Efficacy of a Neuro-Developmental Treatment Program to Improve Motor Control in Infants Born Prematurely

Gay L. Girolami, PT, MS, and Suzann K. Campbell, PT, PhD, FAPTA

Pathways Center for Children, Glenview, Ill (G.L.G.); and University of Illinois at Chicago, Chicago, Ill

The purpose of this study was to evaluate the efficacy of a Neuro-Developmental Treatment protocol designed to improve motor control in infants born prematurely and at high risk for developmental disability. In a randomized, controlled clinical trial, a treatment group (n = 9) received the Neuro-Developmental Treatment–based intervention protocol, whereas the preterm control group (n = 10) received an identical amount of nonspecific handling. A group of infants born at term (n = 8) also received no intervention. Outcome was assessed by testers blind to preterm group assignment using the Neonatal Behavioral Assessment Scale and a Supplemental Motor Test designed to assess quality of postural control. The term control group performed significantly better than either of the preterm groups on the motor performance cluster of the Neonatal Behavioral Assessment Scale, and the preterm control group performed better than other groups on the autonomic regulation cluster. On the Supplemental Motor Test assessment of postural control, the preterm treatment group outperformed both control groups on spontaneous behavior items and the preterm control group on elicited activity items. Preterm groups did not differ in average weight gain. A Neuro-Developmental Treatment–based intervention was efficacious in improving postural control in infants born prematurely but did not significantly improve tone, behavioral state, reflexes, or autonomic regulation. (***Pediatr Phys Ther*** **1994;6:175–184**)

The evolution of high-technology neonatal care units has resulted in the preservation of life for a growing number of infants at high risk for mortality; an additional result, however, has been the large number of children who survive and are at high risk for developmental disabilities.[1] Approximately 25% to 30% of infants at risk exhibit some form of neuromotor disturbance early in life.[2,3] As a result, physical therapists have increasingly become incorporated as regular members of the neonatal special care team. Despite the generally accepted relevance of their involvement in specialized neonatal care, little support exists for the value of physical therapy in ameliorating motor dysfunction, and only vague specifications exist for directing service planning and evaluation. The purpose of this study was to assess the efficacy of Neuro-Developmental Treatment (NDT) administered in a controlled clinical trial of nursery intervention for infants born at less than 35 weeks gestational age and showing aberrant motor development.

0898-5669/94/0604-0175$3.00/0
PEDIATRIC PHYSICAL THERAPY
Copyright © 1994 by Williams & Wilkins

Address correspondence to: Gay L. Girolami, PT, MS, Pathways Center for Children, 3633 West Lake Ave, Glenview, IL 60025.

Motor Performance of Premature Infants

The infant uses movement to communicate and to interact physically with objects or people in the environment, to change postures, to entrain movements in response to environmental demands, and for self-comforting. Active movement has been shown to be necessary for optimal perceptual development,[4] an area that is often problematic in children born prematurely.[5] A goal of physical therapy for young infants is to assist them in developing these functional uses of movement.

Overall, children born prematurely have lower motor performance scores on standardized tests than infants born at term even when age is adjusted for prematurity.[6] The smallest infants and those with central nervous system insults are at greatest risk for poor motor outcome. For example, the rate of cerebral palsy is 25 to 30 times higher in infants of very low birth weight (<1500 g) than in infants of full size,[1] and Papile and colleagues[7] reported that the 16% of infants of very low birth weight who sustained the most severe grades (III and IV) of intraventricular hemorrhage

Supplied by The British Library - "The world's knowledge"

represented 51% of those with severe developmental disabilities and 61% of those who were multiply handicapped.

Intervention in the Special Care Nursery

Despite several decades of involvement of therapists in special care nurseries, little research exists to document the effectiveness of their services. Before the late 1980s, most intervention studies in which motor outcome was assessed included as subjects those now considered to be at relatively low risk for poor motor developmental outcome.[8] Two studies reported significant differences on the Brazelton Neonatal Behavioral Assessment Scale[9] or the Graham-Rosenblith[10] test dimensions related to neonatal motor functioning,[11,12] and two others[13,14] had negative results. None of these studies assessed specific interventions delivered by physical therapists.[8]

Typical of recent non–physical therapy interventions is a study by Resnick and colleagues in which infants of very low birth weight were provided with two daily 20-minute sessions by infant developmental specialists that included massage, passive range of motion, use of water mattresses, oral and visual stimulation, auditory stimulation with parents' voices or a heartbeat, and social interaction.[15] When compared with a control group, treated infants had motor scale scores about 4 points higher at 1 year and 13 points higher at 2 years of age; each difference was statistically significant. The treatment group, however, also had postdischarge parent education, so the relative effectiveness of nursery intervention versus the education provided after discharge was unclear.

None of the described studies have specifically had as their goal improved motor functioning. It remains unclear whether an approach structured to address the development of posture control would enhance motor development more than other approaches.

Effects of NDT on Motor Performance in Infancy

Although the NDT approach is the most commonly used model for provision of intervention to children with developmental motor delays or central nervous system dysfunctions by physical therapists,[16] little evidence exists to support its efficacy.[17,18] Only three studies have specifically provided intervention to infants born prematurely and at high risk for developmental disabilities in controlled clinical trials during the early months of life, and none have provided experimental intervention in the nursery.

Piper and colleagues studied 56 experimental and 59 control subjects who were provided NDT once every 2 weeks after hospital discharge until 3 months adjusted age and then monthly therapist visits to provide a home program until 1 year of age.[19] No significant differences were found between groups in motor outcome at 1 year of age. Only 10 children in the entire sample of 134 infants ultimately were diagnosed as being neurologically abnormal. The study, therefore, basically administered therapeutic intervention to a noninvolved population despite selection of a relatively high-risk group. A similar problem exists with a second study by Goodman and colleagues, which used a similar design but began intervention on a monthly basis with a home program from 3 months until 12 months adjusted age for 20 infants who were chosen specifically because they did not have abnormal neurologic signs at entry to the study.[20,21] No differences between treated children and a similar-size control group were found.

In neither study was treatment given at the frequency common in clinical practice. Weekly physical therapy for children with cerebral palsy has been shown to promote significantly better rates of motor development than monthly treatment,[22] and 5 hours per week of treatment improves outcome even more.[23]

Finally, a study by d'Avigon and colleagues compared the outcomes of 9 children treated with Vojta therapy with those of 11 children treated with NDT beginning at less than 6 months of age and continuing for up to 4 years.[24] Seven in the Vojta group were considered normal in the preschool period compared with 3 in the NDT group. All children were selected for this study on the basis of the finding of a number of abnormal postural reflexes on a test that has not been shown to have high predictive validity, so it is impossible to tell whether the two groups contained comparable children at the start of the study. Different proportions in the groups having mental retardation (2 vs 6) suggest that they were probably not comparable. The small sample size was also problematic.

In summary, the efficacy of NDT provided to infants during a stay in the special care nursery has not been studied in a controlled clinical trial. In this study, we hypothesized that NDT would improve the motor performance of infants in the treatment group without compromising physiologic control or weight gain during a period of intervention in the special care nursery.

METHODS

Subjects

Infants born prematurely and having the greatest risk for long-term neurologic dysfunction were selected from the special care nursery of the North Carolina Memorial Hospital (Chapel Hill, NC). Infants who were average for gestational age born before the 35th week of gestation and weighing less than 1800 g were considered for inclusion if they evidenced at least three of the following medical complications: 5-minute Apgar scores of 5 or less, intraventricular hemorrhage documented by ultrasound, seizures, respiratory distress syndrome, respiratory arrest, birth weight less than 1000 g, central nervous system depression or irritability, asphyxia, need for mechanical ventilation, and thermal instability. The preterm treatment (PT) group had an average of 4.3 medical complications; the preterm control (PC) group had an average of 3.7 complications. In both preterm groups, respiratory arrest (PT, 67%; PC, 60%), ventilation (PT, 67%; PC, 70%), and respiratory distress syndrome (PT, 78%; PC, 90%) were the most commonly noted complications.

Infants meeting these criteria were pretested at 34 to 35 weeks postconceptual age using the Neonatal Behavioral Assessment Scale (NBAS).[9] Subjects ($n = 33$) with at least three abnormal or asymmetrical reflexes on the NBAS were recruited and randomly assigned to treatment or control groups, after receiving informed consent of each child's family and attending physician.

In addition, a group ($n = 8$) of healthy infants born full-term, matched with the preterm treatment group for sex, were recruited as a control group and tested within 24 to 72 hours of birth using the NBAS.

Research Design

The infants born prematurely who were recruited for this study were randomly assigned to either the treatment or control group at 34 or 35 weeks of postconceptual age to insure that all the infants began treatment at the same level of maturity. The infants participated in the study for a total of 14 to 28 treatment sessions during a period of 7 to 17 days. Infants who were discharged back to local hospitals before completion of the protocol were dropped from the study if they had not completed 7 days (14 treatments) on the protocol. The treatment sessions were administered

Supplied by The British Library - "The world's knowledge"

twice daily for 12 to 15 minutes. All treatments were administered by the first author, a licensed physical therapist and certified NDT instructor. Infants in the full-term control group received no intervention.

Intervention Protocol

The NDT protocol for the preterm treatment group was designed to influence the infants' ability to lift and turn their heads in prone, bring hands to the mouth, hold the head in midline in supine, and lift and hold the arms and lower extremities up against the force of gravity (See "Appendix" for more detail). All of these are functional movements and postures commonly seen in infants born full-term.

During each intervention session the infants were handled to facilitate movement and active postures in the prone, sidelying, supine, and supported sitting positions. The infants in the preterm control group were placed in the same positions for an identical period of time and received similar amounts of social interaction but not the NDT protocol. Intervention was provided in the infant's isolette with monitors in place and turned on. At no time during the study did treatment need to be discontinued because of tachycardia, bradycardia, increased or decreased respiratory rates, excessive crying, or apnea.

Measures

Posttesting of the infant participants was performed within 72 hours of completion of the protocol, or before discharge from the special care nursery, by one of two examiners unaware of group assignment of the infants born prematurely. When testing infants in the term control group, examiners could not be unaware of group status, because these infants resided in the newborn nursery. The NBAS[9] and a Supplemental Motor Test (SMT; Fig. 1)[25] specifically developed for this study were administered during a single session by the same tester. Testers had achieved a level of 90% interrater reliability on the NBAS at a certification center.

OBSERVED ITEMS (scored 0/2)

Head in midline for 5 seconds
Head turn right to left
Head turn left to right
Hands together
Right hand to mouth
Left hand to mouth
Right hand open
Left hand open
Pelvic lifting
Hip flexion with neutral rotation/abduction
Head turn right to left (prone)
Head turn left to right (prone)
Head lift for 5 seconds (prone)
Roll to right
Roll to left

TESTED ITEMS (scored 0-4)

Neonatal neck righting to right
Neonatal neck righting to left
Head in midline (hands held on chest)
Head in midline with visual stimulation
Maintain hands in midline (head stabilized)
Antigravity hip and knee flexion
Extend neck in supported sitting[1]
Flex neck in supported sitting[1]
Head turn in prone to sound on right
Head turn in prone to sound on left
Head lift in prone[1]
Arm flexion from extended position in prone[1]

Figure 1. Items of the Supplemental Motor Test. [1]Based on similar items in Dubowitz L, Dubowitz V. *The Neurological Assessment of the Preterm and Full-term Newborn Infant.* Philadelphia, PA: J. B. Lippincott, 1981. Scoring was revised for the purposes of this scale.

The 27 items and 20 reflexes on the NBAS were statistically analyzed using the seven-cluster scoring developed by Lester and associates (Lester BM, Als H, Brazelton TB, "Scoring Criteria for Seven Clusters of the Brazelton Scale," unpublished manuscript). Five of the clusters, motor performance, range of state, regulation of state, autonomic regulation, and reflexes, were selected for analysis because they represented the test items most likely to demonstrate the effects of a motor intervention program.

Because the NBAS alone was not sufficient to adequately address hypothesized effects of the intervention on the quality of functional postural control, the SMT was developed to reflect the spontaneous and elicited movement patterns and motor control expected in healthy infants born at term and in infants born prematurely at near term adjusted age. Ten observed items, including 5 items scoring right and left sides separately, documented the presence or absence of head, trunk, and limb control, for a total of 15 scored (0 or 2) observations and a total possible score of 30. In addition, 12 elicited items were each ranked 0 to 4 (4 = optimal) on an ordinal scale, for a total possible score of 48. The observed items served to demonstrate what the infant could spontaneously accomplish alone, whereas the elicited items assessed the highest level of performance possible under standard stimulus conditions. Test-retest reliability during a two-day period resulted in item correlations ranging from 0.64 to 0.99 for all but 3 items. Correlations were not able to be determined for these, because there were too few successful responses.

Additional data related to the infants' daily weight gain and any instances of apnea were recorded. It was believed that these data would be helpful in documenting any physiologic differences between the preterm groups that might be attributed to the effects of their respective treatment protocols.

Data Analysis

Posttest group means for the NBAS cluster scores and the SMT observed and elicited item total scores were analyzed using one-way analysis of variance (ANOVA). When significant F values were obtained, planned comparisons were used to determine where significant differences among the means of the three groups occurred. Differences between weight gain in the two preterm groups were analyzed with a t test for independent means. The probability value set for rejection of the null hypothesis of no group differences was $P < 0.05$.

RESULTS

During the 1-year period of this study, 33 infants met the enrollment criteria. Of these 33 infants born prematurely, 19 (9 treatment and 10 control) completed the study, for an attrition rate of 42%. This high attrition rate was related to the large population of infants who, as a result of an unanticipated change in nursery policy, were transported back to home hospitals before completion of a minimum of 7 days on the intervention protocol.

Table 1 shows the distribution of the study infants by sex, ethnicity, and group assignment. Birth weight, gestational age at birth, postconceptual age at the time of entry to the study, number of days participating in the study, and number of treatments received were analyzed for differences between groups to determine whether random assignment had produced approximately equivalent groups despite attrition. The analysis (Table 2) revealed that there were no statistically significant pretreatment differences between the two preterm groups. Analysis of NBAS pretest scores also revealed no statistically significant pretreatment differences between the groups. Subject attrition, therefore,

Supplied by The British Library - "The world's knowledge"

Table 1
Subject Characteristics

	Ethnicity			Mean Birth
	Black	White	Mixed	Weight, g
Preterm treatment (n = 9)				1105.55
Male	3	1	1*	
Female	2	1	1†	
Preterm control (n = 10)				1216.00
Male	3	2	0	
Female	3	2	0	
Term control (n = 8)				3320.00
Male	3	1	1‡	
Female	2	1	0	

* African-American/Hispanic.
† Hispanic/Korean.
‡ African-American/Caucasian.

did not result in subsequent nonequivalence of experimental and control groups on variables that might have selectively influenced responses to the experimental treatment provided in this study.

Posttest analysis of the five NBAS clusters revealed a significant difference among the three infant groups (PT, PC, and term control group [TC]) only on the Motor Performance and Autonomic Regulation clusters (Tables 3 and 4). The analyses of regulation of state (F = 3.19; *P* = 0.06), range of state (F = 1.16; *P* = 0.33), and reflex (F = 0.25; *P* = 0.78) clusters did not demonstrate statistically significant differences among groups. Means for the groups on the regulation of state cluster were PT of 5.75 (SD, 1.55; range, 3.66–7.66), PC of 4.59 (SD, 1.47; range, 1.00–6.00), and TC of 6.14 (SD, 0.95; range, 5.00–8.25). Means for the groups on the range of state cluster were PT of 3.31 (SD, 0.90; range, 1.75–4.75), PC of 2.80 (SD, 0.78; range, 1.50–4.00), and TC of 3.38 (SD, 1.01; range, 2.00–5.25). Means for the groups on the reflex cluster were PT of 7.78 (SD, 3.27; range, 4.00–12.00), PC of 8.80 (SD, 4.92; range, 4.00–20.00), and TC of 7.50 (SD, 3.96; range, 0.00–13.00).

Table 3
NBAS Motor Performance Cluster Scores: Means, SDs, and Ranges, ANOVA and Planned Comparisons

Groups	n	Mean	SD	Range
PC	10	4.26	0.73	2.75–5.40
PT	9	4.62	0.35	4.00–5.00
TC	8	5.34	0.64	3.80–5.80

Analysis of Variance

Source	*df*	SS	MS	F	*P*
Group	2	5.159	2.579	7.15	0.004*
Error	24	8.663	0.361		
Total	26	13.822			

Planned Comparisons

Group	F Value	*P*
PT vs PC	1.77	0.20
PT vs TC	5.80	0.02*

* Statistically significant.

Motor Performance Cluster

On the motor performance cluster of the NBAS, the PT group obtained a mean score of 4.62 vs 4.26 for the PC and 5.34 for the TC groups (Table 3). The differences among the means were statistically significant (F = 7.15; *P* = 0.004), and the planned comparisons indicated that the TC group performed better than either of the preterm groups (F = 5.80; *P* = 0.02), which did not differ significantly from each other. Item-by-item analysis of the cluster revealed that superior performance of the TC group on the pull-to-sit item was primarily responsible for the group's higher mean score.

Autonomic Regulation Cluster

On the autonomic response cluster, the PT group obtained a mean score of 5.59 vs a mean score of 6.50 for the PC group and 5.50 for the TC group (Table 4). The differences among the means were statistically significant (F =

Table 2
Tests for Equivalence of Experimental Group Assignment

Variable	Preterm Treatment (n = 9)	Preterm Control (n = 10)	*t*	*P*
Birth weight				
Mean (g)	1106	1216	0.87	0.84
SD	263	285		
Range	880–1590	680–1660		
Gestational age				
Mean (week)	29.8	30.3	0.47	0.52
SD	1.9	2.4		
Range	26–33	25–33		
Age after conception				
Mean (week)	34.7	34.7	0.15	0.55
SD	0.4	0.5		
Range	34–35	34–36		
No. of treatments				
Mean	20.6	19.0	−0.78	0.58
SD	4.7	3.9		
Range	14–27	14–24		
No. of days in study				
Mean	13.7	12.3	−0.93	0.55
SD	3.5	2.9		
Range	7–17	7–17		

Supplied by The British Library - "The world's knowledge"

Table 4
NBAS Autonomic Cluster Scores: Means, SDs, and Ranges

Group	n	Mean	SD	Range
PC	10	6.50	0.69	5.67–8.00
PT	9	5.59	0.68	4.66–6.66
TC	8	5.50	0.85	4.33–6.66

Analysis of Variance

Source	df	SS	MS	F	P
Group	2	5.730	2.865	5.24	0.01*
Error	24	13.117	0.547		
Total	26	18.848			

Planned Comparisons

Group	F	P
PT vs PC	7.14	0.01*
PT vs TC	0.07	0.80

* Statistically significant.

Table 5
Supplemental Test Observed Items: Means, SDs and Ranges

Group	n	Mean	SD	Range
PC	10	13.60	3.86	8.00–20.00
PT	9	19.33	4.12	12.00–26.00
TC	8	14.00	4.66	8.00–20.00

Analysis of Variance

Source	df	SS	MS	F	P
Group	2	185.896	92.948	5.28	0.01*
Error	24	422.400	17.600		
Total	26	608.296			

Planned Comparisons

Group	F	P
PT vs PC	8.85	0.007*
PT vs TC	6.84	0.015*

* Statistically sigifiant.

5.24; $P = 0.01$), and the planned comparisons indicated that the PC group performed better than both the PT and TC groups ($F = 7.14$; $P = 0.01$), which did not differ significantly from each other. The optimal scores on this cluster indicated a higher level of control over such autonomic responses as tremors, startles, and jitteriness. These results indicate that the PC group had superior ability to regulate its autonomic system, and that the performance of the preterm experimental group was similar to that of the infants born at term.

SMT

The observed items represent spontaneously emitted behaviors, which were given a score of 2 if observed during the testing. The maximal score possible for these items is 30. The PT group obtained a mean score of 19.33 vs 13.60 for the PC group and 14.00 for the TC group (Table 5). The differences among the means were statistically significant ($F = 5.28$; $P = 0.01$), and the planned comparisons indicated that the PT group performed better than both the PC ($F = 8.85$; $P = 0.007$) and TC ($F = 6.84$; $P = 0.015$) groups. The results of the planned comparisons indicate that the experimental group performed significantly better than either of the control groups on the observed items of the supplemental test. Treated infants were more likely to pass items requiring antigravity movement, such as hands to midline, pelvic lifting, legs flexed up and abducted, lifting and turning the head in prone, and rotating the head to midline. Figure 2 shows the individual scores obtained by each of the children in the three groups; it can be seen that all but one of the treated children scored higher than the average of the PC group.

On the elicited items of the SMT, the PT group obtained a mean score of 32.89 vs 25.20 for the PC group and 32.86 for the TC group (Table 6). The difference among the means was statistically significant ($F = 7.52$; $P = 0.01$), and the planned comparisons indicated that the PT group performed better than the PC group ($F = 11.33$; $P = 0.002$) but equally

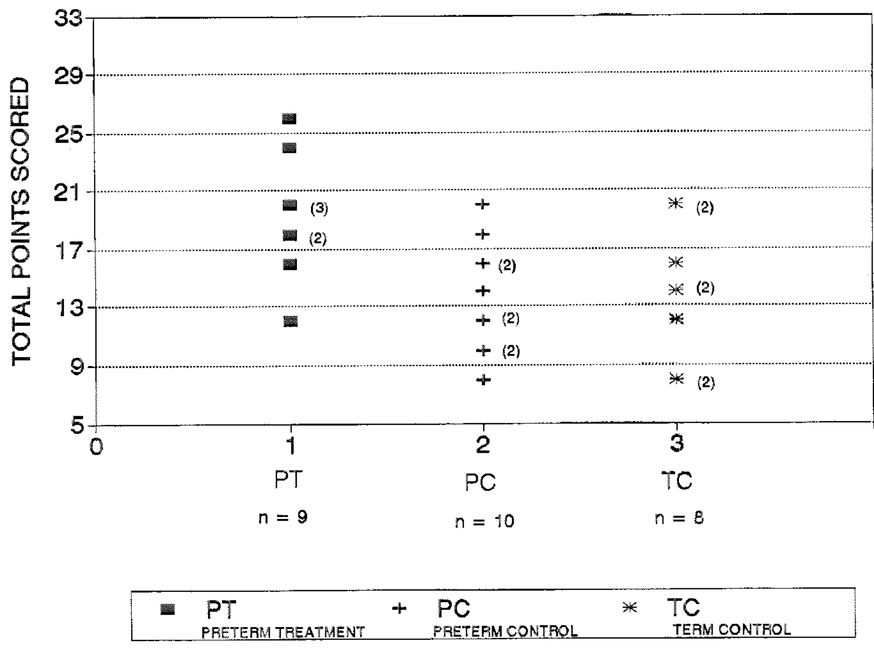


Figure 2. Total points scored by each subject on the observed items of the Supplemental Motor Test.

Supplied by The British Library - "The world's knowledge"

Table 6
Supplemental Test Elicited Items: Means, SDs, and Ranges

Group	n	Mean	SD	Range
PC	10	25.20	6.16	16.00–39.00
PT	9	32.89	4.01	28.00–38.00
TC	8	32.86	4.19	28.00–39.00

Analysis of Variance

Source	df	SS	MS	F	P
Group	2	371.599	185.800	7.52	0.01*
Error	24	593.364	24.723		
Total	26	964.963			

Planned Comparisons

Group	F	P
PT vs PC	11.33	0.002*
PT vs TC	0.00	0.996

* Statistically significant.

as well as the term group (F = 0.00; $P = 0.996$). Both the PT and TC groups demonstrated performance superior to the PC group, particularly on items such as bringing the head to the midline, hands to midline, and antigravity lower extremity movements. Figure 3 illustrates the scores of the individual children in each group. All treated children scored better than the average child in the control group.

Finally, if observed and elicited scores from the SMT are totaled for each child, the average SMT score for the treated group was 52, for the preterm control group was 39, and for the full-term group was 47. To illustrate the clinical meaning of these scores, an infant in the preterm control group with a score of 40 was able to maintain his or her head in midline in supine for 10 seconds and could turn the head to the side when placed face down in prone but did not attempt to lift or turn his head in prone to find an interesting sound and was able to bring only one hand up to the face when both elbows were extended in prone. By contrast, a typical child who received NDT had a total score of 54 on the SMT and was able to hold the head in midline for more than 10 seconds, lift and turn the head to midline in prone in response to a sound, and lift the head off the support surface in prone for at least 5 seconds. When both elbows were extended in prone, the infant was able to bring both arms back up into a flexed position with his hands near his face.

Weight Gain

The weight gain of each preterm infant in the study was calculated by finding the increase in weight from the day before the first treatment to the last day of treatment. The mean weight gain of the PT group was 370 g vs 301 g for the PC group. The t test results revealed no significant difference ($t = -1.31$; $P = 0.21$) in weight gain between the two groups.

DISCUSSION

The results of this study indicated that children in the term control group had better performance than either preterm group on the motor performance cluster of the NBAS. The experimental preterm groups did not differ from each other, indicating that NDT had no significant effect on the types of behaviors assessed by the NBAS. On the autonomic regulation cluster of the NBAS, the best performance was obtained by the preterm control group, whereas the treated group and the full-term infants did not differ significantly from each other. It is believed that this result occurred because the children in the preterm control group were less active than the other two groups, thus allowing less opportunity for them to demonstrate startles and other behaviors assessed by this item cluster.

The three groups did not perform significantly differently on NBAS clusters assessing reflexes, state control, and regulation. NDT did not, therefore, seem to affect reflexes, muscle tone, or state-related behaviors in the neonatal period significantly.

The SMT, designed specifically to assess functional postural control in neonates in this study, revealed significantly higher scores on the part of the infants treated with NDT. On both spontaneous behavior and elicited items, infants

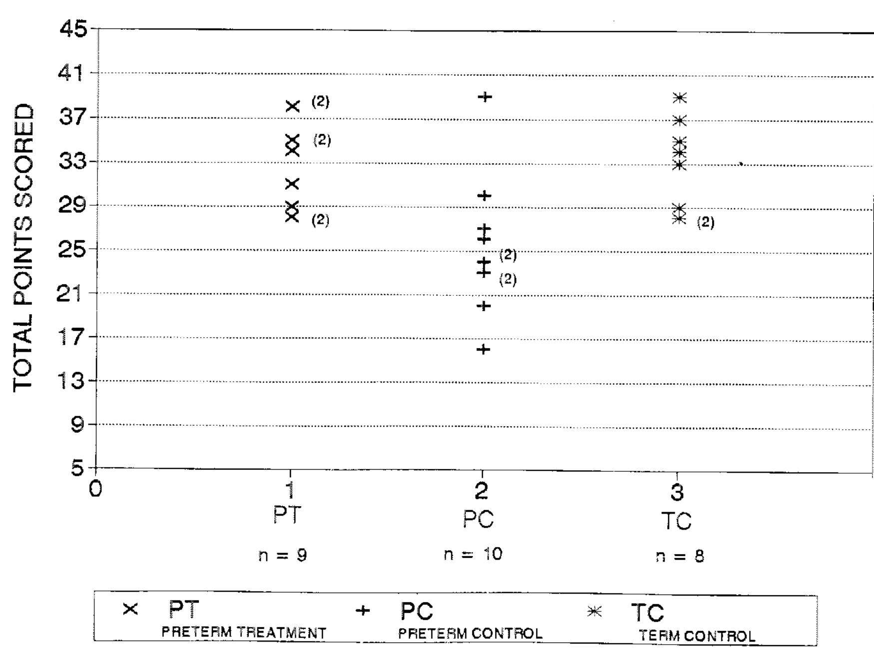


Figure 3. Total points scored by each subject on the tested items of the Supplemental Motor Test.

Supplied by The British Library - "The world's knowledge"

who were treated performed better than infants in the preterm control group. On the elicited items, treated infants demonstrated behavior similar to those of infants born full-term, but the spontaneous behaviors of infants in the preterm treatment group were superior to those of term infants born full-term. This test, therefore, seems to have potential for further development as a physical therapy assessment tool. The authors and several colleagues are currently in the process of expanding the item content (and age range) of this test, now called the Test of Infant Motor Performance.[26]

This study, although it contained small numbers of subjects, provides the first evidence that NDT is an effective method of improving motor performance of infants at high risk for developmental disabilities during their nursery stays. Furthermore, improved motor performance was achieved without evident ill effects on weight gain. Nor were there any problems with respiratory distress or other physiologic variables during the treatment sessions, allaying possible fears regarding the safety of intervention for infants born prematurely who have reached at least 34 weeks postconceptional age. A limitation of the study is the fact that long-term outcome of these infants was not followed to see whether nursery treatment had a continuing benefit and for how long a period the effects last. Future studies should investigate these questions.

A second limitation of this study was the small sample size because of subject attrition. One could reasonably ask how the small number of subjects affects the power available for the several group comparisons made. With n = 9 in each of three groups, statistical power at $P = 0.05$ is 0.88 for an effect size of 0.7, and 0.95, for an effect size of 0.8.[27] In this study, the power of the three nonsignificant comparisons were very different. Excellent power was available to identify differences in state regulation but none were significant. Obtained differences in Range of State were very small with low power so an adequate test would require 80 to 100 subjects to reach statistical significance, and results would not be likely to have clinical relevance. The Reflex score comparisons had a power of close to .50, and it is likely that significant results would be obtained if sample size were merely doubled. The benefit would accrue to the treated group who showed fewer abnormal reflexes than the control subjects (high scores on the Reflex dimension indicate larger numbers of deviant reflexes).

On the other hand, if we had set a more stringent level of probability for rejection of the null hypotheses because of the multiple significance tests carried out, the conclusions would have changed very little. For example, at $p = 0.01$, the results would be the same, with the exception that children in the TC group would be considered no different than children born prematurely on the NBAS motor performance cluster, and the PT group would be considered no different from, rather than superior to, the TC group on the SMT elicited items. The conclusion that NDT is effective in improving the posture control of infants born prematurely would not change. Nevertheless, replication of this study with a larger sample and with the suggested revisions of the treatment protocol that follow is advisable.

Protocol Evaluation

The results of this study are also useful in analyzing the specific effects of the NDT treatment protocol and how it might be improved for use in clinical practice or future research. These issues will be discussed in more detail.

The statistical analysis of the motor performance items of the NBAS indicated that the PT group did not perform significantly better than either of the control groups. The planned comparison, in fact, determined that the TC group performed significantly better than either of the two preterm groups. Further investigation of the five items that make up the cluster (tone, motor control, pull to sit, defensive movements, and motor activity) yielded similar scores by all three groups except on the pull to sit item, in which both preterm groups scored far lower than the term group (TC, 6.8; PT, 3.6; and PC, 3.5). The pull to sit item is most probably the item that caused the significant difference on the statistical analysis of the motor performance cluster.

The superior performance of the infants born full-term on pull to sit may be related to the increased physiologic flexion exhibited by infants born full-term.[28] On the other hand, the intervention may not have been intensive enough to produce the neck flexion strength needed to hold the infant's head in the absence of physiologic flexion in the infant born prematurely when near term age. This aspect of the treatment protocol could be revised to provide the infant with greater opportunity to strengthen the anterior neck and chest muscles in activity in opposition to the force of gravity.

With regard to the observed items on the SMT, the PT group scored significantly better than either of the two control groups. Their performance was particularly outstanding on the antigravity movement items, which require lifting the head, arms, pelvis, and legs. These abilities seem to reflect the results of administering a treatment protocol designed to stimulate movements and facilitate the development of posture control.

All three of the groups scored poorly on head turning in prone, rolling onto right and left sides, and head turning in supine. Perhaps a greater portion of the treatment time should be spent in developing the integrated use of neck flexors and extensors for head turning in prone and supine. Given the asymmetry of head turning observed, care should also be taken to provide the infants with more left-sided stimulation to enhance their ability to turn the head from right to left.

On the elicited items, the infants in the PT and TC groups had identical average scores. Once again, the PT group performed well on items that measured their ability to maintain the head and arms in midline, lift the pelvis and lower extremities, and use the anterior neck muscles in supported sitting. Items performed in prone (ie, lifting and turning the head and use of posterior neck muscles in supported sitting) were performed less well. The intervention should be revised to include more activities designed to influence integration of neck and trunk flexor and extensor muscles to produce postural stability for independent head and extremity movements.

Clinical Observations

Finally, there are a number of clinical observations that may serve a purpose in describing the infants' physiologic and motor behavior as a result of their participation in the study. These observations include the infants' reactions to treatment and their interactions with the therapist.

All of the infants in the treatment group were seen at approximately the same time daily and initially exhibited drowsiness and termination behaviors to limit interaction. The infants in the treatment group, however, gradually became more alert, less restless, and more interactive during their participation in the study. These infants were usually awake and "waiting" shortly before their treatment was to begin. They exhibited prolonged ability to engage the therapist in eye contact, and visual tracking was also present. The infants in the control group slept through most of the treatment sessions and, when awake, continued to exhibit terminating behaviors and restlessness.

As the infants in the treatment group neared 36 to 37 weeks postconceptual age, they began to exhibit more

Supplied by The British Library - "The world's knowledge"

active motor behavior, which may account for their relatively poor performance in the NBAS autonomic regulation cluster. Their performance was more like that of the TC group, who also had less optimal scores on that cluster, presumably because of a greater period of time spent in an active motor state.

CONCLUSIONS

This study evaluated the effects of an NDT protocol administered to infants born prematurely and at high risk for developmental disability. NDT was not found to improve performance on the NBAS relative to infants in the PC group. We must conclude either that NDT is not capable of affecting the dimensions of neonatal performance assessed by the NBAS, that the test is not sensitive enough to reflect changes in motor performance, or both. We suggest that the NBAS lacks sensitivity to motor performance, because children who received NDT did demonstrate improved posture control relative to infants in the control group on a test specifically designed to assess the quality of movement expected of neonates at term-equivalent age. Paludetto and colleagues also reported that rates of improvement in behavioral items on the NBAS were highly variable in infants born prematurely, and some were not sensitive to change during the preterm period.[29] Thus, we do not believe that the NBAS is likely to be useful for assessing motor outcomes of physical therapy.

Although these results describe the effects on only a small sample, therapists in special care nurseries may be able to use this treatment protocol to plan intervention strategies for similar infants. The fact that improved posture control was achieved without evidence of compromised growth or physiologic stability in infants selected because of poor motor performance also provides support for the safety of this type of physical therapy for infants born prematurely when they reach the age of 34 to 37 postconception weeks. In addition, this study can serve as a model for developing future research studies with improved design and intervention strategies to evaluate the performance of larger samples with more specific selection criteria. Finally, we recommend continued development of the SMT to fill an unmet need for a motor performance assessment for use by physical therapists practicing in special care nursery settings.

ACKNOWLEDGMENTS

At the time this project was completed G. L. Girolami was a Graduate Student and S. K. Campbell a Professor, Division of Physical Therapy, University of North Carolina at Chapel Hill. This paper is based on G. L. Girolami's master's thesis entitled "Evaluating the Effectiveness of a Neurodevelopmental Treatment Physical Therapy Program to Improve the Motor Control of High-Risk Preterm Infants," University of North Carolina at Chapel Hill, 1987. Work on this project was partially supported by grants from the North Carolina Physical Therapy Association, the Smith Fund of the University of North Carolina at Chapel Hill, and grant 149 from the Maternal and Child Health Bureau, DHHS. Appreciation is expressed to E. N. Kraybill and I. J. Wilhelm for their assistance with subject recruitment and data collection.

APPENDIX: TREATMENT PROTOCOL

Supine

Treatment will occur in the therapist's lap or the isolette, head in midline, elongation of cervical spine; arms and shoulders on chest with scapular depression/elbow flexion; elongation of thoracic and lumbar spine; pelvis slightly off support surface; hips/knees flexed over abdomen. The goals described include postural control needed for the following functional activities: (1) stabilizing the trunk for free head movement; (2) tucking the body in for attaining positions of comfort; (3) moving into side lying from supine; (4) stabilizing the head in midline or other positions for attending behaviors; and (5) eventually for bringing hands together for reaching.

Goals

1. Head midline; head turning; increase strength and control in anterior neck muscles; elongate posterior neck muscles. Activities: Compression downward through shoulders to activate neck flexors, anterior chest; shoulder and abdominal muscles.
2. Ability to bring arms forward—hands to mouth, hands together on chest; increase strength of anterior shoulder and chest muscles; downward rotation and stabilization of scapulae. Activities: compression horizontally through shoulders to activate anterior chest and shoulder muscles; assist infant to bring hands to mouth or chest.
3. Lift pelvis and flexed legs from support surface; elongation of low back muscles, increased strength and control of abdominal muscles. Activities: compression upward from lifted pelvis with legs flexed over abdomen to activate abdominal, anterior neck and chest muscles.
4. Rolling from supine to right/left side, trunk flexor tone, righting reactions. Activities: weight shifting from side to side using small increments of movement and allowing the infant when possible to maintain his head and arms without help.

Prone

The infant will be treated while lying in the isolette or on the therapist's lap; arms positioned in flexion on either side of infant's chin; pelvis tilted posteriorly with hips flexed and knees under abdomen. The postural control goals are important for the following functional activities: (1) clearing face for breathing in prone and eventually pushing up on forearms; (2) tucking body and bringing hands to mouth for comfortable positioning; (3) looking for caregiver; and (4) eventually rolling from prone to supine.

Goals

1. Ability to lift head from support surface and turn right/left; increased strength and control of neck and upper back extensor muscles. Activities: compression downward through the shoulders to activate the neck and upper back extensor muscles.
2. Ability to bring hands next to mouth and shoulders; increased strength of anterior shoulder muscles. Activities: compression horizontally through the shoulders to activate anterior shoulder and scapular muscles.
3. Ability to stabilize with shoulders to lift and turn head; downward rotation and stabilization of scapulae. Activities: compression combined with elongation of one side and weight shifting over the elongated side to facilitate turning of the head.
4. Ability to maintain pelvis flexed up under abdomen; physiologic flexion and increased abdominal muscle strength. Activities: support under the abdomen to activate muscles.

Sitting

The infant will be treated in sitting in the bed or isolette or on the therapist's lap; head supported from behind with

Supplied by The British Library - "The world's knowledge"

elongation of cervical spine; back straight; pelvic alignment neutral; control over each shoulder to maintain depression and arms forward to midline; the infant should be tilted 10 to 15 degrees backward in space; hips/knees flexed in neutral alignment; slight upward traction of the trunk to inhibit back rounding. The postural goals are important for the following functional activities: (1) holding the head up in a seated position and eventually for controlling the arms for reaching and grasping; (2) maintaining the shoulders relaxed, trunk extended and head controlled against the force of gravity and during movement while being held upright and carried; and (3) stabilizing the head in a variety of positions in space for looking.

Goals

1. Ability to hold head upright and maintain in midline; increased strength and control of neck muscles, elongation of cervical spine. Activities: compression downward through shoulders to activate anterior neck, chest and abdominal muscles.
2. Ability to maintain scapular depression and bring hands to midline; increased strength of anterior neck muscles and downward scapular rotators. Activities: compression horizontally to activate shoulder and chest muscles; assist bringing hands to midline/mouth.
3. Ability to maintain chin tuck and flexed hips and knees in neutral rotation; integrated control of abdominal and back extensor muscles; increased strength of abdominal muscles; physiologic flexion. Activities: movement of supported head and trunk slightly backward to activate neck and abdominal muscles; movement of supported head and trunk laterally with elongation of weight-bearing side of trunk; partial turning movements of supported head and trunk.

Side Lying

The infant will be treated in side lying in the isolette or on the therapist's lap; head flexed slightly forward with capital flexion (chin tuck); arms forward to midline; elongation of thoracic and lumbar spine; neutral pelvis; hips/knees flexed up toward abdomen. The postural control goals are needed for the following functional activities: (1) maintaining a comfortable position in side lying; (2) bringing hands in to mouth; and (3) eventually to roll over and push up into sitting.

Goals

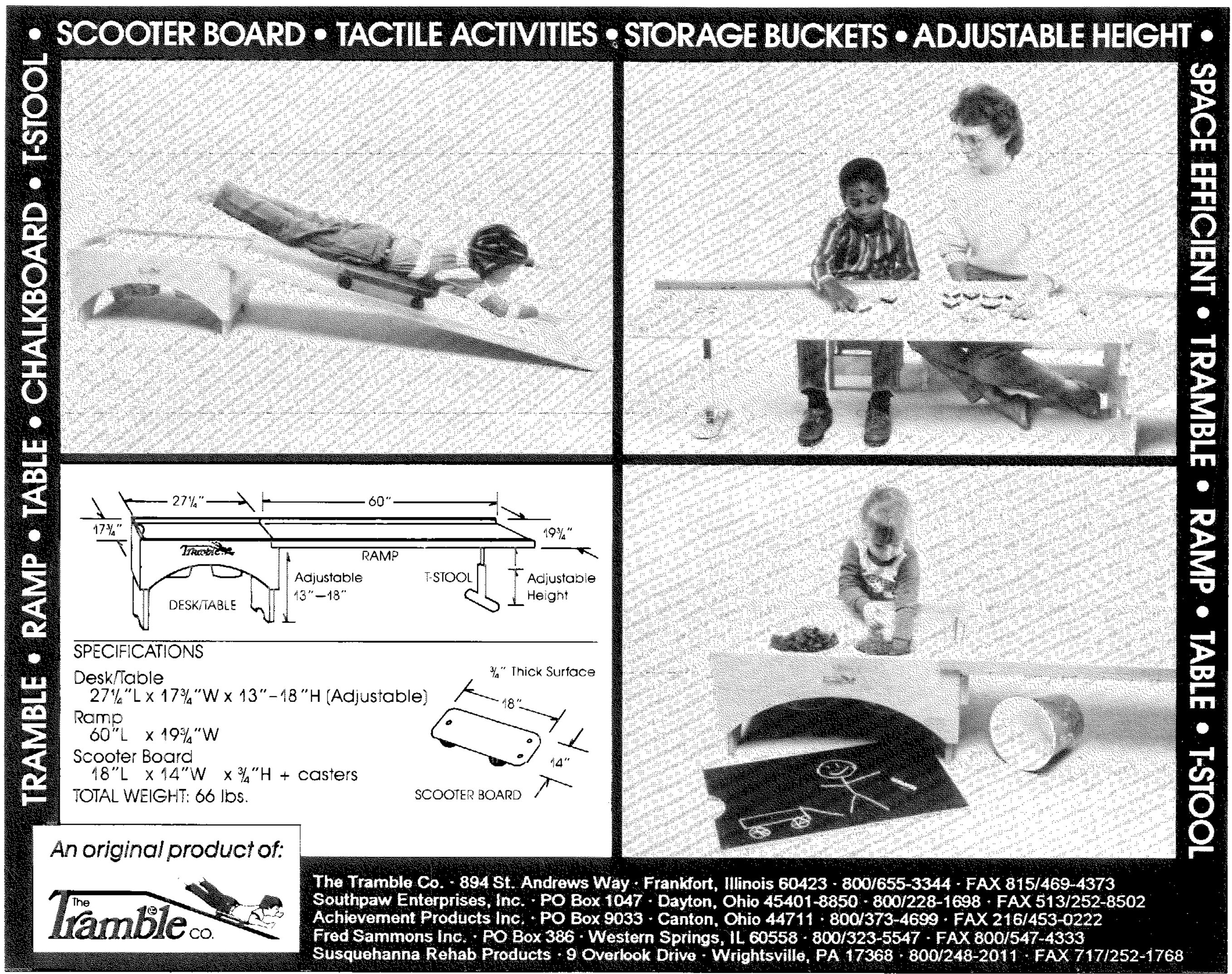
1. Ability to keep head flexed forward; increased strength of anterior neck muscles; elongation of cervical neck muscles. Activities: maintain chin tuck while bringing uppermost shoulder backward to activate anterior neck, chest and abdominal muscles; supporting infant with one hand under head and other over trunk and pelvis, rocking infant slowly backward to activate anterior neck, chest and abdominal muscles.
2. Ability to bring arms forward—hands to mouth, hands together on chest; increased strength of anterior chest and shoulder muscles; downward rotation and stabilization of scapulae. Activities: compression horizontally through the shoulders to activate anterior chest and shoulder muscles; assisting infant to bring hands to mouth/together in midline.
3. Ability to maintain pelvis in neutral alignment; hip and knee flexion; elongation of thoracic and lumbar muscles; increased strength and control of abdominal muscles. Activities: slight lateral lifting of the pelvis to elongate the weight-bearing side of the trunk, allowing facilitation of rolling while maintaining the forward flexed position of the head, neck, trunk and pelvis.

REFERENCES

1. Leviton A, Paneth N. White matter damage in preterm newborns—an epidemiologic perspective. *Early Hum Dev.* 1990;24:1–22.
2. Coolman RB, Bennett RC, Sells CJ, et al. Neuromotor development of graduates of the neonatal intensive care unit: Patterns encountered in the first two years of life. *J Dev Behav Pediatr.* 1985;6:327–333.
3. Piper MC, Mazer B, Silver KM, et al. Resolution of neurological symptoms in high-risk infants during the first two years of life. *Dev Med Child Neurol.* 1988;30:26–35.
4. Bertenthal BI, Campos JJ. New directions in the study of early experience. *Child Dev.* 1987;58:560–567.
5. Saigal S, Szatmari P, Rosenbaum P, et al. Cognitive abilities and school performance of extremely low birthweight children and matched control children at age 8 years. A regional study. *J Pediatr.* 1991;118:751–760.
6. Campbell SK, Siegel E, Parr CA, et al. Evidence for the need to renorm the Bayley Scales of Infant Development based on the performance of a population-based sample of twelve-month-old infants. *Top Early Childhood Special Ed.* 1986;6(2):83–96.
7. Papile L, Munsick-Bruno G, Schaefer A. Relationship of cerebral intraventricular hemorrhage and early childhood neurologic handicaps. *J Pediatr.* 1983;103:273–277.
8. Campbell SK. Effects of developmental intervention in the special care nursery. In: Wolraich M, Routh DK, eds. *Advances in Developmental and Behavioral Pediatrics, Vol 4.* Greenwich, Conn: JAI Press; 1983:165–179.
9. Brazelton TB. *Neonatal Behavioral Assessment Scale. Clinics in Developmental Medicine.* No 88, 2nd ed. Philadelphia: J. B. Lippincott; 1984.
10. Rosenblith J. The modified Graham Behavior Test for neonates: test-retest reliability, normative data and hypotheses for future work. *Biol Neonat.* 1961;3:174–192.
11. Neal MV. Organizational behavior of the premature infant. *Birth Defects.* 1979;15:43–50.
12. Scarr-Salapatek S, Williams ML. The effects of early stimulation of low-birth-weight infants. *Child Dev.* 1973;44:94–101.
13. Brown JV, LaRossa MM, Aylward GP, et al. Nursery based intervention with prematurely born babies and their mothers: are there effects? *J Pediatr.* 1980;97:487–491.
14. Leib SA, Benfield DG, Guidubaldi J. Effects of early intervention and stimulation on the preterm infant. *Pediatrics.* 1980;6:83–90.
15. Resnick MB, Eyler FD, Nelson RM, et al. Developmental intervention for low birth weight infants: improved early developmental outcome. *Pediatrics.* 1987;80:68–74.
16. Cherry D, Knutson L. Curriculum structure and content in pediatric physical therapy: results of a survey of entry-level PT programs. *Pediatr Phys Ther.* 1993;5:109–113.
17. Campbell SK. Efficacy of physical therapy in improving postural control in children with cerebral palsy. *Pediatr Phys Ther.* 1990;2:135–140.
18. Campbell SK. Expected outcomes of physical therapy for children with cerebral palsy: The evidence and the challenge. In: Sussman MD, ed. *The Diplegic Child: Evaluation and Management.* Rosemont, Ill: American Academy of Orthopaedic Surgeons; 1992:221–227.
19. Piper MC, Kunos VI, Willis DM, et al. Early physical therapy effects on the high risk infant: a controlled trial. *Pediatrics.* 1986;78:216–224.
20. Goodman M, Rothberg AD, Houstan-McMillian, et al. Effect of early neurodevelopmental therapy in normal and at-risk survivors of neonatal intensive care. *Lancet.* 1985;14:1327–1330.
21. Rothberg AD, Goodman M, Jacklin LA, et al. Six-year follow-up of early physiotherapy intervention in very low birth weight infants. *Pediatrics.* 1991;88:547–552.
22. Mayo NE. The effect of physical therapy for children with motor delay and cerebral palsy—a randomized clinical trial. AJ PM&R 1991;70:258–267.
23. Bower E, McLellan DL. Effect of increased exposure to physiotherapy on skill acquisition of children with cerebral palsy. *Dev Med Child Neurol.* 1992;84:25–39.
24. d'Avignon M, Noren L, Arman T. Early physiotherapy *ad modum* Vojta or Bobath in infants with suspected neuromotor disturbance. *Neuropediatrics.* 1981;12:232–241.

Supplied by The British Library - "The world's knowledge"

25. Girolami GL. *Evaluating the Effectiveness of a Neurodevelopmental Treatment Physical Therapy Program to Improve the Motor Control of High-Risk Preterm Infants.* Chapel Hill, NC: University of North Carolina; 1987. Master's thesis.
26. Campbell SK, Osten ET, Kolobe THA, et al. Development of the Test of Infant Motor Performance. PM&R Clin NA 4(3):541–550, 1993.
27. Portney LG, Watkins MP. Foundations of Clinical Research—Applications to Practice. Norwalk, CT: Appleton & Lange, 1993.
28. Saint-Anne Dargassies S. *Neurological Development in the Full-term and Premature Neonate.* New York: Excerpta Medica; 1977.
29. Paludetto R, Rinaldi P, Mansi G, et al. Early behavioral development of preterm infants. *Dev Med Child Neurol.* 1984;26:347–353.



A MESSAGE TO OUR SUBSCRIBERS

Williams & Wilkins and most other publishers seal issues of professional journals in polywrap bags to mail to subscribers. Although these bags are very effective in protecting issues from damage during transport, they are not biodegradable and pose serious environmental problems. A number of you have written to us to suggest that we change to biodegradable plastic or paper wrappers or no wrappers at all. We have considered the alternatives and have chosen the one imposing the least environmental threat—no wrappers for issues mailing to addresses within the United States. Second class postage regulations require that wrappers be used to mail issues outside the United States.

We hope your issues of *PEDIATRIC PHYSICAL THERAPY* arrive in good condition. If they do not, please call us at 1-800-638-6423.

ALMA J. WILLS
President
Periodical Publishing

Supplied by The British Library - "The world's knowledge"