

## **AACPDM Evidence Report: Effects of Neurodevelopmental Treatment (NDT) for Cerebral Palsy**

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**Objective**

The objective of the American Academy for Cerebral Palsy and Developmental Medicine (AAPDM) evidence reports is to provide the biomedical research and clinical practice communities with the current state of evidence about various interventions for the management of developmental disabilities. The AAPDM evidence reports aggregate all that has been published about outcomes of an intervention for a medical condition, gauge the credibility (i.e., strength of the internal validity) of that evidence, and identify gaps in our scientific knowledge.

The AAPDM reviews are not evidence-based “practice guidelines”. As yet, the bodies of evidence in many areas of developmental medicine are neither robust nor comprehensive enough to allow confident generalization to groups of people-at-large: a prerequisite for evidence-based practice guidelines. Moreover, absence of evidence of effectiveness in an evidence report should not be construed as proof that a treatment is not effective; rather, it may reflect areas in which more meaningful research is needed. In the meanwhile, clinicians must be circumspect about their treatment recommendations, relying on current “best evidence” to inform individual choice.<sup>a</sup>

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<sup>a</sup> “Best evidence” is represented by the study (or studies) in the evidence report that most closely approximates the patient characteristics of interest to the clinician, that uses a therapeutic regime most like the one the

### **Disclosure Statement**

Every effort has been made to assure that AACPDM Evidence Reports are free from any real or perceived bias. The Academy's editorial review panel is a multidisciplinary group comprised of the current members of the AACPDM Treatment Outcomes Committee who serve 3-year rotating terms. This Committee may invite up to two additional reviewers to encourage substantive input by knowledgeable proponents of all points of view. Potential conflicts of interest by authors and reviewers have been disclosed and are documented in *The AACPDM Database of Evidence Reports*. The Treatment Outcomes Committee is charged and overseen by the AACPDM Board of Directors with this task and operates under an approved methodology of systematic review of the scientific literature and approved procedures.<sup>1,2</sup> Final sanction for each report is granted by the Board.

### **Consensus Process**

The review authors organize intervention outcomes in a predefined manner and answer predefined questions to describe the scientific evidence. Members of the review panel give their input and resolve any differing opinions to reach agreement about statements made therein on behalf of the Academy.

Nevertheless, the data in an AACPDM Evidence Report can be interpreted differently, depending on people's perspectives. Please consider the conclusions presented carefully.

### **Neurodevelopmental treatment (NDT)**

#### **HISTORICAL PERSPECTIVE**

The Bobaths, a physical therapist and a neuropsychiatrist respectively, were pioneers in the treatment of cerebral palsy (CP). As early as the 1940's, they began to develop an approach that grew out of Berta Bobath's clinical observations and was initially understood in the context of the reflex, hierarchial, and maturation theories of neuroscience at that time. Through their writing and lectures, their training courses given by them and other trained instructors, the Bobath approach--also known as 'neurodevelopmental treatment'(NDT)--spread so widely that NDT has heavily influenced physical, occupational and speech therapy for children with CP for half a century.<sup>3</sup>

According to the Bobaths<sup>4</sup>, the motor problems of cerebral palsy arise fundamentally from central nervous system (CNS) dysfunction which interferes with the development of normal postural control against gravity and impedes normal motor development. Their goal was the establishment of normal motor development and function and/or the prevention of contractures and deformities. Their neurodevelopmental approach focused on sensorimotor components of muscle tone, reflexes and abnormal movement patterns, postural control, sensation, perception, and memory (i.e., components thought most likely to be impaired as a result of CNS damage). Handling techniques that controlled various sensory stimuli were used to inhibit spasticity, abnormal reflexes, and abnormal movement patterns and were also

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clinician can provide, that investigates outcomes of greatest concern to this patient, and that provides the most credible or internally valid results.

used to facilitate normal muscle tone, equilibrium responses, and movement patterns. The child was a relatively passive recipient of NDT treatment. The normal developmental sequence was advocated as a framework for treatment.

As the Bobaths gained experience through the years and as additional knowledge of neuroscience became available, they changed their approach to, and emphasis on, certain aspects of the treatment. They described key points of how the treatment approach had evolved in their last publication about NDT in 1984.<sup>4</sup> In the beginning, they advocated placing children in ‘reflex-inhibiting’ postures. While these postures did reduce spasticity, the Bobaths came to recognize in time that there was no carryover into movement and function. They then promoted “key points of control” in which the therapist inhibited abnormal patterns of movement and facilitated more normal movements while the child was moving. Eventually, the Bobaths came to believe that they had concentrated too much on the facilitation of automatic righting reactions under the faulty assumption that the child would spontaneously translate this therapeutic experience into voluntary functional movements. Hereafter, they began to appreciate that it is necessary for the child to, increasingly and systematically, take over control of his own movement, especially of balance. The Bobaths concluded, too, that it had been erroneous to promote the rigid following of normal developmental sequence. Finally, the Bobaths discussed their realization that their treatment had not automatically carried over into activities of daily life, as they had expected it would be. Consequently, systematic preparation for specific functional tasks was instituted with the aim of treating the children in actual settings where they live, play, and learn.

#### IN THE FIELD

Therapists who attended an NDT training course seldom had continuing education in neurodevelopmental treatment although they may have joined the NDT Association.<sup>b</sup> Consequently, the practice of NDT in the field has not necessarily kept pace with the evolution experienced by the Bobaths and their closer associates.

The literature reflects a variable state of practice in the field<sup>5</sup>, as well as confusion about current NDT treatment principles and their theoretical construct.<sup>6-9</sup> There is controversy about whether the principles of NDT treatment influenced initially by the reflex and hierarchical models of motor control are still valid in light of current models which do not focus exclusively on neural explanations of motor performance.<sup>8</sup> Psychological components and environmental contexts are non-neural explanations. In a systems model of motor control, for example, the central nervous system is only one system among many that influence motor behavior.

#### ISSUES IN DETERMINATING EFFECTIVENESS

It is difficult to evaluate the effectiveness of any motor therapy approach for a host of reasons. Chief among them is that these are not specific treatments that are delivered in a standardized manner. In other words, there is no discrete dosage administered under specific, invariable procedures in conditions that are held constant. The dosage or amount of time in therapy could be held constant, but the procedures depend upon the therapists’ skill

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<sup>b</sup> With the death of the Bobaths in 1991, the NDT Association, Inc. carries on the neurodevelopmental approach.

level and specific aims and vary accordingly. While the treatment setting (a condition of treatment) could be standardized, the child's family (another condition of treatment) could never be.

Evaluating the effectiveness of NDT is confounded further because the skill level of the therapists in these studies is seldom clear, the constructs of NDT itself have changed over time, and NDT strategies are commonly combined with other therapy techniques and medical treatments.

There are, also, all the problems attendant on any research involving low incidence and highly heterogeneous conditions complicated by ongoing change in the participants due to the process of growth and maturation. Finally, there are issues of different outcomes of interest among the researchers and the different ways chosen to measure them.

In spite of these obstacles, it is important to document what has been investigated about NDT because of its continuing and widespread influence in management of CP and because of the discrepant practice and understanding about it in the field. The conceptual framework adopted by the AACPD for reviewing treatment-outcomes literature may offer the best means available for aggregating disparate research results to shed light on both biological and social outcomes of this intervention.<sup>10</sup>

## **Method of review**

### INCLUSION CRITERIA

This review included studies in which the intervention (1) was stated to be exclusively NDT, 2) was stated to be NDT but combined with other sensorimotor techniques, or 3) could be identified by the review authors as NDT-based therapy from description of procedures that specified inhibition of primitive and pathological reflexes, facilitation of postural reactions, and normalization of muscle tone.

The review is limited to studies in which all the participants were diagnosed with cerebral palsy (CP) or studies in which there was specific data for those with CP. The participants may have also had additional impairments common in CP, e.g., mental retardation or related developmental disabilities.

### LITERATURE SEARCH

The literature search included MEDLINE (1956 through April, 2001), HealthSTAR (1975-2000), ClinPSYC (1989-2000), CINAHL (1982-April 2001), Best Evidence (1991-2000), and Cochrane Database of Systematic Reviews (4<sup>th</sup> quarter 2000) for studies published in English. The electronic search terms were "NDT OR neurodevelopmental treatment AND therapy AND cerebral palsy". Reference lists in studies and review articles and researchers knowledgeable about this intervention were also consulted. Sixty-five citations were examined. Of that number, 44 articles were excluded for one or more of the following reasons: they were descriptive or review articles, their data contained children with diagnoses other than cerebral palsy or prior to a diagnosis of CP, or intervention could not be determined to be "primarily" NDT. Twenty-one studies met the inclusion criteria.

### CLASSIFICATION OF THE RESULTS

All reported results of NDT were classified on the basis of 1) what kind of evidence there is (i.e., dimensions of disablement) and 2) how good or convincing the evidence is (i.e., levels

of evidence).<sup>c</sup> Dimensions of disablement (Table I) is a concept and a classification system that facilitates the measurement, management, and research of rehabilitation outcomes and minimizes the barriers between medical and social models of rehabilitation.

**Table I. Dimensions of disability<sup>1</sup>**

<b>Dimension</b>	<b>Description</b>
Pathophysiology	Interruption or interference of normal physiology and developmental processes or structures
Impairment	Loss or abnormality of body structure or function
Functional Limitation / Activity	Restriction of ability to perform activities
Disability / Participation	Restricted participation in typical societal roles
Societal Limitation / Context Factors	Barriers to full participation imposed by societal attitudes, architectural barriers and social policies and other external factors, i.e., family circumstances

Levels of evidence classifications and other quality-rating schemes are based on (1) a hierarchy of research designs that range from the greatest to least according to ability to reduce bias combined with (2) a means of assessing the thoroughness with which the particular research study was conducted.<sup>d</sup> Generally speaking, Level I studies produce the most credible evidence and, thus, yield the most definitive results.<sup>11</sup> Level II studies, based on less convincing evidence, produce tentative conclusions. Levels III and IV reflect still less persuasive evidence and merely suggest causation. No conclusions regarding treatment efficacy can be drawn from Level V evidence.

The AACPDm levels of evidence classification (Table II), unlike some other classifications, is limited to gauging only the internal validity of a study, i.e., its ability to demonstrate that the intervention—and not other factors in that study—was responsible for the observed outcomes. External validity, or the confidence with which a finding might be expected to be true for others outside the study, is not reflected in this classification. Instead, whether a finding can be expected to generalize is believed to be more appropriately determined by individual users of the evidence reports who will focus on only the specific aspects of similarity between a patient of interest and the people who have been studied (e.g., their age, type and severity of cerebral palsy, conditions of treatment).

**Table II. Levels of evidence. <sup>1</sup> Maximum level of evidence is determined by research design; conduct of study may result in reduction of level of evidence by one level**

<sup>c</sup> The rationale and specific guidelines followed for classifying the treatment outcomes are available on the Academy’s Internet web site at [www.aacpdm.org](http://www.aacpdm.org). in the document titled “AACPDm Methodology for Developing Evidence Tables and Reviewing Treatment Outcomes Research”.

<sup>d</sup> The concept of a “quality determination” for articles used in systematic reviews is a matter of some debate. The science of critical appraisal of research, initially developed in internal medicine, is an on-going process. It is additionally difficult to apply this concept to research about disabling conditions in developing children. Despite the considerable challenge, there is agreement that teams developing systematic reviews can take certain steps to ensure that their approaches to grading the quality of research results meet current scientific standards.

Level	Non-empirical	Group Research	Outcomes Research	Single Subject Research
I		Randomized controlled trial All or none case series		N-of-1 randomized controlled trial
II		Nonrandomized controlled trial Prospective cohort study with con-current control group	Analytic survey	ABABA design Alternating treatments Multiple baseline across subjects
III		Case-control study Cohort study with historical control group		ABA design
IV		Before and after case series without control group		AB design
V	Descriptive case series or case reports Anecdote Expert opinion Theory based on physiology, bench, or animal research Common sense/ first principles			

**Summary tables**

Table III summarizes the interventions, control conditions, and participants in the 21 studies. In deference to the ethical concern of withholding a treatment intervention from a group of children for the formation of a “no treatment” control group, five studies<sup>13,14,19,27,30</sup> compared NDT to some other intervention, and one compared a greater intensity of NDT to a lesser intensity<sup>25</sup>. Two studies compared a “no treatment” control period with a group that got NDT.<sup>12,15</sup> Seven studies<sup>16,17,22-24,28,29</sup> used single subject methodology in which participants acted as their own controls during relatively short phases of no treatment (i.e., 25 days to 4 months) and four compared motor status before and after treatment with no control condition.<sup>18,26,32</sup> In two studies, NDT was the control for another intervention investigating maternal and child factors.<sup>21,26</sup>

**Table III. Summary of studies--interventions and participants**

Study	NDT Intervention	Control Intervention	Population	Total n	Ages
1973 Wright <sup>12</sup>	Bobath method	Untreated period	Spastic type: 11 diplegia, 16 hemiplegia, 20 quadriplegia; no mixed or post-natal types, previous ortho surgery or "intensive" PT; 12 epileptic; 19 MR	47	> 6 mo-6 yr
1975 Carlsen <sup>13</sup>	Facilitation ① group therapy 1 hr. 2/wk.	Functional	Mild-moderate spastic, athetoid or both, diplegia, hemiplegia, or quadriplegia	12	1-5 yr.
1976 Scherzer <sup>14</sup>	Neurophysio-logic individual therapy ① 2/wk	Traditional therapy	Mild-severe: 6 spastic, 13 athetoid, 1 ataxic, MR-normal IQ; ②	20	5-17 mo.
1981 Sommerfeld <sup>15</sup>	NDT ① individual therapy 30 min. 2/wk.	Group 1 Untreated period Group 2 ③	Severely MR with mild-severe CP: 15 spastic quadriplegia, 11 other spastic types, 2 athetoid, 1 ataxic	29	3-22yr
1983 DeGangi <sup>16</sup>	NDT individual therapy 25 min. 2/wk.	Play	1 mild hemiplegia, 1 quadriplegia, 1 mild diplegia, 1 moderate hypotonia; 3 normal cognition, 1 borderline	4	10-22 mo.
1985 Laskas <sup>17</sup>	NDT individual therapy 20 min. daily + 1 h/wk.	Play	Mild spastic quadriplegia; normal IQ and receptive language; delayed speech	1	2.5 yr.
1987 Herndon <sup>18</sup>	NDT individual therapy 1 h/day	None	11 spastic, 1 athetoid: 7 mild, 2 moderate, 3 severe	12	6-14 yr.
1988 Palmer <sup>19</sup>	<u>Part 1:</u> NDT individual therapy 1h /every 2 wk + home program  <u>Part 2:</u> NDT continued	<u>Part 1:</u> Infant stimulation: "Learning games"  <u>Part 2:</u> same as NDT protocol	Spastic diplegia by specified neurologic/functional measures ④; moderate MR to normal IQ; no confounding variables ⑤	48	12-19 mo.
1989 Hanzlik <sup>20</sup>	NDT: OT 1h individual session	1h mother-child interaction instruction	Cerebral palsy: hemiplegia, diplegia, quadriplegia; mild-severe; mobile and non-mobile	20 ⑥	8-32 mo.
1990 Palmer <sup>21</sup>	NDT individual therapy 1h/2 wk.	Infant stimulation "Learning games"	Same Palmer 1988 study	47 ⑥	12-19 mo.

NDT 8

1990 Lilly <sup>22</sup>	NDT individual therapy 1 and 2h/wk	Play	Spastic diplegia ④; near or normal IQ	2	27, 32 mo.
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(Table III, continued)

1990 Embrey <sup>23</sup>	NDT individual therapy 20 min.	None	Ambulatory spastic diplegia ④	1	2 yr.
1990 Kluzik <sup>24</sup>	NDT individual therapy 35 min.	None	Spastic quadriplegia; mild-moderate involvement	5	7-12 yr.
1991 Law <sup>25</sup>	Intensive NDT 45 min./wk.+ 30 min/day home program	NDT 45 min. 1/mo. to 1/wk. + 15 min. 3/wk. home program	Spastic hemiplegia or quadriplegia; spasticity of wrist and hand; no fixed wrist contracture or severe developmental disability	36⑦	18 mo.-8 yr.
1994 DeGangi <sup>26</sup>	NDT individual therapy 30 min. 2/wk.	None	Severe spastic quadriplegia; cognitive and language delay	1	2 yr.
1994 Bower <sup>27</sup>	Bobath individual therapy 30-60 min. 1-2/wk.	Group 1: Conductive ed. Group 2: aim-oriented therapy Group 3: eclectic therapy	Spastic quadriplegia: mild to severe	30	18 mo.-8 yr.
1996 Fetters <sup>28</sup>	NDT individual therapy 35min., 5X	Skill practice	Spastic quadriplegia, normal IQ, able to sit, see and reach object, understand and carry out spoken directions, use computer	8	10-15 yr.
1997 Jonsdottir <sup>29</sup>	NDT individual therapy 35 min., 5X	Skill practice	Same participants as Fetters study	8	10-15 yr.
1997 Law <sup>30</sup>	Intensive NDT 45 min. 2/wk.+ home program 30 min./day + UE cast 4 h/day	Functional skills OT	Moderate-severe upper extremity involvement CP with flexed hand posture; no fixed wrist contracture, severe cognitive impairment, or use of antispasticity drugs	50	18 mo. -4 yr.
1999 Trahan <sup>31</sup>	NDT individual therapy 45min 2/wk	None	Mild-severe; 24 quadriplegia; 16 hemiplegia; 10 diplegia; no behavior problems	50	12-79 mo.
2000 Adams <sup>32</sup>	NDT 1h 2/wk.	None	Ambulatory, 11with aids; spastic diplegia 18, hemiplegia 11, triplegia 3; ataxia 5; athetoid 3; severe 15, moderate 19, mild 3	40	2-10 yr.

Legend:

①	Included neurodevelopmental treatment principles advocated by Bobath, Rood and Ayres
②	Two participants did not have CP but, given individual data reported, review authors recalculated results on data for the 20 who did have CP
③	Supervised PT management but no direct therapy
④	Specific motor responses and/or abilities detailed in article
⑤	Absence of degenerative disorders, use of tone-altering drugs, contractures, hip dislocation or

	subluxation, severe pharyngeal impairment, previous PT or orthopedic surgery, hearing or visual impairment, IQ lower than 40, parents judged to lack compliance
⑥	Mother-child dyads
⑦	Total n=76 in 4 groups but results related to the 2 other groups which included casting +NDT are excluded

Table IV summarizes the research methodologies. Level of evidence was determined on the basis of research design modified by the actual conduct of the study to indicate quality of the evidence. In other words, studies were first weighted by the type of research design used, then reduced one level if the particular study did not control threats to internal validity that are theoretically possible within the research design.<sup>e</sup>

**Table IV. Summary of studies--research methods**

Study	Research Design	Level of Evidence	Treatment Duration	NDT Rx n	Control Rx n
1973 Wright 12	RCT (3 groups) External comparison 1 External comparison 2 Internal comparison	II	~ 6 mo. 12 mo. 6 mo.	~ 16 7 9	~ 31 10 9
1975 Carlsen 13	RCT (Paired then assigned to 2 groups)	II	6 wk.	6	6
1976 Scherzer 14	RCT (2 groups)	II	7-21 mo.	14	6
1981 Sommerfeld 15	Concurrent cohort study Control group 1 Control group 2	II	5 mo.	10	~ 9 10
1983 DeGangi 16	Multiple crossover trial	II	5 wk.	4	①
1985 Laskas 17	ABA design	III	25 days	1	①
1987 Herndon 18	Before and after case series without controls	IV	6 wk.	12	None
1988 Palmer 19	RCT (2 groups) Part I Part II	I I	6 mo. 12 mo.	25 25	23 23
1989 Hanzlik <sup>20</sup>	Concurrent cohort study	II	2 wk.	10 ③	10 ③
1990 Palmer 21	RCT (2 groups)	I	12 mo.	25 ③	22 ③
1990 Lilly 22	Multiple crossover trial	II	12 wk.	2	①
1990 Embrey 23	A-B-A-BC-A trial	II	15 wk.	1	①
1990 Kluzik 24	AB design	IV	4 wk.	5	①
1991 Law 25	RCT (2 of 4 groups reported: intensive vs. regular amt. NDT)	I	9 mo.	18	18
1994 DeGangi 26	Case study	V	8 wk.	1	0

<sup>e</sup> The AACDPM methodology is based on current scientific standards for analyzing and weighting studies for bias and error. Nevertheless, this type of critical appraisal is a new endeavor in medicine, in general, and within the Academy, in particular. The AACDPM methodology will continue to evolve both with experience and as the science of critical appraisal improves. Therefore, the assigned level of evidence should be regarded as an estimate, and relative to other studies, rather than an absolute.

1994 Bower <sup>27</sup>	Concurrent cohort study (4 groups)	III	1-6 mo.	8	22
1996 Fetters <sup>28</sup>	Multiple crossover trial	II	4 wk.	8	①
1997 Jonsdottir <sup>29</sup>	Multiple crossover trial	II	4 wk.	8	①
1997 Law <sup>30</sup>	RCT (2 groups) crossover with washout	I	4 mo.②	50	①
1999 Trahan <sup>31</sup>	Before and after case series	IV	8 mo.	50	0
2000 Adams <sup>32</sup>	Before and after case series	IV	6 wk.	40	0

Legend:

①	Participants were their own controls
②	Each group received 4 months of treatment then crossed over to the opposite treatment after a 2-month washout period
③	Mother-infant dyads

Table V summarizes 101 results from the studies and shows the coding of each for the dimension of disability and level of evidence it represents. Clinical importance or relevance (seldom explicit in studies), and statistical information are included, to the extent these are available.

**Table V. Summary of studies--outcomes, measures, and results. These results reflect effects of NDT when compared to another condition, to status before treatment, to a period of no treatment when participants acted as their own controls, or when a greater intensity of NDT was compared to a lesser intensity.**

Study	Outcome of Interest	Dim. of Disability	Measure	Result	Clin. Imp.	Statistics	Level of Evidence
1973 Wright <sup>12</sup> ①	Automatic reflexes	I	Rated observation	ND		NS	II
	ROM (2 movements)	I	Not specified	ND		NS	II
	Gross motor activities	FL/A	Rated observation	-		NS	II
1975 Carlsen <sup>13</sup>	Motor age	I	Bayley Motor Scale	+		p<.05	II
	Gross motor age	I	DDST, Motor Scale	+		p<.05	II
	Fine motor age	I	DDST, F. Motor Scale	+		NS	II
	Social age	I	DDST, Social Scale	+		NS	II
	Language age	I	DDST, Lang. Scale	+		NS	II
1976 Scherzer <sup>14</sup>	Physiologic function	I	Motor Dev. Evaluation	+	yes		II
	Social activities	FL/A	Questionnaire	ND			II
	Home management	SL/C	Questionnaire	ND			II
1981 Sommerfeld <sup>15</sup>	Dev. reflexes	I	Wilson DR Test	-		NS	II
	Gross motor age	I	Gross Motor	-		NS	II
	ROM (6 movements)	I	ROM Scale	~		NS	II
1983 DeGangi <sup>16</sup>	Positioning/activities	FL/A	Rated observations			NS	II
1985 Laskas <sup>17</sup>	ROM (dorsiflexion)	I	Biofeedback instrument	+		p=.002	III
	ROM (heel strike)	I	Biofeedback instrument	+	yes	②	III
1987 Herndon <sup>18</sup>	ROM (hip flexion)	I	Goniometer	ND	~	~	IV
	ROM (hip abduct.)	I	Goniometer	ND	~	~	IV
	ROM (knee)	I	Goniometer	ND	~	~	IV
	ROM (dorsiflexion)	I	Goniometer	+	yes	~	IV
	Rising from chair	FL/A	Video analysis	ND		NS	IV
	Walking	FL/A	Video analysis	ND		NS	IV
	Turning	FL/A	Video analysis: walking	ND		NS	IV
	Trunk rotation	I	Video analysis: walking	ND		NS	IV
	Trunk rotation	I	Video analysis: sitting	ND		NS	IV
	Postural alignment	I	Video analysis: sitting	ND		NS	IV
	Weight shift	I	Video analysis: sitting	ND		NS	IV
	Assuming position	FL/A	Video analysis: sitting	ND		NS	IV

1988 Palmer <sup>19</sup> ③	<u>Part I</u>	~	~		~	~
	Motor age	I	Bayley Motor Scale	-	p=.02	I
	Motor milestones	FL/A	Attainment defined skills	ND	NS	I
	Walking attainment	FL/A	Observation/defined skill	ND	NS	I
	Tone/spasticity/reflexes	I	Neurological exam	ND	NS	I
	Mental age	I	Bayley Mental Scale	+	NS	I
	Social age	I	Vineland Social Maturity Sc.	ND	NS	I
	<u>Part II</u>	~	~		~	~
	Motor age	I	Bayley Motor Scale	-	p<.01	I
	Spasticity	I	Neurological exam	-	NS	I
	LE reflexes	I	Neurological exam	-	p<.05	I
	Joint limitation/ROM	I	Bracing recommended	ND	NS	I
	Contractures/ROM	I	Surgery recommended	ND	NS	I
	Motor milestones	FL/A	Attainment defined skills	~	NS	I
	Age/independent walking	FL/A	Observation/defined skill	-	p=.01	I
	Mental age	I	Bayley Mental Scale	ND	NS	I
	Social age	I	Vineland Social Maturity Sc.	ND	NS	I
1989 Hanzlik <sup>20</sup>	Infant compliance	I	Video analysis: DMIB	-	p<.05	II
	Infant responsiveness	I	Video analysis: DMIB	-	p<.003	II
	Independent play	FL/A	Video analysis: DMIB	ND	p=.18	II
	Maternal directness	SL/C	Video analysis: DMIB	-	p<.02	II
	Maternal initiation	SL/C	Video analysis: DMIB	-	p<.001	II
	Maternal responsiveness	SL/C	Video analysis: DMIB	-	p<.05	II
	Adaptive seating provision	SL/C	Video analysis: DMIB	-	p<.0005	II
	Maternal holding	SL/C	Video analysis: DMIB	ND	p=.199	II
	Face to face contact	SL/C	Video analysis: DMIB	-	p<.00005	II
	Physical contact	SL/C	Video analysis: DMIB	-	p<.002	II

(Table V. continued)

1990 Palmer <sup>21</sup>	Infant activity	I	CITQ	-	~	NS	I
	Infant rhythmicity	I	CITQ	+	~	NS	I
	Infant adaptability	I	CITQ	-	~	NS	I
	Infant approach	I	CITQ	+	~	NS	I
	Infant threshold	I	CITQ	ND	~	NS	I
	Infant intensity	I	CITQ	+	~	NS	I
	Infant mood	I	CITQ	ND	~	NS	I
	Infant distractibility	I	CITQ	+	~	NS	I
	Infant persistence	I	CITQ	+	~	NS	I
	Maternal acceptance	SL/C	RMCRE	-	~	NS	I
	Maternal overprotection	SL/C	RMCRE	+	~	NS	I
	Maternal overindulgence	SL/C	RMCRE	+	~	NS	I
	Maternal rejection	SL/C	RMCRE	-	~	NS	I
	Maternal responsiveness	SL/C	HOME	+	no	p>.04	I
	Maternal involvement	SL/C	HOME	+	~	NS	I
	Restriction avoidance	SL/C	HOME	+	~	NS	I
	Environment organization.	SL/C	HOME	+	~	NS	I
	Play materials	SL/C	HOME	+	~	NS	I
Variety of stimulation	SL/C	HOME	+	~	NS	I	
1990 Lilly <sup>22</sup>	Physiologic function	I	Rate of movements	ND	~	Ⓣ	II
1990 Embrey <sup>23</sup>	ROM (knee flexion)	I	Goniometer ; video	+		Ⓣ	II
1990 Kluzik <sup>24</sup>	UE movement time	I	Video; kinematics	+	~	p<.025	IV
	UE movement unit	I	Video; kinematics	+	~	p<.075	IV
	% of reach in 1 <sup>st</sup> unit	I	Video; kinematics	+	~	p=.025	IV
	UE associated reactions	I	Video; kinematics	ND	~	NS	IV
1991 Law <sup>25</sup> Ⓣ	Fine motor age	I	Peabody FM Scale	-		p=.63 NS	I
	Physiologic hand function	I	QUEST	ND		p=.82 NS	I
1994 De Gangi <sup>26</sup>	Qualitative movement	I	Video analysis; checklist	+	yes		V
1994 Bower <sup>27</sup>	Gross motor skills	FL/A	Goal setting/GMFM	+	small	NS	III
	Parent satisfaction	SL/C	Questionnaire	+	~	NS	III
1996 Fetters <sup>28</sup>	UE movement time	I	Kinematic analysis: reach	ND		NS	III
	UE movement unit	I	Kinematic analysis: reach	ND		NS	III
	UE reaction time	I	Kinematic analysis: reach	ND		NS	III
	UE displacement	I	Kinematic analysis: reach	ND		NS	III
1997 Jonsdottir <sup>29</sup>	Postural alignment	I	PAS	ND	~	NS	III
	Postural alignment	I	Kinematic analysis	ND	~	NS	III
1997 Law <sup>30</sup>	Fine motor age	I	Peabody Fine Motor Scale	ND	no	NS	I
	Physiologic UE function	I	QUEST	ND	no	NS	I
	Hand activities	FL/A	COPM	ND	no	NS	I
	Parent satisfaction	SL/C	Rating scale	ND	no	NS	I
1999 Trahan <sup>31</sup>	Gross motor activities	FL/A	GMFM	+	~	p<.05	IV
2000 Adams <sup>32</sup>	Gait: stride length	I	Pedographs	+	small	p=.003	IV
	Gait: step length	I	Pedographs	+	small	p=.001	IV
	Gait: cadence	I	Pedographs	+	small	NS	IV
	Gait: velocity	I	Pedographs	+	small	p=.001	IV
	Gait: foot angle	I	Pedographs	+	small	p=.036	IV
	Gait: base of support	I	Pedographs	+	small	NS	IV

Legend for Table V:

DDST	Denver Developmental Screening Test
COPM	Canadian Occupational Performance Measure
QUEST	Quality of Upper Extremity Skills Scale
RMCRC	Roth Mother-Child Relationship Evaluation
CITQ	Carey Infant Temperament Questionnaire
HOME	Home Observation for Measurement of the Environment
PAS	Postural Assessment Scale
DMIB	Dictionary of Mother-Infant Behaviors
GMFM	Gross Motor Function Measure
①	Results of Rx group compared to aggregated control groups
②	Trend and level analysis
③	Power calculations reported, but sample size not achieved
+	Result favored NDT
-	Result did not favor NDT
ND	Result not different between groups or after treatment
NS	Result not statistically significant
~	<i>Holding space in table for clarification to publisher-should appear as blanks in publication</i>
UE; LE	Upper extremities; lower extremities
I; FL/A; SL/C	Impairment; Functional Limitation/Activity; Societal Limitation/Context Factors

**Evidence table**

ORGANIZATION

Table VI aggregates these 101 types and frequencies of results in columns that allow a quick visual assessment of the number of results that favored NDT (17) versus those that favored the control condition (12) versus those that were either unchanged, not different between groups, or the difference was not statistically significant (72). Each result is entered as a superscript citation associated with a level of evidence (I through V). By rows, one can see which dimensions of disability have been targeted for investigation and which types and how often outcomes have been measured. For example, motor activities have been investigated 14 times, in eight different studies, with one result that showed an advantage for children who received NDT or more intensive NDT. The confidence with which one can regard these findings about motor activities is relatively high considering that all but two of the results reflect Level I or II evidence.

**Table VI. Evidence table--outcomes of NDT for CP. Each outcome is indicated by a subscript that is the citation number of each study that produced this result associated with a level of evidence (coded I - V)**

Each entry reflects how NDT fared when compared to another condition, to status before treatment or to a period of no treatment when participants acted as their own controls, or when a greater intensity of NDT was compared to a lesser intensity (see bold items **I<sup>19,25,30</sup>**).

<b>Outcomes by Dimensions of Disability</b>	<b>Results Favoring NDT (Statistically Significant)</b>	<b>Results Favoring NDT (But Not Statistically Evaluated )</b>	<b>Results Favoring Control (SS)</b>	<b>Results Not Different or Not Statistically Significant</b>
<b>Pathophysiology</b>				
<b>Impairment</b>				
<u>Motoric responses</u> : physiologic motor function, qualitative movement; tone; spasticity; reflexes; weight shift; posture, postural alignment; trunk rotation; UE associated reactions, reaction time, displacement, movement time, movement units, % of reach; gait stride length, step length, velocity, foot angle, cadence, base of support	IV <sup>24, 24, 32, 32, 32, 32</sup>	II <sup>14</sup> V <sup>26</sup>	<b>I<sup>19</sup></b>	I <sup>19</sup> <b>I<sup>19, 25, 30</sup></b> II <sup>12, 15, 18, 18, 18, 18, 22</sup> III <sup>28, 28, 28, 28, 29, 29</sup> IV <sup>24, 24, 32, 32</sup>
<u>Contractures and deformity</u> : range of motion or joint limitation of hip, knee, ankle	II <sup>23</sup> III <sup>17, 17</sup>	IV <sup>18</sup>		<b>I<sup>19, 19</sup></b> II <sup>12, 15, 18, 18, 18</sup>
<u>Motor development</u> : motor age, gross motor age, fine motor age	II <sup>13, 13</sup>		I <sup>19</sup> <b>I<sup>19</sup></b>	<b>I<sup>25, 30</sup></b> II <sup>13, 15</sup>
<u>Other domains development and function</u> : social age, mental age, language age, temperament (compliance, responsiveness, activity, rhythmicity, adaptability, approach, threshold, intensity, mood, distractibility, persistence)			II <sup>20, 20</sup>	I <sup>19,19, 21, 21, 21, 21, 21, 21, 21, 21, 21</sup> <b>I<sup>19, 19</sup></b> II <sup>13, 13</sup>
<b>Functional Limitation/Activity</b>				
<u>Motor activities</u> : Gross motor milestones and activities, walking, turning, rising from sitting, hand activities, independent play	IV <sup>31</sup>		<b>I<sup>19</sup></b>	I <sup>19, 19</sup> <b>I<sup>19, 30</sup></b> II <sup>12, 16, 18, 18, 18, 18, 20</sup> III <sup>27</sup>
<u>Social activities</u>				II <sup>14</sup>
<b>Disability/ Participation</b>				
<b>Societal Limitation / Context Factors</b>				
<u>Maternal behaviors</u> : Home management; maternal responsiveness, overprotection, acceptance, overindulgence, rejection, involvement, restrictions, directiveness, positive initiations, holding; face-to-face and physical contact with infant	I <sup>21</sup>		II <sup>20, 20, 20, 20, 20</sup>	I <sup>21, 21, 21, 21, 21, 21</sup> II <sup>14, 20</sup>
<u>Environment</u> : Arrangement, play materials, variety of stimulation, adaptive seating use			II <sup>20</sup>	I <sup>21, 21, 21</sup>

Parent satisfaction				I <sup>30</sup> III <sup>27</sup>
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MORE INDEPTH INTERPRETATION OF THE EVIDENCE

One can delve into any data in Table VI by using the subscript citations and refer back to the summary tables to elaborate the meaning of a data point (roman numerals refer to the level of evidence). For example, in the row that showed the effects of NDT on motor responses in the Impairment dimension of disability, there is a single entry (II<sup>14</sup>) that represents the strongest evidence that NDT changed or improved abnormal motor responses.

Reference 14 in the summary of studies (see Table III) shows that this evidence came from a study reported in 1976 that contained 20 children with CP, who varied from 5-17 months old at the time of entry, into one of two interventions given individually twice a week for a varied duration of 7 to 21 months. Published results were actually based on 22 children, two of whom did not have CP. As the diagnosis and results for each of the 22 were shown, however, the authors of this review were able to calculate the results for the 20 participants with CP; these are the results reflected in the summary tables (Table III-V) and the evidence table (Table VI) in this review. The participants with CP were a heterogeneous group: 6 were spastic, 13 were athetoid; one had ataxia. The severity of their CP ranged from mild to severe; and their intellectual status ranged from impaired to normal. The experimental intervention, called neurophysiologic therapy, was defined as using the neurodevelopmental treatment principles advocated by Bobath, Rood, and Ayres. The control intervention was traditional therapy, undefined.

From the summary of research methods (see Table IV), this II<sup>14</sup> evidence can be further elaborated as follows. It came from a randomized controlled trial which has the potential to produce the strongest or most valid evidence (coded as Level I). However, the level of evidence for this randomized controlled trial is reduced one level because, according to the review authors' judgment based on criteria in the AACPDm methodology, the study was not conducted with sufficient thoroughness to dispel some important threats to the internal validity of its results. One reason can be seen in Table V, that is, there were uneven numbers of participants in each group: 14 in the experimental group and six in the control group.

Final elaboration of this II<sup>14</sup> evidence from the summary of results (see Table V) reveals that the outcome of interest was a composite reflection of physiologic motor functions. The Motor Development Evaluation was created by the investigators to measure this motor function. The investigators indicated that they regarded the improvement seen with NDT as clinically important, but they did not perform any statistical evaluation of this result.

TARGETING EVIDENCE OF PARTICULAR INTEREST

Readers can also focus on any desired aspect(s) of the data included within the table (Table VI). For example, a clinician may need to make a recommendation about intervention for an 18-month-old child with spastic diplegia in which the parents have specifically raised a question about walking. Using the summary table of studies (Table III), the reader will note that there were four studies<sup>19,21-23</sup> pertinent to children with spastic diplegia who started NDT therapy about this age. Highlighting all the results from the four studies in the

evidence table (Table V) shows that these four studies yielded evidence related to physiologic motor responses, motor and other aspects of child development, contractures and deformities, maternal-child behaviors, and motor skills or activities. There are four results about attainment of motor milestones including walking, two after six months and two, after 12 months.<sup>19</sup>

Referring back to the summary tables (Tables III-V) to elaborate, one can identify that two of these studies are actually the same study involving 48 children in which different types of outcomes were published two years apart (i.e., motor and learning outcomes<sup>19</sup> and mother-infant interaction outcomes<sup>21</sup>). Another study<sup>22</sup> looked at the effects of short-term therapy (1 to 2 hours/week for 12 weeks) using a crossover design in which two children acted as their own controls producing Level II evidence suggesting there was no difference between physiologic motor function following NDT versus play. The fourth study<sup>23</sup> also investigated short term effects of NDT using a single subject design with one participant. Knee flexion during walking was repeatedly measured in a trial that last 15 weeks. Trend and level analysis of measures of knee flexion during walking compared alternating NDT and no treatment phases through a 15 week period and showed there was improved range of motion with NDT. The evidence from the latter two studies has little external validity (or ability to be generalized to a population-at-large) because it comes from only one<sup>23</sup> and two<sup>22</sup> participants. However, it has good internal validity (or ability to demonstrate that the findings reflect the effect of the intervention in that study and were not contaminated by other factors) because they used single subject designs that can produce Level II confidence about results and conducted the study thoroughly so that threats to its internal validity were controlled.

#### CAUTION

Caution is advised concerning the correct interpretation of results that are not statistically significant (*ns*). Results may be *ns* because of lack of adequate power in the study sample and design. The power of a study is the probability that the study, given its design and sample size, can detect a true difference of a predetermined magnitude (effect size). In the absence of a power calculation in a study description, there is always the possibility that a true difference existed between the two treatments being compared, but that there was inadequate power to detect the difference. However, if a power calculation is reported and the sample size needed to produce the power is obtained, then a *ns* result statistically supports the conclusion that there is no difference between the two treatments compared. Only two studies in this body of evidence reported power calculations. Palmer and colleagues<sup>19</sup> reported that a sample size of 100 would be needed for a full evaluation of treatment differences among all the outcome variables, but had to proceed with only 48 children. Law and co-workers<sup>25</sup> calculated that 76 participants were needed to provide sufficient power to detect a difference that they regarded as clinically important. However, calculations made after the study using the observed effect, confirmed that the 73 participants had provided adequate power to detect that difference if it had existed (Mary Law, personal communication). Unfortunately, the majority of studies in this review do not report power calculations and sample sizes were often small enough that adequate power is questionable.

## Analysis of the evidence about NDT

### 1. WHAT KIND OF EVIDENCE IS THERE ABOUT EFFECTS ON MOTOR IMPAIRMENT OR ABOUT IMPAIRMENT IN OTHER DOMAINS OF DEVELOPMENT?

*Motoric responses.* The primary goal of NDT is to change the neural-based motoric responses of the central nervous system. Thirty measures have evaluated various aspects of motoric response named as qualitative movement or physiologic motor function (i.e., a composite of muscle tone, spasticity, reflexes, etc.), reflex activity, weight shift, postural alignment, trunk rotation, associated reactions, and several aspects of upper extremity (UE) movement and gait.

Eight results showed that better motoric response was associated with NDT: physiologic motor function (II<sup>14</sup>) or qualitative movement (V<sup>26</sup>), movement time (IV<sup>24</sup>), percent of reach (IV<sup>24</sup>); and gait stride (IV<sup>32</sup>) and step (IV<sup>32</sup>) length, velocity (IV<sup>32</sup>) and foot angle (IV<sup>32</sup>). However, this evidence of improvement in physiologic motor function and qualitative movement is not consistent. There were five contrasting findings with stronger validity that tone, spasticity, and/or reflex responses (I<sup>25,30</sup>, II<sup>14,17,23</sup>) were either not different or were more improved in the children who received the control treatment (I<sup>19</sup>). More intensive NDT interventions (see items I<sup>19,26,30</sup>) produced no better results..

*Contractures and deformity.* Another major goal of NDT is to slow or prevent progressive deformity. Measures of joint range of motion and/or recommendations for bracing or surgery were used to probe the presence and degree of contractures after exposure to NDT. NDT consistently conferred an advantage in the three measures of dynamic joint range of motion at the ankle and knee (II<sup>23</sup>, III<sup>17,17</sup>). In other words, joint limitation was less when it was repeatedly assessed immediately following a 20-25 minute therapy session. NDT also conferred a benefit in one static measure made after a 6-week treatment period (IV<sup>18</sup>). Conversely, no difference between treatment conditions was detected in six other results of static range of motion that represented overall stronger evidence (i.e., level II); these measures of lower extremity joints assessed effects of treatment periods that lasted up to 12 months.

Due to the fact that spasticity and discomfort may often appear to be increased by ordinary handling during caregiving activities, this finding about dynamic range of motion may explain the clinical perception that therapeutic handling using NDT techniques reduce spasticity and discomfort during handling (Pam Mullens, personal communication). This, in turn, may also explain the clinical impression that individuals are also more able to actively participate during therapeutic caregiver-assisted movement.

*Motor development.* Standardized tests are designed to sample selected activities in a particular developmental domain, yielding a developmental quotient or age that reflects the extent to which development is impaired compared to normal.

Motor age has been measured eight times in five studies. All three measures of fine motor age (I<sup>25,30</sup> and II<sup>15</sup>) found no advantage conferred by NDT. Two measures of gross motor age were not consistent: one favored NDT (II<sup>13</sup>); the other showed no difference between NDT and the control condition. Three measures of overall motor age (i.e., average of gross and fine motor ages) were also not consistent: one favored NDT (II<sup>13</sup>) but two more convincing results favored the control condition (I<sup>19</sup> and I<sup>19</sup>). Surprisingly, the I<sup>19</sup> result

shows that six months of an infant stimulation program was associated with greater gains in overall motor development than six months of NDT. In Part II of this study, the infant stimulation group subsequently got six months of NDT while the NDT group continued with NDT. Assessment at the end of Part II of the trial showed that the group with lesser exposure to NDT still made greater gains in overall motor development (**I<sup>19</sup>**).

*Other domains of child development and function.* In developmental theory, physical and psychological development are interrelated. Thus, other lines of development may also be affected when abnormal motor behavior improves through an intervention.

Seventeen results are consistent in not finding an advantage in cognitive, language, social or emotional domains of development for children exposed to NDT. In most instances, there were no differences between the NDT and control groups, but in two instances, the control intervention was associated with better outcomes that are related to infant temperament (i.e., infant compliance and responsiveness).

*Quantity of therapy.* Three studies investigated whether more intensive intervention demonstrated greater reductions in measures of impairment (**I<sup>19, 25, 30</sup>**). These results are shown in bold in the evidence table and concerned motoric responses, contractures, motor and other domains of development, and attainment of motor skills or activities. Intensive NDT in one study<sup>25</sup> was defined as 45 minutes twice a week plus a 30-minute-a-day home program, and it was compared to a less intensive NDT regime given 45 minutes once a week or no less than once a month plus a 15 minute, three times a week home program. Intensive therapy (as defined above) was compared in another study<sup>30</sup> to a regular OT program given 45 minutes once a week or no less than once a month. In the third study, intensive NDT was defined as one hour twice a week plus an unclear home program which lasted for 12 months, and it was compared to less intensive NDT in which the same amount of therapy was given for only six months. No statistically significant beneficial effect of NDT was detected either when the amount of therapy each week was increased or when the number of months of treatment was extended.

## 2. WHAT EVIDENCE IS THERE ABOUT EFFECTS IN OTHER DIMENSIONS OF DISABLEMENT?

*Pathophysiology.* There is none regarding effects on cellular or molecular structure or function in individuals as a result of NDT.

*Functional Limitation/Activity.* Whereas standardized tests that yield developmental ages and reflect impaired development include activity or skill attainment items, the Functional Limitation/Activity dimension is concerned with common functional activities themselves, such as sitting, walking, dressing, playing, or interacting with other people. There were 14 measures that investigated the effect of NDT on functional motor activities including various types of moving around, using hands, and playing and one measure that documented effect on activities of a social nature. Only one measure (**IV<sup>31</sup>**) demonstrated increased gross motor function of NDT, but this study included no means to differentiate any gains from maturation. Surprisingly, in another most robust study, more children attained walking earlier in the control group that was exposed to six months of an infant stimulation program

followed by six months of NDT, compared to the experimental group which got 12 months of NDT (I<sup>19</sup>).

*Disability/Participation.* Effects of NDT on participation in family, school, or community roles were not addressed in these studies.

*Societal Limitation/Context Factors.* Given the intensive parental involvement advocated in the NDT approach, it might be expected that NDT would indirectly benefit children by improving the parent-child relationship or by reducing the stress parents experience in caring for a child with atypical motor function. It might improve the parents' understanding of how to arrange the environment to stimulate the children and maximize their ability to access objects and people. Finally, being an integral part of the therapeutic endeavor, instead of an outsider in the child's treatment, might increase the parent's sense of satisfaction about the intervention.

Only one of 14 results supports the expectation that NDT would confer a greater benefit to maternal-child interaction. Although greater maternal responsiveness to the child (I<sup>21</sup>) was reflected by statistically significant higher scores for mothers in one NDT group, it was not in another group (II<sup>20</sup>).

NDT did not confer any advantage to the environment of children in any of the four measures that probed variety of stimulation, play materials, arrangement of environment, or use of adaptive seating.

There was no difference in satisfaction between parents whose children were in NDT programs versus another intervention in either of two results about this outcome.

Other societal or family effects, such as the financial cost of long term NDT, or cost in terms of family time, energy or relationships (i.e., what happens to parent relationship when parent assumes role of therapist) have not been addressed by any of these studies.

### 3. WHAT LINKAGES EXIST FOR TREATMENT EFFECTS ACROSS THESE DIMENSIONS?

No linkages have been reported or can be determined given the inconsistent findings and/or general lack of treatment effect documented in any dimension.

### 4. ARE THERE SUBGROUPS FOR WHOM NDT MAY BE MORE OR LESS EFFECTIVE OR HAS CONTEMPORARY NDT BEEN MORE EFFECTIVE THAN EARLIER NDT?

Although the information is not shown in any of the tables, six of the 21 studies analyzed potential factors expected to identify subgroups of children who might experience greater or lesser benefit from NDT: according to age at entry to treatment, type and severity of disability, intelligence, maternal education, family income, and parental compliance with home programs.<sup>12,14,15,25,32</sup> Four studies analyzed age as a variable<sup>14,15,25,31</sup>, but the expected association between younger age and positive outcome was statistically significant in only one of the four<sup>25</sup>. Severity of disability did not identify any subgroups in one analysis<sup>14</sup>, but children mildly affected did better than those severely affected in another study<sup>19</sup>. Children with spastic diplegia (one type of CP) benefitted most according to two studies<sup>31,32</sup>. However, when one of these studies went further to analyze only motor behaviors that would be expected to change in children with diplegia versus hemiplegia versus quadriplegia, it found that the percent of mean change was not different.<sup>31</sup> The

effect of intelligence was statistically significant in only one<sup>14</sup> of three analyses.<sup>12,14,25</sup> Family factors were also examined: maternal education<sup>25</sup>, and family income<sup>25</sup> failed to identify any sub-groups, but parental compliance with the home program in the one analysis was statistically significant<sup>25</sup>.

Given that NDT evolved over time, later studies might be expected to reflect more positive results than earlier studies. Contemporary NDT, as described by the Bobaths in their final publication<sup>4</sup> in 1984, should have been reflected in clinical practice and research by 1990. An analysis comparing the 10 studies published before 1990 with the 11 published between 1990-2000 showed that the later studies, presumably using contemporary NDT, had a greater percentage of results that favored NDT (10 of 47) than did the earlier studies (6 of 54 results). When only motor impairment or motor activity measures were considered, NDT showed still more positive results for later studies (10 of 18 results) compared to earlier studies (7 of 31).

5. WHAT MEDICAL COMPLICATIONS AND ADVERSE EFFECTS HAVE BEEN DOCUMENTED?  
None were reported in these studies.

6. WHAT IS THE STRENGTH OF THE EVIDENCE?

How convincing a body of evidence may be depends on several factors: the levels of evidence (i.e., strength of the internal validity of the results), how extensively the population has been sampled (i.e., number of different studies and number of participants), as well as the number of times outcomes have been measured and the consistency of their results across the studies. A related and important issue is whether the magnitude of change was large enough to be clinically important.

The levels of evidence gauge the extent to which the studies are more likely to inform than to mislead in regard to the likelihood that the observed changes are attributable to the interventions and not to extraneous factors. Fourteen of the 21 studies were coded as Level I (definitive) evidence<sup>19,21,25,30</sup> or Level II (tentative) evidence<sup>12-16,20,22,23,28,29</sup> suggesting this body of evidence can be regarded as relatively credible. Statistical evaluation was available for almost all the results; however, the sample sizes themselves are all relatively small calling into question the power of the studies to detect effects that did exist. Power calculations were reported for only two studies, and only one of them contained the prescribed number of participants. The weakest aspect of this body of evidence is the limited population that has been sampled and its considerable heterogeneity. The 21 studies include only 416 different individuals who varied considerably in their type of cerebral palsy and its severity, associated disabilities, and age at treatment. Such heterogeneity in study participants can obscure treatment effects in group analyses.

Consistency of outcomes measured and consistency of the results across studies is important. Although the specific outcomes that have been measured vary, the same *types* of outcomes have been measured across several studies and there is considerable consistency in those results. Eighty-six of the 101 results did not confer an advantage to NDT. Nevertheless, there is some question about whether many of the measures were valid and/or sensitive enough to detect changes that may have occurred.

Finally, the clinical importance of change observed was seldom reported. To the extent it could be determined from the published reports, only four of the 16 results favoring NDT were clinically significant.<sup>14,17,18,26</sup> The magnitude of change was small in each case.

### **Summary and directions for future research**

The preponderance of the results in this evidence table (Table V) did not confer any advantage to NDT over the alternatives to which it was compared. With the exception of immediate improvement in dynamic range of motion, there was not consistent evidence that NDT changed abnormal motoric responses, slowed or prevented contractures, or that it facilitated more normal motor development or functional motor activities. More intensive therapy did not seem to confer a greater benefit. There was also no clear evidence that NDT produced other potential benefits such as enhancement of social-emotional, language or cognitive domains of development, better home environments, improved parent-child interactions, or greater parent satisfaction.

Fourteen of the 21 studies were relatively robust, providing results that can be regarded as definitively or tentatively valid (Level I and II evidence, respectively). The biggest threats to the validity of this body of evidence about NDT are generally small sample sizes in the studies, lack of information about power to detect a true difference if there was one, and considerable heterogeneity of participants in the studies as well as variance in therapy treatment across time and across therapists. Before one can determine whether there is sufficient reason for choosing NDT over another intervention, however, there are substantial gaps in this body of evidence that need to be addressed by future research. Effects of NDT on postural adjustment have not been investigated; there are only one or two measures of many of the outcomes, including muscle tone and spasticity. There is too little data to determine whether very early treatment, severity of involvement, or other factors influence the effect of NDT. There is consistent, albeit scanty, evidence that NDT produced an immediate improvement in dynamic range of motion; if this is so, links to reduced spasticity, greater comfort and active cooperation during assisted movement need to be explored. Longer follow-up on range of motion is needed because the current data may be too short term to detect effects of NDT on development of contractures. Clearly defined, homogeneous participants, operationally defined treatment techniques, and appropriate outcome measures in samples with adequate power are sorely needed in future studies.

Nevertheless, the distribution of data in the evidence table suggests that it is also time for concerted efforts to investigate other therapy approaches that may prove more clearly beneficial. Such new approaches are being discussed in the literature<sup>8</sup>. They grow out of current theories of developmental and motor learning and skill acquisition and include task-oriented approaches, dynamic systems concepts, and other means of rehabilitation such as strength and endurance training as well as use of assistive technologies. Use of NDT as a control intervention in evaluation of new approaches might make it possible to increase the evidence about NDT while simultaneously investigating new approaches.

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