

Sensory Stimulation Improves Neurobehavioral Development in Preterm Infants

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ABSTRACT

Prematurity disrupts critical intrauterine sensory experiences and increases the risk of long-term neurobehavioral developmental impairments in infants, particularly those receiving care in the Neonatal Intensive Care Unit (NICU). Sensory stimulation interventions offer a non-pharmacological approach to support central nervous system maturation in preterm infants. This systematic review aimed to evaluate the effects of sensory stimulation on neurobehavioral development in preterm infants. Literature searches were conducted using the Population–Intervention–Comparison–Outcome (PICO) framework across PubMed, ProQuest, and ScienceDirect, focusing on randomized controlled trials published between 2015 and 2025. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, and methodological quality was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Tools. Seven studies met the inclusion criteria. All reported significant improvements in neurobehavioral outcomes measured using the Neonatal Neurobehavioral Examination Scale (NNES), Neonatal Intensive Care Unit Network Neurobehavioral Scale (NNS), Munich Neuromotor Development Examination (MNNE), Neonatal Behavioral Assessment Scale (NBAS), Dubowitz Neurological Examination, Alberta Infant Behavioral Scale (ABSS), and Infant Behavior Questionnaire-Revised (IBQ-R). Additional benefits included improved suck coordination, increased weight gain, enhanced physiological stability, and reduced length of hospital stay. In conclusion, sensory stimulation, particularly multisensory approaches effectively enhances neurobehavioral development in preterm infants and is recommended for integration into NICU care and early family-centered intervention programs.

Keywords: preterm infants; Neonatal Intensive Care Unit; neurobehavioral development; sensory stimulation

INTRODUCTION

Premature birth and low birth weight remain major neonatal health challenges, with a rising trend observed in recent years. National weighing records from 2023 indicate that 84.3% of newborns were assessed at birth, and 3.9% were identified as having low birth weight (LBW). This figure represents an increase from 2022, when approximately 2.5% of weighed newborns were classified as LBW [1]. The World Health Organization (WHO) defines LBW as a birth weight below 2500 grams, a condition that may result from prematurity, intrauterine growth restriction, or a combination of both factors [2].

Preterm infants are particularly vulnerable to growth and developmental disturbances due to the immaturity of multiple organ systems [3]. One of the most serious consequences of prematurity is the heightened risk of both short- and long-term neurodevelopmental impairments. This vulnerability is closely linked to the fact that fetal brain development undergoes a critical period of rapid growth and maturation between 24 and 40 weeks of gestation. During this period, preterm infants are already exposed to the extrauterine environment, often requiring intensive care in the Neonatal Intensive Care Unit (NICU) [4]. As a result, they face increased risks of neurological complications, including cerebral palsy (5–10%), motor impairments (25–40%), cognitive deficits (25–50%), and intellectual disability up to 62.5%, as well as visual perceptual disorders, visuomotor dysfunction, retinopathy of prematurity, and hearing impairment [5,6,7].

Beyond biological immaturity, the NICU environment itself contributes to altered brain development. Exposure to excessive noise, bright lighting, limited parent–infant interaction, disrupted sleep patterns, and frequent painful invasive procedures can serve as significant stressors for both infants and families [8]. Repeated early-life stress has been shown to negatively affect later neurobehavioral and socio-emotional development [9]. Insufficient social interaction, particularly with the mother may further exacerbate socio-emotional difficulties, given that early maternal–infant bonding forms the foundation of mental health from infancy through adolescence and adulthood [10].

Over the past decades, various interventions have been developed to support the growth and neurodevelopment of preterm infants, including parental mental health programs, optimized nutrition, infant massage, kangaroo mother care, preterm infant caregiving education, and structured mother–infant interaction programs. Among these, sensory stimulation has gained increasing attention as a non-pharmacological intervention that can be initiated early to enhance neurobehavioral development and potentially prevent sensory disabilities [11,12,13].

Sensory stimulation operates by providing peripheral sensory input that promotes brain function through neuroplasticity, the brain's capacity to form new neural connections and reorganize its structural and functional networks in response to experience and environmental exposure [14]. Common forms of sensory stimulation include auditory input (music or maternal voice recordings), tactile stimulation (infant massage), visual stimulation (high-contrast black-and-white images), and vestibular stimulation (gentle horizontal or vertical rocking) [14,15,16]. Evidence indicates that multisensory approaches are more effective than single-modality stimulation in improving neurobehavioral outcomes among high-risk neonates and have become an integral component of neonatal physiotherapy practice [17].

Despite the growing body of research demonstrating the benefits of sensory stimulation, existing findings remain heterogeneous in terms of intervention types, duration, and outcome measures. Therefore, a systematic review is needed to comprehensively evaluate the impact of sensory stimulation on the neurobehavioral development of preterm infants. The purpose of this systematic literature review is to critically analyze the scientific evidence regarding the effectiveness of sensory stimulation in enhancing neurobehavioral outcomes in preterm infants, thereby providing a foundation for evidence-based neonatal care interventions.

METHODS

This systematic review was designed and reported in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Figure 1) [18]. The inclusion criteria were established to ensure the selection of high-quality and clinically relevant evidence. Eligible studies included preterm infants with a gestational age of less than 37 weeks; articles published between 2015 and 2025; studies that evaluated neurobehavioral developmental outcomes; and research employing a randomized controlled trial (RCT) design.

A comprehensive and systematic literature search was conducted across three major electronic databases, PubMed, ProQuest, and ScienceDirect using the Population–Intervention–Comparison–Outcome (PICO) framework. The population of interest was preterm infants, the intervention was sensory stimulation, and the primary outcome was neurobehavioral development. The search strategy incorporated a combination of Medical Subject Headings (MeSH) and relevant keywords, including (“sensory stimulation” OR “multisensory stimulation” OR “early intervention”) AND (“neurobehavioral” OR “neurodevelopment”) AND (“preterm” OR “prematurity” OR “premature”).

All retrieved articles underwent a multi-stage screening process. Initial screening involved title and abstract review to eliminate irrelevant studies. Full-text assessment was then conducted independently by two reviewers to determine eligibility based on predefined criteria. Data extraction was performed using a structured extraction table that captured essential study characteristics, including author names, year of publication, country, study objectives, population or sample characteristics, study design, measurement instruments, and key findings (Table 1).

Methodological quality and risk of bias were evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Randomized Controlled Trials, which consists of 13 assessment items. Each “yes” response was assigned a score of 1, while “no” or “unclear” responses were scored as 0. Total scores were converted into percentages, with $\geq 70\%$ classified as high quality and $\geq 50\%$ considered acceptable quality. Any discrepancies between reviewers were resolved through discussion with a senior third reviewer. Importantly, all studies were retained in the review regardless of methodological quality scores to ensure a comprehensive synthesis of available evidence [19].

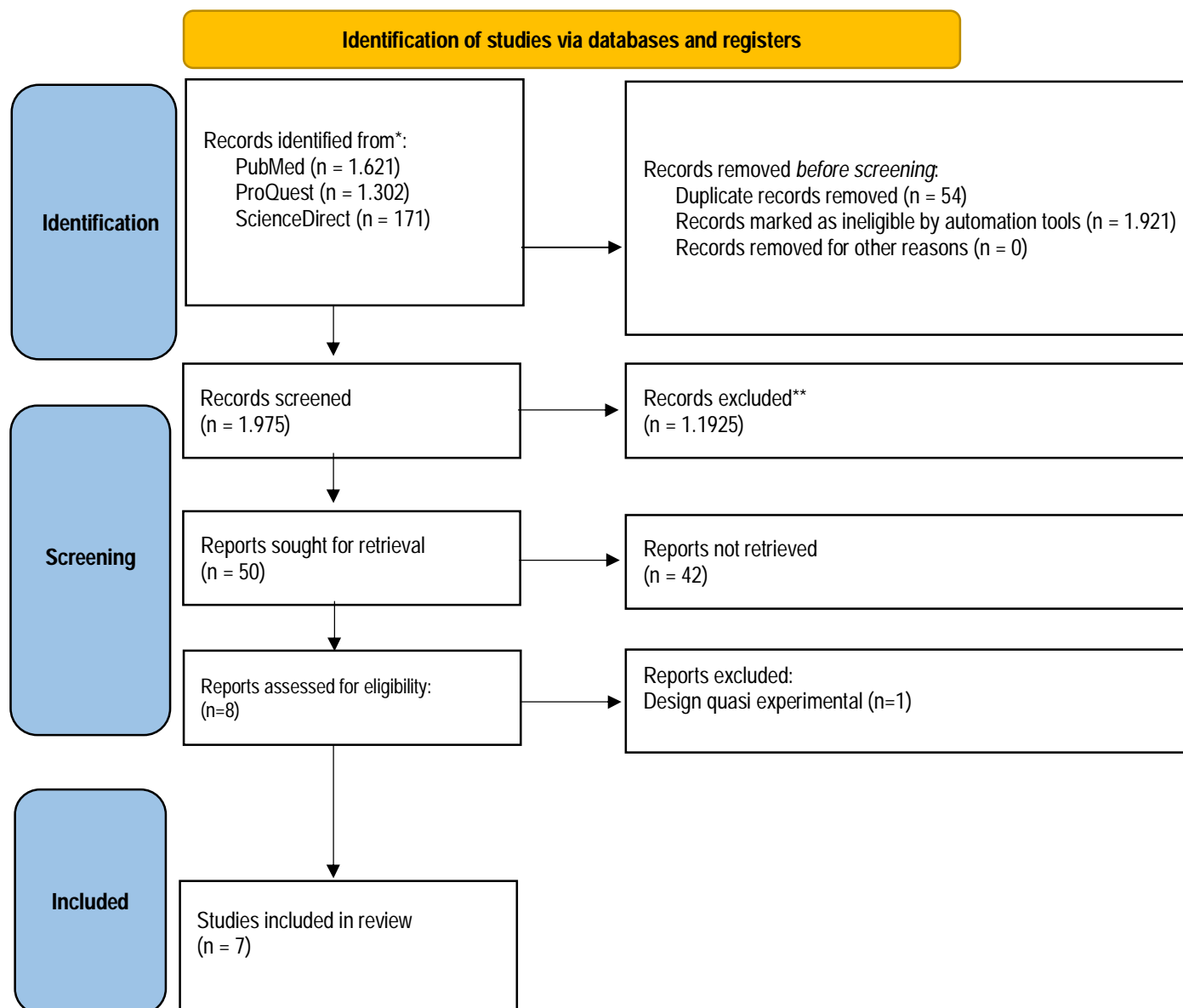


Figure 1. PRISMA flow diagram for article selection

RESULTS

This systematic review identified a total of 3,094 published articles related to sensory stimulation interventions in preterm infants through a comprehensive and structured search process conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Figure 1). Following a rigorous multistage screening procedure, comprising title and abstract screening, full-text eligibility assessment, and methodological appraisal, seven studies employing a randomized controlled trial (RCT) design were deemed eligible for inclusion in the final synthesis.

Collectively, these seven studies involved 818 preterm infants with gestational ages below 37 weeks and birth weights under 2500 grams, representing a diverse range of clinical and cultural contexts. The included trials were conducted across multiple countries, including Egypt, India, the United States, Indonesia, and China, thereby enhancing the external validity and generalizability of the findings. Despite geographical variation,

all studies adhered to standardized methodological principles and implemented clearly defined sensory stimulation protocols tailored to the developmental needs of preterm infants.

Importantly, every included study utilized validated neurobehavioral assessment instruments, ensuring the reliability and precision of outcome measurements. These instruments, such as the Neonatal Neurobehavioral Examination Scale, the Neonatal Intensive Care Unit Network Neurobehavioral Scale, the Neonatal Behavioral Assessment Scale, and other standardized developmental tools provided robust and multidimensional evaluations of neurobehavioral status. The consistent use of validated tools across studies strengthens the credibility of the synthesized evidence and supports the conclusion that sensory stimulation interventions exert measurable and meaningful effects on neurobehavioral development in preterm infants.

Table 1. The results of synthesis

No.	Author	Objective	Design	Respondents	Instruments	Key findings
1	Badr & Ismail (2024), Egypt [36]	To determine the effect of multisensory stimulation on the neurobehavioral status of preterm infants.	Randomized controlled trial (RCT)	N = 60 (I = 30; C = 30)	<ul style="list-style-type: none"> Demographic data Neonatal neurobehavioral examination scale 	Multisensory stimulation improved the mean total neurobehavioral score in the intervention group after two weeks (65.20 ± 7.65) compared with the control (46.87 ± 7.55) ($p = 0.000$).
2	Pineda et al. (2021), USA [21]	To evaluate the impact of a standardized multisensory manual applied throughout NICU care on infants and parents.	RCT	N = 52 (I = 24; C = 28)	<ul style="list-style-type: none"> NICU Network Neurobehavioral Scale (NNNS) Hammersmith Neonatal Neurological Examination Sensory processing assessment Maternal Confidence Questionnaire Pediatric Eating Assessment Tool Pediatric Feeding Assessment Scale 	Infants receiving the SENSE (Supporting and Enhancing NICU Sensory Experiences) program demonstrated consistent improvements in neurobehavioral scores and maternal confidence at NICU discharge ($p < 0.05$).
3	Mohammed et al. (2018), Egypt [37]	To examine the effect of a multisensory stimulation program on neurobehavioral development in high-risk neonates.	RCT	N = 88 (I = 44; C = 44)	<ul style="list-style-type: none"> Morgan Neonatal Neurobehavioral Examination (MNNE) Brazelton Neonatal Behavioral Assessment Scale (NBAS) 	Significant improvements were observed across all measured variables in the intervention group ($p < 0.05$), whereas the control group showed no significant changes.
4	Yonita et al. (2021), Jakarta [38]	To evaluate the effects of tactile-kinesthetic stimulation (TKS) on growth, behavior, and development in preterm infants.	RCT	N = 126 (I = 63; C = 63)	<ul style="list-style-type: none"> Anthropometric measurements Dubowitz Examination Development (Capture Scale Score) 	Over the 10-day TKS, the intervention group showed significant increases in weight and length compared with controls ($p < 0.05$). Improvements in tone, reflexes, and behavior were noted, although no significant differences were found between groups ($p > 0.05$). No significant differences were observed in language or cognitive development ($p > 0.05$).
5	Zheng et al. (2022), China [39]	To determine the effect of 5-Integrated Sensory Stimulation (5-ISS) on social, emotional, and behavioral development in preterm infants.	RCT	N = 200 (I = 98; C = 102)	<ul style="list-style-type: none"> Infant social-emotional development Infant Behavior Questionnaire-Revised (IBQ-R) Ages and Stages Questionnaire – Neurodevelopment Anthropometric measures 	At corrected ages of 1 and 3 months, no significant differences were observed. At 6 months, significant improvements were found in social-emotional development (Mean difference -0.29 ; 95% CI -0.58 ; $p = 0.001$), infant length (Mean difference 0.70 ; 95% CI $<0.001-1.4$; $p = 0.03$), distress to limitation ($p = 0.04$), and sadness ($p = 0.03$).
6	Nadar, Thakkar & Shah (2017), India [24]	To study and compare the effects of specific physiotherapy interventions—multisensory stimulation—on neurobehavior and weight gain in preterm infants.	RCT	N = 64 (I = 32; C = 32)	<ul style="list-style-type: none"> Digital weighing scale Sucking stage (5-stage sucking scale) Anderson Behavioral State Scale (ABSS) 	Both groups showed improved sucking coordination and neurobehavioral scores after intervention ($p < 0.0001$). When compared, the SPI group demonstrated better sucking coordination than the ATVV, although neurobehavioral improvements were similar across groups.

No.	Author	Objective	Design	Respondents	Instruments	Key findings
7	Parashar & Samuel (2018), India [22]	To determine the effectiveness of Yakson touch combined with kinesthetic stimulation (YAKIN) on development in high-risk neonates.	RCT	N = 28 (I = 14; C = 14)	•Neonatal Behavioral Assessment Scale (NBAS)	No significant differences were found between groups ($p > 0.005$). However, significant pre- to post-intervention improvements were observed in the infants' ability to bring hands to mouth and in skin color changes ($p < 0.05$).

Table 2. Summary of the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Randomized Controlled Trials (n = 7)

References	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	%	Overall
Badr & Ismail, (2024) [36]	Y	UC	Y	N	Y	N	Y	N	N	Y	Y	Y	Y	61.5%	Included
Pineda et al, (2021) [21]	Y	Y	Y	N	Y	N	Y	N	N	Y	Y	Y	Y	69.2%	Included
Mohammed et al, (2018) [37]	Y	Y	Y	UC	N	Y	Y	N	Y	Y	Y	Y	Y	76.9%	Included
Yonita et al, (2021) [38]	Y	Y	Y	UC	N	Y	Y	N	Y	Y	Y	Y	Y	76.9%	Included
Zheng et al (2022) [39]	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	92.3%	Included
Nadar, Thakkar, & Shah (2017) [24]	Y	UN	Y	N	Y	Y	UN	Y	Y	Y	Y	Y	Y	76.9%	Included
Parashar & Samuel, (2018) [22]	Y	Y	Y	UC	UC	NA	Y	UC	N	Y	Y	Y	Y	61.5%	Included

Notes: Y = Yes; N = No; NA = Not Applicable; UC = Unclear

Q1 = Randomization of participant allocation

Q2 = Concealment of group allocation

Q3 = Baseline similarity between intervention and control groups

Q4 = Blinding of participants

Q5 = Blinding of intervention providers

Q6 = Blinding of outcome assessors

Q7 = Consistency of treatment across intervention groups

Q8 = Completeness of follow-up

Q9 = Analysis conducted according to initial group allocation

Q10 = Consistency of outcome measurement methods

Q11 = Reliability of outcome measurement

Q12 = Appropriateness of statistical analysis

Q13 = Appropriateness of experimental design

Types and approaches of sensory stimulation

The synthesis of findings indicates that tactile stimulation—primarily in the form of gentle massage and soft touch—was the most consistently applied intervention across all included studies. This modality was frequently combined with kinesthetic stimulation involving passive limb movements, auditory stimulation such as music, maternal voice, or lullabies, visual stimulation using high-contrast toys or black-and-white books, and vestibular stimulation through gentle rocking or cradling. Multisensory approaches that integrate two or more forms of stimulation demonstrated greater effectiveness than single-modality interventions in improving neurobehavioral outcomes. These findings align with theories of sensory integration and neuroplasticity, which posit that multisensory input enhances synaptic connectivity and accelerates central nervous system maturation during the critical developmental period of preterm infants [12,13,14]. In contrast, olfactory stimulation, such as exposure to maternal scent was observed only in home-based programs like 5-ISS and SENSE, which emphasize active parental involvement. This suggests that the intervention context, whether NICU-based or home-based, influences the types of sensory stimuli that can be optimally implemented.

Home-based sensory stimulation programs

Home-based interventions demonstrated promising effects, particularly in enhancing socio-emotional development and parental engagement. The 5-ISS program produced significant improvements in social-emotional development at six months corrected age, as measured by the Ages and Stages Questionnaire: Social-Emotional (ASQ:SE), along with increased infant length compared with controls ($p < 0.05$) [20]. Similarly, the SENSE program resulted in meaningful improvements in sensory and motor development as well as overall neurobehavioral outcomes ($p = 0.05$) [21]. These findings reinforce the principles of nurturing care, which highlight the importance of responsive and stimulating caregiving environments in supporting long-term developmental outcomes among preterm infants [11].

Duration of intervention

The duration of sensory stimulation interventions varied across studies and can be categorized into short-, medium-, and long-term durations. Short-term interventions (several days to one week) produced early benefits in growth and neurobehavioral development, particularly through tactile-kinesthetic stimulation [22]. Medium-term interventions (1–4 weeks), typically delivered during NICU hospitalization, were consistently associated with improved physiological stability and significant neurobehavioral gains [17,23,24]. Long-term interventions (>4 weeks), extending from hospitalization through follow-up, demonstrated more sustained effects on neurobehavioral development and physical growth [20,21,25]. These findings suggest that consistency and continuity of sensory stimulation are critical factors in maximizing intervention benefits.

Neurobehavioral developmental outcomes

A range of validated instruments was used to assess neurobehavioral outcomes, including the NNES, NNNS, MNNE, NBAS, Dubowitz Examination, IBQ-R, and ABSS. Most studies (six out of seven) reported significant improvements in neurobehavioral status following sensory stimulation ($p < 0.05$) [17,20,21]. One study, however, found no significant differences between intervention and control groups, noting that the control group receiving kangaroo care, massage, and oral stimulation demonstrated comparatively better outcomes ($p > 0.05$). Nonetheless, the same study reported significant improvements in specific parameters, such as hand-to-mouth movement and skin color changes after intervention ($p < 0.05$) [25]. Two additional studies also reported non-significant between-group differences, likely influenced by variations in intervention design, duration, and types of stimuli applied [25,26]. These variations underscore the need for standardized sensory stimulation protocols in clinical practice.

Additional benefits

Beyond neurobehavioral improvements, sensory stimulation interventions also yielded additional benefits, including enhanced physical growth (weight and length) [20,23,25,26] and improved physiological stability, such as respiratory rate, heart rate, and oxygen saturation [22,23]. In terms

of oromotor function, both the Specific Physiotherapy Intervention (SPI) and tactile-kinesthetic stimulation improved sucking coordination and accelerated oral function maturation [25,26]. Family-centered programs such as 5-ISS further demonstrated positive effects on infant temperament and socio-emotional development, emphasizing the critical role of parental involvement as an integral component of sensory stimulation interventions [20].

DISCUSSION

Prematurity is defined as birth occurring before 37 weeks of gestation, and in more severe cases may occur before 27 weeks, resulting in marked immaturity across nearly all physiological systems, particularly the central nervous system [27]. During this developmental window, the fetal brain is expected to undergo rapid and highly organized maturation supported by gradual, rhythmic, and integrated intrauterine sensory stimulation. The abrupt cessation of these sensory experiences due to premature birth disrupts the maturation of sensory pathways and neurobehavioral integration, placing preterm infants at substantial risk for both short- and long-term developmental impairments.

The NICU environment, although essential for reducing morbidity and mortality, often fails to provide the sensory conditions required for optimal neurodevelopment. Excessive noise, bright lighting, repeated invasive procedures, and limited meaningful parental interaction can induce physiological and neurobehavioral stress, ultimately exerting adverse effects on brain development and behavioral organization [20,27]. These observations align with developmental care theory, which posits that a mismatch between the infant's developmental needs and the caregiving environment can hinder optimal neurological organization.

In response to these challenges, various forms of sensory stimulation interventions have been developed to compensate for the loss of intrauterine sensory experiences and to support critical periods of brain development. Findings from this systematic review demonstrate that sensory stimulation interventions, particularly multisensory approaches produce significant improvements in the neurobehavioral status of preterm infants. These interventions include combinations of auditory stimulation (maternal voice, music, lullabies), tactile stimulation (massage and gentle touch), visual stimulation (lighted toys or high-contrast black-and-white cards), vestibular stimulation (gentle rocking or hammock positioning), and physiotherapeutic approaches such as kinesthetic and oral stimulation (ATVV). These results are consistent with sensory integration theory, which emphasizes the importance of multisystem stimulation in strengthening synaptic connectivity and supporting coordinated neural development during periods of heightened brain plasticity [17,20,21,24,28].

The effectiveness of multisensory interventions is further supported by evidence showing that programs involving mothers or primary caregivers, such as the Maternal Participant Program (MPP), lead to significant improvements in neurobehavioral scores compared with standard care [28]. This highlights the importance of meaningful, relationship-based sensory input, particularly from primary caregivers in regulating stress responses and promoting central nervous system maturation.

Home-based sensory stimulation programs such as 5-ISS and SENSE provide important insights into the continuity of developmental care following NICU discharge. These programs not only ensure consistent sensory exposure but also strengthen parental involvement as central partners in supporting infant development. Evidence shows that long-term home-based interventions yield positive effects on neurobehavioral, socio-emotional, and physical growth outcomes in preterm infants [20,21]. Beyond infant outcomes, these programs enhance parental confidence, reinforce bonding, and align with the principles of family-centered care.

The duration of sensory stimulation interventions emerges as a critical factor influencing developmental outcomes. This review indicates that short-term interventions (several days to one week) can produce early improvements in growth and neurobehavioral responses [22]. Medium-term interventions (1–4 weeks) delivered during NICU hospitalization provide more stable improvements in physiological regulation and behavioral organization [17,23,24]. Long-term interventions (>4 weeks), extending into the post-discharge period, yield the most substantial and sustained benefits for neurobehavioral development and physical growth [20,21,25]. These findings are consistent with previous research demonstrating that routine multisensory stimulation for approximately 12 minutes per session, five times per week, effectively enhances neuromuscular and neuromotor development in preterm infants [15,29]. However, evidence of sensory adaptation during prolonged tactile stimulation suggests the need for stimulus variation to maintain intervention effectiveness.

In addition to improving neurobehavioral status, sensory stimulation interventions confer several secondary benefits, including increased weight and length, enhanced physiological stability (respiratory rate, heart rate, oxygen saturation), and improved oromotor function such as sucking coordination [15,30,31]. The 5-ISS program, in particular, demonstrated significant improvements in socio-emotional development, underscoring that sensory stimulation influences not only biological domains but also early emotional regulation and social interaction [20]. Collectively, the findings of this systematic review reinforce that sensory stimulation, especially multisensory and consistently delivered interventions is a safe, effective, and feasible approach to integrate into NICU care for preterm infants. Furthermore, adapting these interventions into home-based programs offers substantial opportunities for parental empowerment and continuity of developmental care.

Future challenges include the development of standardized, evidence-based sensory stimulation protocols and the need for longitudinal studies to evaluate the long-term effects of these interventions on cognitive, motor, language, and socio-emotional development throughout childhood.

CONCLUSION

This systematic review demonstrates that sensory stimulation—particularly multisensory approaches—is a safe and effective non-pharmacological intervention that supports neurobehavioral maturation in preterm infants. Structured and consistent stimulation helps compensate for the loss of intrauterine sensory input and promotes central nervous system development during a critical period disrupted by prematurity. Interventions delivered for at least two weeks show more optimal effects, contributing not only to improved neurobehavioral outcomes but also to enhanced physiological stability, growth, and early parent–infant interaction. Sensory stimulation therefore represents a valuable component of developmental care for clinically stable preterm infants in the NICU.

Recommendations

Multisensory stimulation should be implemented in a standardized manner for stable preterm infants, with short, regular sessions tailored to infant tolerance. Healthcare providers—especially neonatal nurses—require evidence-based training to ensure safe and effective delivery of sensory stimulation. Parental involvement should be strengthened through education and guided participation to support continuity of care at home. Future research should employ larger randomized clinical trials with lower risk of bias, detailed reporting of intervention components, and long-term follow-up to evaluate the sustained effects of different sensory modalities on cognitive, motor, language, and socio-emotional development.

Ethical consideration, competing interest and source of funding

-This review was conducted using secondary data from previously published studies; therefore, no direct contact with human participants occurred. All included randomized controlled trials reported obtaining ethical approval from their respective institutional review boards and documented informed consent from parents or legal guardians. Ethical principles of confidentiality, transparency, and responsible reporting were upheld throughout the review process.

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REFERENCES

1. Kementerian Kesehatan Republik Indonesia. Profil kesehatan Indonesia tahun 2023 [Internet]. Jakarta: Kemenkes RI; 2023 [cited 2024]. Available from: https://kemkes.go.id/app_asset/file_content_download/172231123666a86244b83fd8.51637104.pdf
2. World Health Organization. Preterm birth [Internet]. Geneva: WHO; 2021 [cited 2024]. Available from: <https://www.who.int/news-room/factsheets/detail/preterm-birth>
3. Allotey J, Zamora J, Cheong-See F, Kalidindi M, Arroyo-Manzano D, Asztalos E, et al. Cognitive, motor, behavioural and academic performances of children born preterm: a meta-analysis and systematic review involving 64,061 children. *BJOG*. 2018;125(1):16–25. doi:10.1111/1471-0528.14832
4. Aita M, Faugère GDC, Lavallée A, Feeley N, Stremler R, Rioux E, et al. Effectiveness of interventions on early neurodevelopment of preterm infants: a systematic review and meta-analysis. *BMC Pediatr*. 2021;21:210. doi:10.1186/s12887-021-02559-6
5. Bogdan RD, Rusu L, Toma AI, Nastase L. Respiratory outcome of former premature infants. *J Med Life*. 2019;12(4):381–94. doi:10.25122/jml-2019-0123
6. Volpe JJ. Dysmaturation of premature brain: importance, cellular mechanisms, and potential interventions. *Pediatr Neurol*. 2019;95:42–66. doi:10.1016/j.pediatrneurol.2019.02.016
7. Smyrni N, Koutsaki M, Petra M, Nikaina E, Gontika M, Strataki H, et al. Moderately and late preterm infants: short- and long-term outcomes from a registry-based cohort. *Front Neurol*. 2021;12:628066. doi:10.3389/fneur.2021.628066
8. Fumagalli M, Provenzi L, Carli PD, Dessimone F, Sirgiovanni I, Giorda R, et al. From early stress to 12-month development in very preterm infants. *PLoS One*. 2018;13:e0190602. doi:10.1371/journal.pone.0190602
9. Malik F, Marwaha R. Developmental stages of social emotional development in children. In: *StatPearls* [Internet]. Treasure Island: StatPearls Publishing; 2020.
10. Thomson KC, Richardson CG, Gadermann AM, Emerson SD, Shoveller J, Guhn M. Association of childhood social-emotional functioning profiles with early-onset mental health conditions. *JAMA Netw Open*. 2019;2(1):e186694. doi:10.1001/jamanetworkopen.2018.6694
11. Britto PR, Lye SJ. Nurturing care: promoting early childhood development. *Lancet*. 2017;389:91–102. doi:10.1016/S0140-6736(16)31390-3
12. DeMaster D, Bick J, Johnson U, Montroy JJ, Landry S, Duncan AF. Nurturing the preterm infant brain: leveraging neuroplasticity to improve neurobehavioral outcomes. *Pediatr Res*. 2019;85:166–75. doi:10.1038/s41390-018-0203-9
13. Kolb B, Harker A, Gibb R. Principles of plasticity in the developing brain. *Dev Med Child Neurol*. 2017;59(12):1218–23. doi:10.1111/dmcn.13546
14. Pineda R, Guth R, Herring A, Reynolds L, Oberle S, Smith J. Enhancing sensory experiences for very preterm infants in the NICU. *J Perinatol*. 2017;37:323–32. doi:10.1038/jp.2016.217
15. Zeraati H, Akbarzadeh M, Hadianfard MJ. Effect of multisensory stimulation on neuromuscular development of premature infants. *Iran J Neonatol*. 2018;9(2):41–6. doi:10.22038/ijn.2018.28171.14
16. Lordier L. Music in premature infants enhances high-level cognitive brain networks. *Proc Natl Acad Sci U S A*. 2019;116:12103–8. doi:10.1073/pnas.1817532116
17. Mohamed EK, Abdelaziem F, Elshafey MA, Nasef N. Neurobehavioral response to multisensory stimulation programme in high-risk neonates. *Bull Fac Phys Ther*. 2018;23(1):22–9. doi:10.4103/bfpt.bfpt_5_18
18. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020 statement. *BMJ*. 2021;372:n71. doi:10.1136/bmj.n71
19. George PP, DeCastro Molina JA, Heng BH. Methodological quality of systematic reviews comparing intravitreal bevacizumab. *Indian J Ophthalmol*. 2014;62(7):761–7. doi:10.4103/0301-4738.138615
20. Chen S, Gu X, Wang Y. Parenting and child depression: mediating role of self-concept. *Front Psychol*. 2022;13:867529. doi:10.3389/fpsyg.2022.867529
21. Pineda R, Smith J, Roussing J, Wallendorf M, Kellner P, Colditz G. Randomized clinical trial of multisensory exposures in the NICU. *J Perinatol*. 2021;41:2449–62. doi:10.1038/s41372-021-01106-4
22. Parashar P, Samuel AJ. Yakson touch and kinesthetic stimulation in high-risk neonates. *J Clin Neonatol*. 2018;7(1):12–19. doi:10.4103/jcn.JCN_67_17
23. Sadek BN, Abdelhamed TH. Effect of sensory stimulation intervention on neurobehavioral outcomes. *IOSR J Nurs Health Sci*. 2020;9(4):48–61.
24. Nadar UD, Thakkar PA, Shah C. Physiotherapy vs multisensory stimulation in preterm infants. *Int J Contemp Pediatr*. 2018;5(1):178–83. doi:10.18203/2349-3291.ijcp20175582
25. Yoanita R, Gunardi H, Rohsiswatmo R, Setyanto DB. Effect of tactile-kinesthetic stimulation in preterm neonates. *J Bodyw Mov Ther*. 2021;28:180–6. doi:10.1016/j.jbmt.2021.06.023
26. Neel ML, Yoder P, Matusz PJ, Murray MM, Miller A, Burkhardt S, et al. Randomized controlled trial protocol to improve multisensory processing. *BMC Pediatr*. 2019;19:81. doi:10.1186/s12887-019-1455-1
27. Namprom P, Ketsuwan S, Wongsawat W. Maternal participation program in preterm infants. *J Neonatal Nurs*. 2018;24(5):255–60. doi:10.1016/j.jnn.2018.02.001
28. Kanagasabai PS, Mohan D, Lewis LE, Kamath A, Rao BK. Multisensory stimulation and neuromotor development. *Indian J Pediatr*. 2016;80(6):460–4. doi:10.1007/s12098-012-0945-z

29. Sant M, Mathew L, Ramachandran S. Early physiotherapy including oromotor stimulation. *Indian J Pediatr.* 2021;88:713–18. doi:10.1007/s12098-020-03603-z
30. Abdel Mageed HA, Ali MAE, El Sayed HY. Multisensory stimulation on apnea of prematurity. *Egypt Pediatr Assoc Gaz.* 2021;69(1):1–8. doi:10.1186/s43054-021-00073-z
31. Tolsa CB, Zimine S, Warfield SK, Freschi M, Sancho RA, Lazeyras F. Alteration of brain development in premature infants. *Pediatr Res.* 2004;56(1):132–8. doi:10.1203/01.PDR.0000128983.54614.7E
32. Wang L, Liu L, Liu J, et al. Sensory stimulation program in preterm infants. *Front Pediatr.* 2022;10:951236. doi:10.3389/fped.2022.951236
33. Welch MG, Firestein MR, Austin J, Stark RI. Multisensory neural processing in preterm infants. *BMC Pediatr.* 2019;19:81. doi:10.1186/s12887-019-1455-1
34. Widiastuti R, Suarni NM, Suriadi HG. Tactile-kinesthetic stimulation in preterm infants. *Enferm Clin.* 2021;31:S55–8. doi:10.1016/j.enfcli.2020.10.018
35. World Health Organization. Preterm birth [Internet]. Geneva: WHO; 2023 [cited 2024]. Available from: <https://www.who.int/news-room/fact-sheets/detail/preterm-birth>
36. Badr EA, Ismail MS. Neurobehavioral outcome of multi-sensory stimulation intervention in preterm neonates: randomized controlled trial. *J Neonatal Nurs.* 2024;30(6):661–7.
37. Mohamed EK, Abdelazeim F, Elshafey MA, Nasef N. Neurobehavioral response to multisensory stimulation programme in high-risk neonates. *Bull Fac Phys Ther.* 2018;23(1):22–9.
38. Yoanita R, Gunardi H, Rohsiswatmo R, Setyanto DB. Effect of tactile–kinesthetic stimulation on growth, neurobehavior and development among preterm neonates. *J Bodyw Mov Ther.* 2021;28:180–6.
39. Zheng W, Chotipanvithayakul R, Ingviya T, Xia X, Xie L, Gao J. Sensory stimulation program improves developments of preterm infants in Southwest China: a randomized controlled trial. *Front Psychol.* 2022;13:867529.