Review Article

Best evidence summary of sleep protection in premature infants in the neonatal intensive care unit: a narrative review

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Background and Objective: Sleep influences the interaction between infants and their environment, as well as the achievement of crucial milestones in motor and language development. This is particularly significant for preterm infants in vulnerable positions. However, prematurely born infants in the neonatal intensive care unit (NICU) are exposed to various stimuli such as noise and light, which disrupt their normal sleep patterns. This study assesses and consolidates the existing evidence on non-pharmacological strategies for protecting and promoting sleep in preterm infants. By providing an evidence-based data repository, it offers a valuable reference for clinical interventions.

Methods: We conducted computer-based searches using various databases and resources, including UpToDate, BMJ Best Practice, Guidelines International Network (GIN), National Institute for Health and Clinical Excellence (NICE), Scottish Intercollegiate Guidelines Network (SIGN), National Guideline Clearinghouse (NGC), Registered Nurses Association of Ontario (RNAO), Joanna Briggs Institute (JBI), World Health Organization (WHO), Cochrane Library, Web of Science, PubMed, China National Knowledge Infrastructure (CNKI), Wanfang Data, and China Biology Medicine disc (CBM). The search period spanned from January 2014 to May 2024.

Key Content and Findings: We have included a total of 22 articles in our review, comprising two guidelines, 11 systematic reviews, 1 evidence summary, 1 technical report, 2 practice recommendations, and 5 randomized controlled trials. The evidence was synthesized from eight domains: sleep team construction, risk factor assessment, sleep assessment tools, positional management, noise control, light management, sensory stimulation, and hospital-home transition sleep management, resulting in 27 pieces of evidence.

Conclusions: This study summarizes the optimal evidence for the management of sleep in premature infants, providing empirical support for standardizing the management of sleep in premature infants. It is recommended that healthcare professionals judiciously apply the best evidence while considering the clinical context, thus promoting safe sleep for premature infants.

Keywords: Premature infant; sleep; neonatal intensive care unit (NICU); evidence-based nursing

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Introduction

Background

Approximately 15 million preterm infants are estimated to be born globally each year (1), making it one of the leading causes of mortality in children under the age of 5 years (2). Fortunately, the rapid advancement of intensive care technologies has significantly elevated the survival rates of premature infants. Even those born with extremely low birth weights now boast a survival rate of 87.6% (3). However, multiple studies indicate that preterm infants face "high-risk" developmental challenges (such as attention deficit/hyperactivity disorder, cognitive impairments, and social difficulties) throughout their growth (4-6). Among very premature infants (born between 28 and 32 weeks), approximately 40–50% experience varying degrees of neurological developmental disorders, with 27.8% potentially exhibiting language impairments (7,8). Even in late preterm infants (born between 34 and 36 weeks), the risk of neurodevelopmental disorders surpasses that of full-term infants, with 2.67% showing motor delays and 5.01% exhibiting intellectual developmental delays (9). Therefore, studying factors that contribute to impaired growth and development in preterm infants, especially those that are modifiable (such as sleep function), holds significant clinical significance (10).

Sleep plays a crucial role in brain development and synaptic plasticity during the early stages of individual life, and it is considered as the neurobiological foundation for learning and memory in organisms (11). Plasticity refers to the brain's ability to adjust and change in response to various contexts and demands. This process influences the interaction between infants and their environment, as well as the achievement of essential motor and language developmental milestones (12,13). It is worth noting that preterm infants spend as much as 90% of their time in sleep (14). Infants below the age of 6 months experience three sleep states: active sleep (AS), quiet sleep (QS), and indeterminate sleep (IS). The sleep cycle involves the transition from the AS phase, experiencing brief IS, to ultimately entering QS (15). The AS state, equivalent to rapid eye movement (REM) sleep, constitutes approximately 40–60% of the premature infant's entire sleep cycle. During this stage, the sensation feedback from muscle twitches and jerks provides intrinsic stimulation for developing sensory and motor neuronal networks, laying the foundation for higher-level cognitive processing neural circuits (16). QS corresponds to non-rapid eye movement (NREM) sleep, contributing to synaptic reshaping and promoting the maturation of the brain, hippocampus, brainstem, and more, enhancing memory and learning abilities (16). Additionally, sleep is associated with the secretion of crucial hormones such as melatonin and growth hormone in the human body. Research indicates that poor sleep quality in the neonatal period is associated with lifelong developmental outcomes (17).

During intrauterine development, fetuses process the pitch and intensity of human voices in a protected manner. By limiting excessive stimulation and providing a relatively quiet and protected sleep environment, optimal conditions for growth and development are created (18). However, due to the risks of adverse outcomes such as apnea and mortality, preterm infants require specialized medical care and support in neonatal intensive care units (NICUs). In recent years, more and more scholars have focused on studying the correlation between stress responses (such as bright lights, noise, invasive procedures, etc.) in the NICU and neurodevelopmental impairments (19,20). Nist *et al.* proposed the Neonatal Stress Embedding (NSE) model, which suggests that stress responses from the NICU may affect the autonomic nervous system, hypothalamic-pituitary-adrenal (HPA) axis, and gene expression in preterm infants, leading to changes in brain structure and function (21). Exposure to stress may result in sleep deprivation in preterm infants (8). For example, one study indicated that infants experience up to 234 interruptions in sleep within a 24-hour period (22). Despite increasing awareness among healthcare professionals about protecting sleep, the NICU is still considered a hostile environment. Apart from the unfavourable external conditions, inherent pathologies and comorbidities themselves seem to hinder the sleep development of this population (23). However, the adverse effects on neurodevelopment (including social and emotional impairments, as well as attention deficits) are not transient and may persist into adulthood (10). In other words, certain neurodevelopmental issues in preterm infants originate from the NICU. It is imperative to optimize the healthy sleep of premature infants and safeguard the natural progression of sleep.

Unfortunately, the evidence supporting the implementation of sleep interventions in NICUs is limited. Despite some mention of sleep protection knowledge in certain guidelines and practices, the content is verbose, lacks focus, and the recommendations are scattered, hindering clinical dissemination and practice translation. Additionally, healthcare personnel may encounter situations inconsistent

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with infant safe sleep recommendations; for example, preterm infants may require specific therapeutic positions that conflict with the supine position recommended for safe infant sleep (24). Relying solely on clinical experience without scientific-practical guidance is not an optimistic approach to managing sleep in preterm infants. Despite sedatives being able to increase sleep duration to some extent, they often come with side effects such as respiratory depression, which is undoubtedly detrimental for premature infants (25).

Objective

The evidence summary aims to consolidate crucial perspectives, furnish clinical practitioners with dependable resources, and optimize clinical practice (26). Therefore, the primary aim of this review is to conduct a thorough evaluation and comprehensive analysis of the existing evidence on non-pharmacological sleep protection for preterm infants. Concurrently, closely integrating with safe sleep recommendations, given that ensuring a secure sleep environment is an indispensable prerequisite. By providing an evidence-based data repository, it serves as a reference for clinical decision-making protocols. We present this article in accordance with the Narrative Review reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-24-92/rc).

Methods

Establishment of the problem

According to the PIPOST tool, the clinical question was transformed to an evidence-based question: (I) P (population): live-born infants with gestational age <37 weeks; (II) I (intervention): measures associated with sleep protection for premature infants, including assessment and care; (III) P (professionals): pediatric healthcare personnel; (IV) O (outcome): improvement in sleep quality; (V) S (setting): NICU ward; (VI) T (type of evidence): guidelines, expert consensus, expert opinions, practice recommendations, meta-analyses, systematic reviews, best clinical practice manuals, clinical decision, technical reports and randomized controlled studies (RCTs).

Retrieval strategy

We conducted a comprehensive search using the keywords "neonate, preterm infant, very preterm infant, extremely preterm infant, sleep protecting, sleep safety, sleeping environment, sleep position, development care, guideline, consensus, opinion, practice recommendation, evidence summary, meta-analysis, systematic review, RCT and randomized controlled trial" to retrieve relevant information from authoritative sources such as "UpToDate, BMJ Best Practice, Guidelines International Network (GIN), National Institute for Health and Clinical Excellence (NICE), Scottish Intercollegiate Guidelines Network (SIGN), National Guideline Clearinghouse (NGC), Registered Nurses Association of Ontario (RNAO), Joanna Briggs Institute (JBI), World Health Organization (WHO), Cochrane Library, Web of Science, PubMed, China National Knowledge Infrastructure (CNKI), Wanfang Data, and China Biology Medicine disc (CBM)". The detailed steps for searching English databases, using PubMed as an example, can be found in Table S1. The search period was set from January 2014 to May 2024. The primary reason for selecting articles published in 2014 or later is that those published earlier may lack the most current information and thus would be unable to effectively guide our clinical practice. Additionally, only full-text articles that have undergone peer review are included to ensure their academic value. The research methods utilized in this review are detailed in *Table 1*.

Literature inclusion and exclusion criteria

Inclusion criteria: (I) the study population was preterm infants; (II) the content of the literature was related to sleep-related studies; (III) the types of studies were guidelines, expert consensus, expert opinion, practice recommendations, meta-integration, meta-analysis, systematic evaluation, best clinical practice manuals, clinical decision-making, technical reports and RCTs; and (IV) the languages were limited to English and Chinese. Exclusion criteria: (I) the type of literature was guideline interpretation, guideline effect evaluation, guideline research plan or proposal; (II) updated guidelines; (III) duplicated publications, which could not be accessed in the original text; (IV) literature with low quality and (V) RCTs that have already been incorporated into guidelines or systematic reviews. This study was registered with the Centre for Evidence-based Nursing, Fudan University, China (ES20232650).

Quality evaluation of the literature

We have chosen appropriate evaluation criteria based on

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Table 1 The search strategy summary

Items	Specification
Date of search	The initial search was conducted on July 1, 2023, and a follow-up search was carried out on May 7, 2024
Databases and other sources searched	UpToDate, BMJ Best Practice, Guidelines International Network (GIN), National Institute for Health and Clinical Excellence (NICE), Scottish Intercollegiate Guidelines Network (SIGN), National Guideline Clearinghouse (NGC), Registered Nurses Association of Ontario (RNAO), Joanna Briggs Institute (JBI), World Health Organization (WHO), Cochrane Library, Web of Science, PubMed, China National Knowledge Infrastructure (CNKI), Wanfang Data, and China Biology Medicine disc (CBM)
Search terms used	"infant, newborn", "preterm infant", "very preterm infant", "extremely preterm infant", "sleep protecting", "sleep safety", "sleeping environment", "sleep position", "development care", "Guideline", "consensus", "opinion", "practice recommendation", "evidence summary", "Meta-analysis", "systematic review", "RCT" and "randomized controlled trial"
Timeframe	2014 to 2024
Inclusion and exclusion criteria	Inclusion criteria: (I) the study population was preterm infants; (II) the content of the literature was related to sleep-related studies; (III) the types of studies were guidelines, expert consensus, expert opinion, practice recommendations, meta-integration, meta-analysis, systematic evaluation, best clinical practice manuals, clinical decision-making, technical reports and RCTs; and (IV) the languages were limited to English and Chinese
	Exclusion criteria: (I) the type of literature was guideline interpretation, guideline effect evaluation, guideline research plan or proposal; (II) updated guidelines; (III) duplicated publications, which could not be accessed in the original text; (IV) literature with low quality and (V) RCTs that have already been incorporated into guidelines or systematic reviews
Selection process	Independently selected by authors

RCT, randomized controlled trial.

the different types of literature. These criteria primarily include: (I) clinical guidelines were evaluated using the Appraisal of Guidelines for Research and Evaluation Instrument (AGREE II) (27). AGREE II comprises six domains, totaling 23 key items. The degree of agreement for each item is assessed on a scale ranging from 1 (strongly disagree) to 7 (strongly agree). The standardized percentage for each domain is calculated using the formula: (obtained score – minimum possible score)/(maximum possible score – minimum possible score) ×100%. Based on the standardized scores, the recommendation levels are categorized as follows: Grade A (strong recommendation) if all six domains have scores ≥60%, Grade B (weak recommendation) if ≥3 domains have scores ≥30% and at least one domain has a score <60%, and Grade C (not recommended) if ≥3 domains have scores <30%. (II) Systematic reviews and expert consensus were assessed using the criteria established by the JBI Centre for Evidence-Based Healthcare [2016] (28). Evaluation is conducted with the response options "yes", "no", "unclear", or "not applicable". (III) Summaries of evidence, practice recommendations, and technical reports were evaluated using the Critical Appraisal for Summaries of Evidence (CASE) tool (29), which comprises 10 items. Evaluation options include "yes", "no", or "partial yes". (IV) Randomized controlled studies were assessed using the evaluation criteria established by the JBI Centre for Evidence-Based Healthcare (30).

Literature quality assessment was carried out independently by two researchers (1st to 2nd authors of this article) based on inclusion and exclusion criteria, and in case of doubt, the decision was made after a joint discussion by our evidence-based team. All evidence-based team members were trained and passed an evidence-based nursing course.

Evidences extraction and summary

The evidence was comprehensively summarized by members of the evidence-based group according to the following principles: (I) in cases of consistent content, a preference is given to selecting sentences that are more easily understandable; (II) when multiple sources complement each other, they are consolidated into one piece of evidence; (III) in the event of conflicting conclusions from different sources of evidence, we adhere to the principles of prioritizing evidence based on its quality, credibility, and the latest authoritative publications. The classification criteria

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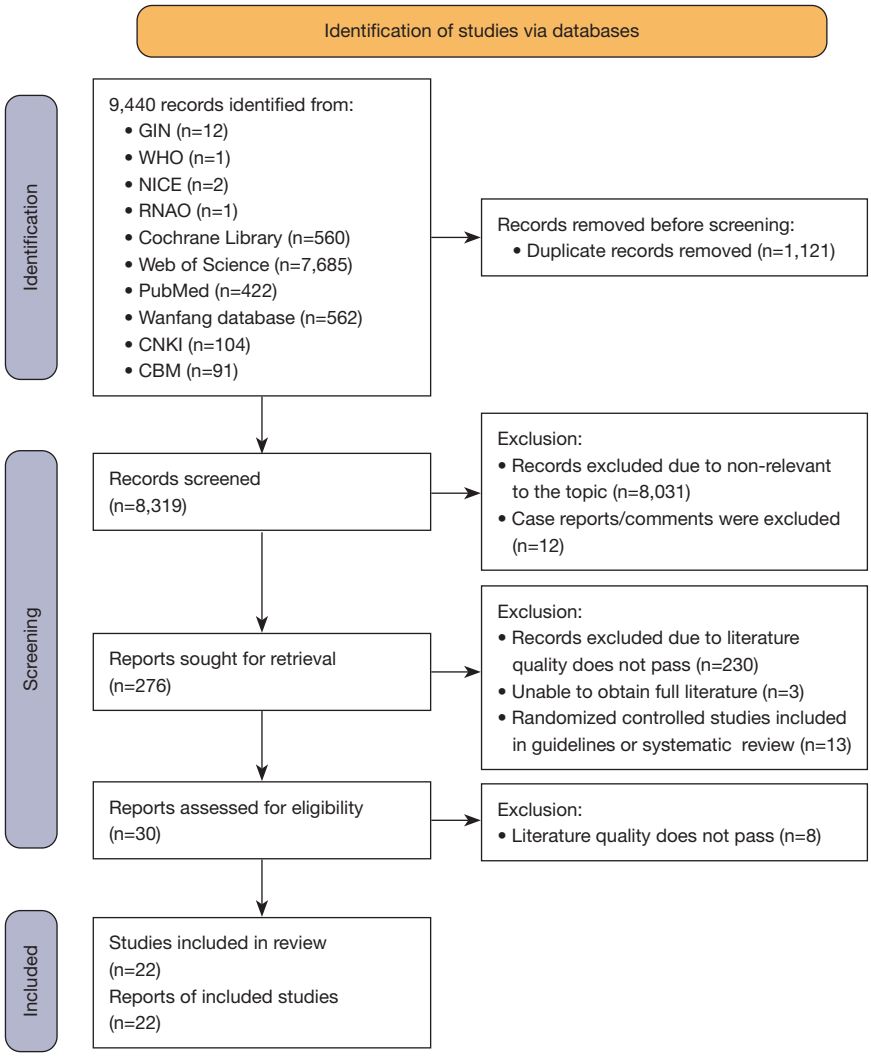

Figure 1 Literature screening flow chart. GIN, Guidelines International Network; WHO, World Health Organization; NICE, National Institute for Health and Clinical Excellence; RNAO, Registered Nurses Association of Ontario; CNKI, China National Knowledge Infrastructure; CBM, China Biology Medicine disc.

for evidence are as follows: Level 1 consists of RCTs or meta-analyses of RCTs, Level 2 includes quasi-experimental studies, Level 3 comprises observational analytical studies, Level 4 encompasses observational descriptive studies, and Level 5 consists of expert opinions and basic research.

Subsequently, we conducted an expert meeting, which included two chief physicians in neonatology, two head nurses, and one deputy director of the nursing department, along with three key neonatology nurses. Based on the FAME principle, which stands for feasibility, appropriateness, meaningfulness, and effectiveness of the evidence, the recommended levels of evidence were determined, including Grade A recommendation (strong recommendation) and Grade B recommendation (weak recommendation).

Results

Results of literature screening

Figure 1 illustrates the literature retrieval process. A total of 9,440 documents were searched in this study, and after de-duplication, reading the title, abstract and full text, 22 documents were finally included (10,12,22,24,25,31-47). These included two guidelines (34,36), 11 systematic reviews

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Table 2 Characteristics of included studies (n=22)

Included articles	Source	Type of the article	Year	Topic of the article
Goodstein *et al.* (24)	AAP	Technical report	2021	Transitioning from the NICU to a safe home sleep environment
Skelton *et al.* (31)	PubMed	Systematic review	2023	The effect of body position on involuntary outcomes in preterm infants
Almadhoob *et al.* (32)	Cochrane Library	Systematic review	2015	NICU noise reduction management
Park (12)	PubMed	Practice recommendation	2020	Sleep promotion in preterm babies
Gogou *et al.* (10)	Web of Science	Systematic review	2019	Factors affecting sleep in preterm babies
Firmino *et al.* (22)	PubMed	Systematic review	2022	Measures to promote sleep in preterm babies
Liao *et al.* (25)	PubMed	Systematic review	2018	Non-pharmacological interventions for sleep promotion
van den Hoogen *et al.* (33)	PubMed	Systematic review	2017	Sleep promotion programme
Queensland Clinical Guidelines (34)	Queensland Department of Health	Guideline	2022	Safe sleep for infants
Yang *et al.* (35)	PubMed	Systematic review	2023	Positional management of preterm infants in the NICU
RNAO (36)	RNAO	Guideline	2014	Safe sleep for infants
Lin *et al.* (37)	CNKI	Evidence summary	2022	NICU developmental support environment management
Costa *et al.* (38)	PubMed	Systematic review	2022	Clinical benefits of music intervention on the health of preterm infants
Browne *et al.* (39)	PubMed	Practice recommendation	2020	Standards, competencies, and best practices for developmental care
Costa *et al.* (40)	PubMed	RCT	2019	Hammock and nesting in preterm infants
Palaskar *et al.* (41)	PubMed	Systematic review	2023	Auditory stimulation in preterm infants
Carneiro *et al.* (42)	PubMed	Systematic review	2024	The impact of the nest position on sleep
Alinejad-Naeini *et al.* (43)	PubMed	RCT	2023	M technique massage on behavioral state
Düken *et al.* (44)	PubMed	RCT	2024	The impact of massage and white noise on sleep
Fadlalmola *et al.* (45)	PubMed	Systematic review	2023	Yakson touch and gentle human touch on preterm infants
Kobus *et al.* (46)	PubMed	RCT	2021	Music therapy
Yan *et al.* (47)	Web of Science	RCT	2020	Music therapy

AAP, American Academy of Pediatrics; NICU, neonatal intensive care unit; RNAO, Registered Nurses Association of Ontario; CNKI, China National Knowledge Infrastructure; RCT, randomized controlled trial.

(10,22,25,31-33,35,38,41,42,45), 1 evidence summary (37), 1 technical report (24), 2 practice recommendations (12,39), and 5 randomized controlled trials (40,43,44,46,47). The basic characteristics of the included literature are shown in *Table 2*.

Quality evaluation results of the included literature

Quality evaluation results of the guidelines

Two guidelines were included in this study, one from Queensland Health (34), and one from the RNAO (36).

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Table 3 Results of the qualitative evaluation of the guides

Included articles	Percentage of standardisation by area (%)						≥60% field number (n)	≥30% field number (n)	Recommendation level
	Scopes and objects	Participant	Rigor	Clarity	Application	Independence			
Queensland Clinical Guidelines (34)	80.56	66.67	52.09	33.33	88.89	83.33	4	6	B
RNAO (36)	72.22	66.67	61.46	66.67	80.56	33.33	5	6	B

Recommendation level: A, the score for each domain is ≥60%; B, ≥3 domains have scores ≥30% and at least one <60%.

Table 4 Quality evaluation findings from systematic reviews

Included articles	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Skelton *et al.* (31)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unclear
Almadhoob *et al.* (32)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gogou *et al.* (10)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firmino *et al.* (22)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Liao *et al.* (25)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes
van den Hoogen *et al.* (33)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Yang *et al.* (35)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Costa *et al.* (38)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Palaskar *et al.* (41)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Carneiro *et al.* (42)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fadlalmola *et al.* (45)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

(I) Evidence-based questions clear? (II) Appropriate literature inclusion criteria? (III) A proper search strategy? (IV) The proper source for a research paper? (V) Criteria for evaluating the quality of literature? (VI) ≥2 evaluators to evaluate the quality of the literature? (VII) Extract information using relevant measures to reduce errors? (VIII) Is the methodology of the synthesis study appropriate? (IX) Assessment of publication bias? (X) Recommendations for policy practice? (XI) Make appropriate recommendations for future research?

Both guidelines had a recommendation of B for inclusion. See *Table 3*.

Quality assessment of systematic reviews

Eleven systematic reviews were incorporated into the study (10,22,25,31-33,35,38,41,42,45). These studies were characterized by their comprehensive and rigorous design, warranting their inclusion. For details, refer to *Table 4*.

Quality assessment of evidence summaries, practice recommendations and technical reports

This research incorporated one technical report from the American Academy of Pediatrics (AAP) (24), one practice recommendation by the Association of Women's Health, Obstetric and Neonatal Nurses (AWHONN) (12), an evidence synthesis by the Chinese Medical Association (37) and a practice recommendation from the Gravens Consensus Committee on Infant and Family Centered Developmental Care (39). Each study was rich in content and was therefore included in the analysis. For further information, please refer to *Table 5*.

Quality assessment of randomized controlled trials

The present study has incorporated a total of five randomized controlled trials (40,43,44,46,47), and the results of their quality assessments are presented in *Table 6*.

Summary of evidence

A summary of the evidence from eight areas of sleep team building, risk factor assessment, sleep assessment tools, position management, noise control, light management,

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Table 5 Quality assessment of evidence summary, practice recommendations, and technical report

Included articles	Items									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Goodstein *et al.* (24)	Yes	Yes	No	Yes	Yes	Partial yes	Yes	Yes	Yes	Yes
Park (12)	Yes	Yes	No	Partial yes	Yes	Partial yes	Yes	Yes	Yes	Yes
Lin *et al.* (37)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Browne *et al.* (39)	Yes	Yes	Yes	Yes	Yes	Partial yes	Yes	Yes	Yes	Yes

(I) Specificity of the application scope and target audience; (II) transparency of the author's identity; (III) transparency of the review process; (IV) clarity of evidence grading; (V) clarity of recommendation statements; (VI) appropriateness of citation for recommendation statements; (VII) timeliness of recommendation statements; (VIII) applicability for the evaluation of the study population; (IX) comprehensive nature of the literature search; (X) disclosure of potential conflicts of interest.

Table 6 Quality assessment results of randomized controlled trials

Included articles	Items									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Costa *et al.* (40)	Yes	Yes	Yes	Unclear	No	Yes	Yes	Yes	Yes	Yes
Alinejad-Naeini *et al.* (43)	Yes	Yes	Yes	Unclear	No	Yes	Yes	Yes	Yes	Yes
Düken *et al.* (44)	Yes	Unclear	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes
Kobus *et al.* (46)	Yes	Unclear	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes
Yan *et al.* (47)	Yes	Yes	Yes	Unclear	No	Yes	Yes	Yes	Yes	Yes

(I) Implementation of random allocation methods; (II) application of blinding to study participants; (III) execution of allocation concealment; (IV) handling of participants with missing data; (V) blinding of outcome assessors; (VI) baseline comparability; (VII) consistency of intervention implementation; (VIII) consistency of measurement methods; (IX) reliability of the measurement personnel; (X) appropriateness of data analysis methods.

sensory stimulation and hospital-home transition sleep management resulted in 27 pieces of evidence, as shown in *Table* 7.

Discussion

Forming a sleep management team

Healthcare professionals are the primary caregivers during the hospitalization of premature infants. Ensuring a high level of sleep management knowledge and practice is fundamental to ensuring good sleep quality for premature infants. However, research indicates that healthcare professionals tend to prioritize the diagnosis, treatment, and care of premature infant illnesses rather than focusing on sleep management (48). Their understanding of sleep management knowledge is relatively lacking, and they underestimate the importance of sleep management. The lack of relevant beliefs and knowledge remains a barrier to safe sleep management. The key to providing high-quality care lies in continuously integrating knowledge, values, attitudes, and skills into practice to enhance nursing capabilities (49). One-time education or internal meetings have a limited impact on knowledge acquisition (50). Therefore, there is an urgent need to establish interdisciplinary teams for safe sleep management, collaborate with obstetric and community nursing staff, and provide continuing education resources related to safe sleep practices. Regular internal and external training should be organized to stay up-to-date with the latest sleep management strategies. Attention should be given to promoting awareness and understanding of safe sleep practices among healthcare professionals, and sleep knowledge should be incorporated into assessment standards. In addition to training healthcare professionals, it is also encouraged to involve premature infants' parents in the implementation of sleep development programs

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Table 7 Summary of best evidence for safe sleep in preterm infants

Category	Evidence content	Evidence level	Recommendation level
Sleep team construction	1. Establishment of an interdisciplinary safe sleep management team with good communication with the primary caregiver of the preterm infant to ensure consistency when educating caregivers about sleep (12,24,34,36,39)	Level 5	A
	2. Develop a comprehensive sleep education plan for medical staff and parents, encouraging parents of premature infants to participate in the implementation of sleep development programs together; regularly evaluate the knowledge mastery of parents and healthcare professionals (12,22,33,34,36,39)	Level 5	A
Risk factor assessment	3. Choking: beware of loose coverings that increase the risk of choking (24)	Level 5	A
	4. Accidental deaths: swaddling can promote sleep in preterm babies, but improper use (too tight, prone or side-lying positions, etc.) can cause hip dysplasia and accidental neonatal deaths, so it is not recommended, and it is always used in the supine position, and it is important to stop it as soon as the preterm baby tries to roll over (24)	Level 3	A
	5. Sudden death: prone positioning during hospitalisation, while promoting quiet sleep in preterm infants, reduces the ability to dissipate heat; prone positioning and high body temperature are independent risk factors for sudden neonatal death (10,24,31,34)	Level 3	A
Sleep assessment tools	6. Factors affecting sleep quality: medical factors (apnoea, pain, medication, uncomfortable positions, frequent medical manipulation, drugs, etc.); environmental factors (noise, lighting, temperature and humidity, etc.) (10,12,22,31,33)	Level 2	A
	7. Regular pain scoring to identify pain-induced decline in sleep functioning (31)	Level 1	B
	8. Sleep-wake state assessment using preterm sleep assessment tools (EEG, activity recorder, direct behavioural observation, etc.); due to the immaturity of preterm infants' neurological functions, EEG should be combined with direct behavioural observation; it is recommended that sleep measurements should be included in the daily check-ups in order to promote process improvement, e.g., all routine nursing care operations should be centralised and avoided as much as possible in the preterm infant's quiet sleep cycle (12,22,33,39)	Level 2	B
	9. We can evaluate the sleep condition of preterm infants by employing the Neonatal Behavioral Assessment Scale (NBAS), Assessment of Preterm Infants' Behavior (APIB), Anderson Behavioral State Scale (ABSS), and Thoman Scoring System (TSS) (12)	Level 5	B

Table 7 (*continued*)

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Table 7 (*continued*)

Category	Evidence content	Evidence level	Recommendation level
Positional management	10. It is recommended that hospitalised preterm infants should be kept predominantly in the supine position from 32 weeks of gestational age (24,34,36)	Level 5	A
	11. In the acute phase of respiratory disease, the prone position facilitates improved ventilation and oxygen saturation, but only during continuous cardiac monitoring, and should be shifted to the supine position once relief is achieved (24,39)	Level 1	A
	12. In preterm infants with gastro-oesophageal reflux, the supine position is preferred; elevating the head of the bed is not effective in reducing gastro-oesophageal reflux but increases the risk of airway obstruction (24)	Level 3	A
	13. There is no difference in the effectiveness of phototherapy for hyperbilirubinaemia between the supine position and regular position changes, and preterm infants should also be kept supine while receiving phototherapy to promote safe sleep (24)	Level 1	A
	14. Maintaining preterm infants in a flexed limb position using postural aids such as bird's nests, waterbeds and hammocks can promote sleep (35,37,39,40,42)	Level 1	B
Noise control	15. Noise in the NICU should be controlled below 45 dB during the daytime and no more than 20 dB at night; use noise monitors to monitor and record the volume of each environment in the NICU over a long period of time; and recommend the use of sound-insulating materials in the NICU wards (32,37)	Level 2	A
	16. When purchasing medical equipment, it is recommended that the level of sound pressure (in dB) generated by the use of the equipment be taken into account in the selection process; and that single-patient rooms be made available where possible (32,39)	Level 5	B
	17. Reduction in the volume of equipment alarms, conversations and exchanges between staff and family visitors (22,32,39)	Level 1	A
	18. Earplugs or noise-cancelling warmers can be used for preterm babies; avoid talking, leaning, or banging on top of the warmer; and close the door gently (10,22,32)	Level 5	A
Light management	19. Light intensity in NICU is 200–300 lux during the day and should be less than 30 lux at night, use dark coloured blackout cloth to cover the warming box to reduce light stimulation (37)	Level 5	B
	20. Correction for corrected gestational age greater than 32 weeks with simulated circadian light to promote sleep (10,12,25,33,37,39)	Level 1	A

Table 7 (*continued*)

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Table 7 (*continued*)

Category	Evidence content	Evidence level	Recommendation level
Sensory stimulation	21. Early mother-infant skin-to-skin contact or kangaroo care as early as possible in the stabilisation of the preterm baby enhances the length of quiet sleep and brain maturation of the preterm baby; during kangaroo care, mothers can also sing to enhance the physiological stability of the preterm baby (12,25,33,37,41)	Level 1	A
	22. When infants are in a state of wakefulness or distress, personalized gentle touch can be administered, encompassing areas such as the head, chest, back, and/or feet. The frequency and duration of touch should be adjusted in real time according to physiological parameters. Additionally, a combination of massage and limb movement can be considered to provide tactile stimulation, aiming to improve the sleep-wake states of premature infants and increase their sleep duration. For infants with heightened sensitivity, touch should be approached with caution, and close monitoring is essential to ensure their safety (10,12,22,25,33,39,43,45)	Level 1	A
	23. Tub bathing aids in preventing thermodynamic instability, stress, and harm to physiological parameters, thereby elevating the comfort of premature infants and fostering sleep. The application of swaddling can be utilized to alleviate the potential stress that may arise during the bathing process (22,39)	Level 1	B
	24. When the gestational age of premature infants reaches or exceeds 33 weeks, auditory stimulation may be beneficial in reducing cardiorespiratory events. The types of auditory stimuli include the mother's voice or heartbeat, lullabies, ocean sounds, white noise, and more. It is recommended to monitor the volume, ensuring that the sound intensity level does not exceed a continuous noise level of 40–45 dB per hour. Ideally, under the guidance of a music therapist, if conditions permit, this can enhance the interaction between the infant and their parents. Even during sleep, music therapy can serve to stabilize the respiratory rate and oxygen saturation levels of premature infants (25,37,38,41,44,46,47)	Level 1	A
Hospital-home transition sleep management	25. Stable preterm and low birth weight infants should be placed in the supine position until expected discharge from hospital (24,34,39)	Level 5	A
	26. The reasons for the prone position during hospitalisation should be explained to parents of preterm infants and the benefits of the supine position in the home environment should be emphasised (24)	Level 5	A
	27. Prior to discharge, inquire with the primary caregiver about the home sleep plan and provide education on safe sleep practices. Ensure that the parents are able to identify potential sleep risks within their home and respond to them appropriately (34,36,39)	Level 5	A

Level of evidence: Level 1 encompasses RCTs and meta-analyses incorporating RCTs; Level 2 comprises quasi-experimental studies; Level 3 includes observational analytical studies; Level 4 features observational descriptive studies; and Level 5 consists of expert opinions and basic research. Level of recommendation: A, strongly recommended; B, weakly recommended. EEG, electroencephalogram; NICU, neonatal intensive care unit; RCTs, randomized controlled studies.

(12,22,33,34,36). However, a study shows that only 22.5% of parents have received relevant sleep education training (51). Providing health education to parents can result in some degree of change in their health behaviors, regardless of the environment they are in. Furthermore, interventions involving parents yield the best results (52).

Risk factor assessment

Sleep-related unexpected death is the primary cause of infant mortality in the United States, accounting for 28% (53). Similarly, in China, Sudden Infant Death Syndrome (SIDS) accounts for approximately 15% to 20% of infant

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deaths (54). Accurately identifying the risk factors for premature infants during sleep is an important measure for effective prevention of death. High-quality evidence indicates that the prone position and elevated body temperature are independent risk factors for sudden infant death in newborns (10,24,31,34). The prone position increases the risk of SIDS by 14 times (55). Currently, it is widely believed that premature infants lack the ability to self-arouse. The prone position/external pressure leads to prolonged oxygen deprivation, resulting in hypercapnia and abnormal serotonergic function in the brainstem, ultimately leading to SIDS (56). Therefore, this study suggests that premature infants should always maintain a supine position during hospitalization unless there are specific medical contraindications, and this practice should be continued until at least reaching 1 year of age (54). Swaddling can reduce crying in premature infants and increase the duration of QS. However, it is important to note that when swaddling, the supine position should always be maintained, and if the premature infant attempts to roll, swaddling should be immediately discontinued to prevent rolling into the prone position, which can lead to SIDS (24,54). Considering the pros and cons, this study does not recommend swaddling as a routine strategy to promote sleep in premature infants. Another risk factor for SIDS is elevated body temperature and heat stress reactions. The pathophysiological mechanisms underlying this need further investigation. Véronique Bach *et al.* suggest that heat stress alters the respiratory function of premature infants and may interact with other factors in the environment (such as smoke), ultimately leading to SIDS (57). It is worth noting that due to the head being the main area for heat dissipation in infants, the use of head coverings and similar items may accelerate overheating of the brain, causing symptoms similar to heatstroke and posing a life-threatening risk. Therefore, this study recommends continuous monitoring of environmental temperature during hospitalization to avoid high body temperature and overheating in the sleep environment. Additionally, loosely covered crib bedding increases the risk of suffocation (24), so it is important to avoid using any loose bedding items and instead choose tight-fitting sheets. In conclusion, healthcare professionals should enhance their insight and be vigilant in avoiding potential risk factors that may lead to accidental death in premature infants, promptly removing any potential hazards.

Sleep assessment tools

The factors influencing sleep quality mainly include iatrogenic factors (such as apnea, pain, medication, uncomfortable positions, frequent medical procedures, drugs, etc.) and environmental factors (such as noise, lighting, temperature, humidity) (10,12,22,31,33). A comprehensive and multidimensional assessment should be conducted based on individual differences. Evaluation tools for sleep quality mainly comprise electroencephalograms (EEGs), actigraphy, and direct behavioral observation (12,33). Although multi-channel sleep EEGs are considered the gold standard for assessing sleep in infants and adults, their reliability is lower in premature infants due to incomplete development of their nervous system (12). Moreover, they are costly and require a significant amount of labor, including skilled technicians for operation, coding, and recording, along with complex equipment support (58), which can itself become a stimulus for premature infants. Regarding actigraphy, relevant research suggests that during AS periods, there is a considerable amount of limb movement (58). The use of actigraphy may mistakenly interpret these movements as wakefulness in infants, thus unable to accurately predict the sleep or wakeful state of premature infants. Direct behavioral observation methods mainly include the Neonatal Behavioral Assessment Scale (NBAS), the Assessment of Preterm Infants' Behavior (APIB), the Anderson Behavioral State Scale (ABSS), and the Thoman Scoring System (12). Among them, NBAS is mainly suitable for infants aged 36 to 44 weeks (12) and assesses three sleep states (deep sleep, light sleep, drowsiness) and three wakeful states (quiet awake, active awake, crying). Its advantage lies in its ability to differentiate the six sleep-wake states relatively simply (59). APIB and ABSS (12) are sleep monitoring scales developed specifically for premature infants, characterized by greater detail and sensitivity in identifying unique sleep patterns in high-risk newborns. The advantage of the Thoman Scoring System is its wider age range applicability. This study suggests incorporating sleep measurements into daily rounds and taking timely measures to optimize the sleep quality of premature infants (12).

Non-pharmacological sleep promotion programmes

The sleep promotion plan for premature infants mainly

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consists of positional management, noise control, light management, and sensory stimulation (12,24,25,33,34,36). Several studies have shown that hospitalized premature infants should primarily maintain a supine position (24,34,36). The authoritative practice standard setter, the AAP, added a section on premature infants with special conditions in their 2021 technical report, supplementing recommendations for positional management (24). For acute respiratory diseases, the prone position has been found to improve ventilation and reduce apnea. However, continuous monitoring of cardiopulmonary function and blood oxygen saturation is also necessary. The supine position is equally preferable for premature infants with gastroesophageal reflux (55). Elevating the head of the bed, contrary to expectations, has been shown to increase the risk of airway obstruction and does not effectively reduce gastroesophageal reflux. Additionally, due to the lack of sufficient evidence, at present, to prove that timed repositioning during phototherapy for hyperbilirubinemia offers a superior bilirubin decline rate within 24 hours compared to the supine position, premature infants receiving phototherapy should also be placed in a supine position to prevent adverse events such as suffocation or aspiration (60). Multiple studies have indicated that the use of positional support tools such as nests, water beds, and hammocks helps establish boundaries around premature infants, maintaining their physiological flexion which promotes sleep (35,37,40). Among them, the hammock position is a specialized posture for preterm infants. It effectively mimics the fetus's comfortable posture within the womb, aiding the infant in maintaining a natural, curled position with both arms and legs close to the midline of the body. This helps the premature infants relax and reduce energy expenditure. When lying on their sides in a hammock with their hands near their mouths, they can more easily engage in self-soothing behaviors, such as sucking on their fingers or fists (40). Nevertheless, the potential adverse effects of the hammock position, including safety risks and the need for optimal standards concerning the hammock's size, material, and angle, require further investigation. It is essential to emphasize that any use of positional support tools must be thoroughly tested and adjusted to ensure they provide stable and reliable support.

The AAP recommends that the daytime noise level in the NICU should be controlled below 45 decibels (dB). Nevertheless, research indicates that the noise in the NICU exceeds the recommended levels significantly (61). It is crucial to employ noise monitoring devices to continuously monitor and record the volume of various environments within the NICU. When designing NICU facilities, it is advisable to utilize soundproofing materials as much as possible. In cases where environmental changes are unfeasible, controlling noise generated by activities becomes an integral component of establishing a "culture of tranquility". Policies in certain countries encourage designated QS periods in the NICU where all lights are turned off, device alarms are silenced, and non-essential procedures are postponed (23). In China, where the number of preterm births ranks second globally, NICU bed occupancy remains overwhelming. While promoting such policies is worthwhile, ensuring their absolute safety during implementation remains debatable. However, it can be affirmed that the most cost-effective method for both staff and family members is to reduce their vocal volume and keep their communication devices on silent or vibrate mode. Whenever feasible, providing individual family rooms should be considered (32). It's important to note that incubators do not prevent high-frequency noise in the NICU and may even act as noise sources, such as when the cabinet doors of incubators open or close, producing significant noise (37). Consequently, healthcare professionals must refrain from engaging in conversations, laughter, or any impacts above the incubators, as the internal space amplifies sound.

The report's another principal concern arises from the 24-hour constant bright light conditions in the NICU (25). Existing study has indicated that most of the photoreceptors and visual proteins emerge during early pregnancy, suggesting that premature infants may also possess a certain photo perception ability (62). Pupils, as the gateway for perceiving light, may stimulate premature infants under irregular or continuous illumination. Therefore, it is recommended to avoid direct light exposure to premature infants' eyes and instead utilize dark shading to cover the incubator (37). The circadian rhythm system, functioning as a fundamental biological clock, plays a crucial role in regulating various physiological processes within organisms. Premature birth may disrupt the development of this system, as preterm infants are frequently exposed to artificial light sources that differ from the intrauterine environment (lacking a discernible 24-hour environmental rhythm and presenting confusing temporal signals), which can hinder the regular secretion of melatonin (12,63). Therefore, for those with a corrected gestational age greater than 32 weeks, implementing a simulated day-night light cycle (approximately 12 hours of light followed by 12 hours

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of darkness) can promote sleep. This lighting regimen aids in the visual development of preterm infants and facilitates the establishment and regulation of circadian rhythms, as well as hormonal levels (10,12,25,33,37).

This article summarizes evidence-based strategies for promoting sleep in premature infants through sensory stimulation. The evidence suggests that, under stable medical conditions, early skin-to-skin contact or kangaroo care should be initiated as soon as possible starting from 31 to 32 weeks of gestation (12,25,33,37). Through direct skin contact with their parents, preterm infants can experience their parents' body temperature, heartbeat, and breathing rhythms. The sound of their parents' heartbeats and breathing serves as a familiar and comforting auditory stimulus, helping the infants relax and facilitating deeper sleep (39). Additionally, personalized gentle touch is recognized as an effective non-pharmacological intervention (39). When infants are awake or exhibit signs of distress, caregivers can employ gentle touch techniques. The frequency and duration of touch should be adjusted according to the infant's physiological responses to ensure appropriateness and safety. Furthermore, touch can be combined with tactile stimulation through limb movements. However, for high-risk infants, caregivers should exercise extra caution when administering touch and maintain continuous monitoring to prevent potential adverse reactions, such as a decrease in oxygen saturation.

In recent years, with the increasing focus on the auditory development and well-being of premature infants, music therapy has gained widespread recognition as an effective intervention. Research by Yan *et al.* suggests that there may be a connection between music, hormones, and the sleep cycles of newborns (47). Music therapy can promote the release of endorphins in the brain, aiding in the regulation of the sympathetic nervous system and having a positive impact on the overall development of preterm infants (38). Additionally, music therapy may be associated with an increase in the release of serotonin within the body. Serotonin is a crucial neurotransmitter that plays a key role in the regulation of sleep architecture (47). However, when implementing music therapy, it is essential to strictly control the volume to ensure that the sound intensity does not exceed the continuous noise threshold of 40 to 45 dB per hour, to avoid unnecessary auditory stress on preterm infants (38). Studies recommend incorporating professional music therapists into interdisciplinary teams, as they possess the specialized skills to provide music interventions and can consciously manipulate musical elements to enhance the potential for interaction with preterm infants and their parents, meeting the multidimensional needs of the natural "musical communication" between mother and child (38,46). The optimal duration, volume intensity, frequency, and the interplay between the effects of music therapy and environmental factors remain subjects for further investigation.

Hospital-home transition sleep management

According to the recommendations of the AAP, healthcare professionals should assume the responsibility of educating families to ensure that infants are in a secure sleep environment after discharge (24). Research indicates that premature infants' mothers have a lower compliance rate with supine sleeping position compared to mothers of full-term infants (64). However, Barsman *et al.* found that only 60% of nurses transition infants to the supine sleeping position before discharge (65). Therefore, based on the combined evidence from this study, it is recommended that stable premature infants should be placed in the supine position for sleep prior to anticipated discharge (24,34,36). For parents who may have chosen prone or lateral positions for their premature infants during hospitalization, it is essential to provide an explanation of the benefits of the supine position in a home environment. Before discharge, it is suggested to inquire about the at-home sleep plan with the primary caregiver. For parents with limited understanding, the frequency of training sessions should be increased. It is suggested to tailor interventions to individual circumstances of premature infants to effectively improve post-discharge sleep safety habits.

Conclusions

This study conducted an extensive search of domestic and international literature concerning the safe sleep management of premature infants. From various aspects including sleep team construction, risk factor assessment, sleep assessment tools, positional management, noise control, light management, sensory stimulation, and hospital-home transition sleep management, a comprehensive compilation of 27 evidence-based recommendations was formed. These findings aim to provide healthcare professionals with evidence-based guidance for clinical practice. It is advised that healthcare personnel take into account the local medical environment and carefully select relevant evidence for evidence-based

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translation in order to enhance the quality of nursing care.

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Footnote

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