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Review

REVIEW

A systematic review and proposed conceptual model of sleep disturbances during pediatric hospitalizations

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Abstract

Study Objectives: The current review aims to examine factors that influence pediatric inpatient sleep and determine the effectiveness of sleep promotion interventions among hospitalized children.

Methods: A systematic literature search was conducted across PubMed, PsycINFO, CINAHL, Cochrane Central, Web of Science, Embase, and Scopus databases. Studies included children with a mean age between 1 and 18 years old that either described factors affecting the sleep of children who are hospitalized on a non-intensive care unit or reported on sleep-related intervention outcomes. We conducted separate narrative reviews for each of the two aims and then synthesized findings from quantitative and qualitative studies across both aims.

Results: Forty-five articles were included for review. Despite most sleep disturbances being attributed to environmental disruptions (e.g. noise, staff interruptions), most interventions targeted the child level using relaxation techniques. Although the majority of interventions were small pilot studies, preliminary findings appear to positively impact sleep duration. The Pediatric Inpatient Sleep Model was proposed to illustrate connections between sleep disturbances, factors influencing sleep, and existing intervention components.

Conclusions: Replication studies are needed, including larger-scale sleep promotion interventions among hospitalized children. Given the identification of environmental factors as the main cause of night wakings, environmental modifications are crucial. Additional research examining contributors to intraindividual variability in disrupted sleep patterns during hospitalizations as well as the consequences of these disturbances is warranted.

Statement of Significance

Pediatric hospitalizations should promote healing and recovery; however, hospitalized children and adolescents experience significant sleep disruptions and reduced sleep duration during inpatient admission. Our systematic review evaluated the causes of inpatient sleep disturbances and the effectiveness of sleep promotion interventions. Most interventions demonstrated preliminary support for improving sleep in the hospital. We synthesized our findings into the Pediatric Inpatient Sleep Model to guide future research and inform evidence-based practice. Although sleep disturbances were most frequently attributed to environmental factors (e.g. noise, staff interruptions), most interventions targeted child-level factors through relaxation techniques. This discrepancy highlights a crucial avenue for future interventions to improve inpatient sleep through environmental modifications, such as reducing unnecessary vital checks or bundling medical care.

Key words: sleep; child; adolescent; hospitalization; inpatient

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Introduction

Sleep duration plays an important role in the maintenance of physical and mental health [1, 2]. Given the substantial neurodevelopment occurring during childhood and adolescence, adequate sleep is vital during this period [3, 4]. Consequences of insufficient sleep during childhood can have lasting effects that persist into adulthood, such as being at increased risk for symptoms of anxiety and depression [5]. Sleep disturbances are associated with increased markers of systemic inflammation, including interleukin-6 and C-reactive protein [6]. Adequate sleep appears to support recovery following diverse injuries across multiple populations [7, 8].

Pediatric hospitalizations are meant to be a period of healing and recovery; however, they can place children at risk for disrupted sleep and circadian rhythm dysregulation due to a novel sleep environment, medical care, and illness-related stress and pain [9–14]. Interruptions for medical care have been associated with increased noise and light exposure, which may contribute to disruptions in circadian rhythm [9, 15]. Medications can also interfere with sleep quality [16, 17]. Pediatric hospitalizations are often associated with poor sleep quality, reduced sleep duration, and increased night wakings [13, 18, 19]. However, results from pediatric pilot randomized control trials suggest behavioral-educational and enhanced physical activity interventions can improve child sleep during hospitalizations [20, 21].

A small number of recent reviews demonstrate that pediatric patients experience reduced total sleep time (TST), increased night wakings, greater wake after sleep onset (WASO), lower sleep efficiency (SE), and poor sleep quality while hospitalized [22–24]. Lee et al.'s [24] systematic review concluded that pediatric oncology patients experience increased disrupted sleep while hospitalized. However, it is difficult to determine the extent to which the observed sleep disruptions were due to cancer treatments or the hospital environment. Berger et al.'s [22] narrative review provided an overview of sleep disruptions in various hospital settings with a particular focus on the neonatal and pediatric intensive care units (ICUs); potential pharmacologic and non-pharmacologic interventions to treat inpatient sleep disturbances were also discussed. Hybschmann et al.'s [23] scoping review mapped the research on how pediatric patients sleep in the hospital and identified broad factors related to sleep disturbances.

These reviews concluded that disordered sleep is prevalent among hospitalized children; however, findings were limited in their discussion and synthesis of factors impacting inpatient sleep. An overview of existing intervention approaches was provided, but intervention effectiveness was not systematically examined. Furthermore, it is difficult to draw conclusions about sleep on general pediatric units, because patients on ICUs were included in the two broad reviews and have unique sleep needs [25]. The next logistical progression in this body of literature is to build upon these narrative and scoping reviews, which serve as helpful precursors to a systematic review [26].

This current systematic review will extend prior work by systematically examining the effectiveness of sleep promotion interventions, using qualitative methods to describe factors affecting sleep on non-ICUs, and utilizing an established framework that integrates both quantitative and qualitative findings into a conceptual model [27]. More specifically, study aims include (1) to examine factors that influence sleep during pediatric hospitalizations and (2) to determine the effectiveness of sleep promotion interventions among hospitalized children.

Methods

Overarching methodology

Findings from quantitative and qualitative studies were synthesized using framework developed by the Evidence for Policy and Practice Information and Coordinating Centre (EPPI-Centre) [27]. An initial scoping review was conducted to map the broader literature base, clarify research aims, and identify appropriate study designs for each synthesis. This initial review yielded three primary groups of literature: (1) quantitative articles measuring the extent to which child sleep is impacted during hospitalizations; (2) qualitative and quantitative articles examining factors that influence sleep during pediatric hospitalization as reported by children, caregivers, and providers as well as by objective measurement; and (3) quantitative articles measuring the effectiveness of sleep promotion interventions. After parallel systematic reviews were conducted to address each aim, findings were synthesized across reviews. To avoid duplicating the results of recently published reviews focusing on pediatric sleep outcomes during hospitalizations [22, 23], we tailored this review to focus on the second and third groups of literature. Due to the heterogeneity of sleep outcomes, a meta-analysis was not feasible; the results of each review were described qualitatively. The study protocol was registered on Prospero [28]. The data underlying this article are available in the article and in its online supplementary material.

Search strategy

PubMed, PsycINFO, CINAHL, Cochrane Central, and Web of Science databases were searched on November 12, 2019. The search was updated on July 1, 2021. In response to peer-review feedback, we also searched Embase and Scopus databases for articles published prior to July 1, 2021. No study period or geographic restrictions were used; however, search results were limited to peer-reviewed English-language publications spanning children aged birth through 17 years. The search strategy utilized variations of the following keywords: ("hospital" or "inpatient") and ("sleep" or "nocturnal" or "circadian") and ("child" or "adolescent" or "youth" or "pediatric"). Supplemental Table 1 details the PubMed search strategy.

Inclusion and exclusion criteria

To be included, the study must: (1) be written in English, (2) be published in a peer-reviewed journal, and (3) report on at least one sleep-related intervention outcome of children who are hospitalized on a non-ICU with a mean age between 1 and 18 years old (e.g. TST, sleep quality, SE, night wakings) or describe factors affecting the sleep of these children. Following EPPI-Centre guidelines, study designs were determined by the initial scoping review. Therefore, aim 1 will be addressed by both quantitative and qualitative descriptions of factors affecting sleep, given the broader literature base as well as the benefit of including multiple perspectives to triangulate findings (i.e. develop a more complex understanding of a topic using multiple data sources or analytic approaches) [29]. Study designs were limited to quantitative measures of child sleep to address aim 2. Single case studies, articles without original data, measure validation studies, and medication/medical device trials were excluded. Studies with participants on psychiatric or ICUs were excluded due to the established impact of psychotropic medications on sleep [30] and the unique sleep needs of patients in ICUs, particularly those who are mechanically ventilated [25]. Samples consisting entirely of children with reported sleep disorders or sleep-disordered breathing were also excluded. Articles were excluded in the following predefined order: (1) written in a language other than English, (2) published in non-peer review journal, (3) not original data, (4) not appropriate population, (5) no report on sleep outcome or description of factors influencing sleep, and (6) inappropriate study design as determined by our initial scoping review (i.e. qualitative measures of child sleep addressing aim 2).

Study selection

The search records were imported into Covidence, a record management software for systematic reviews, and duplicates were removed. A random 20% of the abstracts and full-text articles were selected using a random number generator and double screened as a means of increasing methodological rigor and reliability of findings. Two authors (A.L.F. and S.V.) met to resolve differences and decide which abstracts and articles met inclusion criteria. We resolved disagreements via discussion or 2/3 consensus with another author (D.A.F.). Cohen's kappa was calculated for inclusion versus exclusion. Per our protocol, if interrater reliability was inadequate (i.e. kappa less than 0.70), another random 10% of the abstracts or full-text articles were expected to be evaluated by both authors. Once adequate reliability was obtained, the primary author screened the remaining abstracts or full-text articles. Following the selection of articles, forward and backward reference searches were conducted.

Protocol revision

An aim of our original protocol was to explore the extent to which child sleep was impacted during hospitalizations. However, during our updated search, we discovered that two reviews were recently published on this topic [22, 23]. Given the substantial overlap and similar findings, we chose to eliminate this aim to avoid duplicating existing work. Four articles were excluded following this decision [31–34].

Per the original protocol, a kappa less than 0.70 suggested inadequate interrater reliability. However, despite a high percent agreement (98.7%), our abstract screening kappa was 0.65. Given the known base-rate problems with kappa and the low base rate of moving an abstract to full-text review within this study (0.02%), an adjusted target kappa was calculated in accordance with Bruckner and Yoder [35]. Our kappa was sufficiently above the adjusted target kappa (0.39); thus, we considered interrater reliability to be adequate and did not double screen another 10% of the abstracts. Furthermore, a kappa of 0.60 is generally categorized as "good" agreement [36]. For full-text review, there was 100% agreement between the authors (kappa = 1.00). A protocol revision has been submitted to Prospero [28].

Data extraction and study rating

The primary author extracted data using a standardized log; another author (S.V.) confirmed all extracted data. For aim 1, factors influencing sleep were qualitatively synthesized and organized into a thematic hierarchy. More specifically, all articles were imported into NVivo (Version 12.0.0.71 Plus, QSR International). Two authors (A.L.F., S.V.) coded each article using descriptive content analysis and resolved any coding discrepancies through discussion. We maintained a detailed log of our decisions and created a codebook (Supplemental Table 2). Initial codes were aggregated into themes. The established coding structures of included qualitative articles were used to guide the development of our thematic hierarchy. Relevant quotations from qualitative articles were included to show research participants' descriptions and to increase credibility of findings through convergence of data from multiple sources [29]. For aim 2, we extracted sleep-related intervention outcomes, including sleep duration or TST, sleep onset latency (SOL), night wakings, WASO, sleep quality, SE, bed- and wake-times. Effect sizes were calculated using Campbell Collaboration's web-based calculator when possible [37].

Quality assessments were conducted to categorize the potential risk of bias introduced by study design and execution as well as by reporting of results. Qualitative articles were assessed for quality based on the guidelines set forth by Wu et al. [38]. The quality of quantitative studies was assessed by the Study Quality Assessment Tools of the National Heart, Lung, and Blood Institute (NHLBI) [39]. Each article was evaluated using a standardized form, which included questions related to study design-specific methodology and reporting of results. Study design was determined by the data included in this review. Two authors independently evaluated each article and assigned an overall categorical rating of good, fair, or poor. Quality was considered good if there was a low risk of bias, fair if there was some risk of bias, and poor if there was a high risk of the study's methods or reporting biasing the findings [39]. Disagreements regarding quality assessments were resolved through discussion or through a consensus with another author. A PRISMA flow diagram (Figure 1) and PRISMA checklist (Supplemental Table 3) were also completed.

Results

Participants and study characteristics

Database searches yielded 11 533 non-duplicate records; 178 full-text articles were assessed for eligibility, and 3 articles were identified during forward-backward literature searches (Figure 1). Forty-five articles, including data from a total of 2499 participants across 40 unique studies, were included in this review. Of the four studies published in multiple articles, all nine articles reported different outcomes and were therefore included. Findings from four articles addressed two study aims and were included in each applicable parallel review. In total, 40 articles (36 quantitative, 4 qualitative) examined factors influencing sleep, and nine quantitative articles measured the effectiveness of sleep promotion interventions. Most studies were conducted in the United States (60%, n = 24). The average sample size was 69, ranging from a minimum of 6 participants to a maximum of 394. Of studies involving child participants, 16 studies (44%) did not report race/ethnicity, 11 studies (31%) did not report mean participant age, and 5 studies (14%) did not report sex. Of those reporting demographic information, 46% of participants were male (n = 1102), 43% were white/Caucasian (n = 682), 42% were black/African American (n = 674), 6% were Hispanic/Latino (n = 91), 2% were Asian (n = 39), and 6% were another race/ethnicity or not described (n = 100). The average child age was 8.93 years. Additional study and sample characteristics are listed in Supplemental Table 4.

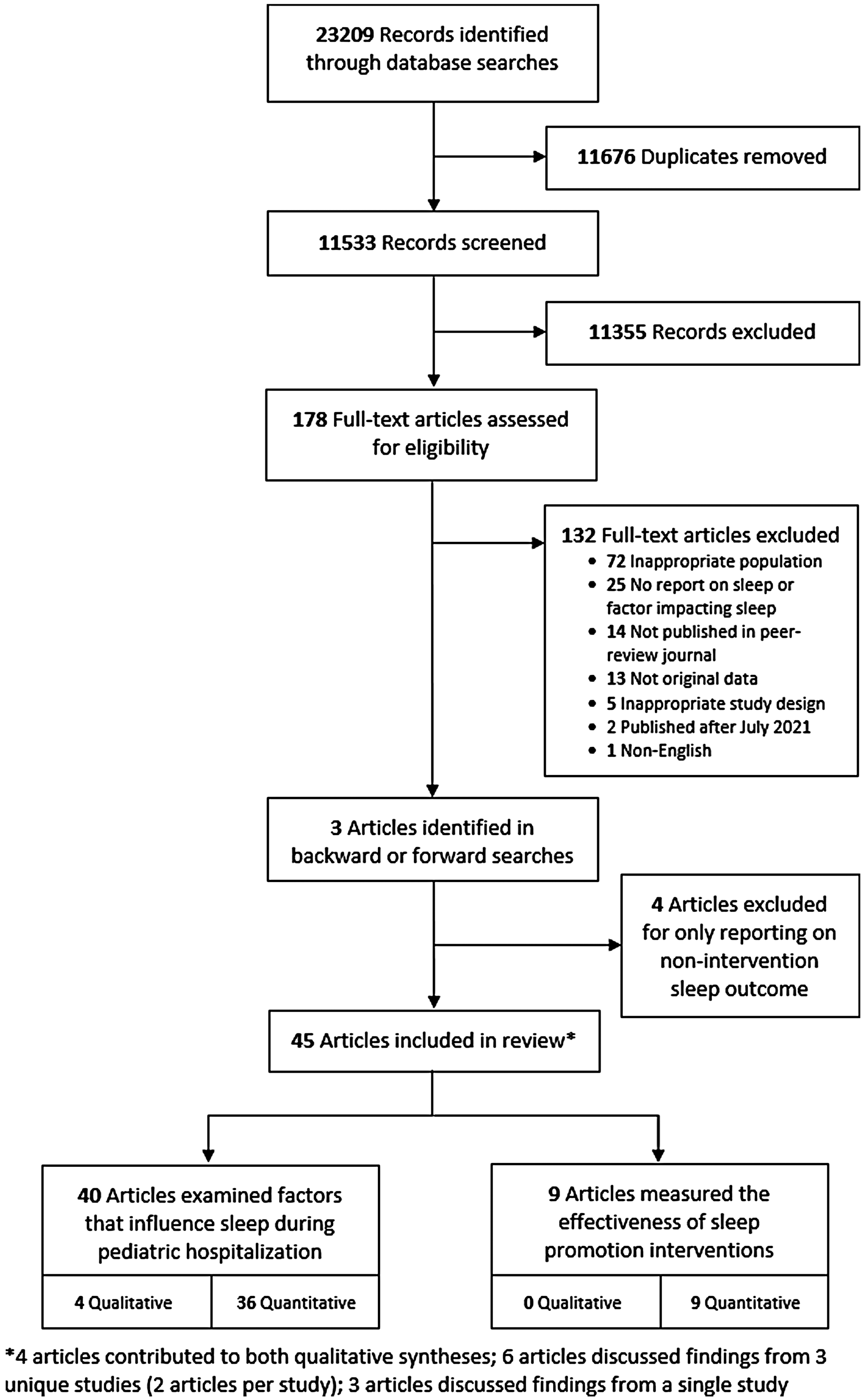

Figure 1. PRISMA diagram.

Aim 1: factors affecting child sleep

Factors affecting pediatric sleep during hospitalizations were categorized into three primary levels: child factors, family factors, and environment factors. We further divided child factors into two broad categories: pre-hospitalization and current hospitalization. The full thematic hierarchy is displayed in Table 1.

Table 1. Factors contributing to sleep disruption

	Articles discussing factor	Articles suggesting factor is related to sleep outcomes
Child factors		
Pre-hospitalization		
Demographics		
Developmental level	9; 10; 12; 13; 17; 19; 40; 41; 42; 43; 44; 45; 46; 47; 48; 49; 50; 51; 52; 53; 54	9; 12; 17; 19; 41; 54
Gender	10; 17; 41; 44; 46; 47; 48; 50; 52	
Insurance status	42	42
Race and ethnicity	42; 52	
Baseline sleep	10; 17; 19; 42; 49; 52; 55	17; 55
Prior hospitalizations	9; 17; 43; 48; 50; 51	9; 48
Medical condition	10; 17; 42; 44; 47; 52; 56	17; 56
Current hospitalization		
Activity	10; 14; 16; 43; 52	10; 14; 16; 43
Admission reason	9; 12; 17; 44; 46; 48; 49; 52; 57	9; 12; 48; 49; 57;
Affect	12; 13; 16; 17; 40; 41; 43; 48; 52; 53	12; 13; 40; 41; 43; 48; 52; 53;
Basic needs	16; 17; 42; 48; 58	16; 17; 42; 48; 58
Illness severity	9; 40; 42; 46; 49; 51	9; 40; 42; 49
Length of hospitalization	10; 12; 41; 47; 50; 59	12; 41; 47;
Medications	17; 16; 49; 52; 60	17; 16; 49; 52
Perception of safety	16	16
Symptoms	10; 12; 13; 15; 16; 17; 41; 42; 43; 44; 46; 48; 49; 52; 53; 54; 59; 61; 62	12; 13; 15; 16; 17; 41; 42; 43; 46; 48; 52; 53; 54; 59; 61
Family factors		
Caregiver affect	41; 57; 63	41; 57; 63
Family dynamics	50; 51; 63	63
Parenting behavior	41	41
Environment factors		
Altered schedule	16; 42; 47; 48; 59; 64	16; 42; 47; 48; 59; 64
Bed comfort	12; 13; 16	12; 13; 16
Interruptions	9; 10; 12; 13; 15; 16; 17; 19; 42; 43; 45; 47; 48; 49; 52; 53; 54; 55; 61; 64; 65; 66; 67	9; 10; 12; 13; 15; 16; 17; 19; 42; 43; 45; 47; 48; 49; 52; 53; 54; 55; 61; 64; 66; 67
Light	9; 11; 15; 16; 43; 48; 49; 52; 58; 61; 64	9; 11; 15; 16; 43; 48; 49; 52; 58; 61; 64
Noise	9; 11; 12; 13; 15; 16; 17; 43; 48; 49; 52; 53; 54; 55; 58; 61; 64; 66; 69; 70	9; 11; 12; 13; 15; 16; 17; 43; 48; 49; 52; 53; 54; 55; 58; 61; 64; 66; 69; 70
Novel environment	16; 43; 47	16; 43; 47
Presence of roommate	10; 16; 17; 42; 43; 48; 49; 52; 58	10; 16; 42; 43; 48; 49; 52; 58
Temperature	11; 13; 15; 16; 17; 53; 61; 64	13; 15; 16; 17; 53; 61; 64

Child factors: pre-hospitalization

DEMOGRAPHICS. Studies examined whether demographics, such as age, gender, insurance status, and race or ethnicity were related to inpatient sleep outcomes. Some studies found younger children slept longer than adolescents or older school-aged children [17, 19, 40, 41]; however, only one article demonstrated statistically significant findings, where age was negatively associated with total daily sleep minutes [41]. Age-related discrepancies may be due to differing levels of situational comprehension or understanding of their surroundings. During focus groups, nurses described adolescents and school-age children as being better able to achieve sleep and return to sleep after awakenings, which they attributed to the older children's increased understanding of the need for hospitalization or medical procedures; whereas, the nurses perceived toddlers and preschool children as more prone to sleep disruption given their developmental level and reduced comprehension [9]. Other studies did not find any significant associations between child age and sleep duration [10, 13, 42–46], night wakings [10, 13, 41, 42, 47–49], SOL [41, 50, 51], SE [41], WASO [41, 44], inadequate sleep [52], or sleep disruptions [53]. The lack of significant differences in sleep duration is meaningful, given younger children's greater sleep requirements. As such, younger children experience a greater difference between their recommended and actual sleep duration in the hospital than their teenage counterparts [17, 19, 40, 54]. Of note, Meltzer et al. [12] found that school-age children experienced shorter sleep durations in the hospital than at home, whereas adolescents reported longer sleep durations in the hospital setting.

Gender was not related to night wakings [10, 41, 47, 48], poor sleep quality [17], sleep duration [10, 41, 44, 46], SE [41], SOL [41, 50], inadequate sleep [52], or WASO [41, 44]. Regarding racial differences, African American children had significantly shorter observed TST and spent significantly more time awake at night when compared to white children [42]. The same study found that children with Medicaid experienced significantly shorter TST, more night wakings, and more time awake than their counterparts with private insurance. However, when race, insurance, care complexity, and bedtime were included in the same model, race was no longer associated with any sleep outcomes; insurance status continued to be related to TST [42]. Other studies found no associations between race or ethnicity and inadequate sleep [52].

BASELINE SLEEP. The literature was mixed on the relationship between baseline sleep characteristics and inpatient sleep. One study found that sleep difficulties in the week prior to admission were significantly associated with poor inpatient sleep, suggesting potential underlying sleep problems [17]. Another found that children who had given up naptime at home were more likely to experience wakefulness during hospital mandated afternoon quiet time [55]. However, within other studies, measures of inpatient sleep were not related to baseline fatigue levels [10] or baseline sleep habits during the prior week [49, 52] or 3 months [42]. Of note, almost a quarter of hospitalized pediatric patients screened positive for sleep-disordered breathing as measured using the pediatric sleep questionnaire, which is higher than the prevalence within the general population [19].

PRIOR HOSPITALIZATIONS. The literature was mixed on whether prior hospitalizations are related to inpatient sleep outcomes. One study found that children aged 3 to 8 years old with a history of prior hospitalizations slept an average of 46 min longer than those who were not previously hospitalized; however, this difference was not statistically significant [43]. Additional findings from this sample suggested that children who were previously hospitalized experience more frequent night wakings related to internal causes of arousal (e.g. pain, hunger, fear) than their counterparts without a history of prior hospitalizations; there were no group differences in external causes of arousal [48]. Nurses described having the perception that sleep was less likely to be disrupted among children with previous experience in the hospital [9]. Other studies did not find any statistically significant relationships between number of prior hospitalizations and poor sleep [17] or SOL [50, 51].

MEDICAL CONDITION. Participants attributed night wakings in the hospital to their underlying medical condition [56]. One study found that 62% of children with chronic medical conditions reported poor sleep, whereas only 33% of children with cancer reported poor sleep in the hospital setting [17]. However, other studies found no statistical relationship between diagnoses and sleep duration [10, 42, 44], night wakings [10, 42, 47], inadequate sleep [52], or WASO [42, 44].

Child factors: current hospitalization

ACTIVITY. Children and adolescents with cancer experienced dysregulated circadian activity rhythms while hospitalized for high-dose chemotherapy [14]. More specifically, amplitude, 24-h autocorrelation, and dichotomy index appeared dysregulated when compared to published values, which suggests these patients experienced higher activity during sleep, lower activity during the day, and less stable rest-activity patterns over time [14]. In a qualitative study, adolescents described inactivity as having a negative influence on their sleep in the hospital [16]. One adolescent stated:

> You know it's yourself you have to try and keep occupied during the day, cause if you don't do anything during a whole day and just sit and like check your phone or something then you don't burn any energy and that makes that when you're gonna sleep you won't be able to sleep, so I'd like to say just try to do something in general, maybe that's just playing cards for a bit, or try to sit up or try to move a bit, just do something and instead of just lying doing absolutely nothing cause then it will be hard to sleep [16].

On the opposite end of the spectrum, engaging in non-sleep-promoting activities at night can also impact sleep. In over a third of children aged three to eight years old, sleep onset was observed to be delayed beyond 10:00 pm due to self-initiated activities, which included watching television or engaging in play activities, and the lack of an established pre-sleep routine [43]. One study found a trend between four or more hours of screen time and inadequate sleep, but this relationship did not reach statistical significance [52]. Hinds et al. [10] detail the cycle in which disrupted sleep can lead to lengthier sleep periods that then interfere with daytime activities, which can negatively impact sleep during future nights in the hospital.

ADMISSION REASON. Relationships between admission reasons and sleep outcomes appeared mixed. During focus groups, nurses described how planned admissions facilitated less disrupted sleep, which they attributed to the children knowing what to expect and being able to plan for their hospital stay [9]. Parents corroborated this connection and reported more sleep problems during acute admissions [57]. Children who were admitted for a planned surgery slept two hours more and were less likely to wake instantaneously than those who were admitted for exacerbations related to a chronic illness [49]. Patients aged eight to 21 years old who underwent surgeries reported earlier bedtimes than those who were hospitalized for chronic illness or "other" reasons, including medical tests, infections, and blood transfusions [12]. Younger children aged three to eight years old who were admitted for medical reasons had more frequent and lengthier night wakings due to internal cues than those admitted for elective surgeries [48]. However, other studies found no statistical relationship between reasons for hospitalization and sleep duration [44], poor/ inadequate sleep [17, 52], or WASO [44]. Length of operation was also not associated with hourly sleep minutes [46].

AFFECT. Children's affect or emotional experiences also impact inpatient sleep. Sleep disturbances were attributed to worries and being homesick, with over a third of children describing being homesick as bothering them "somewhat" or "a lot" and parents reporting worries kept their child awake on more than half of nights [12, 13, 52]. Worries included concerns related to medical procedures and separation from family members among children aged 3-8 years [43, 48]. Adolescents were concerned about unknown people entering their hospital room at nights and described feeling more comfortable with predictable nightly routines [16]. Pediatric patients across a wide range of ages expressed worries about school and the reason for their hospitalization [12, 13]. Both nurses and physicians were almost twice as likely to endorse general anxiety as a factor disrupting pediatric inpatient sleep when compared to the children's caregivers (40-41% versus 22%) [53]. Within a sample of children aged two to eleven years, increased procedural and treatment anxiety was associated with reduced daily sleep duration, while increased social and separation anxiety was associated with increased total daily nap minutes among preschoolers [41]. Daytime mood predicted the following night's sleep duration and SOL among children with cancer [40]. Among patients aged 0–18 years, parent report of child worries was associated with inadequate sleep [52]. However, another study did not find any significant relationship between parent-reported poor sleep and child anxiety [17].

basic needs. Both family reports and observational studies suggest that night wakings occur due to basic needs (e.g. toileting, thirst) [17, 48]. Bathing, starting feeds, and voiding in general as well as every two hours as part of a bladder-protective protocol disrupted sleep [13, 16, 17, 48, 54]. Eating patterns can also influence sleep. Children who ate snacks after 9:00 pm had significantly later bedtimes and over an hour less TST than their counterparts who ate before 9:00 pm [42]. One qualitative study described how adolescents' reduced food intake while hospitalized may contribute to sleep disruptions [58]. Reported caffeine intake was not related to night wakings, sleep duration, or WASO [42].

illness severity. Nurses in a qualitative study perceived children with worsening conditions as having more sleep disruptions due to the need for more frequent assessment and intervention [9]. This was further supported by quantitative findings demonstrating connections between increasing severity or medical complexity and reduced sleep duration [40, 49], more night wakings [42, 49], as well as higher WASO [42]. One study found a curvilinear relationship with night wakings, where night wakings became more frequent as medical care complexity increased from minimal to moderate; however, the frequency of night wakings reduced as care complexity increased from moderate to severe [42]. Illness severity was not significantly related to SOL among children aged 3–8 years [51] or hourly sleep minutes among postoperative adolescents and young adults [46].

length of hospitalization. During their first night in the hospital, children experienced later bedtimes, earlier wake-times, and significantly shorter sleep than those who already stayed overnight once [12]. Pediatric oncology patients with longer hospital stays experienced longer TST, suggesting that patients may become more accustomed to life in the hospital and be able to sleep more over time [41]. However, children admitted for inpatient chemotherapy experienced, on average, an hour less of TST on nights two and three of their admission when compared to their first night in the hospital [47]. Children with sickle cell disease appeared to experience limited changes in their disrupted sleep-wake patterns over the course of their hospital stay [59]. Other studies did not find any significant relationship between length of hospitalization and night wakings [10], SOL [50], or sleep duration [10].

medications. The impact of medications on sleep appears mixed. Regarding medicine-based pain management, one study found that poor sleep appeared to be more common among children who used opioids than those who did not, but this relationship did not reach statistical significance (p = .08) [17]. Qualitative interviews with adolescents suggested that patients perceived morphine as having both positive and negative impacts on their sleep [16]. For example, they reported it may initially help them fall asleep, but then increase night wakings due to needing to use the bathroom more frequently or the noise from the infusion pump [16]. Taking medications that promoted wakefulness was related to reduced spontaneous awakenings, and medications that promoted sleep were related to an increase in spontaneous awakenings among children aged 1–18 years; Stremler et al. suggested these counterintuitive findings likely reflect the child's state and need for these medications [49]. Benzodiazepine use was significantly associated with inadequate sleep within a sample of patients aged 0-18 years [52]. Among hospitalized oncology patients, the use of corticosteroids was not significantly related to difficulties falling asleep [60].

perception of safety. Adolescents' perception of the hospital as a safe place helped to facilitate their sleep according to one qualitative study [16]. One adolescent stated, "I felt that the hospital was always a safe place, you know you feel safe here and that calms you down a bit" [16]. Some noted how the knowledge that staff were checking in on them and that they could push the alarm button for help if needed increased their feelings of safety while hospitalized [16].

symptoms. Physical discomfort from illness or medication side effects, including fever, pain, nausea, vomiting, and diarrhea, frequently disrupted sleep [12, 13, 16, 17, 42, 43, 46, 48, 52, 54, 56, 61]. Among a sample of Japanese children with cancer, increased symptomology was associated with increased night wakings and WASO, and greater cognitive fatigue was related to earlier wake time [41]. Caregivers, physicians, and nurses all ranked pain as a common disruptor; although physicians and nurses reported that pain disrupted pediatric sleep more frequently than caregivers estimated [53]. Children aged 8–12 years who experienced pain had significantly longer SOL when compared to those without pain [12]. Although quantitative comparisons between adolescents with and without pain did not yield any significant differences in SOL [12], adolescents qualitatively described pain as the most common cause of disrupted sleep, including difficulties falling asleep and night wakings [16]. Among children with sickle cell disease and postoperative patients, increased pain was associated with less sleep time at night [46, 59]. However, the relationship between pain and sleep appears mixed among children with cancer. One study found nausea and pain were significant predictors of total sleep within each two-hour time interval [15]. While other pediatric oncology studies did not find any relationships between pain and sleep duration [44, 62], WASO [44], or SE [44]. In a sample of general pediatric patients, pain measured 2 min before or in the minute of a night waking was not associated with increased risk of spontaneously waking [49]. Parents reported pain interfered with their child's sleep on over 40% of nights; however, this parent-report of pain was not significantly related to inadequate sleep among patients aged 0–18 years (p = .09) [52]. Physiologic factors, such as hemoglobin and hematocrit levels, were not related to night wakings or sleep duration among children with cancer [10].

Family factors

caregiver affect. There were mixed findings regarding the impact of caregiver affect or emotional responses on sleep. Caregiver trait anxiety was positively associated with child SOL among children with cancer in Japan, such that increased anxiety was related to longer SOL [41]. However, another study found increased maternal state anxiety was associated with shorter SOL among children whose parents did not stay overnight; Powell et al. suggested this may be due to the children being able to relax more quickly without the presence of an anxious parent at bedtime [63]. Parents who reported not feeling secure during their child's hospitalization reported significantly greater levels of child sleep disturbances than parents who felt secure [57].

FAMILY DYNAMICS. There appears to be mixed findings regarding the connection between family structure and SOL. One study found family structure was related to SOL among young children staying overnight without a parent present, such that pediatric patients without any siblings and those with four or more experienced a longer SOL than those with two or three siblings [63]. However, other studies did not find any connections between SOL and family social status or family structure [50, 51].

PARENTING BEHAVIOR. Higher levels of regimented attitude or more controlled approaches toward child-rearing were associated with increased child WASO among a sample of pediatric oncology patients in Japan [41]. The same study found that stronger tendencies for parents to have a receptive and focused attitude while child-rearing was related to their children having less total daily nap minutes while hospitalized [41].

Environment factors

ALTERED SCHEDULE. Multiple studies discussed pediatric patients' schedules being altered while hospitalized [16, 42, 47, 48, 56, 59, 64]; however, there is a lack of consistency in how schedules are changed. During qualitative interviews, one parent noted their child "tries to stay up as long as possible because there is so much going on in hospital" [64]. Another study involving younger children found that sleep was frequently terminated at 5:00 am due to hospital routines [48]. Hospitalized adolescents in Sweden described going to bed earlier in the evening and staying in bed later in the morning than their typical schedule at home [16], whereas school-age children receiving inpatient chemotherapy tended to go to bed and wake up later [47]. Napping and resting during the day appears to be common among both children and adolescents [16, 59, 64]. Spending holidays, such as New Year's Eve, in the hospital also contributed to patient's altered schedules [47]. One study in Portugal attributed nighttime wakings to patient's different sleeping schedules while hospitalized [56].

BED COMFORT. Participants identified uncomfortable beds as a source of sleep disturbances in two studies [12, 13]. Swedish adolescents appreciated that beds were height adjustable and generally comfortable; however, one described the bed as "tiny" and suggested it might not be as comfortable for "bigger teens" [16].

INTERRUPTIONS. On average, room entry/exit checklists demonstrated parents and staff entered and exited children's rooms 11–12 times per night [10, 65]. An objective measure using heat sensors revealed an average of seven room entries per night [19]. Multiple studies found that staff interruptions result in increased awakenings or disrupted sleep [13, 15–17, 42, 43, 45, 47–49, 52, 54, 56, 61], with over half of awakenings with clear cause being related to a staff member entering the room to provide care [42]. Nurse interruptions (i.e. vital checks, medication administration, blood draws) more than tripled the risk of patients experiencing inadequate sleep [52]. One study also found that environmental service workers entered patient rooms multiple times per night for trash pulls [66]. Caregivers ranked nurse/physician interruption as the number one sleep disruptor for their children; however, nurses and physicians did not implicate themselves and ranked that item in spots six and seven, respectively [53]. Nurses described how interruptions caused by parents and visitors can also disrupt pediatric patients' sleep [9].

Caregivers, physicians, and nurses all ranked vital checks within their top five sleep disruptors [53]. This was corroborated by multiple studies suggesting medical assessments contributed to frequent sleep disruptions [12, 13, 43, 48, 52, 55, 64]. Approximately a third of children had lab draws at night, and vital signs or other assessments occurred three times per night on average [13]. Parents described the frequency of the assessments as excessive, stating "coming in at 2 am wanting to do temperature and obs. I just think that's unnecessary and can be done at a different time" [64]. During a focus group discussion, nurses expressed understanding parent's frustrations while simultaneously describing a tension between care priorities and safeguarding patient sleep [9]. Some nurses discussed the need to make a concerted effort to place importance on sleep and advocate for their patients when necessary by recognizing when the timeline for ordered procedures may be more flexible and asking "just a second, can we wait until morning?" [9]. One nurse discussed the role of experience in optimizing care to promote sleep:

> So you know that between 7:30 or 8:30 I have to get vitals done because that's what you're supposed to do every four hours. But then as you get more experienced, and more comfortable in your care and your judgment, then you start the negotiation period where okay, the next time the kid wakes up, I'll do vitals. If it's six hours from the last time, it's fine. You just have a better assessment and better judgment on what the acuity is of a child and what they need during the night. Within what's ordered, but with mild variations so that you do optimize their sleep in the nighttime…As I've gotten more experienced, I'm much better at negotiating and optimizing care, and going to the doctor and saying…change it to every six or every eight… [9]

Although some nurses felt comfortable reducing monitoring to avoid sleep disruptions, others expressed concerns for patient safety and liability if monitoring was reduced. They also described a culture where hourly observations and monitoring are expected [9].

Caregivers reported that administering medications disrupts sleep [67]. Among children with cancer, the number of medication doses was significantly associated with sound levels and sleep quantity, indicating that administering medications contributed to increased noise and less sleep [15]. Eighty-five percent of children received medications at night, and over half of parents described the timing of medications as disruptive [13, 64]. One parent stated "Definitely the times the drugs were administered was a problem. With the 6 hourly drugs it always seemed to fall in the middle of the night and that was definitely going to wake him up" [64]. Caregivers view medications as a top sleep disruptor; however, on average, physicians and nurses ranked medications in the lower half of their sleep disruptor lists [53]. Despite that discrepancy, nurses in a focus group viewed modifying care to preserve sleep at night as within their role. They described the considerable work that went into planning "the timing of medications, anticipating when machines might signal the end of infusions," and "maximiz[ing] time between care episodes" [9].

LIGHT. Patients, their families, and researchers described light exposure as contributing to night wakings and sleep disturbances [16, 43, 48, 52, 56, 58, 61, 64]. Participants from one study reported, "A lot of light flooded in, which was unnatural" and "The lights are always on. You don't get a very good night's sleep"

[64]. Parents reported light in the room disrupted their child's sleep on over 20% of nights [52]. During focus groups, nurses discussed tension between having enough lighting to conduct assessments and minimizing sleep disruptions [9]. One participant stated, "sometimes we really try to avoid that light coming into the room, and we're doing it at a cost to how well we can see and how well we assess the kid…. I carry around a flashlight with me, but there's only so much you can do with that, and just to facilitate sleep we sometimes are blind in there" [9]. Taken together, results suggest children partially attribute disrupted sleep to light exposure and nurses attempt to modify care when possible to promote sleep.

Objective measures of light demonstrated differences in exposure by time of night. In contrast to participant report, objective measures of light intensity were generally described as "low" and conducive to sleep between 11:00 pm and 6:59 am [11, 15]. However, light levels were significantly higher from 9:00 pm to 10:59 pm [11,15]. Another study verified this observed shift in luminosity at 11:00 pm. In comparison to the recommended value of less than or equal to 5 lux, all rooms and hallways were within target range from 11:00 pm to 7:00 am; however, from 8:00 pm to 11:00 pm, only 40% of rooms and 20% of hallways were under the recommended value [61]. One study found light at the child's bedside exceeded 150 lux, on average, for between 44 to 100 min at night [49]. Increased luminosity was significantly associated with reduced sleep quantity and increased risk of instantaneously waking [15, 49].

NOISE. Noise was the most frequently discussed sleep-disrupting factor and was examined in 21 studies. Children and caregivers often attributed nocturnal disturbances to noise, with nearly half of adolescents endorsing being bothered by noise in the morning [12, 13, 16, 17, 52, 56, 58, 61]. These findings were corroborated by researchers conducting observational studies on nighttime sleep as well as during afternoon naps [43, 48, 55]. Common sources of noise include other patients/visitors, the hospital staff, equipment on the ward, trash pulls, and doors opening/closing [12, 13, 54, 64, 66]. Nurses and physicians rated noise and alarms on equipment as highly disruptive to child sleep; caregivers, on the other hand, rated those two items in the bottom half of their sleep disruptors list [53]. Despite caregivers' lower rating of noise in the aforementioned study, the overwhelming majority of evidence supports the notion that children experience sleep difficulties due to noise levels. Mean decibels recorded on individual units ranged from 44.1 dB to 62.5 dB; with the exception of a single ward, all units were above the World Health Organization's recommended threshold of 45 dB [11, 13, 15, 61, 66, 68–70]. The average length of time noise exceeded 46 dB at the child's bedside ranged from 84 to 115 min across the night [49]. Increased noise was strongly associated with reduced sleep quantity, increased risk of instantaneously waking, and inadequate sleep [15, 49, 52].

Numerous qualitative studies also discussed noise as a barrier to sleep. One participant stated, "It's very noisy at night. I don't think there's much of an effort made to be quiet. Sometimes you can hear the bins slamming and the talking, the babies crying, and you know it's very hard to sleep" [64]. A 15-year-old participant in a different study also discussed crying children, stating as a result of the screaming children, "I didn't get that much sleep… I felt physically exhausted… I got my sleep during the day because it was quieter" [58]. Both support the notion of noise coming from a variety of sources and suggest some patients may attempt to modify the timing of their own sleep to adjust. Nurses also recognized that they can contribute to the noise on the ward [9]. During a nurse focus group, one participant stated:

> We've all been in the middle of a night shift and we're laughing at the desk and realize the kid over here is asleep. So we've all done that too, where you've had to be quiet, or ask someone to keep it down. We're kind of mixed up too, right, this is our daytime because we're here in the middle of the night [9].

Nurses described insight into their potential contributions to an unconducive sleep environment and discussed the need to remind one another to be quiet. Taken together, both qualitative and quantitative data provide evidence of a variety of noises negatively affecting pediatric inpatient sleep.

NOVEL ENVIRONMENT. Pediatric patients attributed their night wakings to the novel hospital environment and the level of "agitation" at a ward in Portugal [56]. Among preschool and school-age children, the novelty of the hospital environment may lead to a delay in sleep onset [43, 47]. Adolescents described the atmosphere of the hospital as "sterile" and one participant reported the hospital environment negatively impacted her sleep [16].

PRESENCE OF ROOMMATE. Roommates appear to have a mixed impact on sleep, sometimes facilitating and other times disturbing patient sleep. Children with cancer experienced significantly fewer night wakings when at least one other person stayed overnight with them [10]. In a qualitative Swedish study, adolescents described the presence of their caregiver or significant other as contributing to their feelings of security and safety within the hospital [16]. One 17-year-old male stated "[Dad] saw that I couldn't sleep and maybe spurred me on. Then said to me, 'everything is going to be fine' and such. Eventually I slept" [16]. Adolescents stated their parents did not necessarily need to do anything, but that their presence alone helped facilitate sleep [16]. However, disturbed sleep was also caused by families sleeping in the same room, other pediatric patients being admitted to the room, and having a hyperactive roommate [42, 43, 48]. Another study found that adolescents' sleep was disturbed when they had babies rooming next to them, as the adolescents had to try going to bed earlier than usual [58]. Children who shared rooms with other patients slept over two hours less and were more likely to wake instantaneously than those in private rooms [49]; whereas, other studies did not find any relationships between room type (e.g. single, double) and poor or inadequate sleep [17, 52] or between mothers rooming in and sleep duration or night wakings [43, 48].

TEMPERATURE. Multiple studies found that the room temperature can impact pediatric sleep in the hospital [13, 16, 17, 56, 64]. On average, caregivers rated the temperature as their sixth most sleep-disrupting factor, but the temperature was physicians' and nurses' least frequently endorsed item in their eleventh spot [53]. This discrepancy suggests providers may be unaware of the family's discomfort and the potential negative impact of room temperature on inpatient sleep [53]. Some adolescents noted their rooms were too cold and appreciated having extra blankets [16], whereas others perceived the rooms as too hot [64] or noted that the air was too dry [13]. Comparisons of objective measures of temperature to recommendations (less than 75°F/24°C) were not conclusive [71]. One study in the United States found the average nighttime temperature within patients' rooms was less than 75°F/24°C, which is below the upper threshold for recommended temperature for healthy sleep, and that there were minimal fluctuations in temperature over time [11, 15]. However, within a hospital in Portugal, where the recommended temperature is between 68 and 75°F/20 and 24°C, temperatures were higher than recommended 78% of the time [61]. Increased room temperature was significantly related to reduced sleep duration; however, the effect size was relatively small [15].

Aim 2: pediatric sleep promotion interventions

Study designs included randomized trials ($n = 6$), pre-post ($n = 2$), and interrupted time series ($n = 1$). Of those with control groups, six studies utilized usual care controls and a four-arm study did not specify a specific control group. Three interventions were comprised of participants with cancer; the other six studies did not require a specific diagnosis as part of their inclusion criteria. Intervention length ranged from one night to 5 days. Measurements of child sleep included self- or parent-report ($n = 5$), objective measure ($n = 4$), research staff-report ($n = 2$), and not specified ($n = 1$). Intervention content included exclusively relaxation approaches ($n = 4$), multicomponent ($n = 3$), reducing unnecessary overnight blood pressure monitoring ($n = 1$), and enhanced physical activity ($n = 1$). Additional study details and findings are detailed in Table 2.

The relaxation interventions included music therapy ($n = 1$), storytelling ($n = 3$), and massage ($n = 1$) [51, 72–74]. Participants receiving music therapy, which consisted of playing lullaby music for 30 min before bedtime, reported better sleep quality from baseline to post-intervention, $p < .001$, $d = 1.71$ (95% CI: 0.90 to 2.52) [72]. The impact of storytelling was inconclusive across studies. One study found participants who received parent-led storytelling reported better sleep quality from baseline to post-intervention, $p < .001$, $d = 0.64$ (95% CI: −0.10 to 1.37) [72]. Among children who stayed overnight without a parent, a higher percentage of children who listened to a recording of their parent reading a bedtime story fell asleep during the 45-minute observation period ($n = 5$, 72%) compared to those who did not listen to a story ($n = 5$, 45%), $d = 0.04$ [74]. The intervention group was also described as having a shorter SOL and longer sleep duration during the 45-minute observation period ($M_{SOL} = 22$ min, $M_{dur} = 23$ min) compared to the control ($M_{SOL} = 27$, $M_{dur} = 15$) [74]. However, a 4-arm intervention found longer SOL among children who listened to a parent-read storybook ($M = 64.59$ min ± 22.05) or had their parents present ($M = 54.43 \pm 19.00$) compared to those who listened to a stranger-read book ($M = 37.64 \pm 12.28$) or did not listen to a story ($M = 36.86 \pm 18.98$) [51]. Following a pilot massage intervention for adolescents with cancer, the intervention group demonstrated a pre-post improvement in sleep duration ($M_{\Delta} = +53$ min, $p = .06$, $d = 0.96$ [95% CI: −0.01 to 1.94]) [73]. Additionally, a significant interaction between time and intervention existed, such that nighttime sleep episodes increased among those receiving massages and decreased within the control group over the course of the trial [73].

All multicomponent interventions included educational and relaxational components [20, 54, 56]. Rogers et al. also incorporated stimulus control measures to reduce environmental sleep disruptors, including bundling care between 90-minute protective sleep periods, instituting evening lights-out/morning lights-on times, minimizing light entry by placing thick black fabric over windows, and utilizing a white noise machine [54]. Participants received both verbal and written sleep education, and parents were trained to implement a relaxation technique (e.g. storytelling, reading a book, massage) with their child each night before bed. Although there were no significant between-group differences following the intervention, a group by time interaction demonstrated the intervention modestly preserved nighttime sleep duration, such that the mean length of sleep decreased in the control group but remained stable in the intervention group, $b = 9.85$ (95% CI: 2.49 to 17.22), $p < .001$ [54]. The second multicomponent intervention was comprised of a single one-on-one session for the parent and child [20]. Families received an educational booklet containing sleep health information and diaphragmatic breathing instructions. Children practiced diaphragmatic breathing with the researcher and were encouraged to use the technique at bedtime, after nighttime awakenings, or during anxiety-provoking situations. Parents were also encouraged to take their children to areas of the hospital where they could be exposed to bright light during the day as well as to continue good sleep hygiene behaviors and relaxation skills after hospitalization. Children in the intervention group averaged 50 minutes more nighttime sleep ($M = 419.3$) and slept 15 min longer during their maximum length of uninterrupted nighttime sleep ($M = 369.7$) than the control group, respectively, $p = .09$, $d = 0.53$ (95% CI: −0.07 to 1.15) and $p = .37$, $d = 0.28$ (95% CI: −0.33 to 0.88) [20]. Despite experiencing a similar number of night wakings ($M_{int} = 14.67$ vs. $M_{con} = 14.69$), intervention participants averaged 45 min less WASO ($M = 163.9$) than those receiving usual care, $p = .182$, $d = 0.42$ (95% CI: −0.19 to 1.02). Treatment gains were maintained at a post-discharge follow-up, with intervention participants reporting significant reductions in sleep disturbances from baseline and their usual care counterparts reporting increases in sleep disturbances, $t = -2.15$, $p = .04$, $d = 0.65$ (95% CI: 0.04 to 1.26) [20]. The final multicomponent intervention included establishing formal ward schedules, optimizing nighttime medical care, and distributing flyers with sleep-promoting tips to patients and their families (e.g. read a bedtime story, avoid screen time within 1 h of bedtime) [56]. The average number of nighttime awakenings decreased slightly from the pre-intervention group ($M = 2.1 \pm 1.6$) to the post-intervention group ($M = 1.9 \pm 1.3$), $d = 0.14$ (95% CI: −0.30 to 0.59). The average subjective sleep quality remained unchanged ($M_{pre} = 6.7 \pm 2.5$ vs. $M_{post} = 6.7 \pm 2.3$), $d = 0.00$ (95% CI: −0.44 to 0.44) [56].

One quality improvement intervention utilized clinician education and behavioral nudges within the electronic health record order set to reduce unnecessary blood pressure monitoring throughout the night [45]. For patients older than two years, caregivers reported child sleep duration increased by an average of 82 min following the intervention when compared to pre-intervention caregiver-reports ($M_{pre} = 411$ vs. $M_{post} = 494$), $p < .001$, $d = 0.46$ (95% CI: 0.19 to 0.74]. However, caregivers reported patients under two years of age slept an average of 22 min less than those prior to the intervention ($M_{pre} = 415$ vs. $M_{post} = 393$), $p = .44$, $d = 0.13$ (95% CI: −0.19 to 0.44).

The enhanced physical activity intervention targeted children with cancer and consisted of pedaling a stationary bike 30 min twice daily for 2 to 4 days during the hospitalization period [21]. Following the intervention, the physical activity group ($M = 606.29 \pm 144.63$) slept 43 min more than the standard care group ($M = 562.37 \pm 122.38$), $p = .47$, $d = 0.28$ (95% CI: −0.48 to 1.05). A non-statistically significant difference in post-intervention

Table 2. Pediatric sleep promotion interventions

Author (year)	Study design	Intervention description	*n*	Child age *M* ± *SD* (range) diagnosis	Length of intervention	Main findings	Effect size Cohen's *d* [95% CI]
Anggerainy (2019) [72]	Two-arm intervention (pre-post)	Music therapy or storytelling interventions	31	2.7 ± 3.1 (4 months–12 years) various infectious diseases	30 min before bedtime for three consecutive days	Both music therapy and storytelling significantly improved scores on a sleep disturbance scale.	Music intervention: *d* = 1.71 [0.90 to 2.52] Story intervention: *d* = 0.64 [−0.10 to 1.37]
Cook (2020) [45]	Quality improvement intervention	Clinician education sessions and updated electronic health record (EHR) orders that enabled the forgoing of overnight BP checks	394	(30 days–18 years) varied	Throughout hospital stay	Significant increase in sleep duration for patients older than 2 years. No statistically significant change among patients under 2 years.	Age > 2 years *d* = 0.46 [0.19 to 0.74] Age < 2 years *d* = 0.13 [−0.19 to 0.44]
Hinds (2007) [21]	Prospective, two-site, pilot RCT	Enhanced physical activity intervention, consisting of pedaling a stationary bicycle-style exerciser	29	12.5 ± 2.9 (7 years–18 years) cancer	30 min twice daily for 2–4 days	No significant group differences in SE or sleep duration post-intervention. However, intervention arm had greater mean change in SE than the control arm.	Post-intervention group differences: • Sleep duration: *d* = 0.28 [−0.48 to 1.05] • SE: *d* = 0.07 [−0.65 to 0.83] M_Δ group differences: • Sleep duration: *d* = 0.30 [−0.46 to 1.07] • SE:*d* = 0.79 [0.003 to 1.58]
Jacobs (2016) [73]	Pilot RCT	Massage sessions tailored to the patient	34	15.7 ± 2.5 (12 years–21 years) cancer	20 to 30 min sessions for 2–3 days	Among intervention, pre-post improvement in night sleep duration. Significant interaction between time and intervention, with intervention experiencing greater nighttime sleep episodes than control.	Pre/post-intervention: • Night sleep duration: *d* = 0.96 [−0.01 to 1.94] • SE: *d* = 0.59 [−0.35 to 1.54] • WASO: *d* = 0.09 [−0.83 to 1.01] • Awakenings:*d* = −0.43 [−1.36 to 0.50] • Night sleep episodes: *d* = 0.37 [−0.56 to 1.30]
Manuel (2021) [56]	Pilot multicomponent intervention	Multicomponent intervention, including minimizing alarms and other disruptions at night, having set light schedules, encouraging bedtime stories and turning off screens within 1 h of bed, giving patients sleep-promoting flyers, and displaying educational posters on unit	85	6.7 (1 month–18 years) not specified	Throughout hospital stay	Following intervention, average night wakings decreased slightly (mean of 2.1 to 1.9) and average sleep quality did not change (mean of 6.7). Children who knew about the sleep improvement project had significantly fewer night wakings (*p* = 0.03) and better subjective sleep quality (*p* = .02).	Pre/post-intervention group differences: • Night wakings *d* = 0.14 [−0.30 to 0.59] • Sleep quality *d* = 0.00 [−0.44 to 0.44]
Papaconstantinou (2018) [20]	Pilot RCT	Relax to Sleep, a sleep intervention combining sleep health education with diaphragmatic breathing	44	6.5 ± 2.0 (4 years–10 years) not specified	3 days	Intervention averaged 50 minutes more nighttime sleep, 45 minutes less WASO, and longer maximum lengths of uninterrupted nighttime sleep compared to usual care group. At follow-up, intervention had greater improvements in sleep disturbances.	Post-intervention group differences: • TST: *d* = 0.53 [−0.07 to 1.15] • Longest nocturnal sleep period: *d* = 0.28 [−0.33 to 0.88] • Awakenings: *d* = 0.004 [−0.60 to 0.60] • WASO: *d* = 0.42 [−0.19 to 1.02] M_Δ group differences at follow-up: • Sleep disturbances (CSHQ): *d* = 0.65 [0.04 to 1.26]
Rogers (2019) [54]	Unblinded, multicomponent pilot RCT	Age-appropriate sleep education; parent implemented relaxation technique; stimulus control measures to reduce environmental sleep disruptors	33	9.5 ± 3.9 (4 years–19 years) cancer	5 days	No significant differences between groups. Intervention modestly preserved nighttime sleep duration, as demonstrated by group by time interaction.	Group differences: • Mean sleep episode duration: *d* = −0.27 [−0.95 to 0.41] • Longest sleep episode: *d* = −0.18 [−0.87 to 0.50 • Mean wake episode duration: d = 0.11 [−0.58 to 0.78] • Awakenings: *d* = 0.08 [−0.60 to 0.76]
White (1983) [74]	RCT	A recording of the child's parent reading a bedtime story was played as part of the child's bedtime routine	18	5.83 (3 years–8 years) not specified	10-minute recording played nightly for two nights	Intervention fell asleep more often during 45-minute observation period, had lower SOL, and had greater sleep duration than control group.	Fall asleep (binary): *d* = 0.04 SOL/sleep duration: unable to calculate
White (1990) [51]	Four-arm intervention (three arms randomized, one arm convenience sample)	Arm 1: parent-recorded story at bedtime and parent absent; arm 2: stranger-recorded story at bedtime and parents absent; arm 3: no story and parents absent; arm 4: no story and parents present	94	(3 years–8 years) not specified	1 night	Parent presence or listening to a parent-read story book had significantly longer SOL compared to those who listened to a stranger-read story or did not listen to a story at all.	SOL: unable to calculate

SE was also observed, with the intervention group experiencing higher SE (M = 72.98 ± 15.61) than the control group (M = 71.23 ± 16.62), p = .85, d = 0.07 (95% CI: −0.65 to 0.83). However, when considering baseline rates of SE, the intervention group demonstrated a significantly higher mean change in SE than the control group, F = 4.17, p = .05, d = 0.79 [(95% CI: 0.003 to 1.58) [21].

Conceptual model of pediatric inpatient sleep

The synthesis of factors influencing sleep, components of existing interventions, and the extent of sleep disruption is illustrated by the Pediatric Inpatient Sleep Model (Figure 2). Taken together, the influencing factors contribute to hospitalized pediatric patients' decreased sleep duration, more frequent night wakings, increased WASO, decreased SE, and poor sleep quality. These sleep disturbances were caused by a combination of factors at multiple levels: child (e.g. affect, symptoms), family (e.g. caregiver affect, parenting behaviors), and environment (e.g. noise, interruptions). The most frequently discussed influencing factors were at the environment-level; however, the majority of interventions targeted the child-level using relaxation techniques. Other sleep-promoting interventions targeted the family level by providing sleep education to parents, for example, or the environment-level by modulating light exposure or decreasing noise on the ward. Refer to Figure 2 for the full lists of factors impacting sleep and of intervention components.

Risk of bias

The majority of included studies (*n* = 20) were rated as "fair," indicating some risk of bias. Fourteen studies were rated "good" with low risk of bias, and 11 studies were rated "poor" signifying high risk of bias. Figure 3 illustrates the ratio of quality ratings across each study design. Of the cross-sectional studies, increased risk of bias was related to use of unvalidated outcome measures, lack of power analyses justifying sample size, and lack of adjustment for confounders [39]. Of note, questions related to exposure status in cohort studies (6–10; 12) were not applicable for cross-sectional descriptive study design. Across pre-post and controlled intervention studies, most studies used validated and objective measures of sleep; however, the potential for bias was increased by small sample sizes, unblinded participants or outcome assessors, high rates of attrition, not using intent-to-treat analyses, and lack of clarity regarding group differences at baseline [39]. Regarding qualitative articles, lower quality assessments were related to a lack of information regarding data saturation, the systematic analytic process, or how theory informed the study [38]. Supplemental Tables 5–8 provide the quality assessment ratings for each individual study.

Discussion

The purpose of this review is to examine factors that influence sleep during pediatric hospitalizations and determine the effectiveness of non-pharmacological sleep promotion interventions among hospitalized children. As established by existing reviews, pediatric patients experience decreased sleep duration, poor sleep quality, decreased SE, more frequent night wakings, and increased WASO in the hospital setting [22–24]. We found that a combination of factors across the child, family, and environment levels contribute to these sleep disruptions. Although pediatric patients and their families most frequently discussed

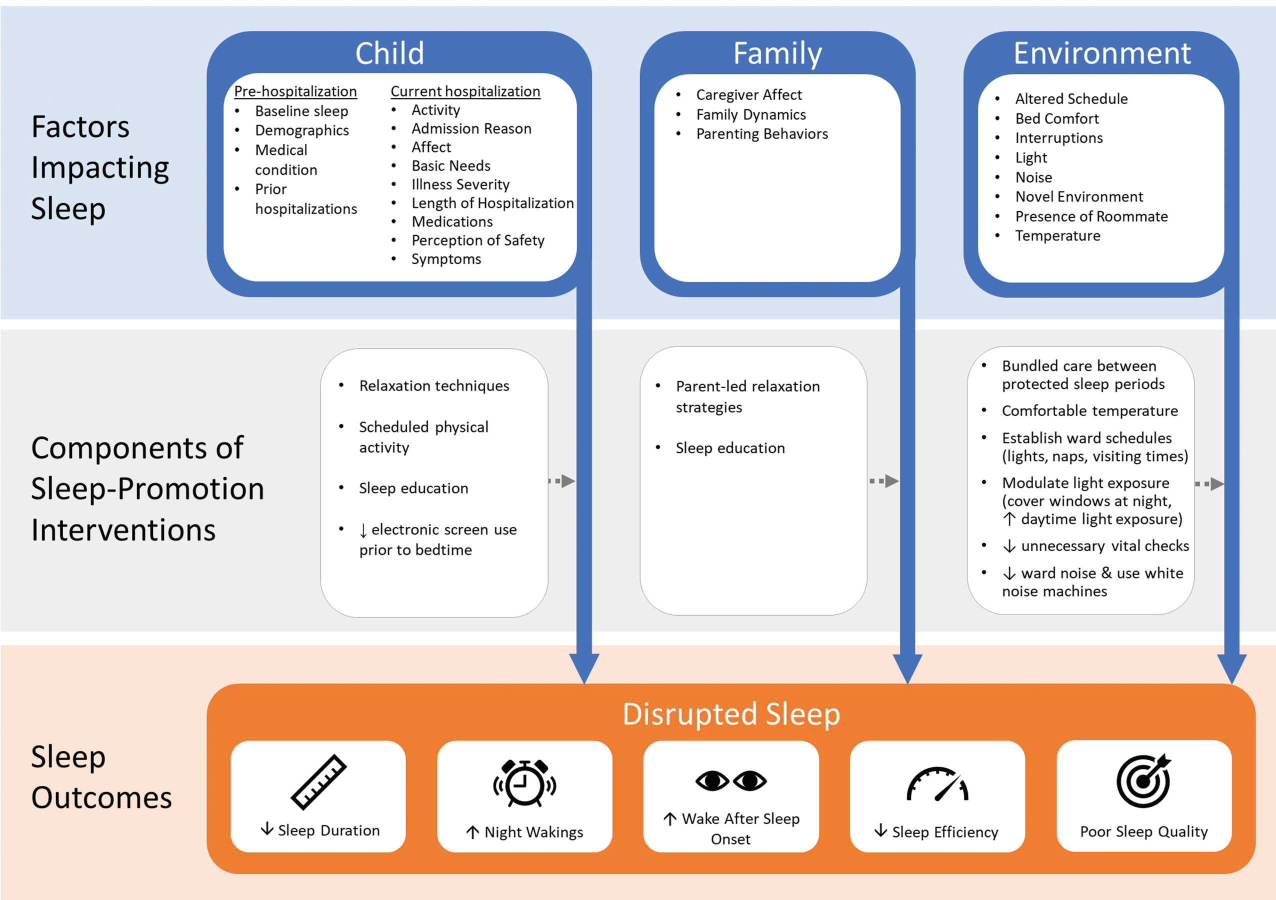

Figure 2. Pediatric inpatient sleep model.

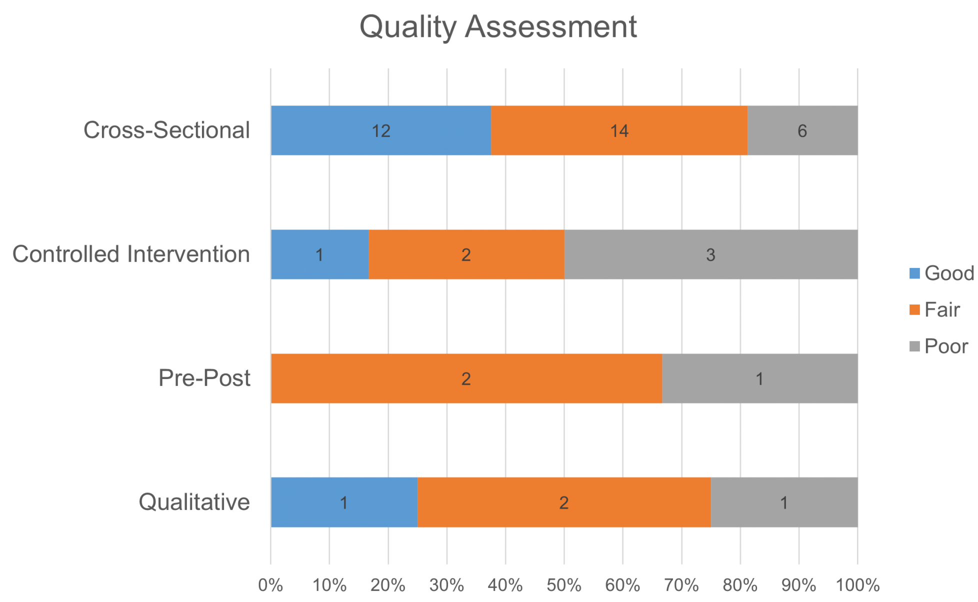

Figure 3. Quality assessment.

the negative impacts of environmental disruptions, most interventions targeted the child-level using relaxation techniques. Most included interventions were small pilot studies; however, preliminary findings suggest a positive impact on sleep duration. We synthesized these findings into the Pediatric Inpatient Sleep Model. This conceptual model is presented as a proposed framework for future research and quality improvement projects and should be further refined as the literature base expands. This appears to be a burgeoning area of research, as evidenced by 55.6% of the included articles being published between 2016 and 2021.

Sleep disturbances are a multifactorial problem, stemming from a combination of factors at the child, family, and environment levels. Participants most often discussed environmental influences on pediatric inpatient sleep. Reduced sleep quality was strongly associated with increased noise and moderately associated with increased luminosity [15]. Noise on the wards frequently exceeded the World Health Organization's recommended threshold for healthy sleep environments [11, 13, 15, 61, 66, 68–70]. Although light was generally conducive to sleep after 11:00 pm, over half of the rooms received light exposure above the recommended threshold between 8:00 pm and 11:00 pm [61]. This distinction in timing is important given the potential for artificial lighting to suppress melatonin production and recommendations to reduce light exposure a few hours before bed [75]. Light exposure between 8:00 pm and 11:00 pm disproportionately impacts younger children, who have earlier bedtimes than their adolescent counterparts. These environmental disturbances are often related to providing medical care, as evidenced by the administration of medications being significantly associated with increased noise and less sleep [15]. Although beyond the scope of this review, environmental factors appear modifiable; the results of two quality improvement initiatives demonstrated significant reductions in nighttime noise [66, 70]. Child- and family-level factors were less frequently discussed within the context of inpatient sleep; however, extant literature has examined relationships between these factors and sleep outside of the hospital. For example, screen time is significantly associated with reduced sleep duration and increased sleep problems outside of the hospital [76]. These potential influences should be further examined within the hospital setting and considered when conducting inpatient sleep research. Additionally, some parenting characteristics may be advantageous when the child is healthy, but disadvantageous in the hospital setting. For instance, hospitalized children with more rigid parents slept worse; however, in the home setting, higher levels of consistent enforcement of family rules and routine is related to improved child sleep [77].

Overall, most interventions demonstrated preliminary support for improving aspects of sleep. Six of the nine included interventions were small pilot or preliminary studies designed to examine feasibility and demonstrate support for larger future interventions [20, 21, 54, 56, 72, 73]. As such, most pilot studies were not adequately powered to detect statistically significant differences. However, some non-statistically significant findings are clinically meaningful. Obtaining an additional 30 min of sleep is related to significant improvements in children's emotional regulation and alertness [78]. Therefore, although not statistically significant, obtaining an average of 43–53 additional minutes of sleep following Jacobs et al.'s massage intervention, Papaconstantinou et al.'s multicomponent intervention, and Hinds et al.'s physical activity intervention should be considered clinically meaningful. It is important to note some interventions were multicomponent and thus the efficaciousness of individual components cannot be established at this time. Taken together, interventions using relaxation strategies such as music therapy, massage, and diaphragmatic breathing, appear potentially beneficial; however, support for storytelling as a relaxation strategy is inconclusive and may be dependent on parent presence or the child's relationship to the reader. Additional support for massage was provided via qualitative report, suggesting children had an easier time falling asleep after the massage [79]. Interventions that provided sleep education, scheduled physical activity, bundled nursing care, used white noise machines, modulated light exposure, and reduced overnight vital checks also appear to have a beneficial impact on certain aspects of sleep. In addition to improving patient outcomes, sleep interventions can also be financially beneficial. Reducing excessive nighttime blood pressure monitoring was estimated to save over $15 000 per year in recovered nursing time [45]. It is important to note that Papaconstantinou et al.'s Relax to Sleep intervention was the only intervention rated as high quality. This may be due to practical limitations of conducting high-quality studies within this environment and population. For example, randomization may not be feasible when conducting larger-scale environmental modifications, attrition may be higher in an inpatient setting, and intervention integrity may be compromised if providers begin to utilize bundled care strategies among usual care groups. Additional research is needed to confirm these preliminary findings regarding the effectiveness of sleep promotion interventions among hospitalized children. Preventative interventions could also help prepare pediatric patients and their families for upcoming hospital stays by providing strategies that ease the transition and promote healthy sleep in the hospital environment.

Findings should be interpreted within the context of the included articles' quality. The individual studies were limited by several methodological weaknesses, including small sample sizes, high rates of attrition, the use of unvalidated measures, inconsistencies in reporting sleep outcomes, conducting multiple statistical analyses without alpha adjustments, a lack of information regarding data saturation, and suboptimal reporting of demographic data. Replication studies are required and should conform to best practices for measuring and reporting sleep. Future research should aim to: (1) utilize objective assessments of sleep, such as actigraphy, and corroborate objective measurement with both parent and child self-report, (2) use validated questionnaires measuring child sleep, (3) report sleep outcomes in accordance with Society of Behavioral Sleep Medicine recommendations [80], (4) report demographic characteristics of the sample, including a minimum of age, sex, race, and ethnicity, (5) describe relevant environmental factors, such as single/shared occupancy rooms and presence of caregivers staying overnight. Qualitative studies should adhere to the recommendations of Wu et al., providing adequate information regarding data saturation, the systematic analytic process, and how theory informed the study [38]. Quantitative studies should use a priori power analyses to determine a target sample size and adjust for confounders when warranted. Future interventions are encouraged to randomize participants to each condition, blind participants and outcome assessors, and use intent-to-treat analyses when possible. Implementing these recommendations and increasing transparency in reporting would enhance the trustworthiness of findings.

Strengths of this review include a thorough search strategy, a systematic approach to analyzing qualitative and quantitative articles examining sleep disruptors, as well as the synthesis of data across multiple domains to create a conceptual model. Despite these strengths, there are several limitations. Due to the heterogeneity in sleep outcomes and the relatively small literature base, a meta-analysis was not currently feasible. However, this would be an important contribution to the field as the pediatric inpatient sleep literature grows. Although not specifically examined in this review, the impact of specific medications on inpatient sleep warrants future attention. Additionally, the use of EPPI-Centre framework required a pre-specification of study types, which resulted in the exclusion of articles relevant to the broad topic. As such, one qualitative article describing the effectiveness of a sleep promotion intervention was excluded from the review; this article was, however, incorporated into the discussion section [79]. Other limitations include the exclusion of articles not published in English and gray literature, which may reduce generalizability of findings and increase publication bias, respectively.

Although the lack of geographic restrictions improves generalizability, it is important to consider the differences in sleep habits and sleep-influencing policies, such as daytime naps or hospital-mandated quiet time, that exist across countries, cultures, and communities [44, 55]. Given the significant variability in sleep between individuals, additional research exploring temporal and intraindividual variations in inpatient sleep is warranted to provide a foundation for the development of more tailored interventions. Preliminary findings suggest among hospitalized children with cancer, daytime mood disturbance predicts shorter sleep duration and increased SOL [40]. Future research should corroborate these findings and explore how temporal variations in other potential predictors, such as anxiety, physical activity level, and sleep hygiene behaviors, impact individual sleep patterns during hospitalization.

Future versions of the model should consider interactions between influencing factors, such as parent and child anxiety or medical acuity and room entries. Although beyond the scope of this review, parent sleep is also negatively impacted by pediatric hospitalizations, and the potential for parents' lack of sleep to influence their perception of their children's sleep should be considered [12, 24, 81]. Relationships between child or family factors and sleep that were established outside of the inpatient literature may also warrant inclusion in future versions of the model. Additional research is needed to confirm whether these findings hold true among hospitalized children. For example, apart from Traube et al.'s work [52], little research has examined sleep hygiene behaviors among hospitalized children to date. Given the negative consequences of screen time and the potentially increased access to television and cellphones while inpatient, further research is warranted. There is also a paucity of research examining outcomes related to these disruptions in sleep and circadian rhythms. One study found changes in nighttime awakenings and sleep duration persisted among toddlers discharged from the ICU [82]. The consequences of pediatric sleep disruptions both during hospitalization and following discharge should be further explored.

Despite the most frequently discussed disruptors being at the environment-level, the majority of existing interventions targeted the child-level using relaxation techniques. Although these relaxation techniques have demonstrated promising preliminary findings, they do not directly address the larger influencers of inpatient sleep disturbances. Given the identification of environmental factors as a main cause of night wakings, interventions targeting the environment (e.g. Cook et al.'s quality improvement project [45]) are paramount. One additional benefit of these environmental modifications is their ability to simultaneously target the sleep of both children and their resident caregivers. Numerous guidelines and articles discuss optimizing inpatient sleep; recommendations range from minor changes, such as providing earplugs, to more systemic modifications, including reducing unnecessary trash pulls, bundling care, and reducing unnecessary vital checks when possible [22, 45, 66, 70, 83, 84].

Conclusions

The results of this systematic review suggest sleep disturbances were attributed to a combination of factors across the child, family, and environment levels; however, patients and their families most frequently discussed the negative impacts of environmental disruptions. Although most interventions were small pilot studies, preliminary findings appear to have promising impacts on sleep duration and support the development of larger-scale sleep promotion interventions among hospitalized children. Based upon the evidence, the Pediatric Inpatient Sleep Model is proposed to illustrate connections between sleep disturbances, factors influencing sleep, and existing intervention components. This model is intended to guide future research and quality improvement projects, serve as evidence-based practice, and should be revised as the literature base expands. Additional research examining contributors to intraindividual variations in sleep patterns during hospitalization as well as the consequences of these disturbances is warranted.

Supplementary Material

Supplementary material is available at *SLEEP* online.

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