Efficacy of Neurodevelopmental Treatment with Primary Focus on Dynamic Postural Control in a Chronic Stroke Individual

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Efficacy of Neurodevelopmental Treatment with Primary Focus on Dynamic Postural Control in a Chronic Stroke Individual

By

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THESIS

Submitted to the Department of Physical Therapy of Grand Valley State University Allendale, Michigan in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN PHYSICAL THERAPY

1997
EFFICACY OF NEURODEVELOPMENTAL TREATMENT
WITH PRIMARY FOCUS ON DYNAMIC POSTURAL CONTROL
IN A CHRONIC STROKE INDIVIDUAL

ABSTRACT

This study examined the efficacy of Neurodevelopmental Treatment (NDT) with primary focus on seated dynamic postural control (DPC) in a chronic stroke individual. Secondarily, the relationship between postural control and upper extremity function was examined. An 11 week ABAB single subject design was utilized. DPC was measured using the Modified Functional Reach Test (MFRT) and DPC Checklists (DPCCs). The MFRT had high interrater reliability ($\geq 0.97$) for the four reach directions and therefore could be clinically useful. Data was graphically analyzed using the two standard deviation band width method. During treatment phase I, significant upward trends were noted in anterior overhead and diagonally posterior MFRT graphs. DPCC scores for lateral shoulder and diagonally posterior reaches were significant. Anterior shoulder reach showed upward trends in the MFRT and DPCC graphs. Gains in MFRT distances and DPCC scores were maintained in phase II. In conclusion, NDT was efficacious in improving functional reach.
ACKNOWLEDGMENTS

The authors would like to thank our committee members Cathy Harro, Barbara Baker, and Arthur Schwarcz for all of their advice and guidance in completing our thesis. We would also like to thank Neal Rogness and Paul Stephenson for their help with the statistical analysis of our data. In addition, we extend a special thanks to Jennifer McQuain who assisted us in finding a subject for our study, and Barbara Baker who volunteered her time and skills in treating our subject. We also thank the MPTA Institute for Education and Research for the grant which allowed us to reimburse individuals for their time. We especially thank our subject for his dedication and interest. Finally, we would like to thank our friends and family members who supported and encouraged us during the completion of our thesis.
DEFINITION OF TERMS

**Chronic stroke patient**: Person who sustained a stroke at least 12 months ago.

**Deficit**: Combination of impairments which prevent normal movement patterns or strategies to perform a functional task (Carr and Shepherd, 1983).

**Impairment**: Psychological, physiological, or anatomical problems related to structure or function, such as decreased strength or range of motion, or the presence of spastic hemiplegia (Shumway-Cook, 1995).

**Independent expert in neurologic evaluation**: An individual with greater than ten years of experience dealing with neurologic clients and observing deficits in dynamic postural control.

**Reaching task**: One of six subtests of the modified functional reach test.

**Modified functional reach test**: Test including six dynamic reaching activities in sitting in which the subject must reach out and grasp a mug without falling, dropping the mug, supporting body mass with either upper extremity, shuffling feet or standing.

**Dynamic postural control**: Ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support (Horak, 1987, p. 1881).

**Dynamic postural control checklist**: Qualitative description which measures components of head, trunk and pelvic movement necessary for postural control, observed during the modified functional reach test.
LIST OF ABBREVIATIONS

ADL'S: Activities of Daily Living

CP: Cerebral Palsy

EMG: Electromyographic

DPC: Dynamic Postural Control

DPCC(s): Dynamic Postural Control Checklist(s)

MMT: Manual Muscle Test

MFRT: Modified Functional Reach Test

NDT: Neurodevelopmental Treatment

PNF: Proprioceptive Neuromuscular Facilitation

PROM: Passive Range of Motion

UE: Upper Extremity

WFL: Within Functional Limits
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CHAPTER 1

INTRODUCTION

There are 400,000 to 500,000 recurrent or new stroke cases in the United States each year and approximately three million stroke survivors (American Heart Association, 1991; U. S. Department of Health & Human Services, 1995). Current rehabilitation of the stroke patient is both costly and time consuming (Loewen & Anderson, 1990). Stroke results in an estimated annual loss of thirty billion dollars in health care and productivity costs in the United States (Matchar, McCrory, Barnett, & Feussner, 1994; American Heart Association, 1991; U. S. Department of Health & Human Services, 1995). At least six percent of hospital costs and five percent of the national health service costs are incurred due to this disabling condition (Wade & Hewer, 1987). These high costs place an economic burden on Medicare and Medicaid (Trombly, 1995). Considering these statistics it is not surprising that stroke rehabilitation is targeted by insurers and managed health care systems for cost containment (Gorelick, 1995).

Stroke impacts the individual and family in many ways. In a study by Ferrucci et al. (1993), the researchers implied that an individual is typically hospitalized up to two months following stroke. Returning home following hospitalization can be difficult for the individual. An estimated 10% to 29% are unable to return home and are transferred to an institution since the individual may need to assume increased responsibility in the absence of a supportive inpatient environment (U. S. Department of Health & Human Services, 1995). Changes in the individual’s functional abilities often lead to a decrease
Contributors to quality of life include neuropsychological functioning, activity level, social roles and level of independence. Kotila, Waltimo, Niemi, Loaksoner and Lempinem (1984) reported that neuropsychological changes were particularly common following stroke. The researchers noted that three months after stroke, 44% of the subjects were depressed and 30% demonstrated abnormal emotional reactions. Several researchers have indicated that activity level, social roles and level of independence all decline following stroke (Gresham et al., 1979; Niemi et al., 1988). Reduced level of independence frequently results from impairments that impact activities of daily living and ambulation. Forty-seven percent to 76% of stroke clients regain independence in activities of daily living and 78% to 85% regain independence in community ambulation (U.S. Department of Health and Human Services, 1995). As the stroke individual’s quality of life declines, the family is also affected. The family may need to assume new roles and increased responsibility to provide support for the involved member (U.S. Department of Health & Human Services, 1995).

Disabilities result from the decline in functional abilities experienced due to stroke. Time course for functional recovery occurs predominantly during the first one to three months following stroke (Kelly-Hayes et al., 1989; Skilbeck, Wade, Hewer, & Wood, 1983). However, functional change continues to spontaneously progress during the first six months (Ahlsio et al., 1984; Bonita & Beaglehole, 1988; Ferrucci et al., 1993;
Skilbeck et al., 1983). Furthermore, functional recovery can be enhanced beyond spontaneous recovery through rehabilitative treatment (DeGangi, 1994b; Tangeman, Banaitis, & Williams, 1990). Disabilities cause partial or total dependency in 25% to 50% of patients six months to five years following a stroke. Disabilities can include the following: dependency in mobility and activities of daily living, decline in community ambulation, socialization, vocational performance and participation in hobbies, as well as decreased ability to live independently (Ahlsio et al., 1984; Dombovy, Basford, Whisnant, & Bergstrath, 1987; Gresham et al., 1979; Kojima et al., 1990; Kotila et al., 1984; U. S. Department of Health & Human Services, 1995; Wade & Hewer, 1987).

The decline in activities of daily living and ambulatory skills observed following stroke result from numerous impairments caused by central nervous system damage. The primary impairment following stroke is hemiparesis, which is present in three quarters of all stroke patients (U. S. Department of Health & Human Services, 1995). As a result of hemiparesis, most self care activities that require bilateral arm function are compromised (Gowland, deBruin, Basmajian, Plews, & Burcea, 1992). Bohannon (1988) reported that although the physical impairment typically documented after stroke is unilateral hemiparesis, strength deficits are often demonstrable in all four extremities. Davies (1990) also reported that there is a loss of trunk strength and movement selectivity. Dyscoordination, poor movement selectivity, as well as sensory deficits are other common impairments demonstrated by stroke patients that result in disabilities.
Considering the human and economic burdens discussed, there is a need for stroke rehabilitation guidelines as well as clinical research on stroke outcomes. The Agency for Health Care Policy & Research recently published Post Stroke Rehabilitation Guidelines. This multidisciplinary panel of private sector clinicians and experts conducted extensive literature searches and critical reviews to evaluate efficacy of stroke interventions. This panel noted:

"Research is urgently needed to address critical questions about the effectiveness and cost effectiveness of stroke rehabilitation. Highest priority should be given to well-controlled experimental studies that assess functional performance and quality-of-life outcomes and the cost effectiveness for alternative service delivery strategies" (U. S. Department of Health & Human Services, 1995, p. 11-12).

One stroke rehabilitation technique widely used in the clinic is the Bobath approach or Neurodevelopmental Treatment (NDT). Efficacy studies on NDT will help answer the questions posed by the agency for Health Care Policy & Research. Current studies have indicated that the NDT approach yields functional gains yet research is inconclusive regarding the most effective approach. Ottenbacher and associates (1986) performed a meta-analysis of nine studies which compared the effectiveness of NDT to other treatment types using a pediatric population with cerebral palsy (CP). These researchers reported a 62.2% treatment effect due to NDT. Other researchers have indicated no difference between non-facilitatory techniques and NDT (Basmajian et al., 1987; Logigian, Samuels, Falconer, & Zagar, 1983; Salter, Camp, Pierce, & Mion, 1991).
Brunhan and Snow (1992) indicated that NDT was a less effective treatment technique than other non-facilitory techniques. The literature is inconclusive regarding the efficacy of NDT. Therefore, additional research is necessary to add to the body of knowledge concerning the efficacy of NDT.

Efficacy studies have not focused on dynamic postural control which is a foundation of NDT. Dynamic postural control is defined as the ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support (Horak, 1987, p. 1881). Components of dynamic postural control are described extensively in the NDT literature. The key components include: elongation/shortening of trunk musculature, pelvic mobility, midline orientation of head and body, and weightshifting (Bobath, 1980; Davies, 1994). Research regarding the efficacy of NDT intervention on dynamic postural control is lacking.

This study focused on evaluating the efficacy of NDT intervention to improve dynamic postural control of the head, trunk and pelvis. One study that involved NDT certified therapists indicated that these sites were the primary areas which would facilitate normal movement (DeGangi & Royeen, 1994). Our research study also examined the relationship between dynamic postural control and upper extremity function. A thorough understanding of all aspects of motor control that contribute to upper extremity function may lead to more efficient rehabilitation.

Several factors support a relationship between dynamic postural control and upper extremity function. A biomechanical relationship has been readily observed and
established through collaginous, muscular and bony connections (Gray, 1977). Research has indicated that head, trunk, and pelvic posture consistently affected upper extremity movements (Myhr, Lennart, Wendt, Norrlin, & Aradell, 1995; Curtis, Kindlin, Reich, & White, 1995; McClenaghan, Thombs, & Milner, 1992). Although the majority of these studies provided insight regarding static postural control, the research that addressed selective trunk activity in relation to skilled upper extremity action holds the most relevance for this study. Even a simple reaching task requires dynamic control over numerous joints and muscles of the trunk and upper extremity for postural stabilization (Frank & Earl, 1990; Keshner, 1990; Zattara & Bouisset, 1988). Individuals poststroke frequently lose this dynamic control and therefore, both postural stabilization and upper extremity function may be impaired.

**Purpose**

The main purpose of this research study was to examine the efficacy of NDT intervention with primary focus on seated dynamic postural control in a chronic stroke individual. A secondary purpose was to examine the relationship between postural control and upper extremity function in sitting. An ABAB single subject treatment design with NDT as the independent variable was implemented. The dependent variable, which consists of the performance of dynamic reaching tasks in sitting, was measured using a modified functional reach test (MFRT) and dynamic postural control checklists (DPCCs).
CHAPTER 2
LITERATURE REVIEW

Motor Control Deficits

Stroke results most commonly from arthereothrombic brain infarction, cerebral embolus or hemorrhage (U.S. Department of Health and Human Services, 1995). This brain damage leads to numerous neurologic impairments which vary in extent from client to client. Over 75% of clients have sensorimotor impairments which affect motor control necessary for functional skills (U.S. Department of Health and Human Services, 1995). As a result of these sensorimotor impairments along with other neurological impairments, stroke clients have a variety of functional disabilities. The focus of rehabilitation is the remediation of underlying impairments as well as teaching strategies to maximize functional abilities.

Motor control impairments are evident in several prerequisites to movement such as strength, tone and movement selectivity. Loss in muscle strength is the most overt movement impairment in stroke clients (Bohannon, 1988; Bohannon, 1992). This strength deficit, known as hemiparesis, is present in three quarters of the stroke population and is frequently the target of therapeutic intervention (Bohannon, 1992; U.S. Department of Health and Human Services, 1995). Although hemiparesis is typically most evident on the side of the body opposite the brain lesion, this impairment is often seen in all four extremities as well as the trunk (Bohannon, 1988; Bohannon, 1992; U.S. Department of Health and Human Services, 1995).
Upper extremity strength loss has been objectively reported by lowered electromyographic (EMG) values in the hemiplegic arm (Gowland, deBruin, Basmajian, Plews & Burcea, 1992). Clients demonstrate an inability to recruit fast twitch motor units which are necessary to generate force at high velocities of movement (Harro, 1985). There is also an atrophy of fast twitch muscle fibers which results in a decreased amount of functioning motor units (McComas, Rica, Upton & Aquileva, 1973). This limited recruitment results in a decreased ability to generate adequate strength to perform motor tasks (Gowland et al., 1992). In addition, there are also alterations in the timing of agonist and antagonist muscle recruitment. According to Gowland et al. (1992) an inadequate recruitment of agonist muscles in the affected upper extremity results in a decreased ability to carry out movement tasks. These changes in motor unit activation and muscle fibers contribute to the dynamic strength deficits observed in stroke clients (McComas et al., 1973).

Although the above research was completed on upper extremities, trunk strength is also compromised as a result of stroke (Bohannon, 1988; Bohannon, 1992; Davies, 1990, p. 31). According to Davies (1991), there are several reasons for the loss of trunk strength and movement selectivity. First, since both sides of the abdominal muscles attach to the linea alba through the central aponeurosis, efficient muscular action is dependent on both sides working together. If the aponeurosis does not provide for a stable insertion, the abdominal muscles on the noninvolved side are effected as well. Since the involved musculature has a decreased ability to generate force, and cannot
counteract pulling forces of the noninvolved muscles, the end result is ineffective abdominal muscle action. Second, abdominal muscle strength is further disadvantaged in the abnormal sitting posture common to a stroke client. The individual often sits with a rounded spine and posteriorly rotated pelvis. This position places the muscles in a shortened position and prevents effective activation. These strength impairments are observed functionally in sitting. The sitting posture assumed by the stroke client is not due to weak extensors, but rather to lack of abdominal strength. Davies (1990) posed that since the abdominal muscles are ineffective and trunk extensors lack a counterbalance, compensatory posture is assumed (Davies, 1990, pp. 33-34, 48).

Tonal changes occurring due to stroke can also limit function (Bobath, 1990, p. 11; Carr & Shepherd, 1983, pp. 35-36; Davies, 1994, p. 7). Stroke causes alterations in neural and nonneural intrinsic properties of muscle fibers, which may lead to hypertonia or hypotonia (Shumway-Cook & Woollacott, 1995, p. 402). Sahrmann and Norton (1977) reported that an inappropriate activation of the stretch reflex will result in an increase in muscle tone. This can be seen in the upper extremities as well as in the trunk. Following stroke, the client with increased tone may posture the involved upper extremity in an abnormal synergy pattern, and develop trunk leans in response to the pulling effect of the spastic musculature (Davies, 1990, p. 4; Crutchfield, 1989, p. 236). Similar to the client with increased tone, the hypotonic individual may also demonstrate comparable losses. Restriction of movement, be it due to tonal abnormalities or weakness, can impede rehabilitation and may limits the client’s potential for recovery (U.S. Department
of Health and Human Services, 1995).

Difficulty with movement selectivity is also observed following stroke. Stereotyped mass movement patterns in which the muscle response is the same for every effort, regardless of task demand, is a common deficit for the stroke client (Davies, 1994, pp. 24-29; Duncan & Badke, 1987, pp. 150-151; Perry, 1969). The client may not demonstrate muscle weakness, but may have apraxias of movement (U.S. Department of Health and Human Services, 1995). Function of the upper extremity requires selective and fine motor control; compensation for lack of control is difficult (Duncan, Goldstein, Matcher, Divine, & Feussner, 1994). Therefore, deficits in movement selectivity can affect the individual’s ability to successfully and efficiently perform activities of daily living.

Sensory deficits also influence abnormal motor control observed following stroke. Frequently, somatosensory and visual deficits are present post stroke. These deficits can impair the control of complex multiarthrodial movements (Duncan & Badke, 1987, p. 140). In a study performed by Jeannerad, Michel and Prablanc (1984), voluntary upper extremity movements were impaired as a result of sensory deficits. Subjects in this study, who had only sensory loss, displayed slowed motor control and were limited to simple monoarticular movements. They also demonstrated excessive cocontraction of both agonist and antagonist muscle groups and had difficulty sustaining a muscle contraction. In addition to altered sensation impaired visual feedback, specifically homonymous hemianopsia, has been reported in numerous stroke samples (Post Stroke
Rehabilitation, 1995). According to Wing and Frazer (1983), visual feedback concerning thumb and finger position are necessary to provide information regarding limb position during tasks. Sensory impairments therefore, can also contribute to functional deficits in stroke clients, especially upper extremity tasks.

**Dynamic Postural Control**

The motor control deficits discussed all contribute to problems in dynamic postural control following stroke. Dynamic postural control is the ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support (Horak, 1987, p. 1881). Functional stability is maintenance of posture despite external perturbation. According to Horak and associates (1984), movement of the arm “causes dynamic forces to be applied to the trunk, and these will act on the multisegmented kinematic chain between the shoulder and the base of support” (p. 1020). In order for stability to be maintained during any voluntary movement of the arm, muscular activation of the trunk is necessary (Horak et al., 1984). Since most activities of daily living require reaching, a postural perturbation, the individual must develop postural control strategies to maintain balance (Abreu, 1995; Horak et al., 1984).

In a stroke client, the postural control strategies which maintain balance are often lacking or impaired (Badke & Duncan, 1983; Detterman, Linder, & Septic, 1987; Hocherman, Dickstein, & Pillar, 1984; Shumway-Cook, Anson, & Haller, 1988). The aforementioned motor control deficits contribute to the decrease in dynamic postural control seen post stroke (Hocherman et al., 1984). Despite adequate muscular strength,
the stroke client may have difficulty maintaining the center of mass within the base of support (Shumway-Cook et al., 1988). In standing, an exaggerated postural sway in stroke clients was demonstrated in both the sagittal and lateral planes by Hocherman and associates, 1984. Detterman and associates (1987) also concluded that the stroke clients showed increased postural sway and a smaller area of stability during weightshifting activities, especially backwards and to the paretic side. In a similar study, Badke and Duncan (1983) concluded that stroke clients are often unable to modulate postural strategies which may result in an inability to adapt and respond to environmental demands. Few studies have focused on the postural control deficits in sitting. Clinicians have noted inadequate or slow transfer of weight, asymmetrical weightbearing, as well as an inability to modify postural strategies to environmental demands in a seated position (Davies, 1994). In summary, there are fundamental difficulties in the strategies for postural control following stroke, resulting in decreased dynamic postural control.

The previously noted deficits seen poststroke contribute to a variety of functional disabilities, including problems with dynamic postural control and upper extremity reaching function. A variety of treatment approaches are used in the rehabilitation of the stroke client, but the most effective approach is questionable.

**Efficacy Analysis: NDT and Other Treatment Approaches**

There are many uncertainties regarding the most effective and optimal approach to stroke rehabilitation. Current intervention strategies including NDT, EMG biofeedback, Propioceptive Neuromuscular Facilitation (PNF) and non-facilitatory approaches have all
been shown to improve functional status of the client; however, significant superiority of one therapy over another within the specificity of each research design was not demonstrated (Basmajian et al., 1987; Dickstein, Hocherman, Pillar, & Shaham, 1986; Logigian, 1983; Lord & Hall, 1986; Mulder, Hulstijn & van der Meer, 1986). Therefore, these studies suggest that an optimal treatment approach has yet to be identified.

Neurodevelopmental treatment (NDT), originally developed by the Bobaths (Bobath & Bobath, 1964), has evolved over the years and is commonly used to treat individuals with stroke. However, studies regarding the efficacy of NDT are limited and inconclusive. Some studies, on pediatric neurological clients, indicated that NDT leads to functional gains. Ottenbacher et al. (1986) compared the effectiveness of NDT over other treatment types through meta-analysis. The research included nine pediatric studies and found a small but significant treatment effect of NDT (62.2% treatment effect) compared to other interventions. They also concluded that the effects appeared related to specific research design and study characteristics. Kluzik, Fetters, and Coryell (1990) supported the efficacy of NDT in children with cerebral palsy as they found immediate changes in the kinematic properties of reaching following NDT intervention. In this study, Kluzik et al. (1990) examined the effect of NDT on reaching using the WATSMART (Waterloo Spatial Motion Analysis and Recording Technique) system in conjunction with videotaping. The number of accelerations and decelerations (movement units) were measured in addition to movement time, distance path (directedness), and associated reactions. Each subject participated in one testing session during which performance of a
reaching task was recorded immediately before and following a 35 minute NDT oriented therapy session. Each therapy session was conducted by a NDT certified therapist who incorporated manual facilitatory techniques for weight shifting, postural reactions, and alteration of muscle tone during movement. Although specific treatment activities varied for each subject, overall goals for all subjects were the same. Goals included improved trunk and shoulder girdle control during reaching, improved smoothness, and efficiency of movement, and improved ability to initiate movement.

When data from the individual subjects were pooled and analyzed, Kluizik and associates (1990) found significant changes in outcome measures following NDT intervention. Movement time and the number of movement units decreased. In addition, the duration of the first movement unit relative to the total movement time increased after treatment, suggesting a more controlled reach. The distance path of the reaching hand remained stable across treatments. This finding suggests that decreased motor time following treatment is related to an actual change in speed of movement as opposed to the hand simply moving across a shorter distance. The researchers claimed that the results support the hypothesis that NDT can produce immediate changes in the kinematic properties of reaching.

Other research showed no difference between non-facilitatory techniques and NDT. Basmajian et al. (1987) randomly assigned 29 stroke subjects to either NDT treatment or a specially designed EMG biofeedback program. After nine months, both groups showed significant improvements in range of motion and strength of the
hemiplegic upper limb. However, the results revealed no significant differences between treatment groups. In this study, the protocol used for NDT intervention was not specified. The researchers failed to provide goals or guidelines used to treat the stroke client. This lack of information made it difficult to compare the differences and similarities of NDT intervention between various studies.

Logigian et al. (1983) performed a study in which 42 stroke subjects were randomly allocated to a “traditional” treatment or NDT. NDT intervention focused on the total body and emphasized close interaction of the therapist and clients. Treatment techniques included bilateral weightbearing and weightshifting exercises, utilization of reflex inhibiting patterns, and tactile, vibratory, and vestibular stimulation activities. The “traditional” treatment intervention emphasized strengthening and range of motion activities. Treatment techniques included passive, active-assistive, active and progressive resistive exercises, and use of upper limb skate boards, weighted sanders, reciprocal pulleys, and springs. The results showed that both NDT and “traditional” exercise therapies improved function and motor performance as measured by the Barthel Index and the Manual Muscle test (MMT), but there were no significant differences between the interventions.

The lack of difference between NDT and “traditional” therapies in Logigian and associates’ study (1983) could be due to the absence of a measurement tool capable of reliably and validly assessing impairments targeted during NDT intervention. The NDT approach to motor loss treats the body as a whole and integrates development of sensory,
perceptual and cognitive skills (Frank & Earl, 1990). Goals are not limited to motor performance, but stress the reduction of spasticity and pain as well as the return of balance and sensation (Bobath, 1980; Davies, 1994). Another limitation of Logigian's study (1983) was that functional and motor performance change in both groups may have been affected by spontaneous recovery; clients had stroke onsets within seven weeks prior to initiation of the study.

The results of the Fetters and Kluzik study (1996) were in agreement with the findings of Logigian (1983) and Basmajian et al. (1987); Fetters and Kluzik (1996) found no differences between NDT and practice on reaching function. Eight children with cerebral palsy were treated for five days with NDT and for five days practicing reaching tasks. NDT sessions focused on activities to improve trunk and shoulder girdle control during reaching, smoothness, and efficiency of movement, and ability to initiate movement. Practice sessions consisted of repeated reaching to play computer games without feedback regarding movement quality. Changes in movement time, movement path, reaction time, and smoothness of reach were quantified and described using kinematic analysis. Improvement in these outcome variables were not apparent after five days of either NDT or practice. This finding, however, maybe due to an insufficient amount of treatment time. Weekly measures over multiple weeks would be a stronger research design to determine which treatment is most effective. Furthermore, the type of treatment (NDT versus practice) might yield different changes in motor performance. Since the NDT approach included postural stability as well as movement path and
smoothness of reach as goals, treatment effects would be most obvious in the postural set used for reaching. Practice of the task might be expected to affect variables such as reaction time and movement time.

In contrast to the previous studies discussed, a study by Brunham and Snow (1992) demonstrated that NDT was less effective than “conventional” treatment. Ten treatments, five NDT and five conventional, were randomly administered to three patients following a stroke or head injury. The fourth patient was given five “conventional” treatments followed by sessions using NDT. Target goals were set for all subjects before treatment was initiated. The subjects were videotaped while performing a targeted task before and after each treatment. Qualitative outcomes were measured using pre- and post-test videotapes, graded by individual raters. All patients attained their goals. Data was analyzed using the two standard deviation band width method. The treatment type that yielded the greatest number of significant data points was claimed to be the most effective intervention for that subject. Based on this criteria, the researchers concluded that “conventional” treatment was favored over NDT.

The results from this study, however, should be viewed with caution, as this study was poorly controlled. The researchers failed to provide protocols and operational definitions of both NDT and “conventional” interventions. According to the graphical analysis, fluctuations in the subjects’ performance did not correlate with the treatment used; suggesting that other factors may be responsible for the effect observed. For example, the fourth subject showed the most variable treatment response which could
have been due to a systematic illness that the subject attained during the study. Additionally, possible confounding variables which could have caused the variable treatment responses in the other subjects were not discussed. The study also failed to develop sensitive, objective outcome measures that would accurately assess the efficacy of NDT.

According to the literature discussed in this review, discrepancies exist regarding efficacy of NDT as compared to other treatment approaches for stroke clients. Although many treatments emphasize the remediation of disability, it is important to consider the primary focus of each approach. The primary focus of NDT is the attainment of normal functional movement which is based on efficient dynamic postural control. Our study will aid in determining if NDT is an effective treatment approach for retraining dynamic postural control in chronic post stroke individuals.

**Components of Dynamic Postural Control**

According to Frank and Earl (1990), “...it is evident that even simple movements require complex control. An act as simple as raising the arm requires control over numerous joints and muscles of the trunk and legs in order to stabilize posture...” (p. 860). The “complex control” referred by Frank and Earl (1990) is defined in the proposed study as dynamic postural control. Dynamic postural control is the “...ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support” (Horak, 1987, p. 1881). In the schema proposed by Frank and Earl (1990), multiple factors impact dynamic postural control. These factors include
central set, peripheral feedback, existing movement strategies and biomechanical
dynamics.

Central set constitutes a postural preparation to movement. The central nervous
system integrates past experience with knowledge of the current situation and responds
through preplanned responses in the trunk and limbs. These responses allow for
accuracy, speed and efficiency of movement (Horak, Diener, & Nashner, 1989; Horak &
Nashner, 1986).

Although central nervous system preparation precedes movement, postural
adjustments also occur throughout the movement and in response to peripheral feedback.
Sensory receptors in the visual, vestibular, cutaneous and proprioceptive systems are
stimulated, triggering automatic postural adjustments (Frank & Earl, 1990).
Environmental perturbation provides sensory input through these systems leading to
reproducible movement strategies even when perturbation is unexpected and central set
has been minimized (Bouisset & Zattara, 1987; Horak, et al., 1989).

Both central and peripheral information is translated into dynamic postural control
with the aid of preexisting movement strategies or synergies (Bouisset & Zattara, 1987;
Horak & Nashner, 1986). Context appropriate synergies are utilized simultaneously to
coordinate movement. This complicated process relies on accurate muscle timing as well
as effective sensorimotor feedback loops (Higgins, 1972; Horak & Nashner, 1986).
Correct timing of muscle activation prevents destabilization and facilitates appropriate
direction of movement to maintain balance (Frank & Earl, 1990). Deficits in this
dynamic postural control is a commonly reported problem in post stroke individuals and is often targeted for rehabilitation. Dynamic postural control is one of the primary areas of focus for NDT intervention.

**Efficacy of NDT on Dynamic Postural Control**

According to NDT theory (Bobath, 1980), the function of the CNS is to provide the ability to move while controlling posture. One primary focus of NDT is treatment of static and dynamic postural control which is necessary for functional tasks (Davies, 1994). Despite the strong emphasis on development of postural control and stability, the efficacy of NDT on the treatment of dynamic postural control in adult stroke has not been the focus of research.

Studies which have measured the efficacy of NDT on dynamic postural control have primarily examined individuals with cerebral palsy (Bertoti, 1988; Girolami & Campbell, 1994). Bertoti (1988) reported that eight out of eleven children who engaged in NDT based therapeutic horseback riding demonstrated improved posture. Changes noted were increased midline head control, decreased neck hyperextension, decreased scapular retraction, improved trunk symmetry, reduced spinal curvatures in both coronal and sagittal planes, more erect trunk posture, and decreased anterior pelvic tilt. The researchers also reported improved symmetry of weightbearing in various positions and improved sitting balance and trunk righting. Since the subjects served as their own control, application of NDT to other clients is limited. Girolami (1994) performed a controlled study in which preterm infants were randomly assigned to either an
experimental or control group. The researcher reported that infants treated with NDT at 34 weeks gestational age had better midline head, pelvic, and trunk control at term age than the untreated control group.

Research support is lacking concerning efficacy of NDT on improvement of dynamic postural control in adult stroke clients, therefore, more research is needed. Focus for this research should be placed on postural improvements and resultant changes in related functional performance. Therefore, valid tools for assessing postural alignment and dynamic stability need to be developed (Alaranta, 1994; Berg, 1989). Our study examined objective qualitative changes in postural control and its relationship to functional reaching performance following NDT intervention. Examining these changes in postural control requires knowledge of theoretical basis of NDT intervention.

Retraining Dynamic Postural Control with NDT

NDT is a neurodevelopmental and neurophysiologic approach to stroke rehabilitation that focuses on attainment of normal functional movement (Borgman & Passarell, 1991). As previously discussed, normal functional movement is based on efficient dynamic postural control. NDT aims to improve functional movements by providing direct facilitation to the client, over multiple treatment sessions, to train muscles to move in coordinated synergies. Clients are provided with the sensation of normal movement with the goal of retraining central set. Normally functioning central set is observed when clients exhibit postural preparation. According to NDT theorists, as the client increases their available movement patterns, dynamic postural control will
become more accurate and efficient (Bobath, 1980; Davies, 1994). Components that allow for dynamic postural control include re-establishment of normal postural tone, reciprocal innervation, and a variety of patterns of movement (Bobath, 1980). Postural symmetry and equilibrium reactions are also stressed in NDT as critical factors to improve dynamic postural control (Berg, 1989; Bobath, 1980). The primary goal of treatment is to retrain trunk components of dynamic postural control following stroke which includes improving active trunk motion, head control, midline orientation and weight-shift ability (Bobath, 1980; Davies, 1994).

NDT promotes using an individualized treatment plan that is constantly modified based on client responses (DeGangi, 1994a; DeGangi, 1994b; Palisano, 1991). Active and guided practice, education on controlled movement, facilitation and home programs are key components of treatment intervention (DeGangi, 1994a; DeGangi, 1994b). Five main areas of client improvement are recognized: postural tone, weight shift, transitional movements, proximal stability and functional gains (DeGangi, Hurley, & Linshcheid, 1983).

Current clinical practice applying NDT treatment principles emphasizes the use of functional activities and active patient participation (Palisano, 1991). Learning requires error analysis to promote problem solving which leads to quality of movement modification. Clients receive extrinsic feedback from the therapist after performing the functional task as well as internal feedback from the sensory systems (Bly, 1991). Facilitation and practice of a variety of movements to improve dynamic postural control
is emphasized in treatment. Our study primarily examined the effectiveness of NDT intervention on dynamic postural control. Since this study secondarily examined the relationship between dynamic postural control and upper extremity function, scientific literature regarding this relationship was also reviewed.

**Relationship between Static Posture and Upper Extremity Function**

The upper limb is anchored to the trunk at the shoulder girdle which consists of the clavicle and scapula. The clavicle acts as the fulcrum for the upper extremity since it attaches to the sternum and creates the sternoclavicular joint. This joint provides the only site of bony stability for the upper limb. The scapula has no bony or ligamentous attachments to the thorax and stability is attained through muscular connection (Gray, 1977, pp. 134-135; Kaput, 1987, pp. 5-6; Moore, 1992, p. 506). A critical relationship between trunk posture and upper extremity function is established by these anatomical and biomechanical connections between the upper extremity and trunk.

Several studies have examined the relationship between static trunk posture and upper extremity functional ability. In a study performed with paraplegics, Curtis, Kindlin, Reich and White (1995) externally imposed trunk stability using belts across the lap, lower trunk or upper trunk. A computer analysis of mean areas of sagittal plane and transverse plane reach were compared between each of the three belting conditions. These researchers found that when trunk motion was limited by external means or by lack of intrinsic stability, reach area decreased. When trunk stability was provided without limiting mobility, reach area increased.
Nwaobi (1987) performed a study on children with cerebral palsy (CP) which utilized a seating device to place the trunk in the desired alignment known as the “Zero degree seating orientation.” This seating orientation placed the subjects in an anterior pelvic tilt to promote neutral position of the spine. Nwaobi (1987) then compared this seating position to three other less stable positions. Upper extremity function was analyzed using an alternating shoulder motion of adduction/abduction. The motion was repeated ten times as fast as possible and required that the children touch a switch at midline to determine speed. The speed of upper extremity performance was the most rapid with the body in the “zero degree seating orientation.” The researchers concluded that upper extremity performance was influenced by seating position; zero degree seating position facilitated the most effective upper extremity function.

Myhr, Lennart, Wendt, Norrlin and Radell (1995) also examined the effect of two different seating positions on upper extremity function in 55 children with CP. The subjects were placed in a position of backward pelvic tilt with center of gravity posterior to the ischial tuberosities, followed by a position of anterior pelvic tilt with center of gravity anterior to the ischial tuberosities. The latter position was similar to Nwaobi’s (1995) “zero degree seating orientation.” The trunk position was monitored using videotape and photographs. Subjects were required to perform five functional tasks in sitting: lean forward and touch a rattle, grasp and release toys, screw and unscrew a jar lid, place dice in a jar and lift a jar with both hands. Myhr and associates (1995) then compared subjects’ ability to perform these tasks in the two different seating postures.
Subjects placed in the anterior pelvic tilt position demonstrated significant improvement in head, trunk, and hand control when compared to subjects placed in the posterior pelvic tilt position. Myhr and associates (1995) findings concurred with Nwaobi’s (1995) findings.

In another study performed on children with CP, McClenaghan, Thombs and Milner (1992) reported that posterior pelvic tilt position, rather than anterior pelvic tilt position, allowed for increased upper extremity functional ability (McClenaghan et al., 1992). This study was not in agreement with the studies conducted by Nwaobi (1995) or Myhr and associates (1995) regarding the optimal positioning of the pelvis for maximal reach. A digitized video analysis of trunk position indicated that within a five degree range of anterior or posterior pelvic tilt, there was little effect on the functional reach measure. The functional reach measure involved six tasks. Children were analyzed as they tapped their fingers alternately on two horizontal targets, tapped their fingers alternately on two targets with an obstacle between them, grasped and placed pellets into a container, turned eight vertically standing pegs, pressed their thumb on a target and pencil traced three figures. Although the researchers reported an improvement in the functional measure with posterior pelvic tilt beyond five degrees from neutral pelvis, they made no judgment concerning optimal sitting posture. The outcome of this study may be unclear because amount of pelvic inclination compared was too small to be reflected in the upper extremity measurement tool.
Contrary to the support that sitting posture effects upper extremity function, McPherson, Schild, Spaulding, Barsamian, Transon and White (1991) reported that trunk position imposed with a seating device did not consistently alter functional arm movements. Arm function was analyzed by computer for acceleration/deceleration phases in a forward reach movement. Results indicated that different trunk positions did not consistently alter the quality of the acceleration/deceleration phases. Methodological concerns, however, bring the results of this study into question. Small sample size, three subjects in control and CP groups, limited the statistical power of this study. Of the three subjects with CP, their movement profiles were heterogeneous and in fact, all three subjects had movement profiles that overlapped with the control group. Another methodological concern is that the three subjects were diagnosed with mild to moderate CP, which may have allowed for adequate postural control to adjust to the four seating positions. In addition, the researchers only considered the immediate effects of the seating device utilizing a single reaching task. A more intensive investigation including multiple upper extremity reaching tasks may have produced different results.

The research performed on the relationship between static sitting posture and reach, as well as the biomechanical and anatomical relationship between trunk and upper extremity, validate the importance of postural control during reaching. Although static trunk control is necessary for activities of daily living, many functional activities are dynamic and require dynamic postural control. It is, therefore, critical to consider research that analyzes dynamic postural control.
Relationship between Dynamic Postural Control and Upper Extremity Function

A primary function of posture is to integrate movements into coordinated action sequences. Thus, movement and posture are tightly integrated rather than separately controlled (Reed, 1989). Postural stability is determined by the support surface, joint position and changes within the body segments. Consequently, with varied internal and external inputs, postural adjustments do not occur in fixed movement patterns. The sequence of muscular activation however, is reproducible for a given task under similar conditions (Keshner, 1990; Zattara & Boiusset, 1988). Considering the multiple directions of movement and number of muscles surrounding the shoulder, the body implements several solutions to a single reaching task with even slight changes in reach conditions (Keshner, 1990).

Voluntary upper extremity movements apply dynamic forces to the trunk which cause changes in the body’s center of gravity. Trunk musculature creates a dynamic base of support to control the shift in center of gravity (Cordo & Nashner, 1982; Horak, 1987; Horak et al., 1984). Consequently, as the upper extremity reaches for an object, there is an interplay between the flexors and extensors of the trunk and the muscles of the shoulder girdle (Davies, 1990, p. 21). This interplay allows for efficient body movement (Horak, 1987).

Friedli, Cohen, Hallett, Stanhop and Simon (1988) studied focal movements of elbow flexion and extension in standing. Specific coordinated patterns of EMG activity were reported in both the legs and trunk for each type of movement. A biomechanical
analysis of ground reaction force was also performed and indicated that ground reaction forces were opposite for elbow flexion and extension. Dynamic postural responses counterbalanced the ground reaction forces.

Cordo and Nashner (1982) performed an EMG and body sway analyses of the lower extremities in response to displacing a handle forward and backward. The task of moving the handle induced forced body sway initiated at the upper limb. The researchers reported that postural adjustment of the lower extremities were initiated shortly before the reaching movements began. The responses elicited were coordinated, reproducible and appeared to be related to ground reaction force. Frank and Earl (1990) repeated the study by Cordo and Nashner (1982) with the addition of EMG analyses of trunk muscles. They reported similar postural adjustments in the trunk as well as lower extremities that were again reproducible and related to ground reaction forces.

Bouisset and Zattara (1987) were also interested in anticipatory postural adjustments. They performed a study using force plate analysis to determine if the adjustments were preprogrammed. Self pertubations of single and bilateral upper extremity movements both with and without additional inertia were studied in normal subjects. Reproducible variations of ground reaction forces were found before and after the onset of upper limb acceleration. These researchers concluded that anticipatory postural adjustments were preprogrammed and corresponded with dynamic upper extremity activity. Zattara and Bouisset (1988) added to their initial study by examining EMG activity under similar conditions. Muscle activity of the lower extremities, upper
extremities, shoulder girdle and trunk appeared to “counteract the disturbing effects of the forthcoming voluntary movement” (p. 956). Again, dynamic postural control was reproducible and context specific.

Few studies have considered dynamic postural responses in hemiplegic subjects as compared to normal subjects. One such study by Horak and associates (1984) indicated that with rapid arm elevation, hemiplegic subjects used essentially the same sequence of muscle activation in the hip, back and shoulder. Muscle activation was recorded through EMG activity and showed a longer latency time for hemiplegic individuals as compared to normal subjects. The major factor that influenced both normal and hemiplegic subjects was velocity of arm elevation. Since less stabilization force is necessary during low velocity movement, the researchers hypothesized that preparatory muscle activity was less rigidly programmed in association with slow movements for both groups.

Badke and Duncan (1983) examined dynamic postural control in normal and hemiplegic individuals using externally imposed perturbations through a platform-pulley system. EMG measurements were taken in the hip, knee and ankle. The most frequent abnormalities noted in the hemiplegic group included: synchronous contraction of lower extremity muscles, inconsistent patterns of muscle activation, longer and more varied latencies and a distorted sequence of muscle activation. Patterns of muscle firing which was different between the normal and hemiplegic groups does not agree with the study by Horak and associates (1984). This disagreement may be due to the difference in type of

Research has indicated that coordinated dynamic postural control is necessary for many upper extremity movements. Our study observed dynamic postural control components during several seated reaching tasks in a chronic stroke subject. The DPCC served as a clinically applicable means to document biomechanical movement components during the reaching tasks. Thus, a clinical relationship between dynamic postural control and upper extremity function was indirectly examined.

**Review of Study**

The purpose of this research study was to examine the efficacy of NDT intervention with primary focus on dynamic postural control in sitting in a chronic stroke individual. A second focus of this study was to examine the relationship between postural control and upper extremity function in sitting. The ABAB single subject design, which provides initial baseline data and ends on an intervention phase, was implemented. This design provided two opportunities to evaluate the effects of the independent variable, NDT. If effects could be demonstrated during two separate intervention phases, the evidence is quite strong that behavioral change was directly related to the treatment (Portney & Watkins, 1993, p. 202). The dependent variable, dynamic reaching function in sitting, was measured using a MFRT and DPCCs during a variety of reaching tasks.
Measures of Dynamic Postural Control

Current NDT intervention emphasizes the improvement of functional performance through goal directed feedforward and feedback mechanisms, active participation, as well as facilitation of normal movement patterns through proprioceptive input (Borgman & Passarella, 1991; Bly, 1991; DeGangi & Royeen, 1994; Mathiowetz, 1994). Therefore, a tool which utilizes voluntary movements, would be a sensitive and appropriate assessment for the efficacy of NDT (DeGangi, 1994a; Palisano, 1991; van der Weel, 1991). The measurement tool used in this study, the Modified Functional Reach Test (MFRT), was designed to use voluntary movement to provide a direct measure of dynamic postural control and is based on the Functional Reach Test developed by Duncan and associates (1990).

The Functional Reach Test is a reliable (interclass correlation coefficients: 0.60-0.71) balance measure that combines current dynamic postural control theory with a practical measurement system. The Functional Reach Test represents the maximal distance an individual can reach forward beyond arms length while maintaining a fixed base of support in the standing position (Duncan, Weiner, Chandler, & Studenski, 1990; Weiner, Duncan, Chandler, & Studenski, 1992). The MFRT developed for this study represented the maximal distance an individual can reach to grasp a mug in a variety of directions while maintaining a fixed base of support in the sitting position.

The Functional Reach Test was shown to have high interrater reliability in a hospital based population (Straube, 1996). Ten subjects with a variety of diagnosis
(stroke, Guillain Barre syndrome, brain tumor and Sickle Cell disease) performed the Functional Reach Test developed by Duncan and associates (1990). Subjects were assessed by two randomly paired therapists for three trials. Each measure was rounded to the nearest half inch and the average score of the three trials was used for analysis. The results indicated a high interrater reliability (ICC=.94) for the Functional Reach Test (Straube & Campbell, 1996).

Reliability of postural control or balance tests, which have used functional reaching measurements in sitting, have been limited. Lynch (1994) performed a study that supported the use of the Functional Reach Test in sitting. In the study, 30 male subjects with spinal cord injury (SCI) were divided into three groups based on their level of injury: C5-6 tetraplegia, T1-4 paraplegia and T10-12 paraplegia. Subjects sat on a mat table with trunk and foot support. Three forward functional reaches were measured in each of two sessions. Interclass correlation coefficients (ICC’s) for the Functional Reach Test in sitting were 0.93, 0.85, and 0.93 for the three groups, respectively. The researchers concluded that the Functional Reach Test in sitting was a reliable and sensitive balance measure in a seated position in SCI individuals.

In addition to performing the Functional Reach Test in sitting, Newton (1996) performed a study assessing the reliability of performing the Functional Reach Test in four directions. Two hundred and fifty-two normal subjects completed the Functional Reach Test in four directions while seated. A yardstick on a free standing pole was placed at the height of the acromion. Subjects were asked to reach as far as possible
forward, right, left, and backward. The researchers concluded that the Functional Reach Test in four directions provided a reliable measure of the limits of stability and was useful in screening balance. Our study utilized an outcome measure similar to the one developed by Newton (1996) since the MFRT was a seated reach test in four directions.

**Single Subject Design**

The design of this study involved a single subject. Single subject design addresses several important issues directly related to systematic assessment of treatment effectiveness with individual clients. According to Bloom and Fischer (1982), “Systematic, consistent use of single system designs will allow practitioners, and agencies, to collect a body of data about the effectiveness of practice that provides more or less objective information about the success of our practice” (p. 15). A single case provides an objective perspective on treatment outcome due to frequency of measures and individual treatment control (Wagenaar, 1990). Since the subject serves as his/her control, confounding factors due to heterogeneity of the stroke population are also diminished (Ottenbacher, 1986, p. 197; Stern, 1994). Furthermore, single subject design emphasizes use of individualized measures of performance that are recorded on a regular basis throughout evaluation and treatment periods. Individualized measures of performance allows for the analysis of the temporal pattern of client performance along with the final outcome and therefore provides the therapist with a more accurate picture of total client function (Ottenbacher, 1986, p. 60).
CHAPTER 3

METHODOLOGY

Study Design

This study implemented a single subject design to assess the efficacy of Neurodevelopmental Treatment (NDT) on dynamic postural control in sitting during dynamic reaching activities with a chronic stroke individual. This study secondarily examined the relationship between postural control and upper extremity function in sitting. An ABAB treatment design (Ottenbacher, 1986; Yin 1984) consisting of a two week baseline assessment phase (A), followed by a three week intervention phase (B), followed by a three week nonintervention phase (A), and ending with a three week intervention phase (B) was utilized. Intervention phases consisted of a NDT based approach with primary treatment focus on improving dynamic postural control. An evaluation, that consisted of dynamic reaching activities in sitting, was completed prior to each treatment session as well as during baseline phases. Functional reaching ability was measured through the MFRT (Appendix A). Observation of components of dynamic postural control were also analyzed utilizing the DPCCs (Appendix B).

Subject Selection

The volunteer subject chosen for this study sustained a hemispheric stroke in January, 1994 and had no previous history of stroke or brain damage. The chronic nature of the diagnosis ruled out the possibility of spontaneous recovery likely to occur within the first three to six months. The subject did not have acute orthopedic disorders of the
involved upper extremity or trunk however, he sustained a chronic left rotator cuff injury. The subject did not have significant spinal deformities. The subject received physician’s approval to participate in the study and was not receiving any other physical or occupational therapy during the study. Admission to the study was based on an initial screen and the following inclusion criteria (Appendices C & D):

1. Score of at least 21/30 on the Mini Mental State Exam (Appendix E), indicating a range from no cognitive deficits to mild cognitive deficits.

2. Pain free passive range of motion within functional limits (Appendix F) of the involved upper extremity in supported sitting, which allowed the subject to complete the MFRT.

3. Reduced postural control as evidenced on all six DPCCs with a score of no greater than 3/6 in four of the DPCCs.

4. Ability to sit unsupported for at least one minute.

5. Intact proprioception of the involved upper extremity (Appendix G) to ensure that limitations were not due to upper limb proprioceptive loss.

6. Intact or impaired light touch of the involved upper extremity and trunk (Appendix G) to provide feedback during movement.

7. Fugl-Meyer scores on the upper extremity section (Appendix H) of at least: 3/6 in the movement out of synergy subsection; 6/10 in the wrist subsection; 10/14 in the hand subsection. These Fugl-Meyer scores represented a subject with upper extremity
movement selectivity of Brunnstrom stage IV to V (Appendix I). These stages ensured that limitations in performance of the MFRT were not due to upper limb movement selectivity.

All inclusion criteria were selected to minimize confounding factors.

**Procedure**

Approval was sought from the Human Subject Review Boards of Grand Valley State University and from Mary Free Bed Hospital And Rehabilitation Center. Subjects were recruited from local stroke clubs and from Mary Free Bed Hospital And Rehabilitation Center. The subjects were screened as indicated in subject selection criteria and the chosen subject signed an informed personal consent form (Appendix J). The subject planned to participate three times a week for a total of 11 weeks at Grand Valley State University’s physical therapy laboratory. The first baseline phase (A) consisted of a total of six 20 minute evaluation sessions of dynamic reaching activities in sitting. The second baseline (A) was planned to consist of nine 20 minute evaluation sessions of dynamic reaching activities in sitting. This second baseline established the subject’s dynamic reaching abilities in the absence of treatment and served as a control for the study. Intervention phases (B) were planned to consist of nine treatment sessions each beginning with the 20 minute evaluation, followed by 30 minutes of NDT intervention. Evaluation of dynamic reaching activities prior to treatment diminished the possibility of immediate practice effect and therefore, more clearly assessed the efficacy of NDT. The
subject was allowed to rest between evaluation and treatment as well as rest upon request. Medical personnel would have been contacted by telephone in case of medical emergency during any phase of the study. Transportation for the subject was provided.

Intervention was carried out by a NDT certified physical therapist who was provided with general goals (Appendix K) and a therapeutic framework for regaining dynamic postural control (Appendix L). Both the goals and framework were designed to improve components of dynamic postural control as defined by Bobath (1980) and Davies (1994). The therapist provided extrinsic feedback strictly regarding head, trunk and pelvic alignment and control. Treatment was geared toward functional activities and active subject participation. Some of the exercises employed by the therapist included passive and active trunk elongation, therapeutic ball exercises, weightshifting, and reaching in sitting and standing. The therapist also emphasized passive and active trunk rotation and disassociation from the pelvis. She had the subject perform activities with the upper extremity while the involved lower extremity was fixed, as well as perform activities with the involved lower extremity while the upper extremity was fixed. Ambulation activities stressed weightbearing on the involved lower extremity, trunk disassociation, involved upper extremity relaxation during arm swing, and facilitation of active control of the involved lower extremity.

Reaching tasks were also practiced during treatment, as they are a typical component of NDT intervention. No other treatment approaches, including PNF or
Brunnstrom, were implemented. Treatment activities were permitted in any position. Active subject participation was also encouraged by the therapist through a home exercise program based on NDT principles during the intervention but was not emphasized during the nonintervention phases. The subject only had contact with the therapist during intervention phases. The evaluation sessions, which occurred during all phases of the study, involved assessment of the subject performing six dynamic reaching activities in sitting. Evaluations were completed by the researchers rather than the NDT certified therapist to eliminate evaluator bias. An independent expert in neurologic evaluation also completed the DPCCs during baseline phase to support the observations of the less clinically experienced researchers.

**Measurement Tools**

The validity of the MFRT as a measure of dynamic postural control was based on construct validity. Dynamic postural control and upper extremity function are both critical components of dynamic reaching activities. Therefore, reach distance is a functional tool which requires dynamic postural control. Theoretically, the greater the distance attained during reach, the greater the amount of postural control required. The MFRT was composed of several functional directions and heights of reach. Since several directions and heights of reach were utilized, a more comprehensive approach to functional postural control was examined.
The MFRT measurement tool also allowed the researchers to indirectly observe the relationship between postural control and upper extremity function. The MFRT provided a direct measure of dynamic reaching ability. Research has shown that multiple directions of reach are useful in determining the limits of stability and may thereby represent functional ability (Newton, 1996). Since upper extremity function is not directly measured, this study could not determine a cause-effect relationship between postural control and upper extremity function. A clinical relationship was examined however, since postural control and upper extremity function are both critical components necessary for dynamic reaching activities.

Consistent verbal instructions were delivered to the subject prior to performing the MFRT (Appendix M). The reaching tasks involved grasping a mug from a shelf and returning it to the body without dropping the mug, supporting body mass on shelf or lap with either upper extremity, standing, or shuffling feet. The shelf was composed of two four by four wooden uprights with a removable four inch wide wooden shelf. Reaching tasks occurred in four different directions. The subject was required to reach anteriorly and laterally at 90° or shoulder height, as well as 130° or overhead. The subject was also required to reach at standard chair height, diagonally anterior and diagonally posterior with shelf positioned 45° anterior and posterior to the lateral direction, respectively. The reaching tasks occurred in a randomized order as determined by drawing numbers from a hat, where each number represented a different reaching task (Appendix N).
The MFRT provided the distance to the nearest quarter inch attained during the reaching task. The measurement was based on the difference between the lateral styloid process at the initial position of the specific reaching task and at the end of the reached position for that task. Distance was observed on a yardstick which was attached to the front of the removable shelf. The greatest distance of two trials was recorded. If the subject failed to complete the task within the specified guidelines for both trials, a score of zero was recorded for that task. The lateral styloid was viewed by the evaluator at a perpendicular angle from the shelf. The upright closest to the chair was placed in a consistent position for each reach. These positions were: nine inches lateral to the right front chair leg for anterior shoulder and anterior overhead reaches, 14 inches lateral to the right back chair leg for lateral shoulder and lateral overhead reaches, 14.5 inches lateral to the right front chair leg and 20.75 inches anterolateral from the right back chair leg for the diagonally anterior reach, and 14.5 inches posterior to the right back chair leg and 20.75 inches posterolateral from the left back chair leg for the diagonally posterior reach.

In addition to the MFRT, DPCCs were completed during each of the reaching tasks. The validity of the DPCCs was also established through construct validity. The checklists contain clinically defined components involved in dynamic postural control based on NDT principles (Bobath, 1990; Davies, 1990). The DPCCs were designed to isolate the fundamental head, trunk and pelvic movement components necessary during evaluation of reach. Ordinal values provided qualitative descriptions of postural control
demonstrated by the subject during reaching. The DPCCs were scored on a scale of zero to two (Appendix B). Zero indicated the component was not observed throughout the task. One indicated the component was partially observed throughout the task. Two indicated the component was observed throughout the task. The highest DPCC score from two trials was recorded for each reaching task. These components were graphically represented by a glyph which is a diagrammatic representation of multiple data.

Reaching tasks were videotaped to allow for randomized viewing in the completion of the DPCCs. Video camera placement was standardized at a distance to allow for observation of head, trunk and pelvic motion during the reaching activity. The distances were measured from the anterior superior iliac crest of the subject in sitting to the eye of the camera with the angles taken from the sagittal plane. The distances and angles were the following: 75 inches for both anterior shoulder and anterior overhead at 90° clockwise, 58 inches for lateral shoulder, lateral overhead and diagonally anterior at 0°, and 55 inches for diagonally posterior at -45°.
CHAPTER 4

RESULTS

The subject selected for this study was a 68 year old male who sustained an ischemic left middle cerebral artery infarct on January 2, 1995 with resultant right hemiparesis and expressive aphasia. Past medical history included hypertension, left knee degenerative joint disease, bilateral restless leg syndrome, and hypercholesterolemia. No significant orthopedic or neurologic disorders were noted which would have influenced reaching ability with the involved upper extremity. However, the subject had a chronic left rotator cuff injury and a two year history of bilateral carpal tunnel syndrome. The subject ambulated independently with a rolling walker and hinged right ankle foot orthosis. He was able to move his right upper extremity and hand out of abnormal synergy patterns, and was in Brunnstrom stage IV. The subject was independent in his activities of daily living and met the inclusion criteria previously outlined by the researchers. A complete initial evaluation was performed by the NDT therapist on the first day of intervention (Appendix O).

The total number of sessions completed for the study was 29, which included: six of six evaluation sessions for the first baseline phase, eight of nine sessions for first treatment phase, nine of nine evaluation sessions for the second baseline phase, and six of nine sessions for the second treatment phase. Missed sessions in the first and second treatment phases were due to inclement weather and scheduling conflicts, respectively.
**Interrater Reliability**

Interrater reliability was established first for the MFRT and then for the DPCCs. Interrater reliability of the MFRT was determined from initial baseline data using the Pearson Product Moment Correlation Coefficient where $r = .80$ was considered significant. Directional reaching tasks that did not fit this criteria were eliminated from the study. The Pearson Product Moment Correlation Coefficient compared only two raters. Since three researchers conducted the testing, there were three coefficients for each reach. The ranges of these correlation coefficients were the following: .99-1.00 for anterior shoulder reach, .99-1.00 for anterior overhead reach, .97-1.00 for lateral shoulder reach, .42-.92 for lateral overhead reach, .99-1.00 for diagonally anterior reach, and .98-1.00 for diagonally posterior reach. Lateral overhead reach was eliminated from the study due to the unacceptably low Pearson Product Moment Correlation Coefficients. All other reaching tasks' reliability was acceptable, therefore, these MFRT measures were used in data analysis.

Interrater reliability of the DPCCs was determined from the initial baseline data using the Kappa Statistic to assertain agreement between the researchers and the expert. If the Kappa value was .80 or greater during baseline phase, videotaped sessions were viewed and postural control data was recorded by the researcher with the greatest overall agreement with the expert. If the Kappa value was between .60 and .80, the data of all researchers was recorded. If the Kappa value was less than .60, the specific reaching task
was eliminated from the study. A random viewing of videotape sessions by the researchers eliminated evaluator bias.

Similar to the Pearson Product Moment Correlation Coefficient, the Kappa Statistic only compared two raters; therefore, multiple comparisons were made with the independent expert. The Kappa ranges were as follows: .67-.75 for anterior shoulder reach, .66-.92 for anterior overhead reach, .75-.83 for lateral shoulder reach, .37-.45 for diagonally anterior reach, and .74-1.00 for the diagonally posterior reach. The diagonally anterior reach DPCC had unacceptably low Kappa values and was thereby eliminated from the study. The rater with the highest Kappa values for the anterior overhead reach, lateral shoulder reach and diagonally posterior reach scored the DPCCs. All three researchers were required to score the DPCC for the anterior shoulder reach since the Kappa values ranged between .67 and .75 based on pre-established criteria. Thus a total of four reaches including anterior shoulder, anterior overhead, lateral shoulder, and posterior diagonal, were utilized for both the MFRT and DPCCs following the interrater reliability analysis of baseline phase 1 data.

**Graphical Analysis**

Values from the MFRT and the DPCCs were graphically analyzed using the two standard deviation band width method (Ottenbacher, 1986). Trends in the data during intervention versus baseline and nonintervention phases were graphically observed. The means and standard deviations were calculated for both the MFRT and DPCC measures
for each phase in the study. These values are presented in Figures 1-8. Raw data for the MFRT values were in inches. Raw data for the DPCC values were ordinal scores. Total DPCC score was determined by adding the component scores of the head, trunk, and pelvis. Data from the first day of the initial baseline phase was not included in calculating the means and standard deviations of both the MFRT and DPCC measures. These data were excluded to allow the researchers time to learn the new tools used in the study.

The researchers determined that a maximal standard deviation of two inches for the MFRT measures represented a stable baseline. This standard deviation was based on a clinical judgment by the researchers of expected variability of reach. A standard deviation of less than one indicated a stable baseline for the DPCC measures. The DPCC standard deviation for stable baseline was chosen because the value was less than the smallest unit of change possible on the DPCC ordinal scale.

The DPCC graphs contain the symbols diamond, circle, and square. Each symbol represents the total score determined by one of the researchers. Glyphs, diagrammatic representation of data, were then enclosed within the symbols to represent head, trunk and pelvic movement component scores. The glyphs were composed of a vertical, left horizontal, and right horizontal line, representing the head, trunk, and pelvis, respectively (Appendix B). The line extended significantly outside of the symbol if the movement component was scored a two. A score of one was represented by a line to the edge of the
diamond and square, and just past the circle. A score of zero was represented with no line. If greater than 60% of the glyphs in the treatment phase (B) were above the two standard deviation band width established in the baseline phase (A), then a positive treatment effect was shown.

**Anterior Shoulder Reach**

The DPCC graph for anterior shoulder reach (Figure 1) revealed a stable baseline phase I with a mean score of 2.9 and a standard deviation of 0.2. During the first treatment phase the mean score was 3.9 and the standard deviation was 0.9. No significant treatment effect or upward trend was observed; however, the glyphs showed a maximal score for the trunk extension component during the later half of treatment phase I. Baseline phase II was also stable with a mean score of 4.1 and a standard deviation of 0.5. Thus, the subject maintained his total score and movement component scores achieved during the first treatment phase. In the last treatment phase the mean score was 4.4 with a standard deviation of 0.8. The change in DPCC scores in this second treatment phase was not significant with no notable trend.

The MFRT graph (Figure 2) for the anterior shoulder reach showed an initial stable baseline with a mean reach distance of 12.3 inches and a standard deviation of 1.5 inches. During the first treatment phase, the subject demonstrated a gradual upward trend with a mean reach distance of 12.2 inches and standard deviation of 2.8 inches. The maximal distance reached was 3.5 inches above the baseline phase I mean distance. On
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<td>Baseline I</td>
<td>Treatment I</td>
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<td>Mean: 3.9, Stnd dev: 0.9</td>
<td>Mean: 4.1, Stnd dev: 0.5</td>
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**Figure 1.** Dynamic postural control checklist graph for anterior shoulder reach. The diamonds, circles and squares represent the scores of the DPCC from the three raters. Glyphs represent head, trunk and pelvic components of the reach in a counterclockwise pattern. The line extended significantly outside the symbol if the component was scored a two. A score of one was represented by a line to the edge of the diamond and square, and just past the edge of the circle. A score of zero was represented by no line. No significant treatment effect was indicated by this graph although reach strategy was more variable following the first baseline.

Glyph key:
- head
- trunk
- pelvis
Figure 2. Modified functional reach test for the anterior shoulder reach. This graph indicates a nonsignificant gradual upward trend in distance during the first treatment phase. Reach distances were maintained in phase II as compared to the maximal reach attained in treatment phase I.
the last day of treatment phase I however, there was a decrease in the reach distance with that data point dropping into the band width.

The second baseline phase was stable for the MFRT during anterior shoulder reach with a mean reach of 16.8 inches and standard deviation of 1.7 inches. The maximal reach distance attained during treatment phase I was maintained during baseline phase II. Moreover, the mean distance for baseline phase II was 0.8 inches higher than the maximal distance reached during treatment phase I. The high mean and small standard deviation noted in MFRT in baseline phase II indicated that the subject slightly increased his reach ability during the second baseline and then remained at that level. The MFRT graph also indicated that improvements during treatment phase I were maintained in phase II. During the last treatment phase the mean reach was 17.3 inches with a standard deviation of 2.5 inches. Although the maximal reach distance was 5.7 inches above the second baseline mean, the majority of data points were within the band width with no significant treatment effect or trend seen.

**Anterior Overhead Reach**

The DPCC graph for anterior overhead reach (Figure 3) had an initial stable baseline with a mean score of 3.0 and a standard deviation of 0.0. During the first treatment phase, the mean score was 3.5 with a standard deviation of 0.9. No treatment effect or trend was noted, and the glyph components were similar to baseline. The second baseline phase was also stable with a mean score of 3.3 and a standard deviation
Figure 3. Dynamic postural control checklist graph for anterior overhead reach. Diamonds represented the total score on the checklist as rated by a single rater. Glyphs represented head, trunk and pelvic components of the reach in a counterclockwise pattern. The line extended significantly outside the diamond if the component was scored a two. A score of one was represented by a line to the edge of the diamond and zero was represented by no line. The graph indicated no significant increase in total DPCC score. Reach strategy, indicated by glyphs, showed a consistent strategy of full head, partial trunk and no pelvic component.
of 0.5. During the final treatment phase the mean score was 3.2 with a standard deviation of 0.4. Although the glyphs revealed no change in components of dynamic postural control during any phase, those glyphs that were above the band width were distinct from those within the band width by the presence of a partial pelvic component. Overall, the anterior overhead reach DPCC graph revealed no significant increase in total scores across all phases. Reach strategy, as indicated by the glyphs, showed a predominantly consistent strategy of full head, partial trunk and no pelvic component.

The initial baseline for anterior overhead reach was stable for the MFRT graph (Figure 4) with a mean reach of 10.1 inches and a standard deviation of 1.3 inches. During treatment phase I, there was a significant upward trend in data points with a mean reach of 12.2 inches and a standard deviation of 3.3 inches. The maximal reach distance was 5.9 inches above baseline phase I mean distance. The second baseline was stable with a mean reach of 15.9 inches and standard deviation of 1.7 inches. The maximal distance reached in treatment phase I was maintained in baseline phase II, indicating that treatment effects were sustained following treatment. During the second treatment phase the mean reach was 17.8 inches and the standard deviation was 1.3 inches. Although the maximal reach distance was 4.1 inches above baseline phase II mean distance reached, there was no significant treatment effect noted in this treatment phase II.

**Lateral Shoulder Reach**

The lateral shoulder reach DPCC graph (Figure 5) showed a stable baseline with a mean score of 3.2 and a standard deviation of 0.4. Treatment phase I indicated a
Figure 4. Modified functional reach test for the anterior overhead reach. This graph indicates a gradual upward trend in data and a significant increase in reach distance during the first treatment phase. Reach distances were maintained in phase II as compared to the maximal reach attained in treatment phase I (* denotes significant treatment effect).
Figure 5. Dynamic postural control graph for lateral shoulder reach. Diamonds represent the total score on the checklist as rated by a single rater. The glyphs represent head, trunk and pelvic components of the reach in a counterclockwise pattern. The line extended significantly outside the diamond if the component was scored a two. A score of one was represented by a line to the edge of the diamond and zero was represented by no line. This graph indicated a significant change in scores during the first treatment phase. Pelvic components were maintained in second baseline. Reach strategy, showed variability during second treatment phase (* denotes significant treatment effect). Glyph key: head

      trunk     pelvis
significant treatment effect with a mean DPCC score of 3.9 and standard deviation of 0.4. The glyphs showed a partial completion of the pelvic component in treatment phase I which was not seen during baseline phase I; however, there was no visible trend. The second baseline was stable with a mean score of 3.9 and a standard deviation of 0.6. The partial pelvic component gained during the first treatment phase was maintained throughout the second baseline phase. The last treatment phase was not significant with a mean score of 3.7 and a standard deviation of 0.8. During this final phase, 50% of the glyphs showed no pelvic component. DPCC score reflected that reach strategy and performance was variable during this final phase.

The first baseline phase for lateral shoulder reach was stable for the MFRT graph (Figure 6) with a mean reach of 7.2 inches and a standard deviation of 1.5 inches. During the first treatment phase the mean reach was 8.8 inches with a standard deviation of 4.5 inches. The maximal reach was 4.3 inches above the baseline phase I mean distance. The MFRT graphs for this treatment phase was not significant and no trend was observed. The second baseline was stable with a mean reach of 11.4 inches and standard deviation of 1.1 inches. This mean reach distance was 0.1 inches greater than the maximal reach attained during treatment phase I. Thus, reach distance was sustained from treatment phase I through baseline phase II. The last treatment phase was insignificant with a mean reach of 11.9 inches and standard deviation of 2.0 inches. The maximal reach was 2.9 inches above the second baseline mean reach.
Figure 6. Modified functional reach test for the lateral shoulder reach. This graph indicates a nonsignificant gradual upward trend in data followed by a drop in reach distance, on the last two days, during the first treatment phase. Reach distances were maintained in phase II as compared to the maximal reach attained in treatment phase I.
**Diagonally Posterior Reach**

The diagonally posterior reach DPCC graph (Figure 7) had a stable baseline with a mean score of 3.0 and a standard deviation of 0.0. During the first treatment phase the mean score was 3.9 with a standard deviation of 0.6. The graph indicated significant treatment effect, however, no trend was observed. Although there was increased variability in reach strategy during this first treatment phase, the subject demonstrated partial pelvic components which were not present during baseline phase I. The second baseline phase was stable with a mean score of 3.7 and a standard deviation of 0.7. The subject inconsistently maintained the pelvic components of dynamic postural control achieved during the first treatment phase. No significant improvement or trend was seen during the last treatment phase. The mean score remained at 3.7 with a standard deviation of 0.6.

The MFRT graph for the diagonally posterior reach (Figure 8) displayed an initial stable baseline with a mean reach of 7.4 inches and a standard deviation of 1.1 inches. During the first treatment phase there was a significant increase in reach distance with a mean reach of 8.7 inches and standard deviation of 3.8 inches. The maximal reach was 3.1 inches above the baseline phase I mean reach. There was a significant trend in data points with a gradual increase in the distance reached. The second baseline phase was stable with a mean of 11.4 inches and standard deviation of 1.6 inches. Maximal reach distance gained in treatment phase was sustained in baseline phase II. During the second treatment phase the mean reach was 13.3 inches with a standard deviation of 1.3 inches.
Figure 7. Dynamic postural control checklist graph for diagonally posterior reach. The diamonds represented the total score on the checklist as rated by a single rater. The glyphs represented head, trunk and pelvic components of the reach in a counterclockwise pattern. The line extended significantly outside the diamond if the component was scored a two. A score of one was represented by a line to the edge of the diamond and zero was represented by no line. This graph indicated a significant treatment effect during the first treatment phase (* denotes significant treatment effect).

Glyph key: head

trunk — pelvis
**Figure 8.** Modified functional reach test for the diagonally posterior reach. This graph indicates a gradual upward trend in data and a significant increase in reach distance during the first treatment phase. Reach distances were maintained in phase II as compared to the maximal reach attained in treatment phase I (* denotes significant treatment effect).
The maximal reach was 3.6 inches above baseline phase II mean distance. During this second treatment phase, there was a slight upward trend; however, this phase was not significant.
CHAPTER 5
DISCUSSION

The purpose of this research study was to examine the efficacy of NDT intervention with primary focus on dynamic postural control in sitting with a chronic stroke individual. Considering the high costs incurred in stroke management, efficacy studies are needed to provide quality, cost effective care. Presently, no studies have indicated the most efficacious physical therapy intervention in caring for clients following stroke. Efficacy studies that have considered NDT have failed to examine dynamic postural control, which is a major tenant of NDT theory. Since this study considers both functional and impairment measures of seated dynamic postural control, this study is the first step in research that addresses seated dynamic postural control and efficacy of NDT for stroke clients.

Reliability of Measurement Tools

The MFRT was determined to have high interrater reliability (≥ 0.97) for the anterior shoulder reach, anterior overhead reach, lateral shoulder reach, diagonally anterior reach, and diagonally posterior reach. Although Duncan (1990) has demonstrated high interrater reliability for the Functional reach test, interrater reliability for seated functional reach in multiple directions has not been previously investigated. The current study indicated that the MFRT is a sensitive and reliable tool to document seated reaching ability, which reflects dynamic postural control in a hemiparetic individual.
The DPCC was determined to have fair interrater reliability with Kappa Statistics ranging from 0.66-1.00 for the anterior shoulder reach, anterior overhead reach, lateral shoulder reach, and diagonally posterior reach. This wide range in interrater reliability confirms that dynamic postural control is difficult to document through observational analysis. This tool could be improved by increasing the sensitivity of the scoring, as well as by enhancing the visual markers placed on the subject to allow for better visual analysis of the components identified. For a more accurate clinical measure of dynamic postural control, palpation may be necessary.

Two reach directions, lateral overhead and diagonally anterior, were eliminated from the study due to low interrater reliability of MFRT and DPCC scores, respectively. Perhaps the low interrater reliability of the MFRT for the lateral overhead reach was due to a variability of location where the evaluator stood while observing distance reached for the MFRT. The probable cause of the poor reliability of the DPCC for the diagonally anterior reach was the position of the video camera. The movement components observed for diagonally anterior reach involved movements in the sagittal, frontal, and transverse planes. These components were difficult for raters to observe because camera placement allowed viewing only in the sagittal plane.

**Baseline and Treatment Phase I**

Analysis of the anterior shoulder reach DPCC graph (Figure 1) revealed no significant change in postural control impairments with NDT intervention. This reach was insignificant due to inconsistent pelvic improvement. On the fifth day of treatment
complete trunk extension was sustained throughout the task. This improvement was sustained throughout the first treatment phase. The anterior shoulder reach was the only reach where maximal improvement in the trunk component was frequently observed by at least one evaluator. Unlike reaches in other directions, during anterior shoulder reach trunk extension was the only component of trunk movement necessary. Therefore, NDT only needed to improve one trunk impairment, extension, to observe a treatment effect of the trunk.

Based on the MFRT graph (Figure 2), significant functional change in anterior shoulder reach ability was not observed. Throughout the first treatment phase however, there was an upward progression in reach function. A similar trend was observed on the DPCC graph (Figure 1) for the anterior shoulder reach. These concomitant trends may reflect convergent validity between the DPCC and MFRT for the anterior shoulder reach. In the anterior shoulder reach MFRT graph (Figure 2), there was a significant drop in function on the final day of treatment phase I. This decline was also noted in the lateral shoulder reach MFRT graph (Figure 6) and may be attributed to the subject’s emotional state on that particular treatment day (Carr & Shepherd, 1987). The subject’s wife had surgery on the last day of treatment phase I, which may have adversely affected the subject’s attention and task performance.

Anterior overhead reach DPCC graph (Figure 3) indicated that NDT intervention did not alter any of the movement components delineated in the DPCC. Although no change was demonstrated in the DPCC graph, the MFRT graph (Figure 4) indicated a
significant positive change and a gradual upward trend in reach function. Since the reaching task was consistently presented as a goal-oriented task and the subject was never requested to focus on the quality and efficiency of reach during the evaluation sessions, the subject may have implemented different strategies to achieve the goal. Thus, improvements in function seen in the MFRT, could have resulted from practicing and learning a new strategy without any change in underlying movement components of the head, trunk, or pelvis. During treatment phase I in the anterior overhead reach, the researchers observed greater elbow extension and increased scapular protraction. This increased use of the upper extremity could explain the observed functional improvements without concomitant change in the DPCC movement components.

The lateral shoulder reach DPCC graph (Figure 5) indicated a significant treatment effect with NDT intervention. A consistent partial performance of the pelvic component during the reach was noted in treatment phase I. Lateral shoulder reach stands out from other reaches due to the focus of the movement components on lateral weightshifting. According to NDT theory, midline orientation and lateral weightshifting are fundamental skills to remediate postural control dysfunction (Davies, 1990). These skills were therefore emphasized during intervention phases (B). These skills were also included in the therapy goals provided to the NDT therapist (Appendix K). Although no trend in the graph was apparent, the pelvic as well as the trunk components may have gradually improved with treatment. However, the DPCC tool may not have been sensitive to small gradations of change. Improved confidence reaching laterally out of
the subject's base of support due to practice is another possible explanation for the improved pelvic component.

In contrast to significant changes in DPCC scores, no functional change in reach ability was indicated by the MFRT graph for the lateral shoulder reach (Figure 6). The researchers observed that the subject demonstrated inefficient upper extremity motor control during the lateral shoulder reach, frequently bumping his arm and hand on the shelf during the reach. This poor motor control may have limited improvement in reach ability. There was no apparent relationship between the DPCC and MFRT scores for the lateral shoulder reach. This lack of relationship may suggest that improvement in the pelvic component alone will not result in functional change in reach ability, especially with inefficient upper extremity motor control and no documented change in trunk component. Perhaps for functional activities at lateral shoulder level, trunk, pelvic, and upper extremity coordination are necessary for improved reach function.

The diagonally posterior reach DPCC graph (Figure 7) demonstrated an inconsistent but significant pattern of improved movement components. Similar to lateral shoulder reach, 75% of the DPCC scores indicated a partial pelvic component during treatment phase I. Since this direction of reach involved lateral weighshift, the observed improvement may again be attributed to the NDT focus on midline orientation and lateral weightshifting (Davies, 1990). Another similarity of the diagonally posterior reach to lateral shoulder reach was the significant increase in subject's DPCC score on the first day of treatment. This increase could again be attributed to improved ability to
weightshift laterally and increased confidence through baseline practice. The inconsistent improvement in the observed postural control components of the trunk and pelvis may indicate that the diagonally posterior reach was a challenging and unfamiliar task. Therefore, as the subject learned new ways to move in therapy, he may have attempted to apply these strategies when performing the diagonally posterior reach (Shumway-Cook & Woollacott, 1995). Since both the strategies and the task were new to the subject, the DPCC graph (Figure 7) may reflect various strategies of movement that were attempted as the subject progressed through the learning process. Another possible explanation for the variability of the DPCC components in the diagonally posterior reach was the single plane analysis of the identified movement components. This reach was video taped -45° from the sagittal plane, therefore the raters were unable to view pure movements in the sagittal, frontal, and transverse planes; all three planes of movements were involved in this reach.

The diagonally posterior reach MFRT graph (Figure 8) also indicated a significant improvement, with a slight decline in reach distance on days five and six. With the exception of these days, an upward trend in performance was noted, which indicated that NDT intervention improved function in this reach. Considering the improvements noted in the DPCC graph, the researchers propose that as the subject's movement options increased, reach function also improved. Since both the MFRT and DPCC graphs were significant convergent validity may be established between the DPCC and MFRT for the diagonally posterior reach.
Treatment Phase I and Baseline Phase II

All four DPCC graphs (Figures 1, 3, 5, and 7) indicated that the scores achieved at the end of treatment phase I were maintained throughout baseline phase II. This finding indicates that the treatment effect was maintained over a course of several weeks in a chronic stroke individual. Movement strategy components were also maintained between these phases. For example, the partial pelvic component demonstrated at the end of treatment phase I in the anterior shoulder reach, lateral shoulder reach, and diagonally posterior reach, was maintained in each of the respective baseline II phases. Thus, movement strategies were learned during treatment and retained in nonintervention phase.

The MFRT graphs (Figures 2, 4, 6, and 8) also indicated a maintained reach ability in baseline phase II as compared to the end of treatment phase I. This sustained function was particularly easy to observe in both the anterior overhead reach and diagonally posterior reach graphs. Reaching function was maintained for several weeks without intervention. Therefore, NDT intervention positively impacted reaching capability in this chronic stroke individual. Other research also supports that NDT intervention is efficacious in improving function in post stroke individuals (Basmajian et. al, 1987; Logigian, 1983).

Baseline phase II was stable across all DPCC and MFRT graphs. The standard deviations of the DPCC graphs during baseline phase II ranged from 0.5 to 0.7. The standard deviations for the MFRT graphs during baseline phase II ranged from 1.1 to 1.7.
inches. This small variability in scores indicated that spontaneous improvements in reach function did not occur when treatment was withheld. Thus, changes observed during treatment phase I could be directly attributed to NDT intervention.

**Baseline and Treatment Phase II**

Due to treatment scheduling conflicts and a reduced number of data points, the second treatment phase was not analyzed. The researchers felt that intervention during treatment phase II was inconsistent and did not reflect the intended ABAB design of the study. Since the subject did not receive treatment during the second week of treatment phase II, treatment phase II was more similar to a multiple withdrawal design. In treatment phase II, the lack of any significant treatment effect in either MFRT or DPCC graphs across all reach directions, may reflect that a duration of greater than one week of NDT intervention may be necessary to mediate change in function or impairment on the MFRT or DPCCs, respectively. One other clinically notable observation was that previous gains in reach function and impairment continued to be maintained throughout treatment phase II with low intensity treatment, reflecting retention of reach strategies learned.

**Limitations and Benefits**

The methodology of this study provided several limitations and benefits. Strong support for the efficacy of NDT on dynamic postural control was limited by the single subject design. The homogenous sample limited both generalizability and the power of statistical analysis. Implementation of an ABAB single subject design, in which the
subject served as his own control, however, diminished the confounding factors due to heterogeneity of the stroke population (Ottenbacher, 1986, p. 197; Stern, 1994). Single subject design allowed the researchers to examine treatment effects over time with repeated measures of dynamic postural control and reach function in one post stroke individual. Therefore, both variability and consistency in performance could be systematically observed and treatment effects more clearly noted. Single case design was a systematic and easy method to document effectiveness of ongoing treatment in an individual stroke subject. The design also reduced the limiting factor of subject accessibility. This study utilized a chronic stroke subject, who was not undergoing other therapeutic rehabilitation. The confounding effects of spontaneous recovery and other treatment intervention were therefore eliminated.

Since NDT intervention focuses on quality of movement, positive outcomes are often seen over longer periods of time (DeGangi & Royeen, 1994). Consequently, a limitation to the methodology may have been the brevity of the treatment phases. Due to the chronic nature of the subject’s stroke, extended treatment phases may have been necessary to effect critical changes in impairments and function. Another limitation was the lack of consistent treatment in phase II. This inconsistency confounded the researchers’ ability to analyze treatment effects and data trends from baseline phase II to treatment phase II. This data would have strengthened the study design and allowed for an ABAB design analysis.
According to NDT theorists dynamic postural control is a foundation for movement (Bobath, 1980; Davies, 1994). A strength of this study was that dynamic postural control was assessed from both a functional and impairment perspective. Other studies that have attempted to determine the efficacy of NDT have failed to measure dynamic postural control (Basmajian, 1987; Fetters & Kluzik, 1996; Kluzik, Fetters, & Coryell, 1990). Unfortunately, NDT intervention in this study utilized occasional reaching activities to improve dynamic postural control. Thus, a practice effect of reaching during both treatment and the evaluation sessions may also have influenced the MFRT and DPCC outcomes. Another limitation may have been that the treating therapist was not blind to this study’s purpose and research design. The therapist’s knowledge of the study’s phase lengths and purpose may have influenced her expectation for subject performance.

The tools utilized in this study have construct validity and are easily administered in the clinic. When used together in the clinic, these tools denote both impairment and disability level of dynamic postural control. A limitation to these measurement tools was that reliability and validity were not previously established since the tools were newly developed for this study. Research does support the use of the standing Functional Reach test on neurologically impaired clients and this test has been shown to be both reliable and valid (Duncan et al., 1990, Straube & Campbell, 1996). This study established reliability of the modified functional reach test in sitting as detailed in the methodology.
One notable improvement from Duncan and associates' (1990) functional reach test was the use of a mug to create a more task-oriented goal.

The DPCC measurement tool had several limitations. Although the interrater reliability was high enough so that only one reach, anterior shoulder reach, required all of the researchers to score the checklist, dynamic postural control was difficult to objectively document solely through observational analysis. The primary limitation in the use of this tool was its lack of sensitivity to small gradations of change. Further research could improve this tool by increasing the range of scores that the subject could be scored on for each movement component. However, with an increased range of scores, reliability may decrease.

Another limitation specific to the DPCC measurement tool was the video camera placement. Due to space limitations in the evaluation room, the subject’s full trunk and extended arm were not simultaneously viewed for all reaches; the full trunk and proximal upper extremity were typically viewed. Vertical and horizontal alignment of the video camera were also inadequately controlled. In addition, since only one video camera was available, DPCC components could only be observed in one plane. This single plane observation was a limitation for those reaches that involved multiple planes of movement.

**Clinical Implications**

This study provides guidance for physical and occupational therapists when planning a rehabilitation program for a patient who has sustained a stroke. As a result of changes in the health care system, there is a need for a clear focus and efficiency of
intervention. This study adds to the existing scientific literature regarding the efficacy of NDT as a rehabilitation technique for improving postural control.

Several other clinical implications can be drawn from this research study. The chronic stroke subject in this study received 30 minute therapy sessions three times a week. In this short period of time, functional improvements were observed. These rapid gains in function indicate that NDT could be a cost effective, therapeutic method for chronic stroke rehabilitation. In addition, this study revealed that chronic stroke individuals are able to achieve and maintain functional improvements with NDT intervention. Finally, the MFRT may be a quick and clinically useful tool, with high interrater reliability, to measure seated dynamic postural control.

Future Research

This study provides a foundation for further research. Considering that other NDT efficacy studies have not attempted to measure dynamic postural control, a foundation of NDT theory, this study provides pioneer knowledge for future researchers. Future research can continue to examine the efficacy of NDT on improving functional skills. This research study implemented a single subject ABAB design. Other studies using similar tools and techniques would be beneficial; multiple single subject designs would add strength to the conclusions regarding the efficacy of NDT. Similarly, efficacy studies utilizing multiple single subject designs which implement other treatment techniques would assist clinicians in selecting efficacious interventions. Additionally, an
experimental group design would allow for powerful statistical analysis and more generalizable conclusions.

The newly designed tools used in this study require continued research. The DPCC utilized in this study were not sensitive enough to measure small gradations of change. Future studies could improve upon these checklists by increasing the range of possible scores to increase the sensitivity of this tool. Additionally, studies focusing on the reliability of the MFRT could support the clinical applications of this measurement tool. Validity of both the DPCC and MFRT could be increased in a study that compares these new measurement tools with other established measurement tools of dynamic postural control. This study provided an important start in examining and supporting the efficacy of NDT on dynamic postural control as measured during seated reaching function.

Conclusions

There were five major conclusions of this study. The first conclusion was that the MFRT was a reliable measure to assess seated functional reach ability in a stroke individual. MFRT is a sensitive and reliable tool that could be easily implemented in the clinic. Regarding the primary purpose, NDT intervention improved functional reach in sitting as indicated by the MFRT. These treatment effects were maintained when treatment was withdrawn, as well as maintained with low intensity treatment. Another conclusion was that an indirect relationship was indicated between the upper extremity...
and trunk through the MFRT. Finally, there was a moderate convergent validity established between the MFRT and DPCC measurement tools.

The reaches that showed significant upward trends in function, as measured by the MFRT, were the anterior overhead and diagonally posterior reaches. These directions of reach were infrequently used in this subject's activities of daily living and therefore, allowed for greater ranges of improvement. Although the anterior shoulder reach and lateral shoulder reach were not significant, some of the distances reached during treatment phase I did fall outside the band width. The anterior shoulder reach also indicated an upward trend. Since the subject was not receiving therapy beyond this study, changes in functional status therefore could be attributed to the NDT intervention phases (B). Thus, NDT was efficacious in improving functional reaching capability, reflecting improved dynamic postural control in this chronic stroke individual.

Although only three reaches showed an upward trend in function during treatment phase I, all four reaches did indicate reach distances above the band width. The maximal reach of all four reaches attained during treatment phase I was maintained throughout phase II. This sustained reach ability across phase II indicated that reach capability gained from treatment was carried over across time. Movement components attained during treatment phase I were also maintained across phase II. The increased partial pelvic component was the primary movement component sustained during phase II and was observed in the anterior shoulder, lateral shoulder, and diagonally posterior reaches.
An indirect relationship was observed between the upper extremity and trunk. The relationship between static posture and upper extremity function has been well documented (Gray, 1977; Myhr et. al, 1995). Dynamic movements also affect the trunk through the application of dynamic forces to the trunk (Cordo & Nashner, 1982). An example of this relationship between dynamic movements and trunk responses was demonstrated in a study by Zattara and Bouisset (1988) in which anticipatory postural adjustments corresponded with dynamic upper extremity activity. This study was in agreement with Bouisset and Zattara’s (1987) findings, supporting a dynamic relationship between upper extremity and trunk based on the MFRT. The researchers proposed that both upper extremity function and dynamic postural control were necessary components of the MFRT. Since intervention focused on remediation of trunk dysfunction, and improvements were observed in reach ability for all four reaches, a relationship between dynamic postural control and upper extremity function was supported.

Three of the MFRT graphs, anterior shoulder reach, anterior overhead reach, and diagonally posterior reach indicated upward trends in function. These trends occurred with concomitant changes in DPCCs for the anterior shoulder and diagonally posterior reaches. Although the anterior shoulder reach DPCC graph was not significant, upward trends were visible. Consequently for two of the four reaches, an improvement in the movement impairments was associated with an improvement in functional reach ability. Further research is needed to validate these tools’ ability to measure dynamic postural control impairment and reaching function.
REFERENCES


APPENDIX A

Modified Functional Reach Test Scoring Sheet
## MODIFIED FUNCTIONAL REACH TEST SCORING SHEET

Date: ___________  Evaluator Initials: ___________

<table>
<thead>
<tr>
<th>Reaching Task</th>
<th>Distance (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Reach: Shoulder Height</td>
<td></td>
</tr>
<tr>
<td>Anterior Reach: Overhead</td>
<td></td>
</tr>
<tr>
<td>Lateral Reach Shoulder Height</td>
<td></td>
</tr>
<tr>
<td>Lateral Reach: Overhead</td>
<td></td>
</tr>
<tr>
<td>Diagonally Anterior: Chair Height</td>
<td></td>
</tr>
<tr>
<td>Diagonally Posterior: Chair Height</td>
<td></td>
</tr>
</tbody>
</table>

Phase: 1A 1B 2A 2B
APPENDIX B

Dynamic Postural Control Checklists
DYNAMIC POSTURAL CONTROL CHECKLISTS

Anterior Reach Shoulder Reach

Date: ____________ Evaluator Initials: ____________ Phase: 1A 1B 2A 2B

For each reaching activity the subject may not:

a. shuffle feet
b. static support: use either upper extremity to support their trunk
c. dynamic support: patient will use unilateral or bilateral upper extremity support to regain uncontrolled balance.
d. stand

Directions:

Please check the appropriate box according to the following scoring description:

0 = component not observed throughout the task
1 = component observed partially throughout the task
2 = component observed throughout the task

<table>
<thead>
<tr>
<th>Direction of Reach</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Reach: Shoulder Height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head: extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk: extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelvis: anterior tilt</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Anterior Overhead Reach

Date:_________ Evaluator Initials:___________ Phase: 1A 1B 2A 2B

For each reaching activity the subject may not:

- a. shuffle feet
- b. static support: use either upper extremity to support their trunk
- c. dynamic support: patient will use unilateral or bilateral upper extremity support to regain uncontrolled balance.
- d. stand

Directions:

Please check the appropriate box according to the following scoring description:

0 = component not observed throughout the task
1 = component observed partially throughout the task
2 = component observed throughout the task

<table>
<thead>
<tr>
<th>Direction of Reach</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anterior Reach: Overhead</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head: extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk: extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelvis: anterior tilt</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Lateral Shoulder Reach

Date:_________  Evaluator Initials:___________  Phase: 1A 1B 2A 2B

For each reaching activity the subject may not:
   a. shuffle feet
   b. static support: use either upper extremity to support their trunk
   c. dynamic support: patient will use unilateral or bilateral upper extremity support
to regain uncontrolled balance.
   d. stand

Directions:

Please check the appropriate box according to the following scoring description:

0 = component not observed throughout the task
1 = component observed partially throughout the task
2 = component observed throughout the task

<table>
<thead>
<tr>
<th>Direction of Reach</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lateral Reach: Shoulder Height</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head: rotation toward target and extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk: rotation toward target and lateral flexion away from target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelvis: elevation of the noninvolved side</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Lateral Overhead Reach

Date:_________  Evaluator Initials:_________  Phase: 1A 1B 2A 2B

For each reaching activity the subject may not:
   a. shuffle feet
   b. static support: use either upper extremity to support their trunk
   c. dynamic support: patient will use unilateral or bilateral upper extremity support
to regain uncontrolled balance.
   d. stand

Directions:

Please check the appropriate box according to the following scoring description:
   0= component not observed throughout the task
   1= component partially observed throughout the task
   2= component observed throughout the task

<table>
<thead>
<tr>
<th>Direction of Reach</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lateral Reach: Overhead</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head: rotation toward target and extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk: rotation toward target and lateral flexion away from target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelvis: elevation of the noninvolved side</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Diagonally Anterior Reach

Date:___________  Evaluator Initials:_____________  Phase: 1A 1B 2A 2B

For each reaching activity the subject may not:
  a. shuffle feet
  b. static support: use either upper extremity to support their trunk
  c. dynamic support: patient will use unilateral or bilateral upper extremity support
to regain uncontrolled balance.
  d. stand

Directions:

Please check the appropriate box according to the following scoring description:
  0= component not observed throughout the task
  1= component partially observed throughout the task
  2= component observed throughout the task

<table>
<thead>
<tr>
<th>Direction of Reach</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagonally Anterior: Chair Height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head: extension and rotation toward target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk: extension, rotation toward target and lateral flexion away from target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelvis: elevation of the noninvolved side</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Diagonally Posterior Reach

Date: ____________  Evaluator Initials: ____________  Phase: 1A 1B 2A 2B

For each reaching activity the subject may not:
a. shuffle feet
b. static support: use either upper extremity to support their trunk
c. dynamic support: patient will use unilateral or bilateral upper extremity support to regain uncontrolled balance.
d. stand

Directions:

Please check the appropriate box according to the following scoring description:
0 = component not observed throughout the task
1 = component partially throughout the task
2 = component observed throughout the task

<table>
<thead>
<tr>
<th>Direction of Reach</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagonally Posterior: Chair Height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head: rotation toward target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk: rotation toward target and lateral flexion away from target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelvis: elevation of noninvolved side</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C

Initial Screen
Initial Screen

1. Subject completes inclusion questionnaire (Appendix D)
2. Subject completes Mini Mental State Exam (Appendix E)
3. Subject screened for severe scoliosis or fixed kyphosis
4. PROM of the involved UE in supported sitting (Appendix F)
5. Fugl-Meyer evaluation of the involved UE (Appendix H)
   a. motor performance of the arm, wrist and hand
6. Sensation screen: light touch and proprioception of involved UE and trunk (Appendix G)
7. Postural control evaluation: deficits noted in 6/6 reaching activities, with at least 50% deficit in 4/6.
APPENDIX D

Questionnaire
Questionnaire

Name: ____________________________
Address: ____________________________
Phone number: ____________________________
Primary care physician: ____________________________
Phone number of primary care physician: ____________________________
Address of primary care physician: ____________________________
Current medications: ____________________________

1. Have you had more than one stroke? (circle)    Yes    No

2. Date of most recent stroke ____________________________

3. Type of stroke if known ____________________________

4. Are you currently receiving physical or occupational therapy? (circle)    Yes    No

5. Do you have a history of any of the following (check those that apply and describe)
   ______ heart problems. Please indicate: ____________________________
   ______ lung problems. Please indicate: ____________________________
   ______ muscle, bone or joint problems. Please indicate: ____________________________

6. Do you experience episodes of dizziness or lightheadedness? (circle)    Yes    No
   If you circled yes please describe when and during what activities.

7. Are there any reaching activities that you are unable to perform due to pain? (circle)
   Yes    No

   List activities: ____________________________
   Describe type and location of pain: ____________________________

8. What is your current mode of transportation?

9. Would you require transportation to participate in this study? (circle)    Yes    No
10. Are you willing to participate in this study from December 30 to March 16 three times a week? (circle and discuss if necessary) Yes No
APPENDIX E

Mini Mental State Exam
## Mini Mental State Exam

### Orientation:

<table>
<thead>
<tr>
<th>What is the (year) (season) (date) (day) (month)?</th>
<th>Score</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Where are we: (state) (county) (town) (hospital) (floor)?</th>
<th>Score</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

### Registration:

<table>
<thead>
<tr>
<th>Name three objects (bed, apple, shoe). Ask the patient to repeat them.</th>
<th>Score</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

### Attention and Calculation:

<table>
<thead>
<tr>
<th>Count backwards by 7s. Start with 100. Stop after 5 calculations.</th>
<th>Score</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alternate question: Spell the word “world” backwards.</th>
<th>Score</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

### Recall:

<table>
<thead>
<tr>
<th>Maximum Score</th>
<th>Score</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask for the three objects used in question 2 to be repeated.</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

### Language:

1. Naming: Name this object. (watch, pencil)
2. Repetition: Repeat the following—"No ifs, ands or buts."
3. Follow a 3-stage command: "Take the paper in your right hand, fold it in half, and put it on the floor."
4. Reading: Read and obey the following: Close your eyes.
5. Writing: Write a sentence.
6. Copying: Copy this design.

### Instructions

1. Ask for the date. Then proceed to ask other parts of the question. One point for each correct segment of the question.
2. Ask for the facility then proceed to parts of the question. One point for each correct segment of the question.
3. Name the objects slowly, one second for each. Ask him to repeat. Score by the number he is able to recall. Take time here for him to learn the series of objects, up to 6 trials, to use later for the memory test.
4. Score the total number correct. (93, 86, 79, 72, 65)
5. Score the number of letters in correct order. (dirow = 5, odirow = 3)
6. Score one point for each correct answer. (bed, apple, shoe)

### Instructions (Language)

1. Hold the object. Ask patient to name it. Score one point for each correct answer. Allow one trial only. Score one point for correct answer.
2. Use a blank sheet of paper. Score one point for each part correctly executed.
3. Instruction should be printed on a page. Allow patient to read it. Score by a correct response.
4. Provide paper and pencil. Allow patient to write any sentence. It must contain a noun, verb, and be sensible. All 10 angles must be present. Figures must intersect. Tremor and rotation are ignored.

### Total Score

(Max. 30) Test is not timed.
APPENDIX F

Passive Range of Motion of Upper Extremities Scoring Sheet
Passive Range of Motion of Upper Extremities Scoring Sheet

Directions:
Please report range in degrees as measured using a goniometer. (Place a * next to the degree value if not WFL)

If movement is painful, place + next to the degree value

<table>
<thead>
<tr>
<th>PROM movement</th>
<th>Involved upper extremity</th>
<th>Noninvolved upper extremity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>flexion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>extension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>abduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>adduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>external rotation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>internal rotation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>flexion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>extension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>flexion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>extension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>radial deviation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ulnar deviation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX G

Sensation Screen Scoring Sheet: Light Touch and Proprioception
Sensation Screen Scoring Sheet: Light Touch and Proprioception

**Directions:**
Please perform light touch on the anterior and posterior surfaces of the involved upper extremity and bilateral on trunk. Perform light touch in all four quadrants of the trunk (See diagram below). Check the appropriate box.

<table>
<thead>
<tr>
<th>Light Touch</th>
<th>Intact</th>
<th>Impaired</th>
<th>Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior surface of upper extremity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior surface of upper extremity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior Trunk: Quadrants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior Trunk: Quadrants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Definition of terms:**

**Intact:** Client able to feel light touch equally on both the anterior and posterior aspect of the right and left upper extremity, and on both the right and left sides of the anterior and posterior surfaces of the trunk.

**Impaired:** Client able to feel light touch, with abnormal or diminished sensation, on either/both the anterior or posterior aspect of the right or left upper extremity, or on either/both the right or left sides of the anterior or posterior surfaces of the trunk.

**Absent:** Client unable to feel light touch on either/both the anterior or posterior aspect of the right or left upper extremity, or on either/both the right or left sides of the anterior or posterior surfaces of the trunk.

**Trunk Quadrant Key:**

[Diagram of trunk quadrant key]
Directions:

Please perform proprioception of the following joints in the involved upper extremity. Check the appropriate box.

<table>
<thead>
<tr>
<th>Proprioception</th>
<th>Intact</th>
<th>Impaired</th>
<th>Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thumb</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Definitions of Categories:

Intact: Greater than 3/5 correct answers
Impaired: 3/5 correct answers
Absent: Less than 2/5 correct answers
APPENDIX H

Fugl-Meyer Measure of Motor Performance
### Fugl-Meyer Measure of Motor Performance

#### Motor Upper Extremity (sitting)

<table>
<thead>
<tr>
<th>Area</th>
<th>Test</th>
<th>Scoring Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Reflexes</td>
<td>0—No reflex activity can be elicited</td>
<td>4</td>
</tr>
<tr>
<td>a. Biceps</td>
<td>2—Reflex activity can be elicited</td>
<td></td>
</tr>
<tr>
<td>b. Triceps</td>
<td>0—Cannot be performed at all</td>
<td></td>
</tr>
<tr>
<td>II. Flexor synergy</td>
<td>1—Performed partly</td>
<td></td>
</tr>
<tr>
<td>Elevation</td>
<td>2—Performed faultlessly</td>
<td></td>
</tr>
<tr>
<td>Shoulder retraction</td>
<td>0—Cannot be performed at all</td>
<td></td>
</tr>
<tr>
<td>Abduction</td>
<td>1—Performed partly</td>
<td></td>
</tr>
<tr>
<td>(at least 90°)</td>
<td>2—Performed faultlessly</td>
<td></td>
</tr>
<tr>
<td>External rotation</td>
<td>0—Cannot be performed at all</td>
<td></td>
</tr>
<tr>
<td>Elbow flexion</td>
<td>1—Performed partly</td>
<td></td>
</tr>
<tr>
<td>Forearm supination</td>
<td>2—Performed faultlessly</td>
<td></td>
</tr>
<tr>
<td>III. Extensor synergy</td>
<td>0—No specific action performed</td>
<td></td>
</tr>
<tr>
<td>Should adduction/internal rotation</td>
<td>1—Hand must pass anterior superior iliac spine</td>
<td></td>
</tr>
<tr>
<td>Elbow extension</td>
<td>2—Action is performed faultlessly</td>
<td></td>
</tr>
<tr>
<td>Forearm pronation</td>
<td>0—No motion or direction change occurs</td>
<td></td>
</tr>
<tr>
<td>IV. Movement combining synergies</td>
<td>1—Initial elbow flexion occurs, or any deviation from pronated forearm occurs</td>
<td></td>
</tr>
<tr>
<td>a. Hand to lumbar spine</td>
<td>2—Faultless motion</td>
<td></td>
</tr>
<tr>
<td>b. Shoulder flexion to 90°, elbow at 90° and forearm pronated</td>
<td>0—Initial elbow flexion occurs, or any deviation from pronated forearm occurs</td>
<td></td>
</tr>
<tr>
<td>b. Shoulder flexion, 90–180°, elbow at 90°, and forearm in mid position</td>
<td>2—Faultless motion</td>
<td></td>
</tr>
</tbody>
</table>
| (contin...
<table>
<thead>
<tr>
<th>AREA</th>
<th>TEST</th>
<th>SCORING CRITERIA</th>
<th>MAXIMUM POSSIBLE SCORE</th>
<th>ATTAINED SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>d.</td>
<td>Grasp 2—Patient is instructed to adduct thumb, all other joints at 0°</td>
<td>0—Function cannot be performed 1—Scraps of paper interposed between the thumb and index finger can be kept in place, but not against a slight tug 2—Paper is held firmly against a tug Scoring procedures are the same as for grasp 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>Grasp 5—Patient opposes thumb pad against the pad of index finger, a pencil is interposed</td>
<td>Scoring procedures are the same as for grasp 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f.</td>
<td>Grasp 4—The patient should grasp a cylinder-shaped object (small can), the volar surface of the 1st and 2nd finger against each other</td>
<td>Scoring procedures are the same as for grasps 2 and 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g.</td>
<td>Grasp 5—A spherical grasp, the patient grasps a tennis ball</td>
<td>Scoring procedures are the same as for grasps 2, 3, and 4</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>

I.V Function Speed—Finger to nose

Five repetitions in rapid succession

<table>
<thead>
<tr>
<th>AREA</th>
<th>TEST</th>
<th>SCORING CRITERIA</th>
<th>MAXIMUM POSSIBLE SCORE</th>
<th>ATTAINED SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Tracer</td>
<td>Marked in any one of the following: 1—Marked by nose 2—No tracer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>Dexterity</td>
<td>Pronounced or unsystematic dysmetria 1—Mild 2—Severe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>Speed</td>
<td>Activity is more than 2 seconds longer than unaffected hand 1—2 to 5 seconds longer than unaffected hand 2—Less than 2 seconds difference</td>
<td>6</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total maximum score of upper extremity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Scoring procedures are the same as for grasp 2.
<table>
<thead>
<tr>
<th>AREA</th>
<th>TEST</th>
<th>SCORING CRITERIA</th>
<th>MAXIMUM POSSIBLE SCORE</th>
<th>ATTAINED SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>c.</td>
<td>Pronation/supination of forearm elbow at 0° and shoulder between 30°–90° of flexion</td>
<td>0—Supination and pronation cannot be performed at all, or elbow and shoulder positions cannot be attained 1—Elbow and shoulder properly positioned and pronation and supination performed in a limited range 2—Faultless motion</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>VI.</td>
<td>Normal reflex activity</td>
<td>Beeps and or finger flexors and triceps</td>
<td>0—At least 2 of the 3 phasic reflexes are markedly hyperactive 1—One reflex is markedly hyperactive, or at least 2 reflexes are lively 2—No more than one reflex is lively, and none are hyperactive</td>
<td></td>
</tr>
</tbody>
</table>

**Hand**

<table>
<thead>
<tr>
<th>TEST</th>
<th>SCORING CRITERIA</th>
<th>MAXIMUM POSSIBLE SCORE</th>
<th>ATTAINED SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>b.</td>
<td>Finger mass extension</td>
<td>0—No extension occurs 1—Patient can release an active mass flexion grasp 2—Complete active extension (compared with unaffected hand)</td>
<td>10</td>
</tr>
<tr>
<td>c.</td>
<td>Grasp I—Metacarpal-phalangeal joints extended and proximal interphalangeal &amp; distal interphalangeal joints are flexed; grasp is tested against resistance</td>
<td>0—Required position cannot be acquired 1—Grasp is weak 2—Grasp can be maintained against relatively great resistance</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX I

Patient Inclusion Criteria: Brunnstrom Stage IV & V of Motor Recovery
Patient Inclusion Criteria: Brunnstrom Stage IV & V of Motor Recovery

Stage 4

Volitional movement that combines or deviates from basic upper extremity flexion and extension synergies can be accomplished. Upper extremity spasticity begins to decline. Hand grasps available to the subject include: lateral prehension, release by thumb movement and semi-voluntary finger extension performed in small ranges (Sawner & LaVigne, 1992, pp. 55, 61).

Stage 5

Increased selective volitional movement out of upper extremity flexion and extension synergy patterns develop. Upper extremity spasticity continues to decline. Hand grasps available to the subject include: palmer prehension and possible cylindrical and spherical. The later two grasps are awkwardly performed and have little functional use (Sawner & LaVigne, 1992, pp. 57, 61).
APPENDIX J

Consent Form
Consent Form

I understand that this is a study examining elements of postural control and its effect on upper extremity function. The knowledge gained is expected to help physical and occupational therapists provide efficient and effective treatment to patients who have had a stroke.

I also understand:

1. Participation in this study will involve the following:
   - initial interview— 60 minutes
   - December 30, 1996 to January 12, 1997— six 20 minute sessions
   - January 13 to February 2—nine 50 minute sessions
   - February 3 to February 23— nine 20 minute sessions
   - February 24 to March 16— nine 50 minute sessions

2. My physician has given me medical clearance to participate in this study.

3. It is not anticipated that this study will lead to physical or emotional harm to myself. However, I understand that treatment may cause temporary mild muscular soreness and possible exercise induced fatigue. I understand that I may request a rest period at any time during sessions.

4. The information I provide will be kept strictly confidential and the data will be coded so that personal identification will not be possible.

5. The summary of results from this study will be made available upon my request.

6. All evaluation sessions will be videotaped and viewed by the researchers and an independent evaluator. These videotapes will be kept confidential and destroyed after completion of the study.

7. Any subsequent treatment related to and following the research study will not be paid for by the researchers or sponsoring institutions. I am responsible for any medical costs.

I acknowledge:

1. "I have been given an opportunity to ask questions regarding this research study, and that these questions have been answered to my satisfaction."

2. "Failure to enter or withdrawal from this study will not effect any current or future treatment."
3. “In giving my consent, I understand that my participation in this research study is voluntary and that I may withdraw at any time by informing the treating therapist and submitting a termination form provided by the treating therapist.”

4. “The researchers Renee Baer, Mary Kathryn Koeninger, and Neha Shah have my permission to review my medical records from the past two years.”

5. “I hereby authorize the researchers to release the information obtained in this study to scientific literature. I understand that I will not be identified by name.”

6. “I have been given the phone numbers of the researcher’s, Renee Baer, Mary Kathryn Koeninger and Neha Shah, as well as Paul Huizenga (616-895-2472), the chairmen of Grand Valley State University Human Subject Review Committee. I may contact them at any time if I have questions.”

7. “The purpose of my participation in this study is to fulfill the educational requirements of the researchers. I understand that treatment within the research study may not directly benefit me.”

“I acknowledge that I have read and understand the above information, and I agree to participate in this study.”

[Signature]

witness date participant signature date
Therapy Goals

**Primary goal:** Improve postural control as demonstrated by dynamic reaching activities in sitting.

1. Improve active trunk motion
   a. elongation of trunk musculature
   b. anterior and posterior pelvic tilt
   c. trunk rotation
   d. shoulder girdle dissociation from trunk
   e. upper trunk dissociation from head and lower trunk

2. Improve head control
   a. independence of head from body movements

3. Improve midline orientation

4. Improve weightshifting ability
APPENDIX L

NDT Intervention: Treatment Framework
NDT Intervention: Treatment Framework

Posture can no longer be thought of as solely a reflex activity (Brooks, 1983, Horak et al., 1984). Rather, posture should be viewed as a feedforward as well as a feedback process (Higgins, 1972). Therefore, dynamic postural control is a learned skill, albeit an automatic task. Based on this philosophy, the subject will be an active participant in treatment (Riolo-Quinn, 1990). Treatment will be individualized, constantly modified according to subject response, and geared toward functional activities (DeGangi, 1994a, Palisano, 1991). Emphasis will be placed on retraining normal movement patterns based on NDT treatment principles. These patterns will be facilitated through appropriate sensory stimulation, direct manual contact and verbal and visual feedback. The subject will receive knowledge of performance and knowledge of results strictly regarding head, trunk and pelvis alignment and control. Quality of movement and postural components that underlie movement will be stressed during treatment (DeGangi & Royeen, 1994).
APPENDIX M

Verbal Instructions for Reaching Tasks
Verbal Instructions for Reaching Tasks

Prior to each reaching activity, the researcher will say the following:

"I want you to reach as far as you can for the mug, grab it and bring it back to your body. Try not to lose your balance or drop the mug. You can not stand up, shuffle your feet or hold on with the other hand; you must remain seated during the reaching activity. This is not a timed task, the goal is to control reaching as far as you can. We will take the best score out of two trials. Are you ready? Reach!"
APPENDIX N

Randomization of the Reaching Tasks
Randomization of the Reaching Tasks

Each number will be drawn from a hat and represent a different reaching task.

<table>
<thead>
<tr>
<th>Number</th>
<th>Reaching Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>Anterior Reach: Shoulder Height</td>
</tr>
<tr>
<td>Two</td>
<td>Anterior Reach: Overhead</td>
</tr>
<tr>
<td>Three</td>
<td>Lateral Reach: Shoulder Height</td>
</tr>
<tr>
<td>Four</td>
<td>Lateral Reach: Overhead</td>
</tr>
<tr>
<td>Five</td>
<td>Diagonally Anterior: Chair Height</td>
</tr>
<tr>
<td>Six</td>
<td>Diagonally Posterior: Chair Height</td>
</tr>
</tbody>
</table>
APPENDIX O

Initial Evaluation
Initial Evaluation

Passive Range of Motion

Passive Range of Motion was within normal limits (WNL) in all extremities, with exception of right ankle dorsiflexion to 5°. Trunk elongation was limited on the right by 50%, and trunk rotation to both the right and left limited by 25%. Pelvic and low back motion was limited by 50% in the anterior direction, and 50% in the posterior direction.

Muscle Tone

Muscle tone was normal in left upper and lower extremities. At rest, muscle tone was normal in right upper extremity and throughout the trunk. With exertion, there was a moderate ↑ in right upper extremity flexor tone and right latissimus dorsi muscle tone. At rest, the right lower extremity demonstrated moderate ↑ in hamstring muscle and gastrocsoleus muscle tone. With stressful activities, the flexor tone in the right lower extremity was severe, but the right foot positioned in an equinovarus position.

Active Control

Selective control was present in left extremities with 5/5 strength in left lower extremity and 3/5 to 4/5 strength in left upper extremity secondary to rotator cuff tear (Kendall, McCreary, & Provance, 1993). In the right upper extremity, the subject was able to perform all selective movements (Brunnstrom stage V) with 4/5 strength in a seated position. During rapid alternating movements, the subject was unable to turn off the flexor musculature of the right upper extremity. In standing, the subject assumed a flexed posture of the right upper extremity which increased with ambulation. The subject’s right lower extremity was in a Brunnstrom stage III.

Balance

The subject was able to maintain normal static sitting balance on a firm surface; his dynamic sitting balance was maintained utilizing abnormal strategies. In standing, the subject’s static balance was fair, requiring upper extremity support to maintain upright posture. The subject’s dynamic standing balance was poor--; he was unable to safely perform small range shifts in standing without upper extremity support and moderate physical assistance. While standing, the subject displayed flexion of the right lower extremity (severe associated reaction) when a small perturbation was provided.
Standing posture

The subject demonstrated decreased weightbearing on the right lower extremity, and held his right upper extremity in a flexor position. The right side of his trunk was shortened, with the right side of the pelvis higher than the left and rotated posteriorly to the right.

Bed Mobility

The subject was independent in rolling to the right and left, and moving from supine to short sitting. However, mass synergy patterns of the right upper and lower extremities were employed to achieve this task.

Transfers

The subject was independent in moving sit ↔ stand from all surfaces. However, minimal weightbearing was evident on the right lower extremity.

Ambulation

The subject independently ambulated on level surfaces up to 100 feet with a rolling walker, right ankle foot orthosis, and step to pattern. The subject demonstrated the following gait deviations throughout the gait cycle: decreased weightbearing on right lower extremity, flexor associated reactions of the right upper extremity, hip hiking on right, flexor pattern used to advance right lower extremity, retraction of the right side of the pelvis, and severe equinovarus positioning in the right foot. The subject required moderate physical assistance to ambulate with a small based quad cane, and moderate to maximal physical assistance to ambulate with a straight cane; gait deviations were exaggerated with these devices.