REVIEW ARTICLE

Childhood sleep: assessments, risk factors, and potential mechanisms

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Received: 18 March 2022 / Accepted: 23 September 2022
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Abstract
Background Sleep problem is a highly prevalent health issue among pediatric populations across the world. In this review, we aimed to identify risk factors contributing to sleep deficiency and poor sleep hygiene in children. Potential biological, psychosocial, and environmental mechanisms as well as research gaps in the literature are also discussed.

Data sources A comprehensive search for relevant English language full-text, peer-reviewed publications was performed focusing on pediatric sleep studies from prenatal to childhood and adolescence in a variety of indexes in PubMed, SCOPUS, and Psych Info. Both relevant data based and systematic reviews are included.

Results This paper summarizes many risk factors for childhood sleep problems, including biological (e.g., genetics, gender, age and puberty, prenatal factors, postnatal factors); nutritional (e.g., macronutrients, micronutrients, omega-3 fatty acids, obesity); environmental (e.g., heavy metals, noise, light, air pollution); interpersonal (e.g., family, exposure to violence, screen media use, physical injury); and community/socioeconomic variables (e.g., racial/ethnicity and cultural factors, neighborhood conditions and socioeconomic status, school factors, public health disasters/emergencies), to better understand the development of sleep problems in children.

Conclusions Poor childhood sleep is a multifactorial issue affected by a wide range of prenatal and early-life biological, environmental, and psychosocial risk factors and contributors. A better understanding of these risk factors and their mechanisms is an important first step to develop future research and prevention programs focusing on pediatric sleep problems.

Keywords Child sleep · Pediatrics · Risk factor · Mechanisms

Introduction

Sleep, the primary brain activity during development, encompasses about 40% of a child’s day throughout childhood and adolescence [1] and is vitally important to children’s health and well-being. However, sleep deficiency has become a rising public health concern [2], affecting 20%–60% of all children globally [3–5]. Sleep deficiency includes insufficient sleep duration, irregular timing of sleep, poor sleep quality (e.g., perceived poor sleep, objectively assessed sleep fragmentation), and sleep/circadian disorders (e.g., insomnia, obstructive sleep apnea) [6].

Many factors contribute to a child’s sleep deficiency, including early childhood risk factors such as genetic, prenatal, postnatal, environmental, psychosocial, and other risk factors. Furthermore, sleep deficiency has been shown to adversely impact physical health [7], behavior [8–10], emotional well-being [9, 11, 12], cognition [13, 14], psychopathology [13, 15, 16], and familial relationships [7, 17].

While several previous studies have systematically reviewed individual factors related to childhood sleep, this review aims to integrate many different aspects into one paper and provide a comprehensive overview. The review focused on analyzing the current literature and knowledge syntheses on particular risk factors. Potential biological, psychosocial, and environmental mechanisms and current literature gaps are also briefly discussed. Understanding the risk factors will inform public health practice for sleep screening and prevention/intervention, thus improving sleep-related child development and health.
Search strategies

A comprehensive literature search for relevant English language full text, peer-reviewed publications was performed focusing on pediatric sleep studies from prenatal to childhood and adolescence in a variety of indexes in PubMed, SCOPUS, and Psych Info. Searches were conducting using keywords such as “child”, “adolescent”, “pediatric”, “sleep deficiency”, “sleep hygiene”, “risk factors”, and “mechanisms”. We grouped our findings from the literature on risk factors for childhood sleep problems into five broad categories, and we further conducted searches specific to each category that we found, with additional keywords including biological (e.g., “genetics”, “prenatal”, “postnatal”), nutritional (e.g., “obesity”), environmental (e.g., “noise”, “light”), interpersonal (e.g., “family”, “screen media”), and community/socioeconomic variables (e.g., “socioeconomic status”, “school”).

Eligibility criteria

We included relevant empirical studies (cross-sectional, longitudinal studies or clinical trials) and systematic reviews on sleep health in infants, children and adolescents published in English. While we focus our search on literature from the past two decades, we also include that which was published earlier if highly relevant and well-cited.

Exclusion criteria

We excluded following types of articles: narrative review, expert opinion, and case report. We also excluded studies focused on participants >18 years of age.

Childhood sleep and measurement

Sleep deficiency in children encompasses several different manifestations, such as altered sleep duration (e.g., short sleep), poor sleep quality, and sleep disorders. Of them, common sleep disorders include insomnia, hypersomnolence (excessive sleepiness), sleep-related breathing and movement disorders, circadian rhythm sleep–wake disorders and parasomnias (disturbances during sleep, e.g., sleep walking). Table 1 summarizes the definitions and manifestations of common sleep deficiency types in childhood. These sleep problems occur differentially across development. For instance, whereas nighttime awakening is most prevalent in infancy and early childhood, older children and adolescents more commonly have difficulty falling asleep [18]. Sleep deficiency problems have also been shown to persist through development, with sleep deficiency manifestations in infancy continuing into early childhood, those from early childhood into middle school, and those from middle school into later adolescence [19].

Sleep deficiency in children and adolescents can be measured, both objectively and subjectively, via child report and parents’ estimation. Despite discrepancies in sleep time and duration assessment between subjective and objective sleep measures (e.g., overestimation in self/parent reports) [20–23], perceived sleep experiences provide patient- or participant-centered information that cannot be characterized by quantified sleep indicators [24]. Because of cost-effectiveness, ease of use, and practicality, validated subjective instruments (self-report or parent report; Table 2) are widely used to measure sleep problems in community-based studies at scale [25, 26]. Key child sleep measures are outlined in Table 2.

Risk factors associated with childhood sleep deficiency

Early childhood is an important period during which a normal sleep-wakefulness cycle is developed. Exposure to biobehavioral, psychosocial, and environmental early-life risk factors could contribute to childhood sleep deficiency. In children, sleep onset latency (the amount of time it takes to fall asleep) may be influenced by bedtime resistance. Sleep problems in adolescents may be due to various adolescent-specific factors, such as pubertal changes in intrinsic sleep regulation (e.g., delayed melatonin onset phase) [27], increased school demands [28], greater access to and use of screen media [29–31], and substance use [30]. Guided by several models (i.e., socioecological/multilevel model [32]; biopsychosocial and contextual model [33]), we synthesized and summarized evidence from the literature on risk factors associated with child/adolescent sleep deficiency in five categories (i.e., biological, physical environmental exposures, interpersonal factors, community and social factors, cultural differences), which are displayed in Fig. 1. These risk factors, along with specific examples for each factor, are briefly discussed in this section.

Biological factors

Genetics

Genetic factors may predispose children to various sleep pathologies. Evidence from twin studies illustrates this role of genetics in specific sleep-related issues, which include
daytime and nighttime sleep duration as well as nighttime awakening. Notably, in a longitudinal study of 995 monozygotic and dizygotic twins, a strong genetic influence was observed on nighttime sleep duration at 6, 30, and 48 months. Notably, the contribution of genetics to sleep duration was most prevalent among children with persistently short sleep duration over the assessment period [34]. Laboratory studies have documented certain genes (BMAL1/Mop3, ABCC9) as potential biological mechanisms [35, 36].

Another study on a smaller population of monozygotic and dizygotic twins found that while additive genetic effects have a moderate impact on infant sleep duration in both nocturnal and diurnal sleep, shared environmental factors have a much more significant impact, almost double that of genetic factors [37]. Nevertheless, this area of research remains limited and requires further study to parse out how genetic and environmental factors interplay in influencing the physiological nature of childhood sleep.

**Gender**

Sex differences in child sleep outcomes have been widely studied, but the results remain inconclusive. Most studies report better sleep among girls, as boys have been shown to have lower sleep efficiency (the ratio of total sleep time to time in bed) [38], less time in bed [39], greater risk for sleep problems [40], and increased activity during sleep [38]. However, insomnia prevalence in one study among school-aged children was highest in girls aged 11–12 years [41]. Conversely, many studies report no significant gender differences in sleep onset [42], sleep duration [43], or other objective sleep measures [42], suggesting that further research is needed to elucidate these relationships.

**Age and puberty**

Sleep behavior changes drastically in early development, from infants to school-aged children to adolescents. Children sleep significantly earlier and for longer periods of time than adolescents [42] due to biological, psychosocial, and lifestyle factors that change with increased age [44]. Pubertal status was associated with changes in intrinsic sleep regulation (e.g., delayed melatonin onset phase) [27] and the tendency toward evening chronotype (e.g., later bed and rise time) [45]. Together with age-specific social/behavioral factors, up to 68.9% of adolescents report insufficient nighttime sleep duration and impaired sleep quality [46, 47], and high school students exhibit > 1-h differences in sleep/wake patterns between school and nonschool days on average [48]. These findings suggest the pervasiveness of chronic
| Tools | Population | Measured factors | Report type | Number of total items | Primary use |
|-------|------------|------------------|-------------|-----------------------|-------------|
| Child behavior checklist (CBCL) [206] | CBCL/1½ to 5: for children aged 1½ to 5 y, CBCL/6 to 18: for children aged 6 to 18 y | Eight behavioral areas anxious/depressed, withdrawn, somatic complaints, social problems, thought problems, attention problems, rule-breaking behavior, and aggressive behavior | Parent-report | 113 | Assess sleep behaviors and emotional problems and compare with other measures of sleep function to determine associative relationships between behavior and sleep |
| Child sleep health questionnaire [207] | School-aged children | Eight sleep domains: bedtime resistance, sleep onset delay, sleep duration, sleep anxiety, night wakings, parasomnias, sleep-disordered breathing, and daytime sleepiness, and total sleep disturbance score | Parent-report | 45 | Assess sleep health and various sleep disorders |
| Sleep disturbance scale for children [208] | School-aged children | Six factors related to sleep disorders: disorders of initiating and maintaining sleep (DIMS), sleep breathing disorders (SBD), disorders of arousal (DA), sleep wake transition disorders (SWTD), disorders of excessive somnolence (DOES), and sleep hyperhidrosis (SHY) | Parent-report | 27 | Assess sleep disorders |
| Pittsburgh sleep quality index [209] | Adolescents and adults | Subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction | Self-report | 19 | Assess sleep quality |
| Sleep diary and maternal report [210, 211] | School-aged children | Cosleeping, sleep quality and duration, and sleep problems including nighttime awakening | Maternal-report | N/A | Track child sleep habits |
| Insomnia severity index [212] | Adolescents (originally designed for adults) | Perceived severity of insomnia symptoms (initial, middle, terminal), the degree of satisfaction with sleep, interference with daytime functioning, noticeability of impairment, and concern caused by the sleep problems | Self-report | 7 | Screen insomnia symptoms |
| Pediatric daytime sleepiness scale [213] | | | Self-report | 8 | Assess daytime sleepiness |
| Epworth sleepiness scale (modified) [214] | Adolescents | Replacing the last item “in a car while stopped for a few minutes in traffic” with “doing homework or taking a test” | Self-report | 8 | Assess daytime sleepiness |
| Tools                                | Population                  | Measured factors                                                                 | Report type | Number of total items | Primary use                                      |
|-------------------------------------|-----------------------------|----------------------------------------------------------------------------------|-------------|-----------------------|-------------------------------------------------|
| Adolescent sleep hygiene scale      | Adolescents                 | Including 4 qualitative items to ascertain usual bedtime and wake time on weekdays and at weekends, and 28 quantitative items that are used to calculate 9 subscale scores: physiological, cognitive, emotional, sleep environment, daytime sleep, substances, sleep stability, bedtime routine and bed sharing | Self-report | 32                    | Assess sleep hygiene practice                    |
| Children’s report of sleep patterns | Children and adolescents    | Three subscales: sleep patterns, sleep hygiene, and sleep disturbances            | Self-report | 76                    | Assess multiple sleep dimensions that are reflective of sleep disturbances |
| Polysomnography                     |                             | Measures sleep and wake states as well as stages, eye movements, and muscle tone during sleep via electroencephalography, electrooculography, and electromyography as well as respiratory disorders, parasomnias, epilepsy, narcolepsy, insomnia, and circadian rhythm disorders during sleep can be assessed using this methodology. Requires technical expertise and an overnight stay in a sleep laboratory, is expensive, and does not measure subjective aspects of sleep such as perceptions of sleep and the sleep environment. |             |                       |                                                 |
| Actigraphy                          |                             | Similarly uses objective measures of sleep and wake patterns using motion sensors as polysomnography. Measured using a mobile device, actigraphy employs built-in scoring algorithms to detect sleep and wake phases, allowing it to be used in the home environment without excessive set-up or cost requirements. Clinically, 7–14 d of consecutive recording are recommended to capture both weekday and weekend sleep. |             |                       |                                                 |
Circadian misalignment (mismatch between an internal circadian clock and behavioral sleep schedule) in adolescents. These adolescent sleep difficulties translate into poor daytime functioning. Chronic poor adolescent sleepers report increased self-reported rates of feeling depressed, fatigued, moody, irritable, less rested, and more tense than their peers who are good sleepers [49]. Despite the tendency for shorter sleep duration in adolescence, sleep disorders may remain stable over time [50]; sleep quality may actually improve with age and puberty status [50].

**Prenatal factors**

Sleep deficiency in children has been linked to prenatal maternal obesity [51] and maternal exposure to psychoactive substances, namely, alcohol [52, 53]. Specifically, sleep deficiency due to these prenatal exposures includes low sleep efficiency [54, 55], increased nighttime awakenings [55, 56], short sleep duration [54–56] and insomnia [57, 58]. A possible underlying factor may be that alcohol from the mother may alter the functioning of the fetal hypothalamic-pituitary-adrenal axis, a system involved in the regulation of sleep infrastructure [54, 59], thus disrupting normal sleep behavior. Future research is needed to tease out the trimester during which exposures may have the greatest impact to develop targeted interventions.

Similarly, maternal emotional health during pregnancy may also impact child sleep. Specifically, high levels of prenatal maternal anxiety and depression are associated with increased sleep deficiency [53, 60], including difficulty initiating and maintaining sleep, short sleep duration, and parasomnias [61, 62]. Conversely, higher levels of maternal happiness in the second and third trimesters are associated with fewer child sleep deficiency manifestations [63]. Although mechanistic pathways are not yet fully understood, it is possible that increased maternal stress experienced during the prenatal period increases glucocorticoid secretion, which may disrupt circadian activity of the developing fetus [62, 64].
Postnatal factors

Postnatal variables affecting infant physical health may also affect sleep behavior. Preterm birth affects both short-term and long-term sleep outcomes, resulting in greater arousability from sleep at 2–3 months [65, 66] as well as a greater risk of sleep-disordered breathing in later childhood (ages 8–11 years) [67, 68]. Additionally, breech birth and prolonged labor were associated with infant sleep difficulties [69]. Similarly, low birth weight (LBW) and shorter length at birth are associated with lower sleep efficiency during childhood and into adolescence [54, 69]. LBW can also have long-term consequences, as young adults born with LBW are more likely to snore and report other respiratory-related sleep disorders [70]. Certain birth stressors (i.e., prolonged labor, LBW, nonsingletons, and breech birth) were found to be negative predictors of sleep duration in adolescents [69].

Another possible postnatal contributor is breastfeeding. Currently, breastfeeding infants are reported to have less consolidated sleep [71], wake more frequently [72] and for longer duration [71] during the night, and have more difficulty sleeping alone at night [72]. This relationship may be moderated by parenting practices of nursing to sleep and returning to sleep during the night [71]. Future research is needed to investigate whether breastfed infants wake more frequently due to consuming less milk than bottle-fed infants or whether it is due to another factor involved in breastfeeding.

Postnatal maternal mental health has also been shown to affect child sleep, notably postpartum depression, which may greatly affect child development by parenting style and child–parent relationships [73, 74]. In general, increased severity of maternal postnatal depression is associated with more deficiency symptoms [75, 76], increased risk of sleep disorders in infancy [75], and more reports of sleep disturbances in childhood [63]. However, the directionality of this relationship is still unknown. Whereas poor childhood sleep outcomes were demonstrated to be an effective predictor of maternal depression scores [76], childhood behavior has been shown to be a significant mediator of the relationship between maternal depression and child sleep [63]. Additionally, poor maternal sleep is associated with poor infant sleep outcomes, maternal postnatal depression, and family dysfunction, suggesting that maternal sleep outcomes could help explain the link between postnatal depression and poor childhood sleep.

Nutrition, dietary intake, and weight

Although prior work has largely focused on how sleep deficiency may be associated with subsequent dietary intake and metabolic outcomes [77], a growing body of work suggests the potential impact of both macronutrients and micronutrients as well as dietary intake factors, such as regularity and timing of eating, on sleep health [78, 79].

Macronutrients

Macronutrients such as carbohydrates and amino acids (e.g., tryptophan), may influence sleep-inducing neurotransmitters, such as serotonin, through tryptophan metabolism [80, 81]. Infants and children (0–6 years) who consume a lower amount of tryptophan at breakfast demonstrate longer sleep latency (the amount of time it takes to go from being fully awake to sleeping), difficulty falling asleep at bedtime, and difficulty being awakened in the morning [82]. Whereas children who ate a high glycemic-index, carbohydrate-based meal in the evening showed longer sleep duration at night [83], eating such a meal near bedtime (e.g., 1 hour before bedtime) was associated with frequent arousals and diminished sleep quality [79].

Micronutrient (e.g., iron and zinc) deficiencies have also been considered risk factors for sleep deficiency [84]. Infants with iron deficiency anemia experience more frequent nighttime awakenings and shorter total sleep duration [85], altered spindle patterns (e.g., reduced density, lower frequency, and longer interspindle intervals) of nonrapid eye movement sleep (NREM) sleep stage 2 and slow wave sleep during infancy [86], and altered distribution of NREM and rapid eye movement sleep at 4 years old [87] compared with better-nourished counterparts. Furthermore, lower serum zinc concentrations at both 3–5 years old and 11–14 years old are associated with insufficient sleep duration, decreased sleep efficiency, poor sleep quality and increased sleep disturbances [88]. Micronutrients are antagonists of excitatory neurotransmitters (wakefulness promoters) in the brain, such as the N-methyl-d-aspartate receptor [78, 89] and dopaminergic neurons [90], as well as agonists of inhibitory neurotransmitters (sleep promoters), such as gamma-aminobutyric acid (GABA) receptors [89], thereby potentially influencing the intrinsic sleep regulation process.

Omega-3 fatty acids

A recent meta-analysis also reported that omega-3 LC-PUFAs (high levels of which can be found in certain fish, seeds, and nuts) may improve sleep health in children with clinical levels of sleep deficiency but not in generally healthy children [91]. Omega-3 deficiency may affect melatonin production and neuronal membrane function in animal models, thus impacting sleep onset and maintenance [92–95]. However, more research is needed in this area to confirm such a relationship.
Obesity

With the increasing prevalence of obesity in children, a majority of studies have focused on the contributing role of sleep deficiency to obesity [96]. However, research also reports that obese adolescents experienced considerably poorer sleep outcomes (i.e., duration, quality, and daytime somnolence) than their peers of normal weight [12]. The exact underlying mechanisms are unclear but involve those at the biological and environmental levels (e.g., dietary intake, media use, physical activity) [12]. Further research should clarify the direction of the relationship between sleep and obesity.

Physical environmental exposures

Children are especially vulnerable to environmental exposure due to their developing physiology. The relationship between environmental exposures and sleep health is relatively underresearched, but emerging studies are beginning to show a link between the two. A recent comprehensive review summarized empirical evidence demonstrating that different antagonistic exposures, such as lead, pesticides, noise (e.g., road traffic), light, and airborne pollutants, predispose children to sleep deficiency during the prenatal and postnatal periods [97].

Early childhood lead exposure is associated with adolescent sleep deficiency [98]. Exposure during the night has been found to contribute not only to shorter sleep duration and other sleep deficiency manifestations in girls at age 7 [99] but also to later bedtimes in adolescents [100]. An example of such disturbances to sleep onset and duration has been found in continuous exposure to noise in the pediatric intensive care unit, which contributed to poor sleep in patients [101]. Light exposure, especially artificial light before bedtime, has been found to suppress melatonin release and to delay sleep onset, reduce sleep duration, and reduce alertness the next morning [102, 103].

A recent systematic review on air pollution exposure on sleep health across the lifespan highlighted the impact on children [104]. This review concluded that both indoor and outdoor air pollution contributed to respiratory-related sleep disorders (e.g., snoring, wheezing) in children. Evidence has also reflected that children are more susceptible to the effects of air pollution due to the immaturity of their nervous and immune systems as well as their respiratory anatomy [105]. Nevertheless, more research is needed to focus on the long-term effects of these exposures on child sleep.

Interpersonal factors: family, peers, behavior, and immediate environment

In addition to biological and early-life risk factors, a child’s immediate home environment as well as social relationships inside and outside the home may greatly impact sleep outcomes. Many of these factors may be modifiable and thus potential targets for improving child sleep behavior.

Family

Child sleep deficiency may affect parental sleep patterns and daytime functioning, which in turn may affect parental behaviors and bedtime routine as well as subsequent child sleep outcomes [106, 107]. One family-related factor affecting childhood sleep is cosleeping or sharing a bed with a parent [108]. Cosleeping is correlated with higher rates of nighttime sleep deficiency [109], including later bedtimes, shorter sleep duration [110], bedtime resistance, sleep anxiety, parasomnias [111], frequent and disruptive night awakening [112, 113], and behavior problems [114]. Furthermore, long-term children who were cosleepers still maintained sleep problems for an additional year post-initial interview compared to nonco-sleepers and children who stopped cosleeping [113]. Nevertheless, cosleeping is a complex issue that may involve several factors, including socioeconomic status due to lack of bed space, which alone may contribute to sleep deficiency in children. Cosleeping may also involve parental behavior, including lack of awareness of sleep hygiene [115] as well as their own anxiety about sleeping alone [107].

Sleep deficiency manifestations could also be associated with parent behavioral issues and parenting styles. Parental laxness [116] and low parental hardiness (i.e., psychological maturity) [117], or lack of emphasis on child self-regulation and autonomy, are significantly related to child sleep problems in toddlers. Furthermore, such adverse parenting styles (including lack of warmth as well as large inconsistencies in behavior and response to children’s behavior and intelligence) are also associated with low sleep quality and greater daytime sleepiness in adolescents [118]. On the other hand, enforcement of regular household rules, such as caffeine intake and child sleep routines, was associated with better sleep health among children and adolescents [119, 120]. Childhood sleep routines may also involve specific hygiene structures and timelines, communication through reading or storytelling, and physical connections through cuddling or rocking for younger children [121]. Sleep routines for this population can often be sustained through parental intervention. Additionally, improved mother–child and father-child relationship quality is associated with a longer duration of sleep in toddlers [122, 123]. Similarly, greater parental warmth [124] and parental encouragement of social maturity [125] are associated with longer sleep duration in young children, and consistent parenting similarly is a protective factor in children with ADHD [126] (a group that commonly has comorbid sleep disorders such as sleep-disordered breathing, insomnia, and circadian rhythm disturbances).
sleep disorders [127]), resulting in decreased sleep resistance and sleep anxiety. Thus, consistent parenting can especially encourage improved sleep in child populations that require specialized care.

A potential mechanism at the psychosocial and environmental level for the role of parental behavior on child sleep may be due to consistent, warm parenting styles allowing for increased child perception of comfort and security and thus greater ability to easily fall asleep [120]. Additionally, these positive parenting techniques reinforce child self-functioning and promote secure attachment styles, which has been linked to better sleep outcomes and lower risk for internalizing and externalizing behavior problems due to a child’s increased ability to self-soothe [128]. Assessments in primary pediatric care settings should include evaluations of children’s sleep routines and parenting styles and should provide advice to parents to promote child sleep health.

Violence and abuse

Exposure to domestic violence (i.e., partner violence), physical abuse, and/or sexual abuse has been found to be associated with sleep deficiency throughout childhood. In particular, domestic violence is linked to poor sleeping habits in infants and problems with bedwetting at night in children [129–132], and increased maternal psychopathology may be a mediator [132]. Sleep issues may further be a mediator between exposure to domestic violence during childhood and depression during adolescence. Research has shown that the relationship between experiencing domestic violence between household members and subsequent depression may be improved by tackling sleep problems first [133]. Living with domestic violence may result in sleep deficiency that persists even after the abuse has ended [134]. Similarly, children who have experienced either physical and/or sexual abuse report more sleep deficiency issues than children who are not abused [135, 136], and these effects on sleep are long-term [137, 138]. Specifically, victims of abuse demonstrate prolonged sleep latency, decreased sleep efficiency, increased nighttime activity and wakefulness, and decreased sleep duration as measured by surveys [135] and polysomnography [139, 140]. Physically abused children demonstrate worse sleep efficiency than sexually abused children [141]. Additionally, sexually abused children show poorer overall sleep quality, as measured by sleep difficulties [142–144] and daytime sleepiness [141]. Compared with controls, victims of sexual abuse also experience more disturbances during the night, including higher nocturnal activity [145], more parasomnias [146], and frequent nighttime awakening [147]. Furthermore, sexually abused girls report more sleep disturbances than boys [148], and there is a correlation between sleep disturbances in sexually abused girls and revictimization [131]. Future research is needed to investigate other adverse childhood experiences and different mechanisms through which these experiences impact child sleep as well as increase the incorporation of assessments for exposure to violence and abuse.

Screen media use

Current literature reports that sleeping with a screen device (especially a mobile phone) in the bedroom is negatively associated with sleep duration [119, 149]. Greater use of screen media similarly negatively influences sleep outcomes [31]. A cross-sectional study [150] found that increased screen media use was associated with longer sleep onset, shorter sleep duration, and increased daytime sleepiness in infants and toddlers. Several studies reported that sleep duration decreased significantly in infants with each additional hour of screen use [150–152], and in toddlers and young children, both increased screen media use at night and viewing of violent content during the day were associated with increased sleep deficiency issues [153]. For school-aged children, greater screen media use, which includes an increased variety of sources—such as mobile phones, computers, television, Internet browsing, electronic gaming, and more [154]—has most commonly been associated with shorter sleep duration and delayed bedtime [155]. Children and adolescents with longer screen usage times are also more likely to report sleep deficiency [156], and sleep disturbances mediate the relationship between prolonged phone use and depression in adolescents [157].

Potential mechanisms of action include increased physiological arousal and suppressed melatonin production, which results in circadian rhythm delay [158]. These mechanisms may contribute to poor sleep outcomes through later bedtimes, longer sleep onset, shorter sleep duration, and altered sleep architecture. However, the exact underlying mechanisms, which may also involve those at the psychosocial and environmental levels, are not fully clear. Notably, a bidirectional relationship between media use and sleep duration is present, possibly attributable to shorter sleep times leading to fatigue or low energy and promoting sedentary behaviors, such as screen media use [159]. However, research has demonstrated that increased use of screen devices and electronic media increases vigilance and arousal of the nervous system, resulting in disruptions to sleep patterns and overall sleep health [160, 161]. Additional longitudinal or intervention studies are needed to further understand this relationship.

Physical injury

Because the brain is critically involved in sleep regulation [162], research has primarily focused on injury to the head and brain. In children suffering from traumatic brain injury (TBI), an increase in sleep deficiency is observed via...
parent report, self-report, and actigraphy measures [163, 164]. Furthermore, children with TBI display a variety of sleep–wake disorders, such as difficulty with sleep onset and maintenance, daytime sleepiness, and nightmares [165]. Similarly, in adolescents, minor head injuries are associated with long-term sleep disturbances [166]. Complaints regarding subjective sleep are often severe, and polysomnography measures show lower sleep efficiency as well as more frequent and longer night awakenings compared with control adolescents [167, 168]. Given the importance of regular brain function in controlling sleep behavior, it is vital to understand the relationship between childhood sleep and head and brain injuries.

Social determinants

Racial/ethnicity and cultural factors

Sleep disparity is a known epidemic, especially among minoritized children. African American, Hispanic, and Asian American children report greater sleep deficiency than White children [169–171], such as shorter sleep duration [172] and sleep-disordered breathing [173]. Similarly, Mexican and Central American adolescents are at greater risk of hypersomnia [174]. Racial/ethnic disparities in sleep may be conflated with cultural and socioeconomic factors. Cross-culturally, sleep may differ due to cultural norms, beliefs and parent perception about the function of sleep [175] and the typical daily lifestyle and schedule. Some European cultures, such as in Italy, engage in late-night activities and allow children to stay and participate. As such, children learn to fall asleep naturally without a set bedtime ritual and may have disrupted sleep due to family activities [176]. South American, African, and Asian cultures commonly rely on biphasic sleep patterns, generally involving daytime naps [177]. Specifically, a study conducted in Chinese adolescents demonstrated that the majority frequently nap throughout the week and nap more frequently or for longer durations was associated with better sleep quality at night and improved cognitive function [178]. However, further comparisons between Western and Asian cultures report later bedtimes, shorter sleep duration, and greater parental perception of child sleep deficiency in toddlers [179], preschool [180], and elementary school children [177] in Asian countries. Even within the U.S., variations in where children sleep, how they are put to bed, and parental concern regarding child sleep arise from the many diverse cultural groups within the U.S. population [181, 182]. Understanding cultural differences in both sleep practice and parental perception of children’s sleep may help in assessments and interventions to promote sleep health in pediatric patients.

Neighborhood conditions and socioeconomic status (SES)

While much research has focused on the social determinants of health in the last two decades, attention has only recently begun to be paid to their application to sleep health. Outside of the immediate home environment, the neighborhood in which the child resides and other related indicators of SES may also contribute to childhood sleep outcomes. Neighborhood conditions may include housing quality, safety, cleanliness of the environment, vandalism, sidewalks, and access to public spaces such as parks [156, 183]. Children living in unfavorable environments, characterized by greater poverty and lower SES, are more likely to have lower sleep efficiency [184], shorter sleep duration [185], and serious sleep deficiency [156]. Specifically, living in socioeconomic disadvantage is linked to a greater incidence of obstructive sleep apnea (OSA) in children [186, 187], and these neighborhood variables better account for OSA in children than individual-level indicators [187]. Parental stress, feeling unsafe, noise or other disruptions to sleep during the night, and other psychosocial and environmental mechanisms may serve to explain this relationship [156, 184]. More research is still needed in this area to understand how a broader social environment interacts with the physical environment on children’s sleep.

School factors

Children spend a significant portion of their daily lives in school, which can also contribute to sleep patterns and sleep behavior in childhood. Notably, school start time is frequently identified as an important factor in determining child sleep duration and quality. Earlier school start times are associated with shorter sleep duration [188, 189], increased daytime sleepiness [189, 190], and more frequent tardiness to school [189].

Whereas the high prevalence of sleep deprivation in students has demonstrated significant effects of poor sleep on academic performance [191, 192], there have been limited studies investigating the potential implications of academic pressures on child and adolescent sleep. Increased academic pressure may result in more time spent on homework or studying [120], greater exam stress [193], or increased worrying [194], which have been shown to negatively impact sleep. The American Academy of Pediatrics released a policy statement advocating for later school start times to allow children and adolescents to receive an optimal amount of sleep of 8 to 9 hours, which would promote physical and mental well-being [195]. Nevertheless, these policies have not been fully implemented.
Public health disasters/emergencies

In the context of the current COVID-19 pandemic, the once tightly regulated daily schedules of children and adolescents have now been dramatically altered and nearly eliminated due to policies dictating social distancing and online schooling [196]. Notably, prolonged school closures, cancelation of extracurricular activities, and confinement to the home cause reduced light exposure, increased sedentary activity, less healthy diets, and increased screen time. These factors may then impact sleep quality and disrupt normal child sleep patterns as well as result in negative effects on health in general [196]. Furthermore, the uncertainty and stress of this unprecedented situation also negatively affects the psychological well-being of children, as seen through clingy, distracted, irritable, and fearful behaviors. These behaviors may manifest in a greater incidence of mental disorders, such as anxiety and depression, or nightmares [197]. Because both anxious [198] and depressive symptoms [157] are associated with poor sleep outcomes, mitigating the psychological effects of public health disasters may help promote better sleep health among children and adolescents.

Major gaps/limitations and future directions

First, sleep deficiency has multidimensional manifestations in pediatric populations. However, the current literature has focused on sleep duration and sleep quality. More work is needed to understand the influential factors for important sleep aspects such as chronotype and sleep regularity. Additionally, whereas risk factors for unhealthy sleep often coexist in the pediatric population, prior research mainly focused on individual risk factors. Using machine learning algorithms to select the most important predictors and build risk predictive models for poor sleep will inform more meaningful interventions for sleep health. Big data-based datasets (e.g., national surveillance, EHR), biobanks (e.g., genetics, biomarkers), and data from research-used and customer-used sleep monitoring devices can be exploited to examine sleep regulations at the neuronal and molecular levels (sleep omics) and inform interventions at the individual (e.g., biobehavioral factors), family, social and systems levels (e.g., school start time). Furthermore, more researches are needed to investigate the bidirectionality of risk factors associated with poor sleep outcomes [199]. Finally, in terms of the quality of this review, we did not follow the standard guideline for systematic review using Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA). Consequently, the quality of the cited research cannot be fully ensured. Nevertheless, this integrated review is an initial step to provide a comprehensive overview of the assessments, risk factors, and potential mechanisms of childhood sleep. More systematic reviews and meta-analyses are needed in the future to provide a more rigorous conclusion.

Conclusions

Many multidimensional factors contribute to child sleep health. Recognizing poor child sleep manifestations and incorporating measurements in practice can help clinicians identify sleep deficiency early on. Furthermore, understanding the risk factors is an important first step to developing targeted prevention/intervention strategies. Gaps in the current literature may help to guide future studies on child sleep.

Author contributions JL conceptualized and designed the study. JL, XJ, ER, and SP drafted the article. JL, XJ, ER, SP, and TL revised it critically. All authors approve of the final manuscript to be published.

Funding None.

Declarations

Conflict of interest No financial or non-financial benefits have been received or will be received from any party related directly or indirectly to the subject of this article.

Ethical approval Not applicable.

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