations in metabolic and endocrine processes during the night remains unknown. Given that sleep is a modifiable health-risk behavior associated with high prevalence of psychiatric illness and physical disease, further research is warranted to understand how to develop and maintain optimal sleep habits in infancy and childhood.

What environmental factors influence optimal sleep?

Maintaining a sleep-friendly environment and bedtime routine is essential to promoting healthy sleep in infants and children. In a study of low-income preschool children, sleeping in a suboptimal environment ("too bright", "too loud", or "too cold/hot") was associated with shorter sleep duration and later sleep onset on weeknights (Wilson et al., 2014b). Although experimental research on the impact of the nighttime lighting environment on sleep outcomes in children is sparse, findings demonstrate that children's circadian clocks are highly sensitive to evening light. 9-year-olds are impacted nearly twice as much by evening bright light (as measured by suppression of melatonin production), compared with their parents (Higuchi et al., 2014). In preschool-aged children, the intensity of evening light in the home influences timing of an individual's circadian clock over and above their bedtime (Akacem et al., 2016), and bright light in the hour before bedtime leads to robust and sustained melatonin suppression (Akacem et al., 2018). Given the important role of melatonin in preparing the body for sleep, these findings suggest children's exposure to bright light at night could contribute to delayed sleep timing and behavioral sleep problems.

In contrast to evening light exposure, data suggest children are less sensitive than adults to environmental noise during sleep, requiring a noise level of at least 10 dB higher to be awakened (Eberhardt, 1988). Nonetheless, children's exposure to nighttime noise from road traffic is associated with poorer reported sleep quality and increased daytime sleepiness (Öhrström et al., 2006). Recent findings suggest that regulation of body temperature during sleep may also be different in young children than in adults (Okamoto-Mizuno et al., 2018), implying that the optimal sleep environment for thermal comfort may vary between age groups. In a study with preschool-aged children, thermal discomfort (feeling either too hot or too cold) was associated with poorer parent-reported sleep quality (Richdale and Schreck, 2019).

Additionally, in the last decade, children's use of mobile devices has risen drastically. Research findings consistently report that children's screen time is associated with poor sleep outcomes, primarily reflected in later bedtimes and shorter sleep durations (Hale and Guan, 2015). Even the presence of a small screen or television in the bedroom is associated with shorter sleep durations in school-aged children (Falbe et al., 2015). The relationship between media use and sleep disruption is likely due to a combination of factors, including the displacement of time normally spent asleep, arousal from the media content, and the circadian effects of the light emitted from screens (LeBourgeois et al., 2017). Ensuring that children have a comfortable sleeping environment without disruption from light, noise, or technology is critical to supporting optimal sleep.

How can we optimize sleep in children with sleep problems?

Sleep problems, such as bedtime resistance, sleep-onset delay, and frequent and/or prolonged nighttime awakenings are common in the first 10 years of life affecting about 25% of the developing population (Owens, 2008). Such sleep disturbances may be long-standing and are associated with poor developmental and health outcomes, such as mood problems, inattention, medical illnesses (e.g., chronic pain, asthma, overweight/obesity), and academic difficulties (see discussion above – Optimal sleep for what?). Findings from a well-established treatment literature indicate that behavioral therapies such as extinction and bedtime routines are efficacious for childhood sleep problems, with an estimated 80% of children showing clinically significant changes maintained for 3–6 months (Mindell et al., 2006). Extinction (unmodified, graduated) for bedtime problems is one of the most common treatment choices, with strong empirical support. With safety monitoring, the unmodified variety involves putting the child to bed at a stipulated bedtime and ignoring the child until a specific time in the morning. Because extinction often results in tantrums, crying, and calling out, it is stressful for parents and can lead to them being noncompliant. In these cases, a graduated extinction method may be preferred, which involves ignoring the child for specific time periods. Many varieties of graduated extinction exist (e.g., checking every 5 min; checking after 5, 10, and then 15 min). The common goal is to help children develop self-soothing skills so that they can fall asleep by themselves and go back to sleep after arousing/awakening in the middle of the night. Another strong approach to bedtime problems is developing a positive bedtime routine (Mindell and Williamson, 2018), including quiet activities that the child enjoys and that unfold each night in a consistent order. Bedtime routines, especially when practiced consistently, have been demonstrated to promote earlier bedtimes, more total sleep, and decrease parent perceived sleep problems (Mindell et al., 2015).

Given the race/ethnic and SES disparities in children's sleep health, a small but growing body of literature focuses on sleep interventions targeting underserved communities. Although their causes are not fully understood, these sleep health disparities are impacted by racism, discrimination, neighborhood segregation, geography, social patterns, access to health care, and cultural beliefs, necessitating the consideration of cultural appropriateness in any intervention devised for reducing sleep health disparities (Slopen et al., 2016). Researchers have focused on reaching these communities with targeted interventions introduced in various settings such as primary care offices (Williamson et al., 2020), in preschools (Wilson et al., 2014a), and in supportive housing (Labella et al., 2017). In response to the growing concern regarding the impacts of screen-based media on children's sleep, a recent addition to sleep interventions target children's screen usage, including overall screen time reduction, moderating screen content, and limiting use of screens before bedtime. A systematic review of the limited work that has been done in this field, demonstrates that reductions in overall and evening screen use in children ages 6 to 13 are associated with increased sleep duration and earlier bedtimes (Martin et al., 2020).

Finally, prevention of sleep problems through caregiver education programs has been found to improve sleep in infants and children, although a systematic review of the literature demonstrates that the findings are mixed regarding the maintenance of effects (McDowall et al., 2017). Most programs include information on normal developmental changes in sleep, recommended sleep durations by age, utilizing good sleep hygiene practices (e.g., no caffeine, a stable sleep schedule, a calm consistent bedtime routine), and strategies for parents to encourage sleep onset at bedtime and sleep maintenance during the night. These recommendations stem from a variety of sources including those given by the National Sleep Foundation (Hirshkowitz et al., 2015), American Academy of Sleep Medicine (Paruthi et al., 2016), and the American Academy of Pediatrics (AAP, 2005). For Newborns, recommendations suggest that caregivers encourage the infant to fall asleep alone in their crib, in the same room as an adult, and putting them to bed when they are drowsy but still awake. It is also recommended that infants are placed on their back with the face and head clear of blankets or any other soft items, a strategy has been shown to reduce the risk of sudden infant death syndrome (Li, 2003). For preschoolers and school-aged children it is recommended to abstain from screen-based media use at least 1 hour before bedtime. Additionally, it is recommended that children sleep in a cool, quiet, and dark room without TVs or screen-based media.

Conclusion

Defining optimal sleep and circadian habits in infants and children is complex. Substantial individual differences in sleep need, sleep duration, and sleep patterns are evident during the first decade of life; thus, the habits of one child at a specific age and developmental stage may not be optimal for another. Furthermore, the culture in which children are raised influences the sleep expectations and practices of caregivers. Understanding maturational changes in sleep and circadian physiology holds promise for uncovering windows of vulnerability in the development and maintenance of sleep problems in infants and children. Ideally, caregivers should employ sleep-related strategies that are a good fit for their individual child's biology; however, this may be difficult due to family demands, institutional policies such as those on napping, personal preferences, or lack of knowledge about normal developmental changes in sleep. Findings from epidemiological and experimental studies suggest that nonoptimal sleep is associated with a wide range of emotional, behavioral, cognitive, and health-related problems in infants and children. Sleep is a modifiable health-risk behavior, and empirically valid treatments for sleep problems show great promise for helping children achieve and maintain optimal sleep.

References

AAP, 2005. The changing concept of sudden infant death syndrome: diagnostic coding shifts, controversies regarding the sleeping environment, and new variables to consider in reducing risk. Pediatrics 116, 1245–1255.

Akacem, L.D., Simpkin, C.T., Carskadon, M.A., Wright, K.P., Jenni, O.G., Achermann, P., LeBourgeois, M.K., 2015. The timing of the circadian clock and sleep differ between napping and non-napping toddlers. PLoS One 10, e0125181.

Akacem, L.D., Wright, K.P., LeBourgeois, M.K., 2016. Bedtime and evening light exposure influence circadian timing in preschool-age children: a field study. Neurobiol. Sleep Circad. Rhythms 1, 27–31.

Akacem, L.D., Wright, K.P., LeBourgeois, M.K., 2018. Sensitivity of the circadian system to evening bright light in preschool-age children. Physiol. Rep. 6, e13617.

Asarnow, L.D., Mirchandaney, R., 2021. Sleep and mood disorders among youth. Child Adolesc. Psychiatr. Clin. N. Am. 30, 251–268.

Bagley, E.J., Kelly, R.J., Buckhalt, J.A., El-Sheikh, M., 2015. What keeps low-SES children from sleeping well: the role of presleep worries and sleep environment. Sleep Medicine 16, 496–502.

Baron, K.G., Reid, K.J., 2014. Circadian misalignment and health. Int. Rev. Psychiatr. 26, 139–154.

Berger, R.H., Miller, A.L., Seifer, R., Cares, S.R., Lebourgeois, M.K., 2012. Acute sleep restriction effects on emotion responses in 30- to 36-month-old children. J. Sleep Res. 21, 235–246.

Borbély, A.A., 1982. A two process model of sleep regulation. Hum. Neurobiol. 1, 195–204.

Chess, S., Thomas, A., 1991. Temperament and the concept of goodness of fit. In: Strelau, J., Angleitner, A. (Eds.), Explorations in Temperament: International Perspectives on Theory and Measurement. Springer US, Boston, MA.

Crosby, B., LeBourgeois, M.K., Harsh, J., 2005. Racial differences in reported napping and nocturnal sleep in 2- to 8-year-old children. Pediatrics 115, 225–232.

Crowe, K., Spiro-Levitt, C., 2021. Sleep-related problems and pediatric anxiety disorders. Child Adolesc. Psychiatr. Clin. N. Am. 30, 209–224.

Crowley, S.J., Van Reen, E., LeBourgeois, M.K., Acebo, C., Tarokh, L., Seifer, R., Barker, D.H., Carskadon, M.A., 2014. A longitudinal assessment of sleep timing, circadian phase, and phase angle of entrainment across human adolescence. PLoS One 9, e112199.

Crowley, S.J., Wolfson, A.R., Tarokh, L., Carskadon, M.A., 2018. An update on adolescent sleep: new evidence informing the perfect storm model. J. Adolesc. 67, 55–65.

Dimakos, J., Gauthier-Gagné, G., Lin, L., Scholes, S., Gruber, R., 2021. The associations between sleep and externalizing and internalizing problems in children and adolescents with attention-deficit/hyperactivity disorder: empirical findings, clinical implications, and future research directions. Child Adolesc. Psychiatr. Clin. N. Am. 30, 175–193.

Eberhardt, J.L., 1988. The influence of road traffic noise on sleep. J. Sound Vib. 127, 449–455.

Falbe, J., Davison, K.K., Franckle, R.L., Ganter, C., Gortmaker, S.L., Smith, L., Land, T., Taveras, E.M., 2015. Sleep duration, restfulness, and screens in the sleep environment. Pediatrics 135, e367–e375.

Fallone, G., Acebo, C., Seifer, R., Carskadon, M.A., 2005. Experimental restriction of sleep opportunity in children: effects on teacher ratings. Sleep 28, 1561–1567.

Fatima, Y., Doi, S.A.R., Mamun, A.A., 2016. Sleep quality and obesity in young subjects: a meta-analysis. Obes. Rev. 17, 1154–1166.

Giannotti, F., Cortesi, F., Sebastiani, T., Vagnoni, C., 2005. Sleeping habits in Italian children and adolescents. Sleep Biol. Rhythm 3, 15–21.

Gómez, R.L., Bootzin, R.R., Nadel, L., 2006. Naps promote abstraction in language-learning infants. Psychol. Sci. 17, 670–674.

Gruber, R., Wiebe, S., Montecalvo, L., Brunetti, B., Amsel, R., Carrier, J., 2011. Impact of sleep restriction on neurobehavioral functioning of children with attention deficit hyperactivity disorder. Sleep 34, 315–323.

Guglielmo, D., Gazmararian, J.A., Chung, J., Rogers, A.E., Hale, L., 2018. Racial/ethnic sleep disparities in us school-aged children and adolescents: a review of the literature. Sleep Health 4, 68–80.

Hahn-Holbrook, J., Saxbe, D., Bixby, C., Steele, C., Glynn, L., 2019. Human milk as "chrononutrition": implications for child health and development. Pediatr. Res. 85, 936–942.

Hale, L., Guan, S., 2015. Screen time and sleep among school-aged children and adolescents: a systematic literature review. Sleep Med. Rev. 21, 50–58.

Hart, C.N., Carskadon, M.A., Considine, R.V., Fava, J.L., Lawton, J., Raynor, H.A., Jelalian, E., Owens, J., Wing, R., 2013. Changes in children's sleep duration on food intake, weight, and leptin. Pediatrics 132, e1473–e1480.

Higuchi, S., Nagafuchi, Y., Lee, S.-I., Harada, T., 2014. Influence of light at night on melatonin suppression in children. J. Clin. Endocrinol. Metab. 99, 3298–3303.

Hirshkowitz, M., Whiton, K., Albert, S.M., Alessi, C., Bruni, O., Doncarlos, L., Hazen, N., Herman, J., Adams Hillard, P.J., Katz, E.S., Kheirandish-Gozal, L., Neubauer, D.N., O'Donnell, A.E., Ohayon, M., Peever, J., Rawding, R., Sachdeva, R.C., Setters, B., Vitiello, M.V., Ware, J.C., 2015. National sleep foundation's updated sleep duration recommendations: final report. Sleep Health 1, 233–243.

Iglowstein, I., Jenni, O.G., Molinari, L., Largo, R.H., 2003. Sleep duration from infancy to adolescence: reference values and generational trends. Pediatrics 111, 302–307.

Iglowstein, I., Latal Hajnal, B., Molinari, L., Largo, R., Jenni, O., 2006. Sleep behaviour in preterm children from birth to age 10 years: a longitudinal study. Acta Paediatr. 95, 1691–1693.

Jenni, O.G., Borbély, A.A., Achermann, P., 2004. Development of the nocturnal sleep electroencephalogram in human infants. Am. J. Physiol. Regul. Integr. Comp. Physiol. 286, R528–R538.

Jenni, O.G., O'Connor, B.B., 2005. Children's sleep: an interplay between culture and biology. Pediatrics 115, 204–216.

Jenni, O.G., Deboer, T., Achermann, P., 2006. Development of the 24-h rest-activity pattern in human infants. Infant Behav. Dev. 29, 143–152.

Jenni, O.G., Lebourgeois, M.K., 2006. Understanding sleep–wake behavior and sleep disorders in children: the value of a model. Curr. Opin. Psychiatr. 19, 282–287.

Knowland, V.C.P., Berens, S., Gaskell, M.G., Walker, S.A., Henderson, L.-M., 2021. Does the maturation of early sleep patterns predict language ability at school entry? A born in bradford study. J. Child Lang. 1–23.

Kocevska, D., Rijlaarsdam, J., Ghassabian, A., Jaddoe, V.W., Franco, O.H., Verhulst, F.C., Tiemeier, H., 2017. Early childhood sleep patterns and cognitive development at age 6 years: the generation r study. J. Pediatr. Psychol. 42, 260–268.

Kurdziel, L., Duclos, K., Spencer, R.M.C., 2013. Sleep spindles in midday naps enhance learning in preschool children. Proc. Natl. Acad. Sci. U. S. A. 110, 17267–17272.

Labella, M.H., Kalstabbakken, A., Johnson, J., Leppa, J., Robinson, N., Masten, A.S., Barnes, A.J., 2017. Promoting resilience by improving children's sleep: feasibility among families living in supportive housing. Prog. Commun. Health Partner. 11, 285–293.

Lassonde, J.M., Rusterholz, T., Kurth, S., Schumacher, A.M., Achermann, P., Lebourgeois, M.K., 2016. Sleep physiology in toddlers: effects of missing a nap on subsequent night sleep. Neurobiol. Sleep Circad. Rhythms 1, 19–26.

LeBourgeois, M.K., Rusterholz, T., Jenni, O.G., Carskadon, M.A., Achermann, P., 2012. Do the dynamics of sleep homeostasis changes across early childhood? Sleep 35, A21.

LeBourgeois, M.K., Carskadon, M.A., Akacem, L.D., Simpkin, C.T., Wright, K.P., Achermann, P., Jenni, O.G., 2013a. Circadian phase and its relationship to nighttime sleep in toddlers. J. Biol. Rhythm. 28, 322–331.

LeBourgeois, M.K., Wright, K.P., Lebourgeois, H.B., Jenni, O.G., 2013b. Dissonance between parent-selected bedtimes and young children's circadian physiology influences nighttime settling difficulties. Mind Brain Ed. 7, 234–242.

LeBourgeois, M.K., Hale, L., Chang, A.-M., Akacem, L.D., Montgomery-Downs, H.E., Buxton, O.M., 2017. Digital media and sleep in childhood and adolescence. Pediatrics 140, S92–S96.

Li, D.K., 2003. Infant sleeping position and the risk of sudden infant death syndrome in California, 1997–2000. Am. J. Epidemiol. 157, 446–455.

Lokhandwala, S., Spencer, R.M.C., 2020. Slow wave sleep in naps supports episodic memories in early childhood. Dev. Sci. 24 (2).

Martin, K.B., Bednarz, J.M., Aromataris, E.C., 2020. Interventions to control children's screen use and their effect on sleep: a systematic review and meta-analysis. J. Sleep Res. https://doi.org/10.1111/jsr.13130.

McDowall, P.S., Galland, B.C., Campbell, A.J., Elder, D.E., 2017. Parent knowledge of children's sleep: a systematic review. Sleep Med. Rev. 31, 39–47.

McGraw, K., Hoffmann, R., Harker, C., Herman, J.H., 1999. The development of circadian rhythms in a human infant. Sleep 22, 303–310.

Miller, A.L., Seifer, R., Crossin, R., Lebourgeois, M.K., 2015. Toddler's self-regulation strategies in a challenge context are nap-dependent. J. Sleep Res. 24, 279–287.

Mindell, J., Kuhn, B., Lewin, D., Meltzer, L., 2006. Behavioral treatment of bedtime problems and night wakings in infants and young children. Sleep 29, 599–606.

Mindell, J.A., Li, A.M., Sadeh, A., Kwon, R., Goh, D.Y.T., 2015. Bedtime routines for young children: a dose-dependent association with sleep outcomes. Sleep 38, 717–722.

Mindell, J.A., Williamson, A.A., 2018. Benefits of a bedtime routine in young children: sleep, development, and beyond. Sleep Med. Rev. 40, 93–108.

Mirmiran, M., Maas, Y.G.H., Ariagno, R.L., 2003. Development of fetal and neonatal sleep and circadian rhythms. Sleep Med. Rev. 7, 321–334.

Morelli, G.A., Rogoff, B., Oppenheim, D., Goldsmith, D., 1992. Cultural variation in infants' sleeping arrangements: questions of independence. Dev. Psychol. 28, 604–613.

Öhrström, E., Hadzibajramovic, E., Holmes, M., Svensson, H., 2006. Effects of road traffic noise on sleep: studies on children and adults. J. Environ. Psychol. 26, 116–126.

Okamoto-Mizuno, K., Mizuno, K., Shirakawa, S., 2018. Sleep and skin temperature in preschool children and their mothers. Behav. Sleep Med. 16, 64–78.

Owens, J., 2008. Classification and epidemiology of childhood sleep disorders. Prim. Care Clin. Off. Pract. 35, 533–546.

Owens, J.A., 2004. Sleep in children: cross-cultural perspectives. Sleep Biol. Rhythm 2, 165–173.

Paruthi, S., Brooks, L.J., D'Ambrosio, C., Hall, W.A., Kotagal, S., Lloyd, R.M., Malow, B.A., Maski, K., Nichols, C., Quan, S.F., 2016. Recommended amount of sleep for pediatric populations: a consensus statement of the American academy of sleep medicine. J. Clin. Sleep Med. 12, 785–786.

Patel, S.R., Hu, F.B., 2008. Short sleep duration and weight gain: a systematic review. Obesity 16, 643–653.

Quach, J., Hiscock, H., Wake, M., 2012. Sleep problems and mental health in primary school new entrants: cross-sectional community-based study. J. Paediatr. Child Health 48, 1076–1081.

Richdale, A.L., Schreck, K.A., 2019. Examining sleep hygiene factors and sleep in young children with and without autism spectrum disorder. Res. Autism Spectr. Disord. 57, 154–162.

Sadeh, A., Gruber, R., Raviv, A., 2003. The effects of sleep restriction and extension on school-age children: what a difference an hour makes. Child Dev. 74, 444–455.

Slopen, N., Lewis, T.T., Williams, D.R., 2016. Discrimination and sleep: a systematic review. Sleep Med. 18, 88–95.

Smith, J.P., Hardy, S.T., Hale, L.E., Gazmararian, J.A., 2019. Racial disparities and sleep among preschool aged children: a systematic review. Sleep Health 5, 49–57.

Swaab, D.F., Hofman, M.A., Honnebier, M.B.O.M., 1990. Development of vasopressin neurons in the human suprachiasmatic nucleus in relation to birth. Dev. Brain Res. 52, 289–293.

Taveras, E.M., Rifas-Shiman, S.L., Oken, E., Gunderson, E.P., Gillman, M.W., 2008. Short sleep duration in infancy and risk of childhood overweight. Arch. Pediatr. Adolesc. Med. 162, 305.

Thomas, A., Chess, S., 1977. Temperament and Development. Brunner/Mazel, New York.

Tomfohr-Madsen, L., Cameron, E.E., Dhillon, A., Mackinnon, A., Hernandez, L., Madigan, S., Tough, S., 2020. Neighborhood socioeconomic status and child sleep duration: a systematic review and meta-analysis. Sleep Health 6, 550–562.

Vasa, R.A., Keefer, A., McDonald, R.G., Hunsche, M.C., Kerns, C.M., 2020. A scoping review of anxiety in young children with autism spectrum disorder. Autism Res. 13, 2038–2057.

Williamson, A.A., Milaniak, I., Watson, B., Cicalese, O., Fiks, A.G., Power, T.J., Barg, F.K., Beidas, R.S., Mindell, J.A., Rendle, K.A., 2020. Early childhood sleep intervention in urban primary care: caregiver and clinician perspectives. J. Pediatr. Psychol. 45, 933–945.

Wilson, K.E., Miller, A.L., Bonuck, K., Lumeng, J.C., Chervin, R.D., 2014a. Evaluation of a sleep education program for low-income preschool children and their families. Sleep 37, 1117–1125.

Wilson, K.E., Miller, A.L., Lumeng, J.C., Chervin, R.D., 2014b. Sleep environments and sleep durations in a sample of low-income preschool children. J. Clin. Sleep Med. 10, 299–305.

Wu, Y., Gong, Q., Zou, Z., Li, H., Zhang, X., 2017. Short sleep duration and obesity among children: a systematic review and meta-analysis of prospective studies. Obes. Res. Clin. Pract. 11, 140–150.