Open Access
Check for updates
International Journal of Medical Science and Dental Health (ISSN: 2454-4191)
Volume 11, Issue 08, August 2025,
Doi: https://doi.org/10.55640/ijmsdh-11-08-26

Nesting for Neuroprotection and Stability: A Narrative Review on the Science, Practice, and Impact of Containment Strategies for the Preterm Infant

Sahar Hassan
Department of Pediatric Nursing, Faculty of Nursing, University of Babylon, Iraq

Received: 08 August 2025, **accepted:** 16 August 2025, **Published Date:** 28 August 2025

Abstract

Background: Preterm infants face a stark sensory mismatch between the contained intrauterine environment and the open Neonatal Intensive Care Unit (NICU), leading to physiological stress that detracts from neurodevelopment. Nesting the use of boundary-forming supports to maintain a flexed, midline posture is a foundational developmental care intervention designed to mitigate this challenge.

Objective: This narrative review synthesizes the current evidence on the science and practice of nesting, with a particular focus on its profound impact on cardio-respiratory stability and its synergistic effects with therapeutic positioning.

Findings: The review outlines the multi-faceted benefits of nesting, including improved thermoregulation, energy conservation, pain mitigation, stress reduction, and sleep organization. A core finding is its significant role in enhancing cardiorespiratory stability: nesting reduces pathological bradycardia and tachycardia, regularizes respiratory rate, and improves oxygen saturation by reducing energy expenditure and providing biomechanical support to the chest wall. Crucially, the benefits are position dependent. Evidence synthesis demonstrates that nesting in the **supine** position is essential for safety and stability, nesting in the **prone** position yields the greatest improvement in respiratory parameters under supervision, and nesting in the **lateral** position provides stable support for procedures.

Conclusion: Nesting is a simple, cost-effective, and powerful neuroprotective intervention. It is most effective as a core component of a developmental care bundle. The review strongly recommends the universal implementation of individualized, safe nesting as a standard of care for all preterm infants to promote physiological stability, optimal positioning, and improved neurodevelopmental outcomes.

Keywords: Preterm infant; Nesting; Developmental care; Cardiorespiratory stability; NICU; Positioning; Neuroprotection.

1. Introduction

The Preterm Infant's Dilemma and the Promise of Nesting

The global burden of preterm birth remains a significant public health challenge, with an estimated 13.4 million infants born prematurely (<37 weeks' gestation) each year [1]. While advances in neonatal intensive care have dramatically improved survival rates, the focus has rightly shifted from mere survival to the optimization of long-term neurodevelopmental outcomes [2,3]. The extrauterine environment of the Neonatal Intensive Care Unit (NICU) presents a stark sensory contrast to the contained, fluid-filled, and kinetically dampened

intrauterine space [4]. This mismatch can overwhelm the preterm infant's immature autonomic and sensory systems, leading to physiological instability and increased stress, which are known detractors from optimal brain development [5,6].

Table 1: Key Challenges of the NICU Environment for a Preterm Infant vs. the Intrauterine Environment.

Intrauterine Environment	NICU Environment (without intervention)	Potential Negative Impact
Constant containment & boundaries	Open space, lack of boundaries	Limb extension, startles, energy loss, stress
Flexed, midline posture	Flattened, frogged posture (hips abducted, legs extended)	Hip dysplasia, musculoskeletal maldevelopment
Dampened sensory input (muffled sound, low light)	High levels of light, sound, & handling	Autonomic stress, physiological instability, sleep disruption
Continuous vestibular input	Static, flat surfaces	Arousal dysregulation, poor self-regulation
Constant thermoregulation	Thermolabile environment	Cold stress, increased metabolic demand, poor weight gain

The theoretical foundation of nesting is built upon the principle of developmental care, which aims to create a NICU environment that minimizes stress and supports the infant's neurobehavioral organization [7]. Nesting, the practice of using soft, boundary-forming materials to contain an infant in a flexed, midline position, is a fundamental intervention designed to simulate the comforting boundaries of the womb [8]. This review synthesizes the current evidence on the science and practice of nesting, with a particular focus on its profound impact on cardio-respiratory stability across different positions. Our objective is to provide a comprehensive overview that translates research into practical, evidence-based recommendations for clinical practice, ultimately advocating for the systematic integration of nesting as a standard of neuroprotective care.

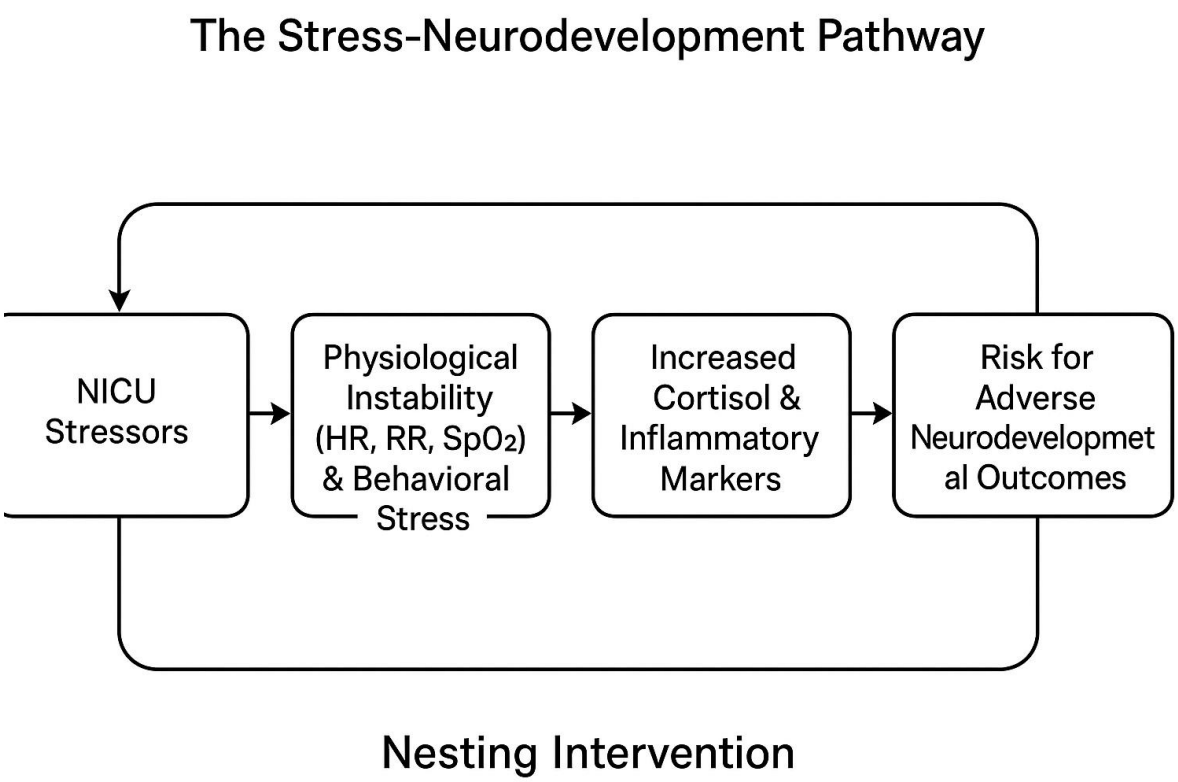

Figure 1: The Stress–Neurodevelopment Pathway and the Role of Nesting Intervention

2. **Physiological and Immediate Clinical Benefits of Nesting**

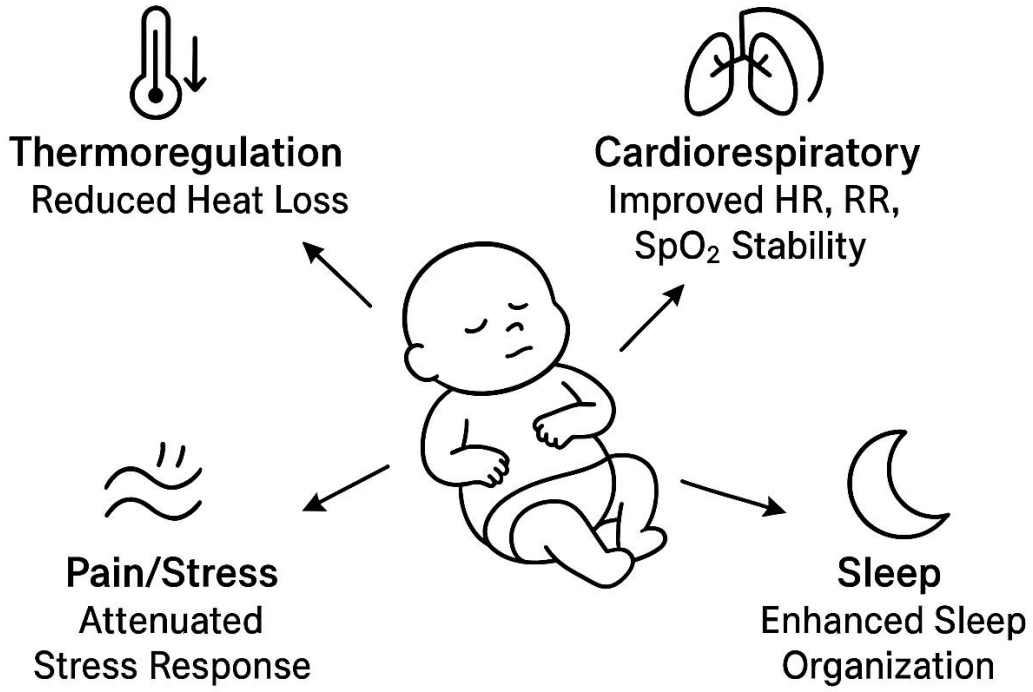

Figure 2: The Multisystem Mechanisms of Nesting.

2.1 Promoting Thermoregulation and Energy Conservation

Preterm infants are profoundly susceptible to heat loss due to a high surface area-to-body weight ratio, thin skin, and minimal subcutaneous fat [9]. The resulting cold stress significantly increases oxygen consumption and metabolic rate, diverting precious calories away from growth and development [10]. Nesting aids thermoregulation by reducing the infant's exposed surface area and minimizing heat loss through convection and radiation [11]. By promoting a flexed posture, nesting decreases muscle activity and overall energy expenditure, allowing calories to be directed towards weight gain and organ maturation [12]. Studies have demonstrated that nested infants maintain a more stable body temperature and show improved weight gain trajectories compared to their non-nested counterparts [13,14].

2.2 Enhancing Cardiorespiratory Stability: A Core Benefit

The immature autonomic nervous system of the preterm infant is ill-equipped to manage the stressors of the extrauterine world, leading to frequent episodes of cardiorespiratory instability, including bradycardia, tachycardia, and oxygen desaturations [15]. Nesting acts as a powerful regulator of this system.

2.2.1 Heart Rate (HR) Stability: The containment provided by a nest reduces random, uncontrolled movements and attenuates the startle reflex, a common trigger for bradycardic events [16]. This promotes vagal tone, leading to a lower, more stable baseline heart rate and a significant reduction in the frequency of pathological tachycardia and bradycardia [17,18].

2.2.2 Respiratory Rate (RR) Regulation

The preterm chest wall is highly compliant and prone to distortion, leading to paradoxical breathing and increased work of breathing [19]. By supporting the infant's back, shoulders, and pelvis, a nest provides crucial biomechanical stability to the chest wall. This improves the efficiency of diaphragmatic contraction, leading to a more regular respiratory pattern, a lower respiratory rate, and a reduction in the work of breathing [20,21].

2.2.3 Oxygen Saturation (SpO_2) Improvement

The synergistic effects of reduced energy expenditure and improved respiratory mechanics directly translate to enhanced oxygenation. Nested infants experience fewer and less severe hypoxemic events, maintain higher baseline oxygen saturations, and often require lower levels of supplemental oxygen or respiratory support [22,23]. This stability is crucial for protecting the developing brain from hypoxic-ischemic injury [24].

2.3 Pain Mitigation and Stress Reduction

NICU infants are subjected to a high number of painful procedures, and their immature pain processing systems can lead to amplified and prolonged pain responses [25]. Nesting is a core non-pharmacological intervention for pain management. The deep tactile pressure and containment provided by the nest are believed to modulate afferent sensory input, calming the infant's nervous system [26]. Numerous studies utilizing validated pain scales (e.g., PIPP, NIPS) have consistently shown that nested infants exhibit significantly lower physiological and behavioral stress responses during and after heel lance, venipuncture, and other procedures compared to non-nested infants [27,28,29].

2.4 Improving Sleep Organization

Sleep is not a passive state but an active, critical process for brain maturation, memory consolidation, and synaptic pruning [30]. The disorganized sleep-wake cycles of preterm infants are frequently disrupted by NICU caregiving [31]. Nesting promotes sleep by dampening environmental stimuli and reducing startles. Studies using polysomnography and behavioral sleep scales have demonstrated that nested infants spend more time in quiet sleep, a restorative state characterized by regular breathing and HR, and have better-organized sleep-wake cycles [32,33].

2.5 The Synergy of Nesting and Position: A Detailed Analysis on Cardio-Respiratory Parameters

The benefits of nesting are profoundly modulated by the infant's body position. Gravity exerts different effects on pulmonary function, gastric emptying, and airway patency, making the integration of nesting with positioning a critical clinical consideration [34].

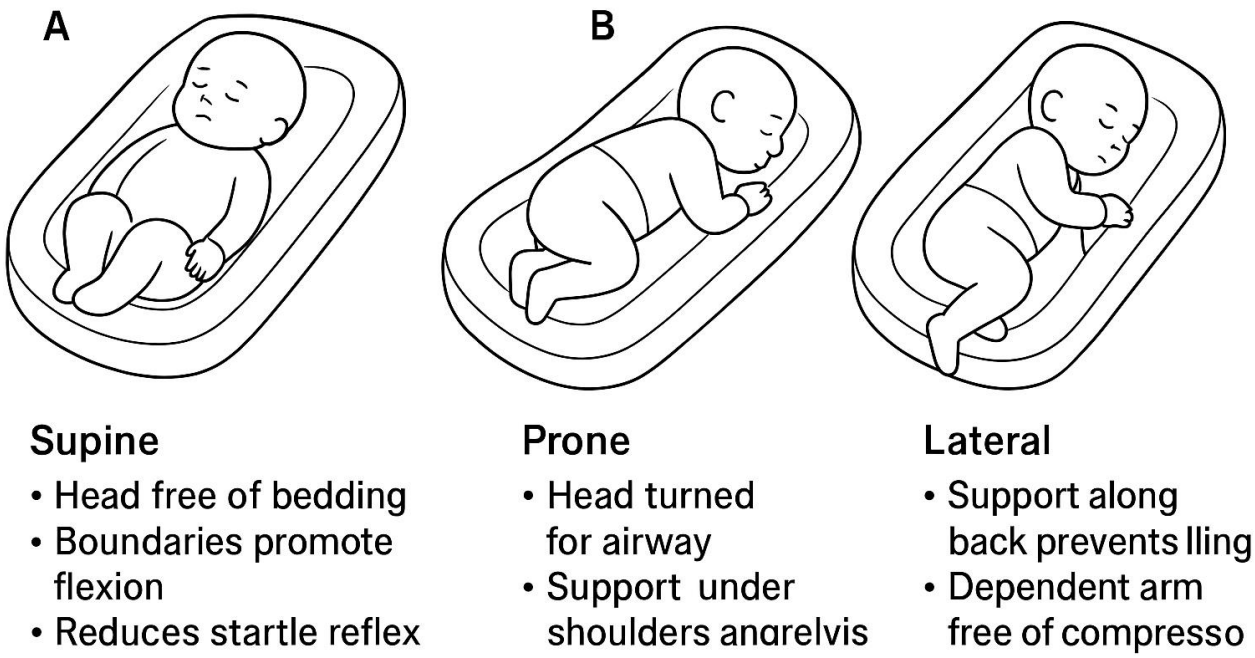

Figure 3. Optimal Nesting by Body Position

Figure 3: Optimal Nesting by Body Position.

2.5.1 Physiological Rationale for Positioning

The prone position improves ventilation-perfusion matching, enhances diaphragmatic function, and reduces energy expenditure, leading to superior respiratory outcomes [35]. The supine position is the standard for safe sleep to prevent Sudden Infant Death Syndrome (SIDS) but can exacerbate gastroesophageal reflux and startles [36]. Lateral positions are often used therapeutically for procedures or feeding but require careful support to prevent rolling and ensure safety [37].

2.5.2 Evidence Synthesis: Nesting in Supine Position

The challenge of supine positioning is mitigating its potential to increase stress and reflux. Nesting is essential here. By containing the limbs and providing flexion, nesting in supine significantly reduces startle-induced bradycardia and desaturation events [38]. It improves overall autonomic stability, making supine positioning safer and more tolerable, which is paramount for adhering to safe sleep guidelines upon discharge [39].

2.5.3 Evidence Synthesis: Nesting in Prone Position

Prone positioning is often used as a therapeutic intervention for infants with respiratory distress. Nesting does not merely complement this; it enhances it. A nest in prone ensures perfect head-to-side alignment for a patent airway, optimal shoulder and pelvic alignment to maximize diaphragmatic excursion, and prevents the arms from sliding into a compromising position [40]. This supported prone position has been shown to yield the **greatest improvement in SpO_2 and the most significant reduction in respiratory rate** compared to all other positions [41,42]. It is a powerful strategy for improving oxygenation and reducing work of breathing under supervised conditions.

2.5.4 Evidence Synthesis: Nesting in Lateral (Right/Left) Position

Nesting is *critical* for safe and effective lateral positioning. Without proper support, an infant can easily roll into prone or supine, potentially compromising the airway. A nest provides firm support along the infant's back to maintain the desired lateral posture, ensures trunk alignment, and crucially, keeps the dependent arm free from compression to avoid impeding chest expansion [43]. This results in stable heart rate and SpO_2, making nested lateral positioning ideal for procedures, post-feeding, or simply providing positional variety in a controlled manner [44].

Table 2: Impact of Nesting on Cardio-Respiratory Parameters by Position.

Position	Effect on Heart Rate (HR)	Effect on Respiratory Rate (RR)	Effect on Oxygen Saturation (SpO_2)	Key Clinical Implication
Supine + Nesting	Significant stabilization (↓ Bradycardia/tachycardia) [17,38]	Moderate reduction & regularization [20,21]	Moderate improvement (↑Baseline, ↓Desats) [22,23]	**Safe sleep standard; reduces events related to startles and reflux**
Prone + Nesting	Stabilization [41]	**Greatest reduction** [41, 42]	**Most significant improvement** [41,42]	**Supervised therapy for respiratory distress; optimizes mechanics**
Lateral + Nesting	Stabilization [43,44]	Stabilization [43]	Improvement [43,44]	**Stable positioning for procedures/feeding; provides variety safely**

3. **Neurodevelopmental and Musculoskeletal Outcomes**

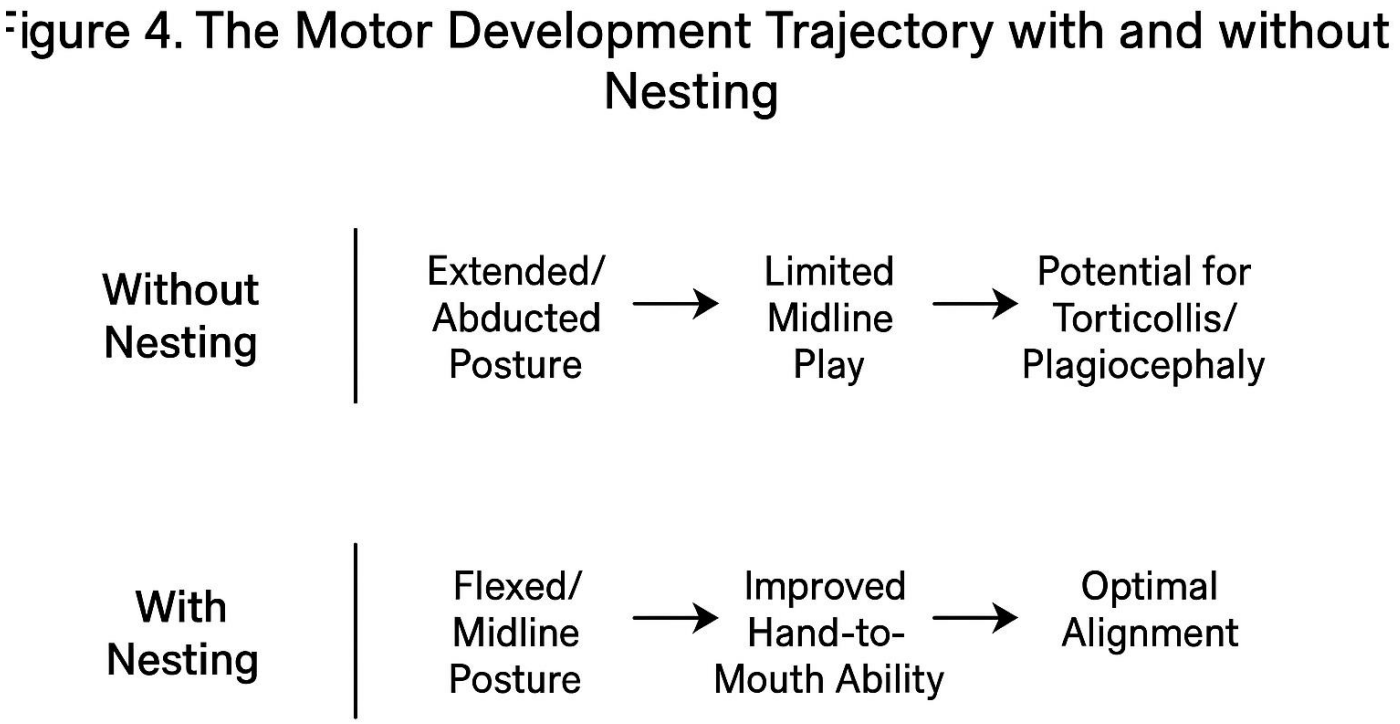

Figure 4: The Motor Development Trajectory with and without Nesting

The physiological stability afforded by nesting provides the foundation for optimal neurodevelopment. The fetal posture of flexion and midline orientation is crucial for the progression of normal motor development [45]. Nesting facilitates this by enabling infants to bring their hands to the mouth and midline, a key step in self-regulation and the development of hand-to-mouth coordination [46]. This containment also minimizes excessive, disorganized movements, allowing for more purposeful motor activity and reducing the risk of extraneous energy expenditure that can detract from brain growth [47].

Table 3: Neurobehavioral Assessment Findings (e.g., NNNAS).

Domain	Non-Nested Infant (Typical Findings)	Nested Infant (Typical Findings)	Interpretation
Motor System	Fluctuating tone, jerky movements, extremity extension	More regulated tone, smooth movements, flexion	Nesting improves motor organization and maturity.

Domain	Non-Nested Infant (Typical Findings)	Nested Infant (Typical Findings)	Interpretation
Self-Regulation	Poor habituation, inability to calm, high irritability	Improved ability to achieve and maintain quiet alert state, hand-to-mouth for self-soothing	Nesting enhances the infant's capacity to manage stimuli.
Stress Responses	Frequent, high-intensity stress cues (e.g., gaze aversion, finger splay)	Fewer, less intense stress cues; more r	Nesting reduces autonomic and behavioral stress.

Studies on neurobehavioral organization, using assessment tools like the NNNAS (Newborn Individualized Developmental Care and Assessment Program), consistently show that nested infants have better scores in the motor, self-regulation, and stress-abatement clusters [48,49]. They exhibit less hypertonicity and hypotonicity and demonstrate more mature motor patterns [50]. Furthermore, by maintaining hips in adduction and flexion, nesting is a primary strategy for preventing musculoskeletal deformities like external rotation hip contracture and head flattening (plagiocephaly) [51,52]. While long-term studies are still needed, the theoretical and empirical evidence strongly suggests that the early support of nesting contributes to improved cognitive and behavioral outcomes by protecting the brain from stress and promoting organized development [53,54].

4. **Practical Implementation in the NICU: Materials, Techniques, and Safety**

Figure 5: Comparison of Nesting Materials.

4.1 Materials and Design

Nests can be commercially produced or handmade. Ideal materials are soft, malleable, washable, and breathable. Common options include rolled cotton blankets, silicone bead pillows, and specialized foam supports [55]. The design should allow for easy shaping around the infant to create a "nest" with high, firm boundaries around the feet and lower boundaries around the shoulders and head [56].

4.2 The "How-To" of Effective Nesting

The goal is to achieve a posture that mimics the natural fetal position: neck slightly flexed, shoulders rounded forward, hips and knees flexed and adducted, and hands accessible to the face and midline [57]. The nest should be snug enough to provide support and containment but loose enough to allow for gentle movement and chest expansion. It must be reassessed and reshaped with every caregiving interaction as the infant moves and grows.

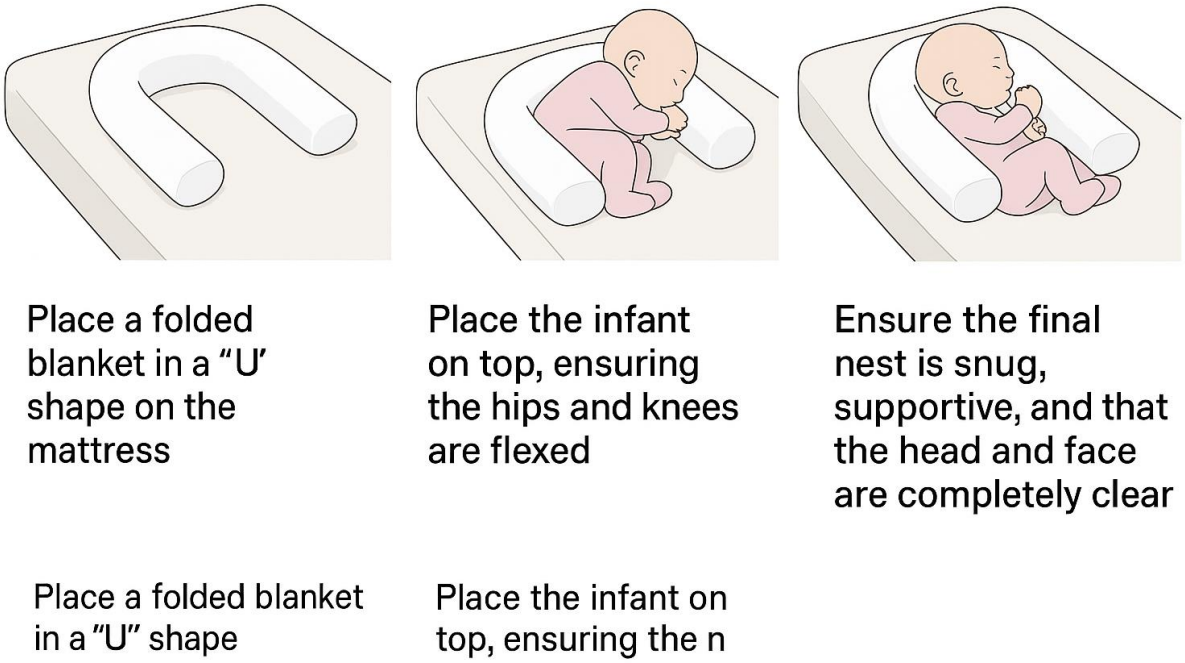

Figure 6: Step-by-Step Guide to Creating a Nest.

4.3 Paramount Importance of Safety

Safety is the absolute priority. Nests must **never** compromise the infant's airway.

Table 4: Safety Checklist for Nesting Practice.

Checkpoint	Yes	No	Action Needed
The infant's head is free from all bedding and positioning devices.	☐	☐	Adjust nest to keep head clear.
The airway is patent and the neck is in a neutral position.	☐	☐	Reposition infant.
The nest is secured to the mattress to prevent shifting and gaps.	☐	☐	Tuck nest securely under mattress.
The nest promotes flexion without forcing it.	☐	☐	Loosen if too tight.
The nest is made of breathable materials.	☐	☐	Replace if non-breathable.
The nest is clean and follows infection control policy.	☐	☐	Change according to protocol.

The infant's head should be free from bedding and kept in a neutral, face-up position when supine [58]. Nests must be secured to the mattress to prevent them from being pushed aside and creating unsafe gaps. Rigorous infection control policies must be in place, as nests can become reservoirs for microorganisms if not cleaned properly between patients [59]. Education for all staff and parents on safe nesting practices is non-negotiable.

4.4 Individualization and Assessment

The approach to nesting must be individualized based on the infant's gestational age, physiological status, and therapeutic goals (e.g., a very tight nest for extreme flexion in a 25-weeker vs. a looser nest for a 35-weeker working on self-regulation) [60]. The infant's response to nesting should be continuously assessed through vital sign stability, behavioral cues, and physical alignment.

5. Comparative Approaches and Integrating Nesting into Developmental Care

Table 5: Nesting vs. Swaddling.

Characteristic	Nesting	Swaddling
Posture Promoted	Flexion, midline orientation	Often extension, legs adducted
Hip Health	Promotes healthy hip flexion and abduction	Can predispose to hip dysplasia (DDH) if legs are extended and tightly wrapped
Hand Access	Allows for hands to reach mouth for self-soothing	Typically restricts hand movement
Primary Use	24/7 developmental support, physiological stability	Primarily for promoting sleep in term infants

While swaddling is a common containment technique, it differs fundamentally from nesting. Swaddling typically involves wrapping an infant tightly in a blanket with legs extended, which can predispose to hip dysplasia and does not facilitate flexion and midline orientation [61]. Nesting, in contrast, is designed to promote healthy hip flexion and abduction.

Nesting is most effective not as a standalone intervention, but as a core component of a comprehensive developmental care bundle, such as the Age-Related Care Plan (ARCP) or the Core Measures for Developmental Care [62,63]. Its success relies on a multidisciplinary team: nurses for daily implementation, therapists for assessment and positioning guidance, and physicians championing its neuroprotective benefits. Crucially, involving parents in creating and maintaining their infant's nest empowers them, enhances bonding, and prepares them for continuing developmental supportive practices at home [64].

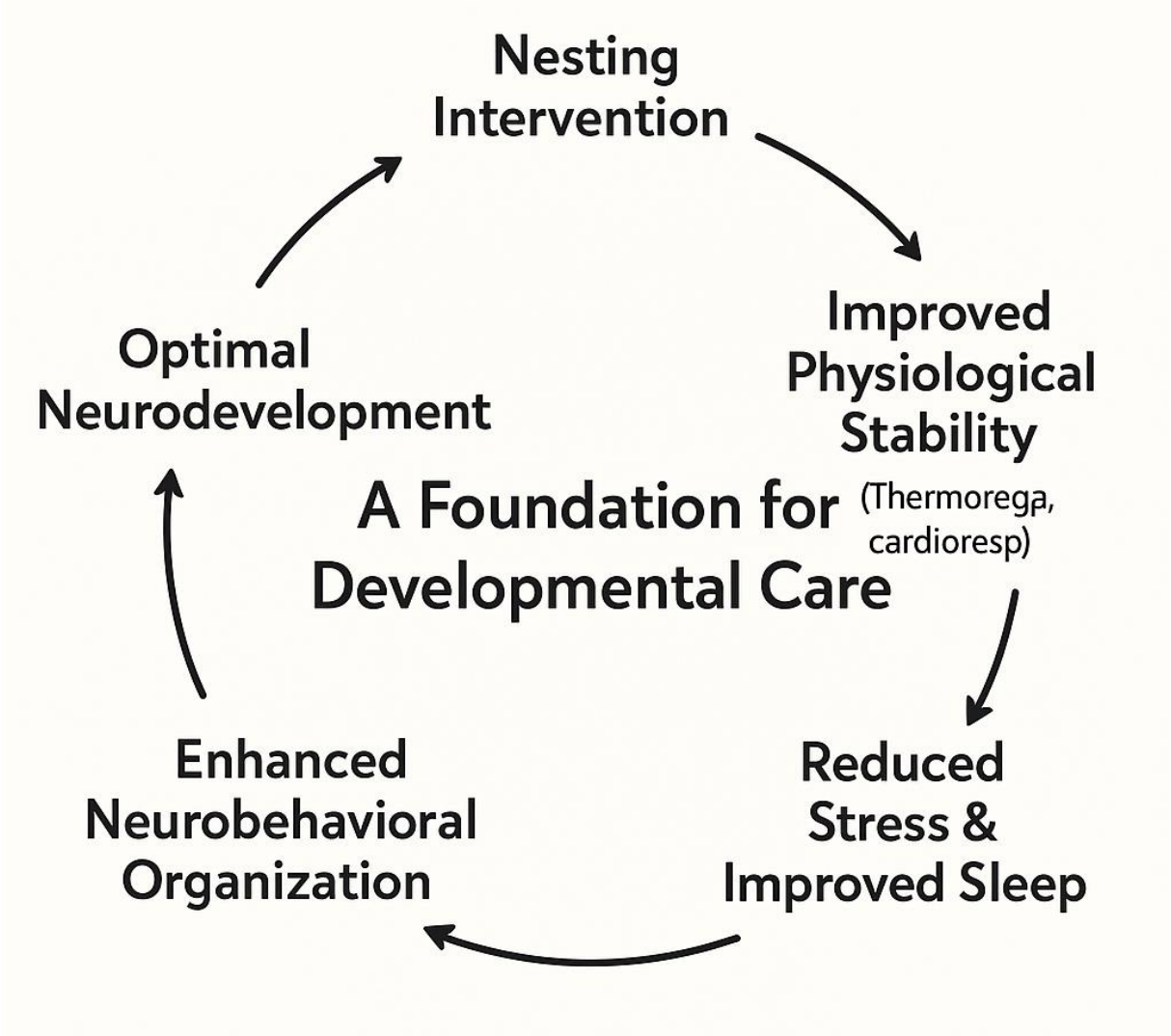

Figure 7: The Nesting Cycle for Neuroprotection.

6. **Gaps in Evidence, Global Perspectives, and Future Directions**

Despite strong biological plausibility and encouraging evidence, there remains a need for larger, high-quality randomized controlled trials with long-term neurodevelopmental follow-up to solidify the evidence base [65]. Future research should specifically investigate the biomechanical effects of nested positions on diaphragmatic work and tidal volume using advanced imaging techniques [66]. Furthermore, there is a need to develop and validate standardized tools for assessing the "quality" of a nest.

Globally, access to commercial nesting devices is limited by cost. Therefore, research into effective, low-cost, and culturally adaptable nesting solutions using locally available materials is a critical direction for global neonatal health [67]. The future may also see the integration of technology, such as smart textiles that can monitor infant position and vital signs within the nest itself [68].

Conclusion and Recommendations for Practice

This review consolidates substantial evidence affirming nesting as a simple, cost-effective, and powerful neuroprotective intervention in the NICU, demonstrating its significant role in stabilizing cardio-respiratory parameters—heart rate, respiratory rate, and oxygen saturation—an effect that is synergistically enhanced when combined with appropriate therapeutic positioning, most notably in the prone position for respiratory support. Based on this evidence, we strongly recommend the universal implementation of nesting as a standard of care for all preterm infants under 37 weeks gestation to promote physiological stability and neurodevelopment, with a strategic position-specific application: supine for all unsupervised sleep to ensure safe sleep practices, prone during supervised care to optimize respiratory function, and lateral for supported

positioning during procedures and post-feeding. Furthermore, unit-wide competency-based education for all healthcare staff and parents on safe techniques is mandatory, and the approach must be individualized, with the nest tailored to the infant's specific needs and reassessed frequently. In conclusion, a nest is far more than a comfort item; it is a fundamental therapeutic tool that bridges the gap between the womb and the world, safeguarding the developing brain and body of the vulnerable preterm infant by providing containment, support, and physiological stability, thereby paving the way for a healthier future.

References

1. Adams, M., Bassler, D., Bucher, H. U., Roth-Kleiner, M., Berger, T. M., Braun, J., & Swiss Neonatal Network. (2021). Variability of very preterm birth rates in 16 high-income countries and their impact on the comparison of stillbirth and infant mortality rates between those countries. *BJOG: An International Journal of Obstetrics & Gynaecology, 128*(9), 1504–1512. https://doi.org/10.1111/1471-0528.16666

2. Als, H. (1982). Toward a synactive theory of development: Promise for the assessment and support of infant individuality. *Infant Mental Health Journal, 3*(4), 229–243. https://doi.org/10.1002/1097-0355(198224)3:4<229::AID-IMHJ2280030405>3.0.CO;2-H

3. Als, H., Lawhon, G., Duffy, F. H., McAnulty, G. B., Gibes-Grossman, R., & Blickman, J. G. (1994). Individualized developmental care for the very low-birth-weight preterm infant. Medical and neurofunctional effects. *JAMA, 272*(11), 853–858. https://doi.org/10.1001/jama.1994.03520110033025

4. Altimier, L., & Phillips, R. (2013). The Neonatal Integrative Developmental Care Model: Seven Neuroprotective Core Measures for Family-Centered Developmental Care. *Newborn and Infant Nursing Reviews, 13*(1), 9–22. https://doi.org/10.1053/j.nainr.2012.12.002

5. Altimier, L., & Phillips, R. (2016). The Neonatal Integrative Developmental Care Model: Advanced Clinical Applications of the Seven Core Measures for Neuroprotective Family-centered Developmental Care. *Newborn and Infant Nursing Reviews, 16*(4), 230–244. https://doi.org/10.1053/j.nainr.2016.09.030

6. Ammari, A., Schulze, K. F., Ohira-Kist, K., Kashyap, S., Fifer, W. P., Myers, M. M., & Stark, R. I. (2009). Effects of body position on thermal, cardiorespiratory and metabolic activity in low birth weight infants. *Early Human Development, 85*(8), 497–501. https://doi.org/10.1016/j.earlhumdev.2009.04.005

7. American Academy of Pediatrics Task Force on Sudden Infant Death Syndrome. (2005). The changing concept of sudden infant death syndrome: diagnostic coding shifts, controversies regarding the sleeping environment, and new variables to consider in reducing risk. *Pediatrics, 116*(5), 1245–1255. https://doi.org/10.1542/peds.2005-1499

8. Aucott, S., Donohue, P. K., Atkins, E., & Allen, M. C. (2002). Neurodevelopmental care in the NICU. *Mental Retardation and Developmental Disabilities Research Reviews, 8*(4), 298–308. https://doi.org/10.1002/mrdd.10040

9. Balaguer, A., Escribano, J., Roqué, M., & Figueras, J. (2013). Infant position in neonates receiving mechanical ventilation. *Cochrane Database of Systematic Reviews, 2013*(7), CD003668. https://doi.org/10.1002/14651858.CD003668.pub3

10. Bertelle, V., Mabin, D., Adrien, J., & Sizun, J. (2005). Sleep of preterm neonates under developmental care or regular environmental conditions. *Early Human Development, 81*(7), 595–600. https://doi.org/10.1016/j.earlhumdev.2005.01.008

11. Brummelte, S., Grunau, R. E., Chau, V., Poskitt, K. J., Brant, R., Vinall, J., Gover, A., Synnes, A. R., & Miller, S. P. (2012). Procedural pain and brain development in premature newborns. *Annals of Neurology, 71*(3), 385–396. https://doi.org/10.1002/ana.22267

12. Buehler, D. M., Als, H., Duffy, F. H., McAnulty, G. B., & Liederman, J. (1995). Effectiveness of individualized developmental care for low-risk preterm infants: behavioral and electrophysiologic evidence. *Pediatrics, 96*(5 Pt 1), 923–932.

13. Carbajal, R., Rousset, A., Danan, C., Coquery, S., Nolent, P., Ducrocq, S., Saizou, C., Lapillonne, A., Granier, M., Durand, P., Lenclen, R., Coursol, A., Hubert, P., de Saint Blanquat, L., Boëlle, P. Y., Annequin, D., Cimerman, P., Anand, K. J., & Bréart, G. (2008). Epidemiology and treatment of painful procedures in neonates in intensive care units. *JAMA, 300*(1), 60–70. https://doi.org/10.1001/jama.300.1.60

14. Cavalier, A., Picot, M. C., Artiaga, C., Duran, D., Vanlieferinghen, P., & Déchelotte, P. (2011). Prevention of head flattening in preterm infants. *Archives de Pédiatrie, 18*(2), 143–151. https://doi.org/10.1016/j.arcped.2010.11.003

15. Chang, Y. J., Anderson, G. C., & Lin, C. H. (2002). Effects of prone and supine positions on sleep state and stress responses in mechanically ventilated preterm infants during the first postnatal week. *Journal of Advanced Nursing, 40*(2), 161–169. https://doi.org/10.1046/j.1365-2648.2002.02358.x

16. Chawanpaiboon, S., Vogel, J. P., Moller, A. B., Lumbiganon, P., Petzold, M., Hogan, D., Landoulsi, S., Jampathong, N., Kongwattanakul, K., Laopaiboon, M., Lewis, C., Rattanakanokchai, S., Teng, D. N., & Thinkhamrop, J. (2019). Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *The Lancet Global Health, 7*(1), e37–e46. https://doi.org/10.1016/S2214-109X(18)30451-0

17. Chen, W., Dols, S., Oetomo, S. B., & Feijs, L. (2010). Monitoring body temperature of newborn infants at neonatal intensive care units using wearable sensors. *Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2010*, 2748–2751. https://doi.org/10.1109/IEMBS.2010.5626580

18. Corff, K. E., Seideman, R., Venkataraman, P. S., Lutes, L., & Yates, B. (1995). Facilitated tucking: a nonpharmacologic comfort measure for pain in preterm neonates. *Journal of Obstetric, Gynecologic, and Neonatal Nursing, 24*(2), 143–147. https://doi.org/10.1111/j.1552-6909.1995.tb02456.x

19. Coughlin, M., Gibbins, S., & Hoath, S. (2009). Core measures for developmentally supportive care in neonatal intensive care units: theory, precedence and practice. *Journal of Advanced Nursing, 65*(10), 2239–2248. https://doi.org/10.1111/j.1365-2648.2009.05052.x

20. Deguines, C., Décanini, A., Pelletier, A., & Tourneux, P. (2013). Effects of bedding arrangements and nesting on heat loss in preterm infants. *The Journal of Maternal-Fetal & Neonatal Medicine, 26*(3), 295–300. https://doi.org/10.3109/14767058.2012.733758

21. Di Fiore, J. M., Martin, R. J., & Gauda, E. B. (2013). Apnea of prematurity--perfect storm. *Respiratory Physiology & Neurobiology, 189*(2), 213–222. https://doi.org/10.1016/j.resp.2013.05.026

22. Domanico, R., Davis, D. K., Coleman, F., & Davis, B. O. (2011). Documenting the NICU design dilemma: comparative patient progress in open-ward and single family room units. *Journal of Perinatology, 31*(4), 281–288. https://doi.org/10.1038/jp.2010.120

23. Fairchild, K., Mohr, M., Paget-Brown, A., Tabacaru, C., Lake, D., Delos, J., Moorman, J. R., & Kattwinkel, J. (2016). Clinical associations of immature breathing in preterm infants: part 1-central apnea. *Pediatric Research, 80*(1), 21–27. https://doi.org/10.1038/pr.2016.43

24. Fearon, I., Kisilevsky, B. S., Hains, S. M., Muir, D. W., & Tranmer, J. (1997). Swaddling after heel lance: age-specific effects on behavioral recovery in preterm infants. *Journal of Developmental and Behavioral Pediatrics, 18*(4), 222–232.

25. Field, T. (2017). Preterm newborn pain research review. *Infant Behavior and Development, 49*, 141–150. https://doi.org/10.1016/j.infbeh.2017.09.002

26. Goldman, S. L., Brady, J. P., & Dumpit, F. M. (1979). Increased work of breathing associated with muscle paralysis in preterm infants. *Pediatric Research, 13*, 468.

27. Graven, S. N. (2006). Sleep and brain development. *Clinics in Perinatology, 33*(3), 693–706, vii. https://doi.org/10.1016/j.clp.2006.06.009

28. Grenier, I. R., Bigsby, R., Vergara, E. R., & Lester, B. M. (2003). Comparison of Motor Self-Regulatory and Stress Behaviors of Preterm Infants Across Body Positions. *The American Journal of Occupational Therapy, 57*(3), 289–297. https://doi.org/10.5014/ajot.57.3.289

29. Heimler, R., Langlois, J., Hodel, D. J., Nelin, L. D., & Sasidharan, P. (1992). Effect of positioning on the breathing pattern of preterm infants. *Archives of Disease in Childhood, 67*(3), 312–314. https://doi.org/10.1136/adc.67.3.312

30. Heller, C., Constantinou, J., Vandenberg, K., Massey, L., Schouten, M., & Mörelius, E. (2017). The premature infant: A framework for positioning and care. *Journal of Neonatal Nursing, 23*(3), 140–146. https://doi.org/10.1016/j.jnn.2016.10.002

31. Holditch-Davis, D., Brandon, D. H., & Schwartz, T. (2003). Development of behaviors in preterm infants: relation to sleeping and waking. *Nursing Research, 52*(5), 307–317. https://doi.org/10.1097/00006199-200309000-00005

32. Leipälä, J. A., Bhat, R. Y., Rafferty, G. F., Hannam, S., & Greenough, A. (2003). Effect of posture on respiratory function and drive in preterm infants prior to discharge. *Pediatric Pulmonology, 36*(4), 295–300. https://doi.org/10.1002/ppul.10326

33. Long, J. G., Philip, A. G., & Lucey, J. F. (1980). Excessive handling as a cause of hypoxemia. *Pediatrics, 65*(2), 203–207.

34. Lyon, A. J., Pikaar, M. E., Badger, P., & McIntosh, N. (1997). Temperature control in very low birthweight infants during first five days of life. *Archives of Disease in Childhood: Fetal and Neonatal Edition, 76*(1), F47–F50. https://doi.org/10.1136/fn.76.1.f47

35. Maastrup, R., & Greisen, G. (2010). Extremely preterm infants tolerate skin-to-skin contact during the first weeks of life. *Acta Paediatrica, 99*(8), 1145–1149. https://doi.org/10.1111/j.1651-2227.2010.01807.x

36. Mahan, S. T., & Kasser, J. R. (2008). Does swaddling influence developmental dysplasia of the hip? *Pediatrics, 121*(1), 177–178. https://doi.org/10.1542/peds.2007-1618

37. Martin, R. J., Herrell, N., Rubin, D., & Fanaroff, A. (1979). Effect of supine and prone positions on arterial oxygen tension in the preterm infant. *Pediatrics, 63*(4), 528–531.

38. Masterson, J., Zucker, C., & Schulze, K. (1987). Prone and supine positioning effects on energy expenditure and behavior of low birth weight neonates. *Pediatrics, 80*(5), 689–692.

39. Meyer, M. P., Payton, M. J., Salmon, A., Hutchinson, C., & de Klerk, A. (2001). A clinical comparison of radiant warmer and incubator care for preterm infants from birth to 1800 grams. *Pediatrics, 108*(2), 395–401. https://doi.org/10.1542/peds.108.2.395

40. Monterosso, L., Kristjanson, L., & Cole, J. (2002). Neuromotor development and the physiologic effects of positioning in very low birth weight infants. *Journal of Obstetric, Gynecologic, and Neonatal Nursing, 31*(2), 138–146. https://doi.org/10.1111/j.1552-6909.2002.tb00034.x

41. Montirosso, R., Del Prete, A., Bellù, R., Tronick, E., Borgatti, R., & Neonatal Adequate Care for Quality of Life (NEO-ACQUA) Study Group. (2012). Level of NICU quality of developmental care and neurobehavioral performance in very preterm infants. *Pediatrics, 129*(5), e1129–e1137. https://doi.org/10.1542/peds.2011-0813

42. Moon, R. Y., & Task Force on Sudden Infant Death Syndrome. (2016). SIDS and other sleep-related infant deaths: evidence base for 2016 updated recommendations for a safe infant sleeping environment. *Pediatrics, 138*(5), e20162940. https://doi.org/10.1542/peds.2016-2940

43. Moon, R. Y., & Task Force on Sudden Infant Death Syndrome. (2022). SIDS and other sleep-related infant deaths: updated 2022 recommendations for reducing infant deaths in the sleep environment. *Pediatrics, 150*(1), e2022057990. https://doi.org/10.1542/peds.2022-057990

44. Mörelius, E., Örtenstrand, A., Theodorsson, E., & Frostell, A. (2015). A randomised trial of continuous skin-to-skin contact after preterm birth and the effects on salivary cortisol, parental stress,

depression, and breastfeeding. *Early Human Development, 91*(1), 63–70. https://doi.org/10.1016/j.earlhumdev.2014.12.005

45. O'Brien, K., Bracht, M., Macdonell, K., McBride, T., Robson, K., O'Leary, L., Christie, K., Galarza, M., Dicky, T., Levin, A., & Lee, S. K. (2013). A pilot cohort analytic study of Family Integrated Care in a Canadian neonatal intensive care unit. *BMC Pregnancy and Childbirth, 13*(Suppl 1), S12. https://doi.org/10.1186/1471-2393-13-S1-S12

46. Ohlsson, A., & Jacobs, S. E. (2013). NIDCAP: a systematic review and meta-analyses of randomized controlled trials. *Pediatrics, 131*(3), e881–e893. https://doi.org/10.1542/peds.2012-2121

47. Peters, K. L. (1992). Does routine nursing care complicate the physiologic status of the premature neonate with respiratory distress syndrome? *The Journal of Perinatal & Neonatal Nursing, 6*(2), 67–84.

48. Pillai Riddell, R. R., Racine, N. M., Gennis, H. G., Turcotte, K., Uman, L. S., Horton, R. E., Ahola Kohut, S., Hillgrove Stuart, J., Stevens, B., & Lisi, D. M. (2015). Non-pharmacological management of infant and young child procedural pain. *Cochrane Database of Systematic Reviews, 2015*(12), CD006275. https://doi.org/10.1002/14651858.CD006275.pub3

49. Pineda, R. G., Neil, J., Dierker, D., Smyser, C. D., Wallendorf, M., Kidokoro, H., Reynolds, L. C., Walker, S., Rogers, C., Mathur, A. M., Van Essen, D. C., & Inder, T. E. (2014). Alterations in brain structure and neurodevelopmental outcome in preterm infants hospitalized in different neonatal intensive care unit environments. *The Journal of Pediatrics, 164*(1), 52-60.e2. https://doi.org/10.1016/j.jpeds.2013.08.047

50. Platt, M. J. (2014). Outcomes in preterm infants. *Public Health, 128*(5), 399–403. https://doi.org/10.1016/j.puhe.2014.03.010

51. Samsom, J. F., & de Groot, L. (2000). The influence of postural control on motility and hand function in a group of 'high risk' preterm infants at 1 year of age. *Early Human Development, 60*(2), 101–113. https://doi.org/10.1016/s0378-3782(00)00108-6

52. Samsom, J. F., de Groot, L., Cranendonk, A., Bezemer, P. D., Lafeber, H. N., & Fetter, W. P. (2002). Neuromotor function and school performance in 7-year-old children born as high-risk preterm infants. *Journal of Child Neurology, 17*(5), 325–332. https://doi.org/10.1177/088307380201700503

53. Sauer, P. J., Dane, H. J., & Visser, H. K. (1984). New standards for neutral thermal environment of healthy very low birthweight infants in week one of life. *Archives of Disease in Childhood, 59*(1), 18–22. https://doi.org/10.1136/adc.59.1.18

54. Smith, G. C., Gutovich, J., Smyser, C., Pineda, R., Newnham, C., Tjoeng, T. H., Vavasseur, C., Wallendorf, M., Neil, J., & Inder, T. (2011). Neonatal intensive care unit stress is associated with brain development in preterm infants. *Annals of Neurology, 70*(4), 541–549. https://doi.org/10.1002/ana.22545

55. Symington, A., & Pinelli, J. (2006). Developmental care for promoting development and preventing morbidity in preterm infants. *Cochrane Database of Systematic Reviews, 2006*(2), CD001814. https://doi.org/10.1002/14651858.CD001814.pub2

56. Sweeney, J. K., & Gutierrez, T. (2002). Musculoskeletal implications of preterm infant positioning in the NICU. *The Journal of Perinatal & Neonatal Nursing, 16*(1), 58–70. https://doi.org/10.1097/00005237-200206000-00006

57. Sweeney, J. K., Heriza, C. B., Blanchard, Y., & Dusing, S. C. (2010). Neonatal physical therapy. Part II: Practice frameworks and evidence-based practice guidelines. *Pediatric Physical Therapy, 22*(1), 2–16. https://doi.org/10.1097/PEP.0b013e3181cdba43

58. Sweeney, J. K., & Swanson, M. W. (1991). The changing profile of pediatric physical therapy: a 10-year analysis of clinical practice. *Pediatric Physical Therapy, 3*(1), 2–7.

59. Vaivre-Douret, L. (2010). Developmental and cognitive problems of the preterm infant. *Archives de Pédiatrie, 17*(Suppl 3), S79–S83. https://doi.org/10.1016/S0929-693X(10)70907-4

60. Vaivre-Douret, L., Oriot, D., Blossier, P., Py, A., Kasolter-Péré, M., & Zwang, J. (2009). The effect of multimodal stimulation and cutaneous application of vegetable oils on neonatal development in preterm infants: a randomized controlled trial. *Child: Care, Health and Development, 35*(1), 96–105. https://doi.org/10.1111/j.1365-2214.2008.00907.x

61. van der Zwet, W. C., Kaiser, A. M., van Elburg, R. M., Berkhof, J., Fetter, W. P., & Parlevliet, G. A. (2005). Nosocomial infections in a Dutch neonatal intensive care unit: surveillance study with definitions for infection specifically adapted for neonates. *Journal of Hospital Infection, 61*(4), 300–311. https://doi.org/10.1016/j.jhin.2005.03.014

62. Vandenberg, K. A. (2007). Individualized developmental care for high risk newborns in the NICU: a practice guideline. *Early Human Development, 83*(7), 433–442. https://doi.org/10.1016/j.earlhumdev.2007.03.008

63. van Sleuwen, B. E., Engelberts, A. C., Boere-Boonekamp, M. M., Kuis, W., Schulpen, T. W., & L'Hoir, M. P. (2007). Swaddling: a systematic review. *Pediatrics, 120*(4), e1097–e1106. https://doi.org/10.1542/peds.2006-2083

64. van Vlimmeren, L. A., van der Graaf, Y., Boere-Boonekamp, M. M., L'Hoir, M. P., Helders, P. J., & Engelbert, R. H. (2008). Effect of pediatric physical therapy on deformational plagiocephaly in children with positional preference: a randomized controlled trial. *Archives of Pediatrics & Adolescent Medicine, 162*(8), 712–718. https://doi.org/10.1001/archpedi.162.8.712

65. Vergara, E. R., & Bigsby, R. (2004). *Developmental and therapeutic interventions in the NICU*. Brookes Publishing.

66. Volpe, J. J. (2009). Brain injury in premature infants: a complex amalgam of destructive and developmental disturbances. *The Lancet Neurology, 8*(1), 110–124. https://doi.org/10.1016/S1474-4422(08)70294-1

67. Wallander, J. L., Bann, C. M., Biasini, F. J., Goudar, S. S., Pasha, O., Chomba, E., McClure, E., & Carlo, W. A. (2014). Development of children at risk for adverse outcomes participating in early intervention in developing countries: a randomized controlled trial. *Journal of Child Psychology and Psychiatry, 55*(11), 1251–1259. https://doi.org/10.1111/jcpp.12247

68. Wells, D. A., Gillies, D., & Fitzgerald, D. A. (2005). Positioning for acute respiratory distress in hospitalised infants and children. *Cochrane Database of Systematic Reviews, 2005*(2), CD003645. https://doi.org/10.1002/14651858.CD003645.pub2