Effectiveness of Developmental Intervention in the Neonatal Intensive Care Unit: Implications for Neonatal Physical Therapy

Marla C. Mahoney, MPT, MS PT, and Meryl I. Cohen, DPT, MS, CCS

Jackson Memorial Hospital, Miami (M.C.M) and University of Miami School of Medicine, Division of Physical Therapy, Miami, FL (M.I.C.)

Purpose: Interdisciplinary team members interact with infants to facilitate progressive physiologic stability. The focus of the physical therapist's role is promotion of sensorimotor development in infants born preterm. The aim of this review was to examine evidence for physical therapist practice in the neonatal intensive care unit (NICU) as it relates to developmental intervention (DI) for infants born prematurely and to present the evidence of physical therapy techniques used in the NICU. **Summary of Key Points:** A literature review was performed resulting in identification of 26 articles that examined specific developmental intervention techniques. The articles were critiqued based on their design. Twelve articles were rated highly, indicating that sensory techniques implemented by physical therapists appear to be an appropriate and effective component of DI. The general consensus was that there is a lack of large, well-controlled, randomized studies in this area of pediatric outcome research. **Conclusions:** Neonatal physical therapy falls under the umbrella of DI. There is substantial agreement about the benefits of DI, but the multimodal and interdisciplinary nature of the evidence limits the ability to identify the effectiveness of any one healthcare professional in the provision of DI in the NICU. **(Pediatr Phys Ther 2005;17:194–208)** *Key words: infant, premature, infant care, treatment outcome, developmental disabilities/prevention and control, physical therapy/methods, review*

INTRODUCTION

During their hospitalizations in the neonatal intensive care unit (NICU), infants who were born prematurely are known to encounter many obstacles on their developmental paths. Texts, manuals, chapters, and reviews have been written addressing these impediments. The obstacles may be extrinsic to the infant and related to the NICU environment, including noise and lighting levels. Other obstacles are intrinsic and related to pathologic conditions that affect multiple organ systems. Neurologic issues include neonatal seizures and intraventricular hemorrhage.[1] Respiratory disorders include respiratory distress syndrome/hyaline membrane disease and chronic lung disease, any of which may necessitate the use of mechanical ventilation.[1] Pathologies affecting the cardiac, endocrine, and gastrointestinal systems are also commonly seen.[1–3] Impairments from any of these conditions may consist of abnormalities in tone, range of motion, quality of movement, and an inability to control state of arousal and automatic postural reactions. The resulting activity limitation is delay in achieving developmental milestones. Specific examples are poor motor abilities in activities such as midline orientation and head control.[2–4] Infants who were born prematurely have been found to be at risk of disability at school age, demonstrated by poor attention, lower IQ score, and behavioral problems.[5–9] An interdisciplinary team of healthcare professionals including nurses, physicians, and speech language pathologists routinely interact with these infants, and each of these professionals has the ability to decrease the risk of developmental delay.[2]

Physical and/or occupational therapists are also included on the NICU team. In efforts to streamline and

0898-5669/05/1703-0194
Pediatric Physical Therapy
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Address correspondence to: Meryl I. Cohen, University of Miami, Miller School of Medicine, Department of Physical Therapy, 5915 Ponce de Leon Blvd., 5th floor, Coral Gables, FL 33146. Email: mcohen@miami.edu

DOI: 10.1097/01.pep.0000176574.70254.60

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maximize efficiency of healthcare resources, it is important to study the effectiveness of the physical therapist as a team member trained to address the problem of developmental delay in the NICU setting. The role of the physical therapist in the NICU has been noted to have an impact by lessening impairments and activity limitations and in the provision of family education.[2,3,10] According to the 2001 Guide to Physical Therapist Practice, the physical therapist treats infants born preterm and neonates under two preferred practice patterns: cardiovascular/pulmonary pattern G (A) and neuromuscular patterns B (B) and C (C).[11] This article only addresses the neuromuscular patterns. According to these practice patterns, physical therapists perform treatment on patients with prematurity, developmental delay and alterations in senses (auditory and visual). Interventions listed in the Guide include movement pattern training, developmental activities training, sensory training, perceptual training, neuromuscular education, vestibular training, and family education.[11] Some of these techniques were discussed in reviews by Tucker-Catlett and Holditch-Davis,[12] D'Apolito,[13] Lotas and Walden,[14] and Anderson.[15]

Table 1 summarizes general information from these and other sources that address the significance of developmental intervention in the growth of infants in the NICU

TABLE 1

Articles Describing of NICU Developmental Interventions for Infants Born Prematurely

Article	General information	Significance to developmental intervention
Hussey-Gardner[4]	Review of literature to support the synactive theory of development and suggestions for handling to promote infant organization	Useful for family education to teach parents the signs of distress and handling techniques
Tucker-Catlett and Holditch- Davis[12]	Infant physiologic responses to stress and nursing interventions, which can help organize behavior (review article)	Techniques to change environmental factors and reduce stress on infants in the NICU*
D'Apolito[13]	Characteristics of organized versus disorganized infants; gave principles of nursing care that can be used to promote infant organization (review article)	Practical techniques that can be implemented to promote behavioral organization of infants in the NICU*
Lotas and Walden[14]	Review article of the current research on the components and efficacy of developmental care	Although studies varied in instrumentation, definitions, and methodology, all infants who received individualized developmental care showed improvement in outcomes
Anderson[15]	Infant sensory systems and the impact of the NICU environment; evaluation and treatment of each sensory system (review article)	Treatment of infants born preterm and modification of their environment may help prevent developmental delay
Als[16]	Sensory organization of infants divided into subsystems including autonomic, motor, state, attentional-interactive and self-regulatory (theoretical model)	Method for assessment infant's organization and response to stimulation
Als et al[17]	The development of the brain and the impact of the NICU environment; review of the evidence for individualized neurodevelopmental care	Framework for delivery of care to promote infant organization and improved outcomes
Miller and Quinn-Hurst[18]	Theories of behavioral organization and descriptions of neurobehavioral assessments	Provides the basis for interventions that require the observer to modify intervention based on the infant's behavioral organization
Lecanuet and Schaal[19]	Development of sensory competencies in infants born preterm including structural development, evidence of fetal sensory functioning, and potential sources of stimulation (review article)	Gestational age and infant maturity at birth are critical for development of the preterm infant in the NICU environment
Gorski[22]	Theories of NICU environmental care; compared various developmentally based interventions	Promotion of developmental intervention can be based on diverse models; however, they all promote infant organization and family involvement
Fetters[23]	Review article of models of intervention for infants born preterm; also gives intervention strategies for parent involvement, improvement of muscle tone, and preventing movement limitation	Models for intervention and interventions for prevention of developmental delay
Fay[24]	Principles of positioning and handling to promote flexion and infant organization (review article)	Infants born preterm in the NICU environment are susceptible to developmental delay, which can be avoided by proper positioning and handling
Bremmer et al[25]	Supports theories of the harmful effects of environmental noise on the development of infants in the NICU setting (review article)	Offers practical methods for decreasing noise levels in the NICU
Aita and Gaulet[26]	Assessment of nurses' attitudes, current behaviors, and intention to change behaviors to promote behavioral organization in infants born prematurely	Provides practical changes that can be implemented in the NICU environment by nurses and other personnel to promote infant organization
Connors and Lenke[28]	Implications of development of the nervous system on motor outcomes of infants born preterm (review article)	Defines the diagnosis and forms of cerebral palsy; offers a schedule and pertinent assessment information for developmental clinics

*NICU, neonatal intensive care unit.

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environment. Even though the definitions varied slightly, Lotas and Walden[14] summarized developmental intervention as "implementation of an individualized plan of care based on an ongoing structured assessment of the infant's responses to care-giving procedures and processes." In addition, much of the literature addressing developmental intervention also addresses ways to identify an "organized infant" and the theories behind systems organization. Details of theories of infant organization are discussed in the following section.

Theories of Infant Organization

Signals of Infant Organization. Since a focus of developmental intervention is to promote infant organization, it is important to define what the term "organization" means in a developmental context. D'Apolito[13] described infant organization as homeostasis between the physiologic and behavioral systems. Als et al[16,17] proposed the Synactive Theory of Development, which identified four major subsystems: autonomic, motor, state, and attentional/interactive. Each subsystem provides specific signals to identify whether the infant is stable or unstable. The infant's ability to regulate these subsystems is expected to improve with development. The signals of behavioral organization or stability can be used by interdisciplinary team members for assessment purposes. The caregiver can adjust the intervention based on the signals of the infant's tolerance. Practical handling and positioning techniques can be implemented by caregivers and family members to assist in promoting progression of the infant's behavioral organization. Refer to Table 2 for details of these signals.[4,13,16,18]

Systems Development. The difference between the behavioral and physiologic organization of an infant born preterm and one born at term is due in part to the environment in which each infant develops. The progression of fetal sensory maturation was documented by Lecanuet and Schaal.[19] Their review contrasts the uterine and NICU environments in the development of the auditory, visual, and tactile systems. Other authors have also documented the progression of the response of the infant born preterm to sensory stimulation, especially auditory and visual, in the NICU environment.[20,21] It has been established that as infants develop, they are better able to tolerate stimulation and show better organization. Observation of an infant's organization and progression of development are part of the therapist's assessment, and aid in making a treatment plan.[15]

Theories of System Organization. Individuals who interact with infants in the NICU have many models and theories available to provide the framework for developmental intervention. In a review article, Gorski[22] described three methods for providing stimulation. Those that promote supplemental stimulation give a variety of stimuli to infants to compensate for what they miss by not developing in the womb. Those that want to spare the infant from all unnecessary stimulation advocate "protection at all costs." "Contingency-based" or "developmentally based intervention" is a compromise of the two in which the infant is provided with the necessary stimulation that will promote

TABLE 2

Signals of Behavioral Organization in Infants Born Preterm*

Signals of disorganization		
Physiologic system signals	**Motor system signals**	**Behavioral function signals**
Changes in breathing pattern Changes in skin color Gag/spitting up Hiccough Tremore[16,18] Sneeze Yawn Increased stools[13,16]	Changes in trunk and extremity tone, either high or low tone[16,18] Finger splaying Arching of neck and trunk Grimace Tongue thurst Salute signal of arms Stretching of extremities Hyperflexion of trunk or extremities	Indistinct sleep states Whimpering Twitching or jerky movements of the extremities Eye floating- random eye movements with no focus Frown Fussy "Hyperalert" state Irritable Gaze aversion Abrupt changes in state Staring
Signals of organization		
Physiologic system signals	**Motor system signals**	**Behavioral function signals**
Smooth breathing pattern No color changes No sign of disorganization	No fluctuation of posture between flexion and arching[16,18] No fluctuations in tone[16,18] Signs of "coping signals" such as hand and foot, clasping, hand to mouth/face, grasping, sucking	Distinct sleep states Maintaining quiet awake state Ability to self-console, relaxed facial expression and extremities, "Ooh" face, pursed lips, smile, smooth movement of extremities. attending to stimulation (visual or auditory)

* Information presented combines and adapts findings.[4,13,16,18] Specific references are cited as appropriate.

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organization while protecting the infant from undue stress. Fetters,[23] Lotas and Walden,[14] Tucker-Catlett and Holditch-Davis et al.,[12] and Hussey-Gardner[4] reviewed the literature of infant organization models in which techniques and interventions should be performed to promote the infant's tolerance to stimulation.

NICU Environment

Medical care is the primary concern of physicians and nurses in the NICU. Equipment, lighting, and monitors are designed to optimize their interventions. However, several reviews suggest that the NICU environment provides abnormal stimuli.[15] Factors such as supine positioning,[24] timing of handling, and excessive light and noise levels have been hypothesized to contribute to the brain of the infant born preterm developing differently than the brain of the infant born at term.[17] Nurses can affect noise levels by decreasing radio and voice volume, being aware of alarm levels, and asking physicians to conduct discussions during rounds farther away from the bedside.[25] Adjusting lighting levels could be difficult because procedures need to be performed 24 hours per day. Nurses can assist by lowering the lights when possible and by providing protection with blankets and draping the isolette.[12,26]

Physical therapists can promote and support nurses in providing a developmentally appropriate environment. All team members reinforce handling and augmentative techniques, but physical therapy is often focused on techniques that promote neuromuscular development including vestibular, visual, and tactile stimulation within the tolerance of the infant.

PURPOSE

The purpose of this review is twofold: (1) to present the evidence for physical therapist practice under the neuromuscular practice pattern as it relates to developmental intervention for infants born preterm in the NICU setting and (2) to present the evidence of techniques used in the NICU that can be provided by physical therapists.

METHODS

The original question of this review was "what is the efficacy of physical therapy in the NICU?" A search of the literature prior to 2004 was performed using both PubMed and MEDLINE. The search was limited to articles written in English. The question was intentionally left very broad, so the key words used during the search were equally general in nature. The primary key word was "premature infants." Searches were also performed using AND to combine "premature infants" with "early intervention," "physical therapy," "functional outcomes." Two other reference lists were examined for appropriate articles.[4,27] Specific articles on physical therapy practice in the NICU were difficult to identify; however, the search revealed articles addressing general developmental intervention, not just physical therapy practice in the NICU.

In light of the findings, the question was modified to "What is the strength of the evidence for developmental intervention and does physical therapy fit under this umbrella?" More literature searches were performed using PUBMED with the key words including the topics discussed in the developmental intervention literature. "Premature infants" was combined using AND with ″sensory stimulation," "sensory integration," and various forms of stimulation such as "visual," "vestibular," "kinesthetic," "tactile," and "auditory," Another search was done with key word "premature infants" in combination with "motor stimulation" and "motor integration." "Developmental intervention" was combined with "motor." Only one paper, a review by Connors Lenke,[28] discussed motor outcomes. The vast majority of these searches produced articles addressing sensory stimulation or caregiver handling techniques. Consequently, this review is limited to the sensory aspect of the neuromuscular practice patterns. A search was also done for literature that pertained to family or parent education in the NICU. Articles were obtained based on their availability at three local universities with medical libraries.

The American Physical Therapy Association's (APTA) template for submitting information for the "Hooked on Evidence" initiative Web site[29] was used as a framework for collecting information from each article reviewed. Once the articles were collected and reviewed, each was rated based on the strength of the evidence. Several methods for rating the strength of the evidence were reviewed.[30–32] Study design including sample size, recruitment method, and group assignment were the primary factors in evaluating the strength of the evidence. These factors were combined to create an original four-level scale used in this paper (Appendix 1).

RESULTS

Forty-nine articles were identified. Due to the scope of this review focusing on developmental interventions beginning in the NICU, eight articles were omitted. These eight articles did not address intervention that began in the NICU. Fifteen papers were review articles and were not subjected to the rating scale. The resulting 26 articles were reviewed and rated to determine the strength of the evidence.

Table 3 lists 13 articles describing clinical studies[5,33–44] that reported *positive* outcomes for infants who were born preterm and received developmental intervention. According to the criteria presented in Appendix 1, two of these articles were highly rated at level at 1 and 11 were rated at level 2.

Ten articles described results of observations of cohort groups.[10,20,21,45–51] Table 4 lists the evidence from these studies, all of which reported *positive* outcomes. Four of these were rated at level 3. These articles had a control or comparative group but were descriptive in nature. The remaining six articles were rated level 4 as they followed the subjects' responses to stimulation over time but no intervention was performed and they had no control group.

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TABLE 3

Clinical Studies Resulting in Positive Outcomes After Intervention

Study	Design	Level	No. of subjects	Intervention	Intervention provided by	Outcome measures	Results
Lekskulchai and Cole[33]	Clinical trial, random, controlled	1	CTRL = 45, treatment (Rx) = 45, comparison group (low risk) = 27	Positioning, family, education, range of motion, handling, developmental activities	Mother, physical therapist (PT) monthly	Test of Infant Motor Performance	At term: comparison group scored significantly higher than CTRL and Rx groups ($p < 0.001$) At 4 mo adjusted age: Rx group significantly better than CTRL group ($p < 0.001$) but not significantly different from comparative group
Resnick et al[34]	Clinical trial, random, controlled	1	CTRL = 124, Rx = 131	Stimulation: vestibular, visual, auditory, tactile, kinesthetic, family education	Infant development program staff: psychologist (PSY), nurses, occupational therapist (OT), early childhood educators (ECEs), parents	Bayley Scales of Infant Development (BSID)	Rx group had a significantly lower frequency of developmental delay ($p < 0.05$). At 12 & 24 mo:CTRL group had significantly more infants with developmental delay ($p < 0.05$). Rx group scored significantly higher on BSID on mean mental and physical indicators at 12 and 24 mo ($p < 0.05$)
Achenbach et al[5]	Clinical trial, random, controlled	2	Low-birth weight CTRL (LBWC) = 31, low-birth weight Rx (LBWE) = 24, normal birth weight (NBW) = 36	Handling, family education	Nurses, parents	Kaufman Mental Processing Scales, Child Behavior Checklist (CBCL), Teacher's Report Form (TRF)	Achievement test scores by age 9 yr: LBWE significantly higher than LBWC ($p = 0.009$) LBWE children had significantly fewer behavior problems on the CBCL ($p = 0.002$) and TRF ($p = 0.006$)
Als et al[35]	Clinical trial, random, controlled	2	CTRL = 18, Rx = 20	Family education, monitoring state of arousal, positioning, monitoring lighting and noise levels	Nurses	Weight, no. of days on mechanical ventilation, and gavage feeding, length of stay, medical complications, hospital charges Assessment of Preterm Infant's Behavior (APIB), BSID	Rx group had significantly fewer days on supplemental O2 ($p = 0.05$), earlier nipple feeding ($p = 0.05$), decreased incidence of medical complications, shorter length of stay with reduced hospital charges ($p = 0.04$); APIB scores improved in autonomic system ($p = 0.01$), motor system ($p = 0.002$), self-regulation ($p = 0.04$); BSID Mental Developmental Index ($p < 0.001$), psychomotor developmental index ($p < 0.001$)

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TABLE 3
Continued

Study	Design	Level	No. of subjects	Intervention	Intervention provided by	Outcome measures	Results
Becker et al[36]	Clinical trial, non-random, controlled	2	CTRL = 21, Rx = 24	Nonnutritive sucking; staff education: decreased light and noise levels, positioning, monitoring state of arousal, cluster care procedures	Nurses	O_2 saturation, motor activity, posture, sleep-wake states	Education. changed nursing practice, decreased lighting ($p < 0.001$) and decreased noise levels ($p < 0.01$); oxygenation significantly better in Rx group ($p < 0.001$)
Fleisher et al[37]	Clinical trial, random, controlled	2	CTRL = 18, Rx = 17	Positioning, monitoring state of arousal, nonnutritive sucking, family education, monitoring environmental factors	Nurses, parents, developmental specialists	Medical outcomes: no. of days on ventilatory support or continuous positive airway pressure, no. of days to full nipple feeding, age at discharge, length of and cost of hospitalization APIB	Medical outcomes: Rx group had significantly fewer days of positive pressure ($p = 0.05$) and fewer days of hospitalization ($p = 0.05$). APIB: Rx group significantly better in motor ($p = 0.02$), state ($p = 0.03$), attention ($p = 0.05$), and regulatory ($p = 0.02$) systems Reduced charges $128,670 per patient in Rx group
Lieb et al[38]	Clinical trial, non random	2	CTRL =14, Rx = 14	Stimulation: auditory, kinesthetic, tactile, vestibular, visual	Nurses	Neonatal Behavior Assessment Scale (NBAS), BSID Nutritional intake and weight	NBAS: Rx group performed better in interactive processes pre- and post-Rx ($p < 0.002$ and 0.005, respectively) BSID: Rx group scored higher on mental ($p < 0.01$) and motor ($p < 0.02$) scalesRx group received significantly fewer calories per kg per day ($p < 0.006$)
Mathai et al[39]	Clinical trial, nonrandom, controlled	2	CTRL = 23, Rx = 25	Stimulation: tactile, kinesthetic, baby massage	Researcher (department of neonatology), mother	Physiologic: heart rate (HR), respiratory rate (RR), temperature, O_2 saturationAnthropometric: head circumference, weight NBAS	Rx group: HR significantly increased during stimulation ($p < 0.005$), greater weight gain (21.92) per day, better on NBAS in orientation ($p < 0.001$), range of state, regulation of state and autonomic stability ($p< 0.005$ for all)
Petryshen et al[40]	Clinical trial, non- random, controlled	2	CTRL = 61, Rx = 63	Positioning, monitoring state of arousal, nonnutritive sucking, cluster care procedures, techniques to promote self-regulation	Nurses	Physiologic Stability Index Time in acute care, healthcare cost	Rx group: fewer days in acute care Healthcare cost benefit averaged $4,340 per first 35 days of hospitalization for Rx group

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TABLE 3
Continued

Study	Design	Level	No. of subjects	Intervention	Intervention provided by	Outcome measures	Results
Scarr-Salapatek and Williams[41]	Clinical trial, nonrandom, controlled	2	CTRL = 15, Rx = 15	Stimulation: visual, tactile, kinesthetic, family education	Nurses, social workers, mother	Brazelton Cambridge Newborn Scales (BCNS), Cattell Infant Intelligence Scale (CIIS)	Rx group: scored higher on BCNS, higher developmental status on CIIS ($p = 0.05$)
White-Traut et al[42]	Clinical trial, random, controlled	2	CTRL = 16, Rx = 21	Stimulation: auditory, tactile, visual, vestibular	Researcher nurse	Infant behavioral state, feeding progression, length of hospitalization	Infant behavioral state: Rx group increased state of alertness during first 5 min of intervention ($p < 0.05$) Feeding progression: transition to complete nipple feeds faster in Rx group ($p = 0.0001$) Length of hospitalization: Rx group discharged 1.6 wk earlier ($p < 0.05$)
White-Traut et al[42]	Clinical trial, random, controlled	2	CTRL = 14, A group = 9, T group = 10, ATVi group = 11, ATViVe group = 10 (A, auditory; T, tactile; Vi, visual; Ve, vestibular)	Stimulation: auditory, tactile, visual, vestibular	Researcher nurse	HR, RR, O2 saturation, behavioral state (BS), body temperature	Groups with tactile stimulation showed increased BS, HR, and RR Significant differences during Rx in HR ($p < 0.001$), RR ($p = 0.01$), BS ($p < 0.02$) HR in group T was more often >180 bpm. HR in group ATViVe was more often <140 bpm ($p = 0.0001$) Group ATViVe least alert during Rx (11) but increased alertness after Rx (24)
White-Traut et al[44]	Clinical trial, random, controlled	2	CTRL = 16,Rx = 21	Stimulation: auditory, tactile, visual, vestibular	Research assistant	HR, RR, pulse oximetry	Increased HR in experimental group with stimulation. ($p < 0.001$ at 33 & 35 weeks, $p < 0.05$ at 34 weeks Infants with neurologic injury may have delayed maturation of the autonomic system

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TABLE 4

Observational Studies

Authors	Design	Level	No. of subjects	Observation/intervention	Intervention provided by	Outcome measures	Results
DeGroot et al[45]	Prospective cohort study	3	Infants born preterm (IPT) = 35, infants born full term (FT) = 17	Evaluated at 18 wk and 1 yr corrected age	No intervention	Asymmetrical active muscle power, passive tone, infantile reactions	IPT group showed asymmetrical active muscle power ($p < 0.05$); more than half of IPT group showed motor asymmetries at 1 yr
Majnemer et al[46]	Prospective cohort study	3	Neonates who are healthy CTRL = 23, high-risk group (HRG) = 51	Evaluated at 1 and 3 yr	No intervention	Einstein Neonatal Neuro-behavioral Assessment Scale (ENNAS) Griffiths Developmental Scale (GDS) neurologic exam	Two groups initially different on the ENNAS ($p < 0.001$) GDS: significant difference with HRG performing worse than CTRLs at 1 yr in 4 of 7 subscores and differences in all subscores except personal-social at 3 yr ($p < 0.05$ to <0.005) Abnormal neurologic exam for HRG (52.2) at 1 yr and (37.8) at 3 yr
Mauradian and Als[47]	Retrospective cohort study	3	Cohort I = 20 in NICU before intervention, cohort II = 20 in NICU after intervention initiated	Positioning,decreased light and noise levels, swaddling, family education	Nurses	Assessment of Preterm Infants' Behavior (APIB)	Better function for cohort II in autonomic cluster ($p = 0.0446$), motor cluster ($p = 0.0005$), state cluster ($p = 0.0226$)
Santman-Wiener et al[48]	Cross-sectional correlational analyses	3	Infants without disorders (ND) = 228, infants with regulatory disorders (RD) = 45,IPT = 56	Tested at 7–18 mo	No intervention	Test of Sensory Functions in Infants (TSFI), BSID, Infant/Toddler Symptom Checklist	IPT and RD groups scored lower than ND group overall and have more sensory processing problems at all agesI PT group scored lower on oculomotor subtests at 10–12 mo compared to RD group
Bozynski et al[49]	Prospective cohort study	4	18	Positioning (comparing supine, right side lying and left side lying)	No intervention	Transcutaneous O_2/CO_2 measurements, and sleep states measured every 30 s for 5 min	No significant difference in outcome measures among positions
Hack et al[50]	Prospective cohort study	4	5	State of arousal, visual stimulation	No intervention	Observer 1 = visual fixations; observer 2 = facial behaviors including eye opening, eye and mouth movements, vocalizations and facial expression	Amount of time in awake state increased significantly with repeated tests between 30 & 35 wk postmenstrual age ($p < 0.05$) Visual pattern fixation was noted starting at 30 wk postmenstrual age; amount of fixation also increased with repeated tests ($p < 0.05$)

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TABLE 4
Continued

Authors	Design	Level	No. of subjects	Observation/intervention	Intervention provided by	Outcome measures	Results
Hack et al[51]	Prospective cohort study	4	26	State of arousal,visual stimulation	No intervention	Visual Pattern Fixation Indices of Attention (each scored on 1–4 scale): holding of fixation and coordination, widening of the eye with attention, brightening of the eye, scanning, sucking	Composite mean scores per gestational age: 31 wk = 0.7, 34 wk = 1.8, 35 & 36 wk = 2.7 Demonstrated correlation between visual fixation and age (Pearson r = 0.58)
Kelly et al[10]	Repeated-measures during baseline, intervention and recovery	4	Rx = 14,CTRL = 0	Positioning, stimulation: kinesthetic, tactile	PT	Pulse oximetry, HR	Difference in HR only during intervention ($p < 0.001$) No difference in SaO_2 as a result of position or duration of the Rx
Neal[20]	Prospective cohort study	4	16	80-dB auditory stimulus for 20 s	No intervention	HR response preintervention and during auditory stimulation at 2-s intervals	Gestational age: 31 wk: decreased HR; 32 wk: initial increased HR; 34–36 weeks: habituation to repeated auditory stimulation
Newman[21]	Prospective cohort study	4	10	Auditory environment tactile, experience: both self-generated and externally generated	No intervention	Auditory environment, self-generated touch: reaching, stretching, and touch seeking External touch: nursing care and procedures and parental visitation	Auditory environment: average decibel level in isolette 62 dB; human voice was muffled unless into porthole; mechanical noises were easily heardSelf-generated touch: infants perform "range finding" to establish boundariesExternal touch: infants wince and close out noxious touch but open eyes and attend during parent visitation

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Although these studies did not provide direct intervention, they describe longitudinal infant development.

Table 5 presents the details of the three clinical studies[52–54] that reported *no change* in outcomes after developmental interventions. Of these three studies, one study was rated level 1 and the remaining two studies were rated as level 2.

DISCUSSION

Much of the evidence supports the physical therapist's role as a member of the interdisciplinary team that provides developmental intervention. Some of the evidence showed no significant effect on development after starting early physical therapy intervention in the NICU. It is important to note that none of the articles reviewed reported *negative* effects as a result of developmental intervention.

The following is a discussion of interventions that can be implemented by interdisciplinary team members including physical therapists. The effects of developmental intervention on the infants and the strength of the evidence for those interventions are also discussed.

Developmental Techniques Used in Promoting Infant Organization

Developmental intervention encompasses *specific procedures* used to minimize the infant's stress and also *techniques* used to promote infant organization. The literature provides evidence of stimulation and handling techniques. Tables 3 through 5 show that most of the research studies reviewed used more than one intervention simultaneously. This makes it difficult to determine which treatment technique is the most effective.

Handling Techniques

One purpose of handling techniques is to provide proper positioning of the infant. Positioning procedures include promoting the prone position or using towel rolls to maintain flexion while the infant is side-lying. In addition to trunk flexion, authors suggest that the baby's hands should be brought to midline to enable the hand to reach the mouth for self-consoling behavior.[13,24] A study by Bozynski et al[49]compared transcutaneous oxygen and carbon dioxide levels in intubated infants when placed in right side lying, left side lying, and supine. No significant differences were found, but no detrimental effects were found either. Side lying was reported to provide more options for positioning in flexion. Benefits of prone positioning were reported to include improved oxygenation, increased quiet sleep, improved respiration and heart rates, and reduced incidence of reflux. All these are believed to be beneficial for promoting development.[4,14] White-Traut et al[44] showed that infants with neurologic injury may have delayed development of the autonomic system. They recommended that handling techniques be adjusted to avoid excessive increases in heart rate.

Augmentative Techniques

Additional techniques for promoting behavioral organization have been cited in the literature. These include providing swaddling and containment with blanket rolls to provide "nesting";[4,12–14,16,24] decreasing handling when the infant displays signs of stress;[12,16] bundling care procedures together to provide longer periods of sleep;[4,12,13,16] providing nonnutritive suckling with a pacifier, which helps to both progress the infant to bottle feed faster and to decrease energy expenditure through decreased crying;[4,12–14] and promoting social interactions when the child is awake.[4,16]

Sensory Techniques

Nurses typically provide most of the interventions mentioned thus far. Nurses, parents, or other interdisciplinary team members including occupational or physical therapists can employ additional interventions. These include sensory techniques such as auditory, kinesthetic, tactile, vestibular, and visual stimulation. Table 6 provides a summary of these techniques and presents the strength of the evidence for each sensory treatment or intervention. In general, sensory techniques were implemented similarly in each study. Subtle differences were noted in operational definitions of sensory technique as found in Appendix 2.

Family Education

The evidence from the literature supported the importance of parental involvement and family education. Appendix 3 summarizes the content and method of family involvement.

Effects of Developmental Intervention on Infants in the NICU

The articles reviewed supported the effectiveness of developmental intervention. The benefits fall under three main categories: medical outcomes, cost-effectiveness, and infant growth and development.

Medical benefits of developmental intervention include improved oxygenation and faster weaning from supplemental oxygen.[14,17,35–37] Infants were able to progress faster to bottle feeding[14,17,35,37,42] and showed better outcomes in growth indicators such as weight gain, height and head circumference.[17,35,39] They also had improved medical status with fewer complications.[14,17,35,40]

Treated infants had fewer complications, grew faster, and progressed quicker. Consequently, they could be discharged home sooner. Shorter length of hospitalization[14,17,35,37,42] resulted in lower nursing cost and improved cost-effectiveness.[14,17,35,37,40]

One outcome measure reflective of progress in developmental milestones is state of arousal or the infant's ability to regulate his/her sensory systems. Infants who received developmental intervention were able to show faster improvement in these measures.[35,36,42,43] During hospitalization, and even after discharge, these infants demonstrated improved performance on developmental outcome indicators such as vital signs,[36,39] growth measures[35,39,41]

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TABLE 5

Clinical Studies Resulting in No Change in Outcomes After Intervention

Study	Design	Level	No. of subjects	Intervention	Intervention provided by	Outcome measures	Results
Piper et al[52]	Prospective, randomized, controlled study	1	CTRL = 59, Rx = 56	Family education, positioning, handling, stimulation techniques (no details given)	PTs, parents	Wolanski Gross Motor Evaluation, Wilson Developmental Reflex Profile, Milani-Comparetti Motor Development Screening Test, Griffiths Mental Development Scale, Neurological Examination of the Collaborative Perinatal Project, physical measurements	Assessed at 12 mo; no significant main group effects for dependent variables Smaller infants (birth weight <750 g) performed worse on many measures than heavier infants
Brown et al[53]	Clinical trial, randomized, controlled	2	Infant stimulation = 13, maternal training = 14; both of the above = 14, infants born preterm = 26	Stimulation: tactile, vestibular, auditory, visual Monitoring state of arousal, family education	Researcher, mother	NBAS, weight, length of hospitalization	No differences noted between groups for any indicators Maternal involvement increased while the mother was hospitalized
Saylor et al[54]	Clinical trial, randomized, controlled	2	N = 65 randomly divided into CTRL group and Rx group	Phase I: Rx group received sensorimotor intervention twice a month with family education Phase II: Both groups received weekly contacts with an infant specialist and family education	PT, developmental specialist	Multiple developmental scales: general development, communication, perceptual motor skills, adaptive, social, behavior	No significant difference in those who started intervention early versus those who started late, at 2 yr

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TABLE 6

Strength of the Evidence for Sensory Treatment and Family Education: Articles Rated at Each Level of Evidence for Each Treatment

Intervention	No. of studies reviewed	Level of evidence	Articles
Auditory stimulation	6	1	White-Traut et al,[43] Resnick et al[34]
		2	Leib et al,[38] White-Traut et al,[42,44] Brown et al[53]
Kinesthetic stimulation	5	1	Resnick et al[34]
		2	Leib et al,[38] Scarr-Salapatek & Williams,[41] Mathai et al[39]
		4	Kelly et al[10]
Tactile stimulation	9	1	Resnick et al,[34] White-Traut et al[43]
		2	Leib et al,[38] White-Traut et al,[42,44] Brown et al,[53] Scarr-Salapatek & Williams,[41] Mathai et al[39]
		4	Kelly et al[10]
Vestibular stimulation	6	1	Resnick et al,[34] White-Traut et al[43]
		2	Leib et al,[38] White-Traut et al,[42,44] Brown et al[53]
Visual stimulation	9	1	Resnick et al,[34] White-Traut et al[43]
		2	Leib et al,[38] White-Traut et al,[42,44] Brown et al,[53] Scarr-Salapatek & Williams[41]
		4	Hack et al,[50] Hack et al[51]
Family education	10	1	Resnick et al,[34] Lekskulchai & Cole,[33] Piper et al[52]
		2	Achenbach et al,[5] Als et al,[35] Fleisher et al,[37] Brown et al,[53] Scarr-Salapatek & Williams,[41] Saylor et al[54]
		3	Mauradian & Als[47]

and motor performance.[14,17,33–37,39,47] They continued to show better performance on outcome indicators when they reached school age, as measured by IQ, social competence, and behavior[5,7,41]

The evidence supported many benefits from implementing a developmental approach in the NICU. However, other evidence provides room for discussion. Three studies showed no significant differences in infants who received developmental intervention. While they do not cite any harmful side effects in the infants, they raise questions as to the effectiveness of the intervention. Two of the three found that infants who started intervention early in the NICU had no difference in outcome measures compared to infants who started treatment when they were older[52,54] (Table 5). Another study noted maternal socioeconomic factors as an obstacle to carrying over the techniques.[53] The question remains, when is the most effective time for intervention to begin?

Strength of the Evidence for Implementing Developmental Intervention

The impact of evidence is lost if findings are not integrated into treatment. The rating scale used in this paper determined which studies offered stronger evidence of practice. The scale primarily addressed study design, subject assignment, and sample size. However, other issues of internal and external validity were also considered.

Issues of internal validity pertinent to the reviewed articles included the individual's medical-surgical history or hospital course and control of the interventions. Infants who are born prematurely have a variable medical course. The history of each subject in a longitudinal study is a difficult variable to control. Hence, interventions lose their strength because the improvements may have occurred with the passing of time alone. In some studies, nurses who were trained to execute developmental intervention techniques were also responsible for treating infants in a control group. Environmental modifications appropriate for the intervention group may have also been unintentionally applied to control infants, thus biasing the results. Attempts were made to avoid these threats to internal validity by putting the treatment group in a different room or having interventions begin after the control group was discharged from the hospital.

Issues of external validity include the ability to generalize the outcome to the population, selection of the population, exposure of subject to multiple simultaneous treatments, and the description of the experimental intervention. Many of the studies had comparable inclusion criteria for the gestational age of subjects. But birth weight criteria varied from study to study, making it difficult to compare results between studies. In addition, publication bias is an important factor to consider. Authors may choose not to submit a paper for publication if their study results do not support the initial hypothesis.

Two articles by White-Traut et al[42,43] showed good internal validity by controlling the variables of the study design. However, their gain in internal validity further compromised the external validity of these studies. In addition, these studies were weakened by the small sample sizes (N = 25 and 42, respectively).

These two articles provide important evidence that techniques can be offered simultaneously and with great effect. For example, after comparing auditory, tactile, visual, and vestibular stimulation, White-Traut et al[42] found vestibular stimulation is a potential moderator of the rapid heart rate response found with tactile stimulation. In clinical practice, physical therapists frequently use multisystem stimulation. Time spent simply rocking the infant during the treatment session can provide vestibular stimulation while potentially minimizing heart rate elevation. Another finding was that the infants who had vestibular stimulation added to the treatment had increased state of arousal after the end of the session. The conclusion was

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that vestibular stimulation may offer the benefit of increased infant organization.

The second article by White-Traut et al[43] also supported the importance of multimodal stimulation. Providing nonnutritive sucking (ie, pacifier) can be beneficial for increasing and organizing the infant's state of arousal. The infant then may be able to focus on other forms of stimulation (ie, visual) more effectively.

The degree of detail given in the description of the interventions was variable among the studies reviewed. Some of the articles gave details of the intervention, enabling practitioners to reproduce the intervention. The study by Kelly et al[10] monitored physiologic responses of infants born prematurely to tactile stimulation in side-lying and supported sitting positions. Specific information is given on therapist hand placement and degrees of movement for each position. Other authors gave no description of the intervention such as the report by Brown et al.[53]

Of the 26 articles reviewed, only three studies demonstrated a high level of scientific rigor (level 1). Two of the level 1 studies found statistically significant differences between those infants receiving developmental intervention compared to those without intervention. The third study by Piper et al[52] found no statistically significant difference between the infant groups at their 12-month follow-up assessment. Thus, it is apparent that there is very little literature available that provides evidence of the effectiveness of developmental intervention in the NICU. This includes the lack of evidence regarding specific physical therapy interventions. In addition, significant differences in inclusion/exclusion criteria, operational definitions of terms, and training levels of caregivers/researchers limit general comparisons of results and weaken possible recommendations for clinical application.

Future Research

The paucity of well-designed pediatric outcomes research including the NICU setting has been addressed elsewhere. In a recent review, Forrest et al[55] conclude that outcomes research in pediatric settings is lacking "depth in any single content area." Their review of 39 articles published between 1994 and 1999 in peer-reviewed journals revealed that more research is needed to evaluate the effectiveness of management and services for the pediatric population.

Any research done with this population has inherent challenges. There is the ethical limitation of needing a control group that has treatment withheld. Also, the physical therapist must have the cooperation of the interdisciplinary team. This is difficult as interventions may be perceived as an interruption to routine care. If nurses are recruited for assistance, there is a risk of contaminating the control group with treatments depending on staffing assignments.

The sample size was a limiting factor in many articles. A multicenter trial that focuses on functional outcome indicators of infants born prematurely would provide results that may be more easily generalized to the population.. Studies should focus on unimodal treatments to determine which one is more effective than another. Finally, the skill level of the physical therapist providing the intervention should be standardized. Following the criteria set forth in the Practice Guidelines for the Physical Therapist in the NICU is one way of providing a more consistent level of proficient intervention.[56]

CONCLUSION

The Guide to Physical Therapy Practice[11] under the neuromuscular practice pattern defines what is within the scope of the physical therapist's practice. Many of the techniques addressed in the Guide are cited in the studies reviewed in this paper. Consequently, these aspects of physical therapy practice fall under the umbrella of developmental intervention.

Although rigorous study of specific techniques used in a program of developmental intervention is still warranted, there is good evidence that infants progress toward matching the development of their full-term counterparts earlier if they receive appropriate intervention. Physical therapists who practice in the NICU setting should feel empowered that what they do contributes to supporting the development of the premature infant. Several studies have been reported in the literature, yet larger, randomized controlled studies are still needed to contribute to the body of evidence related to the individual interventions.

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APPENDIX 1

Scale for Rating the Strength of the Evidence

Level of evidence	Description of rating level
1	Randomized, controlled clinical study, N >100
2	Randomized, controlled clinical study, N < 100, or controlled, nonrandom
3	Descriptive, observational study, longitudinal with control group
4	Descriptive, observational study, longitudinal with no control group

APPENDIX 2: Description of Sensory Techniques

Auditory stimulation

Nurses sang or talked to the infant while they were bottle feeding or the researcher spoke to the infant during treatment.[38, 42, 43]

Playing cassette recordings of human heartbeat, classical music, or the parent's voice.[34]

One article listed auditory stimulation as an intervention but gave no specifics on the method of delivery.[53]

Kinesthetic stimulation

Kinesthetic stimulation was specifically defined in this article as having nurses hold the infant while sitting in a rocking chair and attempting to promote eye-to-eye contact during feeding and play time.[38] Passive range of motion exercises.[34]

"Baby massage" defined as tactile-kinesthetic stimulation.[39]

Specific intervention activities to facilitate midline orientation and facilitation of trunk flexion in side-lying and supported sitting positions.[10]

Tactile stimulation

Nurses provided "soothing and rubbing" during feeding.[38]

Researcher or nurse provided massage for 10 minutes or other methods, which did not specify time limits.[34,42,43]

No specific technique given except that nurses patted the babies during feeding.[41]

"Baby massage" defined as tactile-kinesthetic stimulation.[39]

Specific intervention activities to facilitate midline orientation and facilitation of trunk flexion in side-lying and supported sitting positions.[10]

Observer sat next to the isolette and recorded the tactile experience of the baby, both self-generated by reaching and externally generated by family, nursing care procedures, etc.

No specifics except that tactile (including oral) stimulation were provided.[53]

Vestibular stimulation

Researcher provided five minutes of rocking.[42,43]

Nurses held the infant while sitting in a rocking chair during feeding and play time defined in another article as part of kinesthetic stimulation.[38]

Use of an insulated water mattress.[34]

No specifics for vestibular stimulation given.[53]

Visual stimulation

Attempting to make eye contact with the infant.[42,43] Note: This was also defined in another article[38] as part of kinesthetic stimulation.

Placing pictures of faces, mobiles, and color patterns in the warmer or isolette.[34,38]

Provided visual stimulation by taking birds from a mobile and placing them about nine inches away from the baby.[41]

Assessment of the baby's facial behavior, visual fixation, and rating of measures of attention while they focused on a pattern.[50,51]

No specifics for visual stimulation given.[53]

Parents were educated in and expected to carry out the developmental intervention home program.[33,54]

Education in the Infant Development Program.[34]

Parents educated infant behavioral organization and how to modify interaction to decrease stress levels.[5,34,41]

Promoting parental involvement in the care of the infant.[35, 37, 47]

Education of the parent in specific handling, positioning, and stimulation techniques.[52,53]

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