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The Effects of Prosthesis Use Versus Non-use on Forward Reach Distance in Children Ages 5 to 15 with Unilateral Upper Extremity Amputation as Measured by the Functional Reach Test

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The Effects of Prosthesis Use Versus Non-use on Forward Reach Distance in Children Ages 5 to 15 with Unilateral Upper Extremity Amputation as Measured by the Functional Reach Test

by

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Scot G. Smith

THESIS

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

MASTER OF SCIENCE IN PHYSICAL THERAPY

1999
The Effects of Prosthesis Use Versus Non-use on Forward Reach Distance in Children Ages 5 to 15 with Unilateral Upper Extremity Amputation as Measured by the Functional Reach Test

ABSTRACT

The purpose of this study was to investigate the possible differences in maximal forward reaching distance in children with unilateral upper extremity amputations while wearing and not wearing a prosthesis using the Functional Reach (FR) test. Trends were noted between FR scores of these children and children without disabilities.

Four children, ages 5 - 8, completed the FR test using the intact arm under two conditions, “prosthesis-off” and “prosthesis-on”. A paired, two-tailed t test (α = .05) was used to determine the statistical significance of the means of differences in FR scores between the two conditions.

No statistically significant difference was found in the FR test scores between the two conditions noted above. Two trends were observed: 1) 3 of 4 subjects reached farther in the “prosthesis-off” condition and 2) 3 of 4 subjects attained a FR score within the 95% CI range described by other researchers for children without disabilities.
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CHAPTER 1
INTRODUCTION

Background

Current trends toward managed care in the United States are pushing medical professionals to refine their treatment strategies. Cost reduction measures are becoming requisites for physical therapists who wish to be reimbursed by contemporary payers. These measures include increased emphasis on patient education and elimination of adjunctive, non-critical evaluations and interventions. Justification for specific assessments and treatments is becoming increasingly important.

Traditionally, high priority has been placed on the evaluation and treatment of patients with postural control problems by physical therapists. Numerous studies indicated that children with disabilities often show deficits in postural control (Deitz, Richardson, Crowe, & Westcott, 1996; Niznik, Turner, & Worrell, 1995; Crowe & Horak, 1988; Potter & Silverman, 1984; Siegel, Marchetti, & Tecklin, 1991; Kowalski & DiFabio, 1995; Bhattacharya, Shukla, Dietrich, Bornschein, & Berger, 1995; Shumway-Cook & Wollacott, 1985; Connolly & Michael, 1986). Children with upper extremity amputations are typically evaluated and treated to ensure optimal functional use of a prosthesis during activities of daily living (ADL). Yet, assessment in the area of postural control, as it pertains to prosthesis use versus non-use, is variable in this patient population.
Statement of Problem

One reason for this variance in assessment may be that a relationship has not been established between upper extremity prosthesis use and postural control. Numerous studies exist relating upper extremity function to postural control (Cordo & Nashner, 1982; Friedli, Hallett, & Simon, 1984; Friedli, Cohen, Hallett, Stanhope, & Simon, 1988; Zattara & Bouisset, 1986). However, no research was uncovered directly relating the presence or absence of an upper extremity artificial limb with an alteration in postural control.

Purpose of Study

Data will be statistically analyzed to determine a relationship between prosthesis use versus non-use and forward reach distance in children ages 5 to 15 with unilateral upper extremity amputations. The Functional Reach test will be used as a screening tool to indicate maximal voluntary forward reach distance. A significant difference in distances reached between the two conditions of prosthesis use and non-use may indicate a change in the voluntary aspect of postural control between conditions.

Significance

This study addresses an area of concern to the scientific community, clinicians, and clients. Scientifically, a connection has been established between upper extremity movements and aspects of postural control. The shortening of an upper extremity, traumatically or congenitally, produces an off-weighting of a generally symmetrical body.
Numerous authors have researched the effects of an asymmetrical weight distribution on a subject’s postural control (Horak, Esselman, Anderson, & Lynch, 1984; Zattara & Bouisset, 1988; Crowe & Samson, 1997). Yet, there is a paucity of information on the effects of an upper extremity prosthesis on the ability of a subject to maintain postural control during reaching tasks. This study will produce preliminary information on the effect that prosthesis use and non-use place on forward reach distance.

Clinicians need an awareness of possible deficits in their clients. Knowing that a prosthesis has the potential of improving or hindering forward reach distance will improve clinicians’ awareness of possible postural control abnormalities. Having research that indicates no difference in forward reach with and without a prosthesis may allow clinicians to test postural control in only those clients exhibiting functional deficits. Establishing a relationship between unilateral upper extremity prosthesis use or non-use and forward reach distance will help clinicians choose appropriate evaluations of postural control and interventions during their limited time with each client.

Through education and experience, clients with upper extremity amputations will become aware of the impact prosthesis use may have on their postural control. Those clients then may adapt their strategies and/or environments to complement their needs. The data obtained by this research may motivate clinicians and clients to allot time in therapy for prosthesis use training if warranted. The data also could give clinicians the information necessary to help clients decide if prosthesis use is advantageous for each of the multitude of varied activities encountered daily involving forward reach.
Null Hypothesis

No statistically significant difference will be found between subject use and non-use of an upper extremity prosthesis in children ages 5 to 15 with unilateral upper extremity amputation and resulting forward reach distance as measured by the Functional Reach test.
CHAPTER 2
LITERATURE REVIEW

Upper Extremity Amputation

Upper extremity (UE) amputation is defined as the acquired (limb removed due to disease or injury) or congenital absence/shortening (present at birth) of some portion of the upper limb (Copeland, Lundeen, Novotny, & Swagman, 1996). This removal, absence, or shortening can be at any site on the arm, from the digits up to the axilla. Types of amputations can be categorized as follows: partial hand, wrist disarticulation, transradial (below the elbow joint), elbow disarticulation, transhumeral (above the elbow joint) and shoulder disarticulation (May, 1997, p. 10). UE amputations are far less common than those of lower extremity (May, p. 203). Several pathologies can lead to the amputation of the UE, including vascular insufficiency, trauma, bone tumor, osteomyelitis, and congenital malformation (May, p. 10; Silcox, Rooks, Vogel, & Fleming, 1993; Bender, 1974, pp. 3-4). Researchers have cited trauma as the most common cause of UE amputations among adults (May, p. 204; Silcox et al.; Bender, p. 4.; Herring & Birch, 1998, p. 37). Some authors have stated that trauma is also the most common cause of UE amputations in juveniles (May, p. 10; Silcox et al.). Other authors have cited congenital limb deficiencies as the most prominent cause of UE amputations in children (Bender, p.4; Herring & Birch, p. 40).
Upper extremity amputation affects the patient on several levels. The psychological impact of losing an arm varies with the individual (Bender, 1974, p. 26). UE amputations are often due to trauma. The loss is usually sudden, leaving the patient no time for mental preparation. This sudden loss produces an increased psychological impact as compared to the surgical excision of a lower extremity which is usually performed following a lengthy period of vascular insufficiency (May, 1997, pp. 10 & 206). An arm is more readily visible than a leg, which is often covered up by pants or a skirt. Furthermore, hands are used for many activities which are thought to be crucial to social interaction (e.g., holding hands with a loved one, shaking hands, gesturing during conversation, etc.). Therefore, “for most people, the hand has much more psychological importance than the foot” (May, p. 206).

Some trends in psychological adjustment have been identified. Patients who have displayed timid or self conscious behavior patterns, shown notable concern regarding their physical appearance, or suffered from depression prior to the amputation are more likely to exhibit “more disabling psychological stress” (May, 1997, p. 100) following amputations. Bender (1974) agreed that persons preoccupied with body image are more likely to exhibit disabling psychosocial withdrawal (p. 26). Conversely, patients who are confident and outgoing prior to the loss often adjust well. Following the amputation, patients who exhibit motivation to master the use of a prosthesis and return to an active lifestyle generally adjust better psychologically to their amputations (May, p. 100). The degree and type of support that people with UE amputations receive from their social contacts (family, peers, physician, and therapist), functionality of the family, and the ease
of reintegration into their prior occupation are also factors which affect psychological adjustment (May, p. 100; Livingston, Keenan, Kim, Eucavage, & Malangoni, 1994; Bender, p. 26; Herring & Birch, 1998, pp. 464-465).

Several physical complications can occur following UE amputation. Some of these complications stem from disuse of the residual limb (the portion of the arm remaining following surgery) (May, 1997, p. 13). These complications include muscular weakness and decreased joint range of motion due to adaptive shortening of the muscles and joint tissues (May, pp. 11 & 205-206; O'Sullivan & Schmitz, 1994, pp. 378-379, 387).

Muscular weakness or paralysis also may occur due to nerve trauma incurred from surgery, injury, or entrapment (Bender, 1974, pp. 23-24). Residual limb problems can include infection of the post-surgical wound and skin ulceration secondary to ill fit or overuse of a prosthetic device (May, pp. 205-206; Livingston et al., 1994; Wood, Hunter, & Millstein, 1987; Bender, pp. 27-28). Neuromas, bundles of nerve tissue located in the residual limb, also can create hyperalgesia in the residual limb and may require surgical treatment (Livingston et al.; Bender, p. 22).

Livingston et al. (1994) reported that “most patients will experience phantom pain early after amputation which diminishes over time” (p. 498). This observation was confirmed by Melzack (1992) who suggested that at least 70 percent of all amputees experience phantom pain following limb excision. Phantom pain is defined as a painful sensation felt following amputation which is perceived by the patient as being located in a missing portion of the residual limb. The pain tends to fall into three broad categories of 1) cramping or squeezing, 2) burning, or 3) shooting and shocking (American Academy of
Another effect of an arm amputation is the change in total body weight (TBW). Le Veau (1992) has cited sources placing the weight of a single upper extremity from 4.8% to 6.2% of a person's TBW (p. 304). Smith, Weiss, and Lehmkuhl (1996) rounded the figure off at 5.0% (p. 255). The weight lost due to an amputation depends upon the level of amputation and the individual's body build. As UE amputations are unique to each individual, the actual change in weight of the affected arm will vary from one subject to another. However, the proportional weight of the arm can be divided up as follows: the upper arm (humerus and accompanying musculature) accounts for 3.3% to 2.6% TBW, the forearm accounts for 2.1% to 1.6% TBW, and the hand accounts for 0.8% to 0.6% TBW (Le Veau, p. 304).

Prosthetics

A prosthesis is defined as "the replacement of an absent part by an artificial one" (Anderson, Bechtol, & Sollars, 1959, p. 5). For the person with an UE amputation there are several models of prostheses. These models include prostheses which generate functional movement through the use of cables and the wearer's own body power (mechanical), prostheses which are powered externally by a battery and activated by the contraction of the biceps/triceps (myoelectric), and prostheses which possess no movement properties, but serve an aesthetic or cosmetic purpose (Silcox et al., 1993; Popat et al., 1993; May, 1997, pp. 207-208; Bender, 1974, pp. 68-69).
Prosthetic use among people with UE amputation varies. Some patients utilize their artificial limbs heavily while other patients reject the prosthesis altogether. In a study conducted by Silcox et al. (1993), 50 percent of subjects who had utilized a myoelectric prosthesis rejected the prosthesis. In the same study, 33 percent of subjects who had used conventional prostheses also rejected the devices (Silcox et al.). All subjects in this study had utilized various prostheses from 2 to 17 years (Silcox et al.). In a study entitled “Extent of Disability Following Traumatic Extremity Amputation”, 29 subjects with lower extremity amputations and 13 subjects with UE amputations were questioned regarding the extent of their disability following amputation (Livingston et al., 1994). Among the areas of inquiry was prosthesis use versus non-use. Of those with UE amputations, 4 subjects with transradial amputations and 1 subject with a transhumeral amputation opted not to utilize prosthetic devices (Livingston et al.).

Patients cite many reasons for their preference to use or abandon the prosthesis. Livingston et al. (1994) found the primary reason for non-use among people with UE amputations was the weight and bulk of currently available prostheses. In another study, subjects rejected the use of myoelectric prostheses for one or more of the following reasons: difficulty with operation, poor fit, excessive perspiration, weight, and lack of durability (Silcox et al., 1993). Two studies found that decreased comfort and complaints due to repair problems led children to spend less time wearing their prostheses (Boyle, Tebbi, Mindell, & Mettlin, 1982; Tebbi, Petrilli, & Richards, 1989). Conversely, many factors have led subjects to accept their prostheses. The cosmesis of a prosthesis is preferred by many individuals. An easy to use prosthetic device that has fewer straps and
cables is also more likely to be worn. If the prosthesis fits well, distributes pressure evenly on the residual limb, and feels natural as compared to earlier models, then a patient is more likely to continue using it (Silcox et al.; Popat et al., 1993).

One of the factors most valued by individuals wearing an UE prosthesis is sensory feedback from the artificial limbs. This feedback usually comes in the form of auditory cues. The specific sounds of gears and moving parts become familiar, giving the wearer some idea where the limb is in space or what motion the prosthesis is performing (Silcox et al., 1993). Changes in the weight of the prosthesis, patterns of pressure on the residual limb, and alterations in positions of the straps also may provide the tactile input many people with amputations claim to feel (Silcox et al.).

Several trends were identified in prosthesis use. The type of amputation relates to prosthetic use. Individuals with transradial amputations are more likely to use a prosthesis than others with UE amputations (Millstein, Herger, & Hunter, 1986; Sturup et al., 1988; Van Lunteren, Van Lunteren-Gerritsen, Stassen, & Zuithoff, 1983). Patients with longer partial hands and wrist disarticulations may find they have greater functional abilities using their residuums rather than a prosthesis, and thus may opt not to use a prosthetic device. Conversely, patients with elbow disarticulations or higher UE amputations may find adaptation to most skills with one arm to be less demanding than learning to use a prosthesis. This idea is confirmed by the American Academy of Orthopaedic Surgeons (AAOS)(1981) who state, “... the complexity of the upper limb prosthetic substitution and the ability of the patient to function quite effectively with the remaining normal arm,
combine to decrease motivation for prosthetic fitting and training of amputees with unilateral amputations” (p. 92).

Training in the use of the prosthesis by a rehabilitation professional also influences acceptance of the UE prosthesis. Bender (1974) stated that his experience in the field showed that, “Patients who obtain their prostheses without prescription are likely to receive no checkout or formal instruction in its control or use. These are the people who don’t wear their prostheses.” (p. 108).

Another relational trend for use or non-use of a prosthesis was demonstrated between length of time from amputation to initial fitting of the prosthesis. Most patients with UE amputations who are fitted with a prosthesis soon after trauma are more likely to accept the device (Malone et al., 1984; Fletchall & Hickerson, 1991; Herring & Birch, 1998, p. 425). Many rehabilitation texts urge therapists to begin training individuals with amputations in the use of a prosthesis as soon as wound healing will allow (Clark, Shaw-Wilgis, Aiello, Eckhaus, & Eddington, 1997; AAOS, 1981, p. 21; O'Sullivan & Schmitz, 1994, p. 390). These authors indicate that earlier prosthetic use will increase effectiveness of the patient’s ability to learn to use the prosthesis well.

**Functional Measures of Prosthetic Use**

Increased functional use of the prosthesis is of importance to clinicians and patients (Greenfield, Solomon, Brook, & Davies-Avery, 1978; Kantz, Harris, Levitsky, Ware, & Davies, 1992; Lembcke, 1952; Livingston et al., 1994; Silcox et al., 1993). Duration of prosthesis use versus non-use is the most common measure of functional integration.
The Child Amputation Prosthetics Project-Functional Status Inventory, "a recently developed standardized measure," and another measure described by Pruitt, Varni, Seid, and Setoguchi (1997) both rely on the duration of wear as a functional measure of prosthetic use (Pruitt, Varni, & Setoguchi, 1996; Herring & Birch, 1998). The amount of time taken to perform ADL tasks also was reported to be a reliable measure for evaluation of prosthetic performance (Kay & Peizer, 1958; Stein & Walley, 1983; Lamb, Dick, & Douglas, 1988). Daily use of the upper extremities involves both open- and closed-chain UE movements with involvement of the glenohumeral, elbow, and wrist joints. Therefore, Popat et al. (1993) advocated the use of both open-and closed-chain movements in functional testing along with movement components at all prosthetic joints.

Consensus exists that bimanual tasks should be included in any functional assessment of UE prosthetic use (Thornby & Krebs, 1992; Popat et al., 1993). The rationale for this consensus is that one-handed tasks will most often be performed by people with UE amputations with the intact extremity. This performance will be equal to or better than the performance of people without amputations and does not test the use of the prosthetic limb (Krebs, 1985). Specific bimanual tasks utilized in prior studies included cutting meat, donning socks, rolling dough, turning a crank, opening jars, grasping bicycle handles, cutting paper with scissors while grasping, donning trousers or a skirt, catching a ball with both hands, sharpening a pencil, and drying dishes with a dish towel (Thornby & Krebs; Popat et al.). These tasks were tested on children with UE amputations and determined to be reliable and valid (Krebs, Lembeck, & Fishman, 1988;
Berger & Edelstein, 1989; Kay & Peizer, 1958; Krebs, 1987). This battery of tasks was not only bimanual, but also used open- and closed-chain movements, could be timed, and utilized all of the UE joints.

Postural Control

Postural control, or balance, has been defined differently by authors of varying theoretical perspectives. In this study, balance was viewed from a systems theory of motor control. A definition from this theoretical perspective was proposed by Shumway-Cook (1996), “the process by which we control the center of mass (COM) of the body with respect to the base of support (BOS)” (p. 5). This process includes maintaining or returning the center of gravity over the base of support (Lewis, 1996).

According to this systems theory, control of balance is orchestrated by numerous interacting systems. The central nervous system organizes sensory, musculoskeletal, neuromuscular, and higher level cognitive systems to create balance. This organized group of systems creates solutions to changing environmental constraints. Each component is affected by interaction with other systems. Control is distributed according to the particular task (Crutchfield & Barnes, 1993). The postural control system encompasses all these systems “to achieve the goal of balance” (Shumway-Cook, 1996, p. 5).

Pathology can change the ability of the various systems that contribute to balance. Decreases in passive range of motion, trunk and limb strength, and movement selectivity will change the ability to preserve postural stability. Increases in muscle tone and pain will
affect the ability to use postural strategies to maintain balance. Vestibular, vision, and/or somatosensory impairments will impact postural control (Crutchfield & Barnes, 1993; O'Sullivan & Schmitz, 1994).

Due to neural plasticity, some effects of pathology may be muted regarding postural control. Since strategies for maintaining balance are not stereotyped, many solutions are possible for each balance task. "Balance is a problem solving process .... The patient who has a musculoskeletal problem, such as an amputation, is subject to the same rules or principles for achieving balance but the effector system has changed. Thus, the patient must find new solutions that are effective in achieving balance despite the new constraints" (Shumway-Cook, 1996, p. 6). These new solutions may not totally overcome the postural control deficits to allow fully functional balance in all situations.

**Aspects of Postural Control**

Postural control is often separated into specific aspects for assessment and treatment. Automatic postural responses occur when a subject receives an external postural perturbation; a sudden change (sensory or mechanical) that displaces body posture away from equilibrium. This reactive or feedback response elicits the use of reliable muscular reactions which are centrally organized for efficiency (Horak & Nashner, 1986). These postural synergies (e.g., ankle, hip, mixed, and stepping strategies) form a continuum of flexible and adaptable ways to respond to external postural perturbations.

Anticipatory postural adjustments are proactive or feed-forward strategies that prepare the body for a voluntary movement. Postural muscles fire before prime movers
(focal muscles) in anticipation of the imminent disturbance of balance. This postural-focal latency is influenced by “behavioral conditions and movement speed” (Hines & Mercer, 1997, p. 17). Learning affects the amount and type of postural muscle activity which occurs prior to a previously experienced focal movement. This aspect of balance is influenced by experience, perceived stability, and expectations (Shumway-Cook & Wollacott, 1995).

Voluntary postural control is the volitional control of the center of gravity (COG) over the BOS. Conscious attention and effort are demanded to maintain volitional control. This control is demonstrated by the active weight shift of a subject to his or her limits of stability for various BOS conditions. The term “limits of stability” is used to describe the outermost range of dynamic balance in all directions for an individual (Shumway-Cook & Wollacott, 1995). Both anticipatory postural control and voluntary postural control are utilized in reaching tasks.

**Upper Extremity Function and Postural Control**

Numerous authors describe the connection between UE movement and anticipatory postural control in varying conditions. Cordo and Nashner (1982) signaled subjects to pull or push a handle with their right hand while unsupported or supported with a shoulder height cross brace. In the unsupported pull, the gastrocnemius muscle, a postural muscle for this task, responded an average 44 milliseconds (ms) before the biceps brachii, the focal muscle. The hamstrings also fired before the biceps brachii, but after the gastrocnemius. Support at the shoulder extremity reduced the amplitude of the
gastrocnemius activation and shortened the latency between gastrocnemius and biceps brachii firing. Cordo and Nashner concluded that when human subjects performed tasks of pulling or pushing, it resulted in a disturbance to their postural equilibrium. To counteract this disturbance “postural adjustments were initiated shortly before all focal movements” (p. 287).

Friedli and colleagues (1984, 1988) had subjects bilaterally grasp a horizontal bar and rapidly move it up to 90 degrees of elbow flexion with and without an added 1.0 kilogram (kg) weight. Subjects also moved the bar down from 90 degrees of elbow flexion to full extension as quickly as possible with and without weight added. The subjects were either free standing or strapped to a firm wall behind them. Data on kinematics of the body, ground reaction forces produced, and electromyograms (EMG) of arm, leg, and trunk muscles were analyzed for these four conditions in flexion and extension (Friedli et al., 1984; Friedli et al., 1988).

In unsupported, unloaded flexion, the biceps femoris (BF) was the first postural muscle to fire an average of 28 ms before the focal muscle, the biceps brachii. The erector spinae (ES) then engaged 10 ms before the focal muscle activation (Friedli et al., 1984, p. 614). Initial bursts of postural muscles were earlier (BF = 40 ms, ES = 20 ms) and stronger in the unsupported, loaded condition (Friedli et al., 1984, p. 615). The supported, unloaded condition produced reduced postural activity in both intensity and onset time of firing compared to the unsupported condition. The supported, loaded condition (1.0 kg added mass) was similar in influence on the postural muscles to the unsupported, loaded condition; the onset of ES was earlier with load, however, the onset
time of BF was not consistent, though it always fired before the focal muscle (Friedli et al., 1984).

In trials of elbow extension, the triceps brachii (TB) was the focal muscle with the quadriceps and rectus abdominis (RA) as postural agonists. The onset of RA clearly preceded the movement of TB in all subjects. Onset of the quadriceps was more variable (Friedli et al., 1984, p. 617). The authors did not expound on the varying conditions in extension (Friedli et al., 1984).

This study concluded that increased postural demands, such as standing unsupported or adding weight to a task, resulted in earlier and stronger activation of postural muscles responsible for anticipatory postural control. The author stated, “Postural adjustments are pre-programmed motor activity linked to the focal movement, specific for the focal movement including anticipated events and the postural set” (Friedli et al., 1984, p. 611).

In a later study involving the data from the above mentioned study, Friedli and colleagues noted that early activation of erector spinae, hamstrings, and gastrocnemius muscles produced movements opposite those which arose from impending arm flexion (Friedli et al., 1988). In flexion while stabilized against a wall, the same pattern was found, but with less intensity. With extension, both the net joint reaction force movements and body motion were opposite in direction to those found in flexion (Friedli et al., 1988).

Friedli et al. (1988) concluded, “Dynamic perturbations arising from arm movement . . . were found to be compensated by postural adjustments . . . . Postural activity anticipating the arm movement indicates that the body prefers to deal with
postural stabilisation in a feed forward rather than in a feedback mode” (Friedli et al., 1988, p. 242).

Horak and colleagues (1984) confirmed that postural muscles activate before focal muscles during unilateral arm movement in both rapid and slow movements, with and without added weight. In this study, subjects were asked to rapidly or slowly raise an arm while EMG readings were taken of the anterior deltoid (focal muscle) and the postural muscles (biceps femoris and paraspinals). The rapid condition was performed with and without a 0.9 kg weight strapped to the wrist (Horak et al.).

Rapid unweighted movements produced activity in the biceps femoris 90 ms before the anterior deltoids. When the wrist was weighted, the time between EMG initiation and arm displacement was approximately 25 ms longer. Slow paced movements created more variability regarding which postural muscles fired first and the resultant latency periods.

Horak et al. (1984) concluded: 1) that movement of an arm “causes dynamic forces to be applied to the trunk” (p. 1020), 2) the related “early associated postural adjustments presumably provide stability for the ensuing movement” (p. 1028), and 3) that the timing of EMG activity was associated with both mean velocity of the movement and the mass displaced (p. 1027).

Zattara and Bouisset (1988) created a study which examined voluntary shoulder flexion at maximum velocity in the three conditions of bilateral flexion, unilateral flexion without added inertia, and unilateral flexion with added inertia (a 1.0 kg lead bracelet attached to the distal forearm). The subjects stood with their feet normally spread apart, arms at sides. They were instructed to point out at a target at shoulder level when they
were ready. EMG data were collected on the anterior deltoid and 14 trunk and leg muscles. The anterior deltoid was named the prime mover or focal muscle of voluntary movement.

Results of this study indicated that unilateral UE movements demanded earlier and higher amplitude EMG activity in postural muscles than did bilateral UE movements (Zattara & Bouisset, 1988). This confirmed earlier studies by the same authors which showed an increased latency between postural and focal responses when comparing unilateral rapid arm raising (51 ms) and bilateral rapid arm raising (25 ms) latencies (Zattara & Bouisset, 1986). The postural pattern of muscles contracted was also altered, but remained "reproducible and specific to the forthcoming voluntary movement" (Zattara & Bouisset, 1988, p. 959).

In comparing the non-weighted versus weighted conditions, weighted unilateral UE movements utilizing the 1.0 kg bracelet required more anticipatory postural muscle activity than did non-weighted unilateral UE movements. Also, the postural-focal latency increased for every postural muscle tested from the unweighted to weighted condition (Zattara & Bouisset, 1988).

Analyzing these results, Zattara and Bouisset (1988) stated that "anticipatory EMG modifications increased . . . in relation to the dynamic asymmetry of the voluntary forthcoming movement" (p. 959). This again confirmed the results of previous research by the same authors (Bouisset & Zattara, 1981, 1983, 1987) that "voluntary movement constitutes a perturbation of the body balance" (Zattara & Bouisset, 1988, p. 957).
Frank and Earl (1990) in a compilation of these and other previous studies regarding the coordination of posture and movement stated, "... it is evident that even simple movements require complex control. An act as simple as raising the arms requires control over numerous joints and muscles of the trunk and legs in order to stabilize posture, as well as control over the shoulder joint and muscles" (p. 860). All aspects of postural control, along with the varied systems mentioned previously, create this "complex control" needed to maintain balance.

The intimate connection between postural control, with all its interacting systems, and arm movement has been confirmed by numerous authors. "No functional movement, such as reaching, exists, except as embedded in a complex situation and nested into a given postural setting" (Reed, 1989, p. 20). Reed explained that a young child who sets up a chair upon which to stand to manipulate objects above her reach, may set the chair in such a way as she cannot "reach". Actually, reaching is what the child can do, according to Reed, but what she does not know how to do is adjust her posture to the demand of the task. "Such difficulties in organizing posture-movement appropriate to the task appear to be implicated in a number of kinds of accidents in young children" (p. 20). Reed implored researchers to investigate the correlation between movement and posture using functional tasks to document postural development across the life span, as well as how strategies of postural control change as environmental conditions for a task are altered.
Upper Extremity Amputations, Prostheses, and Postural Control

Among the numerous physiologic conditions that surface after amputation, changes in balance and postural control could occur. The loss of an unilateral UE initially leads to a change in body weight via the loss of UE weight. The weight and position of the UEs have been an important consideration in the assessment of the muscles of postural control. Biomechanics texts consider the weight and position of the head, arms, and trunk (HAT) whenever calculating the forces acting on the trunk and the counterforce generated by the muscles of postural control. For example, Le Veau (1992) considered the weight of the freely hanging arms when calculating the erector spinae force needed to support the trunk at a 45 degree angle (pp. 257-258). Smith et al. (1996) also considered the weight and positions of HAT in their discussions of hip mechanics in maintaining static, single leg standing (pp. 294-295). The same authors later stated, “Movement of the center of gravity of the head or HAT . . . immediately activates greater [postural trunk] muscle contraction to resist force and return the trunk to balance” (Smith et al., p. 388). In their discussion of lumbar stability, Ladin, Murthy, and De Luca (1989) provided the following example of the effects of UE weight and position on the postural muscles:

Example: In a situation in which a person is standing holding an object in his or her right hand with arm extended, two bending moments or torques will be created: a forward flexion bending moment and a right lateral flexion moment. The muscles of the lumbar and trunk region will have to contract to exert an opposing moment (countertorque) to maintain equilibrium of the spine in the static upright position and prevent motion of the trunk in the direction of the external moments (p. 927).

The effects of arm weight and position are summarized best by Palastanga, Field, and Soames (1989) who wrote, “. . . because the upper limb itself is heavy, every movement
that it makes has to be accompanied by postural contractions of the trunk and lower limb to compensate for shifts in the body's center of gravity” (p. 52).

As the weight and positioning of the arms impacts the patterns of muscular contractions necessary for postural control, the complete or partial absence of an arm would force a continuous alteration in those contraction patterns. Therefore, a change in postural organization would be required to compensate for the asymmetric distribution of TBW. Unless the postural reorganization completely compensates for the asymmetry, balance deficits could emerge in the individual with a new amputation.

A study completed by Guerts, Mulder, Nienhuis, and Rijken (1992) on postural reorganization in people with lower extremity amputations demonstrated considerable changes in balance strategies following altered body schema. Static standing balance was measured under three conditions: subjects standing with eyes open, subjects standing with eyes closed, and subjects standing with blurred vision. Each subject wore his or her lower extremity prosthesis during all three testing conditions. Utilizing a force platform, measures of ground reaction forces were taken during the early and end stages of rehabilitative prosthetic training. “There was marked improvement in balance control within the amputation group between the start and end of rehabilitation assessed by the eyes-closed condition. In contrast, the eyes open condition revealed only a minor improvement...” (p. 85).

During a review of the literature, no studies were found that examined the effects of an UE amputation on any aspect of postural control. Furthermore, as evidenced above, only one study was found that examined the effects of body-weight redistribution and
asymmetry (Smith et al., 1996). Likewise, only one study was found that examined the effects of any type of amputation on postural control (Guerts et al., 1992). Therefore, further research is required in the area of UE amputation and postural control before any definitive statements can be made regarding the matter.

**Postural Control and Falls**

The relationship between postural control and falls has been examined by many researchers. Ragnarsdottir (1996) stated that balance, or postural control, is the mechanism by which the human body prevents falls. If balance is insufficient in either unilateral or bilateral stance, the likelihood of a fall increases (Lewis, 1996). Falls, in the adult population, although rarely due to a single cause, have balance disorders as a primary factor (Duncan, Studenski, Chandler, & Prescott, 1992).

Safe execution of functional tasks in sitting or standing require the ability to "maintain, assume, and move within and between postures" (Sullivan & Markos, 1995, p. 20). This demands adequate strength as well as functional postural control. Hines and Mercer (1997) stated "maintaining a stable posture during movements of the limbs is crucial for safe and efficient performance of daily activities" (p. 17). "Postural adjustments have to counter balance translational and rotational forces arising from the focal movement in order to accomplish the postural requirements of preventing the body from falling . . ." (Friedli et al., 1988, p. 242).
Balance Impairments in Children

Dysfunction of postural control has been found in numerous studies involving children with disabilities. Children with learning disabilities and motor delays showed significantly lower scores on four of the six Pediatric Clinical Test of Sensory Interaction for Balance (P-CTSIB) scales (Deitz et al., 1996). Children with lower extremity spasticity showed lower mean reach values on the Functional Reach test than similarly aged children without disabilities (Niznik et al., 1995). The incidence of vestibular and motor deficits resulting in decreased postural control is high in children with hearing impairments (Crowe & Horak, 1988; Potter & Silverman, 1984; Siegel et al., 1991). Epilepsy (Kowalski & DiFabio, 1995) and long term lead exposure (Bhattacharya et al., 1995) both are associated with decreased postural control in standing as compared to children without these diagnoses. Children with Down Syndrome exhibit difficulty maintaining stability (Shumway-Cook & Wollacott, 1985) and have shown balance deficits on the Bruininks-Oseretsky Test of Motor Proficiency (Connolly & Michael, 1986).

Clinical Pediatric Balance Tests

Numerous pediatric motor tests are available, and balance assessment is often a subscale of these measures (Cole, Finch, Gowland, & Mayo, 1995). The Gross Motor Function Measure (GMFM) was designed to evaluate children with cerebral palsy and has shown construct validity (responsiveness to change) for children with cerebral palsy (CP) ages 5 months to 15.4 years (Russell et al., 1983). In the validity study, 34 non-disabled children ages 1 month to 4.3 years were included, but the authors stated that this is not a
norming sample. All reliability scores (interrater ICC = .87 - .99, intrarater ICC = .92 - .99, and test-retest ICC = .85 - .98) showed high intraclass correlation coefficients (ICC) (Westcott, Lowes, & Richardson, 1997). Approximately 20 of the 88 items contain static or dynamic balance components in differing developmental postures (Russell et al.). One item requires reaching from a standing position. Training of the tester is necessary to provide testing accuracy. The complete test demands approximately one hour to administer (Cole et al.). It is noted that reliability and validity have not been determined for individual subtests.

The Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) and the Bruininks-Oseretsky Test - Short Form (BOT-SF) both provide a balance subtest as well as subtests on running speed and agility, bilateral coordination, and strength (Westcott et al., 1997). Although BOTMP and BOT-SF in their entirety are reliable, (interrater Pearson $r = .90 - .98$ and test-retest Pearson $r = .56 - .81$) the individual subtests of the two versions have yet to be proven reliable (Bruininks, 1978). These tests were normed on 765 children ages 4.5 to 14.5 years and have proven construct validity ($r = .57 - .86$) and concurrent validity ($r = .52 - .69$) in the moderate to good range. The BOTMP and BOT-SF were designed for children with mild motor impairments and were found to be physically difficult to perform for children with more severe physical disabilities (Donahoe, Turner, & Worrell, 1994; Westcott et al., 1997). Also Connolly, Morgan, and Russell (1984) expressed concern that the use of a balance beam may not validly test the functional balance used in activities of daily living.
The Pediatric Clinical Test of Sensory Interaction for Balance (P-CTSIB) tests sensory function related to balance in 4 to 9 year olds. The test was designed as an inexpensive, clinical version of platform posturography with the same six sensory conditions being tested. Vision is occluded by closing eyes and is impaired by use of a lightweight dome which moves with the subject, relaying incorrect visual input. Somatosensory input from the lower extremities is reduced by having the subject stand on moderately dense foam. The amount of time the subject can stand in position and the amount of postural sway generated by the varying conditions are recorded (Crowe, Deitz, Richardson, & Atwater, 1990; Westcott et al., 1997).

Interrater reliability (Spearman $r = .69 - .90$) has been established for both children with and without disabilities for the P-CTSIB (Crowe et al., 1990). Westcott, Crowe, Deitz, and Richardson (1994) ranked test-retest reliability very low to moderate (Spearman $r = .44 - .83$) while Pelligrino, Buelow, Krause, Loucks, and Westcott (1995) obtained reliability correlations which were slightly better ($r = .55 - .88$) in children with standing balance dysfunction. Construct validity (Spearman $r = .63 - .68$) was demonstrated by measured differences between typically developing children and children with learning disabilities and motor delays (Deitz, Richardson, Atwater, & Crowe, 1991; Deitz et al., 1996) and with cerebral palsy (Polatajko, 1983). Although the P-CTSIB is designed for 4 to 9 year olds, maturation of the sensory system to allow resolution of a sensory conflict does not occur until 7 to 10 years of age (Deitz et al., 1991). Since balance dysfunction may be caused by impairments of numerous systems, this test of only
the sensory system does not provide a general screening tool for functional postural control deficits in children.

**Functional Reach Test**

A new clinical measure of balance, the Functional Reach (FR) test, was created to assess dynamic reaching balance in the geriatric population. The FR test was designed to measure the margin of stability in the same manner as the center of pressure excursion (COPE), an accepted dynamic balance test requiring the use of sophisticated laboratory equipment. The FR test, using only a 48” yardstick attached to a wall, leveled at acromion height, was found to have strong association with COPE measurements (Pearson $r = .71$), establishing criterion validity (Duncan, Weiner, Chandler, & Studenski, 1990). Criterion validity to videotape analysis (ICC = .86) was later assessed (Light, Purser, & Rose, 1995).

Functional reach is operationally defined as “the maximal distance one can reach forward beyond arm’s length while maintaining a fixed base of support in the standing position” (Duncan et al., 1990, p. M192). It was first assessed on 128 volunteers ages 21 to 87 years. The subjects were asked to make a fist, raise their right (dominant) arm horizontally to approximately 90 degrees, and stand perpendicular to the wall upon which a leveled yardstick was attached. Subjects were then told to reach forward as far as possible without taking a step or losing their balance. (See Appendix E for a diagram of the FR test.) No attempt was made to control the subject’s method of reach. Observers recorded the placement of the end of the third metacarpal in the starting position and at
the maximum reach position. If the wall was touched or the subject took a step, the trial was repeated. Subjects were guarded in case of balance loss (Duncan et al., 1990).

The interclass correlation coefficient (ICC) for interobserver FR measures was .98, indicating a strong interrater reliability. The test-retest reliability for this healthy, adult sample was also high with an ICC of .92 (Duncan et al., 1990). Test-retest reliability has also been examined in subjects with Parkinson's disease (PD). Smithson and colleagues (1998) compared FR test scores for repeatability of performance over a seven day period. Subjects with PD who had a history of falls demonstrated a strong temporal stability for repeated measurements with an ICC of .93 compared to subjects with PD who did not have a history of falls which showed a minimal ICC of .42. The control group, elderly subjects with no known neurological impairments, demonstrated a moderate correlation with an ICC of .62 (Smithson, Morris, & Iansek, 1998).

Concurrent validity as a marker of physical frailty was established by Weiner, Duncan, Chandler, and Studenski (1992). Performance on the FR test by 45 community dwelling elderly subjects was correlated to seven other measures of frailty ($r = .48 - .71$). Strongest correlations were exhibited between FR and walking speed ($r = .71$). Instrumental activities of daily living, tandem walk, mobility skills, and one-footed standing also had moderate correlations ($r = .64 - .67$). Probability ($p$) values for all seven correlations were < .001 (Weiner et al., 1992).

Duncan et al. (1992) had found the FR test to have predictive validity in identifying elderly male subjects at risk of recurrent falls. Two hundred seventeen male veterans ages 70 to 104 were given baseline screening tests including a self reported history of falls,
mobility performance, vision test, tests for cognition and depression, and the FR test. Falls were monitored for 6 months with subjects having two or more falls in that time classified as recurrent fallers. Researchers found that subjects who could only reach six inches or less on the FR test were four times more likely to have recurrent falls than subjects who could reach ten or more inches (Duncan et al., 1992).

More recent studies do not reflect this predictive validity for fall risk. In a study of adults age 60 and older, no significant difference was found between the healthy control group and experimental groups from the University of North Carolina Balance and Dizziness Clinic for Older Adults with a history of zero to one and two or more falls in the past year. The Pearson correlation between the FR test scores and the number of falls was very low (r = .18) (Light, Rose, and Cedar, 1993).

O’Brien and colleagues (1998) conducted a study of 49 ambulatory, independent living females aged 65 years and older, one-fourth of which reported one or more falls in the past year. Researchers found that the FR test was unable “to indicate any clear-cut threshold level that differentiated fallers from non-fallers” (O’Brien, Pickles, & Culham, 1998, p. 212). Likewise, in a gender blind study of 16 subjects, the FR test did not differentiate between idiopathic fallers and non-fallers in a functionally independent older adult population (Cho & Kamen, 1998).

Sensitivity, a measure’s ability to detect change over time, was tested by Weiner, Bongiorni, Studenski, Duncan, and Kochersberger (1993) in an intensive rehabilitation setting. Forty-one inpatient male veterans were assessed at baseline and every four weeks during rehabilitation. The correlation of baseline to treatment distances reached was
marginal \( r = .38 \). The authors concluded that improvement in functional reach due to rehabilitation can not be inferred from this study. Weiner et al. (1993) stated the variability of diagnoses and treatments on these subjects may have hidden true gains in FR. Also, if balance was not a problem at baseline, little improvement would be expected. When sensitivity to change was measured using the responsiveness index (RI), it was found to be strong (RI for FR = .97) indicating that the FR test has usefulness in clinical assessment. Due to this high responsiveness index, the authors claimed that only a small sample size \( n = 21 \) is necessary to indicate a difference in performance on the FR test (Weiner et al., 1993).

A study by Light, Rose, and Purser (1996) was designed to determine a difference in reaching strategies between elderly subjects with and without disequilibrium. This study found the FR was not sensitive to the balance problems found in these subjects. No significant difference was found in FR distance nor strategy used between the two groups. The authors proposed that since their subjects were not physically frail, the FR test could not detect, by distance reached, those who were fallers. They recommend that the FR test be used as a screening tool to detect only severe balance problems. Light et al. (1996) also noted that the two populations of subjects for the comparative studies differed markedly by diagnoses.

Although the FR test was designed for the elderly population, it has been used recently with a wide variety of subjects of varying diagnoses in its original and modified forms. A modified FR test performed in sitting by 30 subjects ages 18 to 45 with spinal cord injuries was found to have high test-retest reliability. This FR test was found to be
sensitive to lesions at three distinct levels of injury (Lynch, Leahy, & Barker, 1998). The standard FR test was found to be sensitive to detecting differences between subjects with and without Parkinson's disease (PD), as well as between subjects with PD with and without a history of falls (Smithson et al., 1998). High interrater reliability (ICC = .94) was achieved using the FR test in a hospital based population with diagnoses of cerebral vascular accidents (CVA), Guillain Barre syndrome, brain tumor, and Sickle Cell disease (Straube & Campbell, 1996). Another inpatient population which included subjects with CVA, spinal cord injuries, hip fractures, and multiple osteopenic fractures demonstrated the ease of use of the FR test as a clinical assessment tool (Weiner et al., 1993). A positive correlation between the FR test, the modified FR test, and functional outcome was found in individuals recovering from CVAs (Kahn, McGhee, & Wellmon, 1997).

Donahoe et al. (1994) saw the possibilities for clinical use of the test with children. Interrater reliability calculated for two trials with 116 subjects without disabilities ages 5 to 15 showed an ICC of .98. Intrarater reliability, tested in a single session across four trials per subject, had interclass correlation coefficients ranging from .87 to .97. Test-retest reliability between days was fair (ICC = .64 - .75). Donahoe and colleagues proposed that subject inconsistency, fatigue, or loss of interest may have affected test-retest reliability.

A stepwise regression was performed to correlate age, height, weight, arm length, and gender with the FR scores. Only age was significantly related to functional reach ($R^2 = .38$). The addition of the other variables did not significantly explain more variance ($R^2 = .41$) (Donahoe et al., 1994).
Values for mean reach and critical reach were calculated for each of five age categories i.e., 5-6, 7-8, 9-10, 11-12, and 13-15 years of age. Children in the 5 to 6 year old category exhibited a mean reach value of 21.17 cm. Values increased by 3 to 5 cm for each succeeding category through the 11 to 12 age group. Critical reach (1.96 standard deviations below the mean) may indicate a delay in reaching skills (Donahoe et al., 1994).

Norton and colleagues (1999) recreated the Donahoe et al. (1994) study using subjects in the 3 through 5 year old age range. The children were divided into three groups by age. As in the study by Donahoe et al., FR distance increased with age. Children from 3.0 to 3.9 years had a mean FR of 11.4 cm compared to children in the 5.0 to 5.9 age range who exhibited a mean FR distance of 15.7 cm (Norton, Norris, Richter, & Wilder, 1999). These authors concluded “that the FR is a reliable and feasible tool to assess the balance of three- to five-year-old children” (p.176).

Niznik et al. (1995) found high (ICC = .87 - .98) intrarater reliability both within and between sessions for children with lower extremity spasticity. Since the data from increasing numbers of trials showed no statistically significant differences, the authors recommended one practice trial and one test trial to measure functional reach. Researchers also found a large difference (25.9% to 47.8%) between the mean reach scores of children with lower extremity spasticity and scores of children without disabilities (Niznik et al.; Donahoe et al., 1994).

Another rating of test-retest reliability was made on the FR test with children identified by their current physical therapist as having standing balance problems. Diagnoses for these children included genetic disorders, learning disabilities, neurological
conditions, and developmental delays (Pellegrino et al., 1995). These results (r = -.31) were not as favorable as the results found by Duncan et al. (1990) for adults, nor Donahoe et al. (1994) for children without disabilities. Twelve of the 18 children improved their FR scores in one week from test to retest (Pellegrino et al.). Pellegrino et al. concluded that possibly learning, maturation, or current physical therapy accounted for the improvement.

The FR test is a single item, functional test that can be used for discriminative purposes with children (Westcott et al., 1997). The test provides continuous interval data, increasing its sensitivity beyond categorical or ordinal measures (Duncan et al., 1990). The FR test is easy to administer in varied settings, cost and time efficient, and able to be performed by children with and without disabilities (Niznik et al., 1995; Westcott et al., 1997).

Presently, the FR test is used clinically as a functional assessment tool to measure balance (Fishman, Colby, Sachs, & Nichols, 1997; O’Brien, Culham, & Pickles, 1997; Smithson et al., 1998; Whitney, Poole, & Cass, 1998) and to predict a risk of falls in the elderly population (Thapa, Gideon, Brockman, Fought, & Ray, 1996; Buckler, Dutton, McLeod, Manuge, & Nixon, 1997; O’Brien et al., 1998). In research, the FR test is used as it is clinically to measure balance and risk of falls and also to quantify change after treatment (Mitchell, Grant, & Aitchison, 1998) and as a basis for evaluating newer balance tests (Hill, Bernhardt, McGann, Maltese, & Berkovits, 1996).

The test does not assess lateral or backward reaching balance, but does address forward reaching, a self-initiated movement, in the feedforward mode similar to many activities of daily living (Donahoe et al., 1994). The act of maintaining one’s stability
during a forward reaching task is influenced by the many systems composing postural control including the musculoskeletal components of strength and range of motion, the sensory components of vestibular, visual, and proprioceptive input, the anticipatory and adaptive mechanisms required for motor planning, and anticipatory and voluntary aspects of postural control (Shumway-Cook & Wollacott, 1995). The FR test does not indicate which of these systems or components of postural control may be compromised.

**Summary and Implications**

As demonstrated by the abundance of literature on balance tests, postural control is significant in physical therapy assessment and treatment. Many patients seek physical therapy services as a result of balance dysfunction, and the physical therapy profession recognizes this dysfunction as detrimental to functional activities. Intact postural control is a key component in virtually all activities of daily living.

Varied references were cited regarding upper extremity amputations, prosthetics, and functional measures of individuals with UE amputations. Abundant research was noted on the connection between postural control and upper extremity function. Likewise, numerous studies have documented adjustments in postural control with unilateral off-weighting. However, no research was found examining the effects of a unilateral UE amputation or prosthesis use on any aspect of postural control. If the presence of an upper extremity amputation and subsequent use of a unilateral prosthesis does alter an individual's postural control, then that individual may exhibit functional
impairments in activities of daily living, just as any other patient with postural control disorders might experience.

If children with UE amputations have compromised postural control due to the amputation or prosthesis used, physical therapists need to be aware of this trend. Further evaluation of balance and treatment of any subsequent deficits would then be indicated. If people with UE amputations do not have compromised balance, then physical therapists need to use that knowledge to avoid utilizing valuable clinical time for unnecessary postural control assessments. The financial constraints of health care today dictate that clinicians demonstrate a need for assessments performed. Without data available, it is uncertain whether screening all children with unilateral UE amputations for possible balance dysfunction is appropriate.

This study used the FR test to gather data on postural control in children with unilateral UE amputations. The FR test has been demonstrated to be a reliable and valid screening tool for assessing feed forward postural control abilities. Subjects of varying ages, diagnoses, and abilities have been evaluated using the FR test. These strengths, along with its inexpensive components and ease to administer, make it the tool of choice for this research. This study begins to collect data of the type necessary to make clinical decisions about postural control assessment within this population.
CHAPTER 3
METHODS

Study Design

The researchers utilized a quasi-experimental design method to investigate the following hypothesis: No statistically significant difference will be found between use and non-use of an upper extremity prosthesis in children ages 5 to 15 with unilateral UE amputation and resulting forward reach distance as measured by the FR test. The use of a prosthetic device was the independent variable manipulated to address this hypothesis.

Study Site and Subjects

The subjects for this study were obtained by a convenience sample from the Area Child Amputee Clinic at Mary Free Bed Hospital and Rehabilitation Center in Grand Rapids, Michigan. Possible subjects were first contacted by letter by the clinic (Appendix A). Informed consent was obtained from the parent or guardian of each child prior to participation in this study (Appendix B).

Inclusion criteria for participants encompassed an age of 5 to 15 years and the presence of unilateral upper extremity amputation. Upper extremity amputations were surgical or congenital in origin. Subjects with surgical amputations had a wrist disarticulation or higher; those with congenital shortenings had an affected limb length equal to or less than the length of his/her unaffected arm measured from shoulder to wrist.
Exclusion criteria was assessed via questionnaire (Appendix C) and physical evaluation (Appendix D). Answers of “unsure” on the questionnaire were discussed with the parent/guardian/subject to determine a definitive answer. Injuries or impairments noted on the questionnaire which had occurred within 6 months of the testing date excluded a subject from this study. Exclusion criteria included:

- Accompanying lower extremity amputation
- Bilateral upper extremity amputation
- History of ankle, knee, and/or hip injury resulting in orthopedic dysfunction that will obviously precluded subject from passing the physical screen
- History of unexplained dizziness of greater than 2 minutes duration or a frequency of greater than two times in the previous two months
- Currently existing hearing impairment
- Visual impairment of 20/200 or greater involvement after correction
- Presence of significant cognitive dysfunction which would have impaired the subject’s ability to follow the researchers’ directions

Areas of assessment, corresponding assessment tools, and exclusion criteria were:

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<th>ASSESSMENT</th>
<th>ASSESSMENT TOOL</th>
<th>EXCLUSION CRITERIA</th>
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<tr>
<td>Active and passive range of motion of upper and lower extremities</td>
<td>Goniometric measurement (Norkin &amp; White, 1985)</td>
<td>Within 10% of accepted values as established by AAOS</td>
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<tr>
<td>Strength of upper and lower extremities</td>
<td>Gross Manual Muscle Test (Magee, 1992)</td>
<td>Any score of less than four on a five point scale</td>
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<tr>
<td>Muscle tone of upper and lower extremities</td>
<td>Modified Ashworth scale (Bohannon &amp; Smith, 1987)</td>
<td>Any score of greater than zero (0 = normal tone)</td>
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<td>Static Standing Balance</td>
<td>Bilateral static standing balance test</td>
<td>Any score of less than 30 seconds</td>
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The location for data collection took place at the Area Child Amputee Clinic at Mary Free Bed Hospital and Rehabilitation Center in Grand Rapids, Michigan.

**Instrumentation and Equipment**

A parent/guardian questionnaire and physical assessment, which were designed by researchers Weber and Smith, were utilized to screen candidates for inclusion in this study. Subjects’ parents or guardians completed the questionnaire (Appendix C). Items of inquiry included subject’s age, gender, currently existing amputations, history of excessive falling, lower extremity injury, neurological impairment, dizziness or hearing loss, severe visual deficits, and cognitive deficits.

Physical assessment was performed by the authors for neurologic and orthopedic upper and lower extremity deficits (Appendix D). Active and passive range of motion in the extremities was measured using a standard goniometer (Norkin & White, 1985). Gross manual muscle tests as described by Magee (1992) were performed to assess extremity strength. Muscle tone was graded on the general clinical scale as detailed by Bohannon and Smith (1987) during passive range of motion testing. Static standing balance was examined by having the subject stand in a stationary position for 30 seconds with feet at a comfortable width and arms in the subject’s preferred position.

Instrumentation for the experimental portion of the study included the FR test and a data collection sheet. Functional reach was measured according to the protocol by Duncan et al. (1990) with some noted exceptions (Appendix E). The test was performed utilizing the intact arm regardless of dominance. Only one practice test was performed for
each condition. One recorded trial was performed for each of the following conditions:
1) subject wearing the prosthesis and 2) subject not wearing the prosthesis.

A data collection sheet was designed by the researchers for use in recording measurements (Appendix F). Clear instructions for the subject regarding how to perform the test were available on the sheet. These instructions were read to the subject verbatim prior to test execution. Data recorded included the original and final positions of the fist of the intact arm for both trials as numerically defined in centimeters by the reading on the meterstick.

Validity and Reliability

The reliability and validity of the FR test was previously established in this study's literature review.

Researcher Scot Smith read and recorded the numerical data; no other individual performed this task. This practice eliminated the need to establish interrater reliability. Intrarater reliability (Appendix G) was established via single trial sessions with multiple subjects. During these trials, researcher Scot Smith had 19 individuals separately perform the FR test 5 times each. Mr. Smith took a reading for each trial and recorded the results. The analysis of this data is discussed in Chapter 4.

Both researchers had successfully completed graduate level clinical experience in administering this study's orthopedic and neurologic tests, as well as the standard FR test. This level of competence validated the ability of the researchers to administer these tests for the purpose of this study.
Procedure

Prospective subjects' parents or guardians were contacted through the Area Child Amputee Clinic by letter (Appendix A). Those individuals who were willing to enlist their child's participation completed an informed consent form (Appendix B) and were able to ask any questions they had about the study. Parents or guardians were then asked to complete the inclusion criteria questionnaire (Appendix C). Questionnaires were reviewed by the researchers to assure completeness of answers and determine subject eligibility. Appropriate subjects underwent a physical screening assessment (Appendix D) to further establish the subject's eligibility.

All subjects still included in the study completed the FR test (Appendix E). Each subject was asked to remove his or her socks and shoes, then stand with toes touching a preplaced floor marking. Subjects stood perpendicular to the wall containing the leveled meterstick which was positioned at the height of the subject's acromion process. Each subject was instructed to position the intact arm in shoulder flexion of 90 degrees, full elbow extension, neutral wrist position, and form a fist with the words, "Make a fist and hold your arm out straight in front of you. Stay there until I say 'stop'.” After three seconds, the initial position of the subject’s third metacarpal was read. Then the subject was asked to “reach forward as far as you can without taking a step or losing your balance. Stay there until I say, ‘stop’. ” Three seconds after maximum reach was obtained, the designated researcher read and recorded (Appendix F) the position of the subject’s third metacarpal in reference to the corresponding numeric value of the meterstick. The subject was then asked to relax and stand normally. No attempt was
made to control the subject’s reaching strategy; however, the subject was guarded during the reach. Any trial resulting in a step or the subject touching the wall was disregarded and repeated.

If the subject used a prosthesis, he or she performed the FR test once with his or her prosthesis off and once with the prosthesis on. There was one practice test and one recorded trial for each condition. Randomization of the “prosthesis on” and “prosthesis off” conditions was achieved by a coin toss. Heads denoted the “prosthesis on” condition was to be tested first.
CHAPTER 4
DATA ANALYSIS

Data Analysis of Pilot Study

An intraclass correlation coefficient (ICC) was used to assess intrarater reliability as recommended by Portney and Watkins (1993). The ICC is a one-way analysis of variance (ANOVA) which may be used to analyze ratio and interval data. The ICC allows for measurement of reliability with the use of a single test as opposed to utilizing a separate t test or ANOVA and a correlation measure (Portney & Watkins, p. 509).

Intrarater reliability was assessed on only Scot Smith as he was the only researcher designated to read the test instrument. An ICC of .98 was found regarding intrarater reliability for this rater. The closer a value approaches 1.00, the stronger the reliability. Portney and Watkins (1993) state that reliability should exceed .90 for clinical measures “to ensure reasonable validity” (p. 514). The validity of this rater as reliable was therefore accepted. (Please refer to Appendix G for specific formulae, calculations, and data.)

Characteristics of Subjects

Six subjects, 3 females and 3 males, ages 5 through 8, were recruited for this study. Two subjects exhibited exclusion criteria and were not included. Of the 4 remaining subjects, 3 had congenital limb shortenings and 1 had undergone surgical amputation within one week of birth. One subject had a transhumeral amputation, two
had transradial amputations, and one, an elbow disarticulation. The right limb was shortened in all 4 of the subjects. These subjects considered their left arm as dominant and used the left arm for the FR test. All subjects had worn a prosthesis for greater than 4 years, though the length of wear of the current prosthesis varied from over 2 years to less than 1 hour. Two subjects were fitted with new prostheses just prior to performing the FR test. (Please see Table 1 below.)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gender</th>
<th>Age (years; months)</th>
<th>Type of Shortening</th>
<th>Level of Shortening</th>
<th>Affected Limb</th>
<th>Time since first prosthesis</th>
<th>Time since current prosthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>5 y 3 m</td>
<td>congenital</td>
<td>transradial</td>
<td>R</td>
<td>4 y 9 m</td>
<td>&lt; 1 hr</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>7 y 9 m</td>
<td>congenital</td>
<td>transhumeral</td>
<td>R</td>
<td>6 y 6 m</td>
<td>&lt; 1 hr</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>8 y 6 m</td>
<td>congenital</td>
<td>transradial</td>
<td>R</td>
<td>8 y 2 m</td>
<td>1 y 6 m</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>7 y 8 m</td>
<td>surgical</td>
<td>elbow disarticulation</td>
<td>R</td>
<td>7 y 2 m</td>
<td>2 y 5 m</td>
</tr>
</tbody>
</table>

Data Analysis of “Prosthesis-off” versus “Prosthesis-on” Conditions

The researchers used a paired, two-tailed $t$ test to determine if a statistical difference existed between the “prosthesis-off” and “prosthesis-on” FR test measurements. A $t$ test is only appropriate when two conditions are being compared. In this case, those conditions were “prosthesis-off” and “prosthesis-on”. A two-tailed $t$ test was used since the researchers did not have sufficient information to predict the direction of the difference that might occur between the sample means (Portney & Watkins, 1993, p. 354). The paired $t$ test is used when researchers “use subjects as their own controls, exposing each
subject to all experimental conditions and then comparing their responses across these conditions” (Portney & Watkins, p. 369). A basic assumption when using a $t$ test is that data is drawn from a normally distributed population. This assumption could not be verified with a sample size of only 4 subjects. However, in a paired $t$ test, the number of scores must be the same in each condition tested. Therefore, “it is unnecessary to test this assumption with correlated samples” (Portney & Watkins, p. 369). Since this study used a repeated measures design, compared only two conditions, and examined deviation from the mean in both the positive and negative directions, the paired, two-tailed $t$ test was appropriate for statistical analysis of the data collected. (Please refer to Table 2 for a compilation of the data collected.)

Table 2. Functional Reach Data

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (years/mo)</th>
<th>&quot;Prosthesis-off&quot; (cm)</th>
<th>&quot;Prosthesis-on&quot; (cm)</th>
<th>Difference (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 y 3 m</td>
<td>11.0</td>
<td>11.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>7 y 9 m</td>
<td>28.0</td>
<td>27.0</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>8 y 6 m</td>
<td>36.0</td>
<td>31.0</td>
<td>5.0</td>
</tr>
<tr>
<td>4</td>
<td>7 y 8 m</td>
<td>24.0</td>
<td>23.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The differences between each subject’s “prosthesis-off” condition and “prosthesis-on” condition were assessed, and these differences were totaled and averaged. The sum of squares of the individual differences was divided by the degrees of freedom between subjects. “Degrees of freedom” indicates the number of values within a group that are free to vary; usually $(n-1)$; in this case the number of subjects minus one (Portney &
Watkins, 1993, p. 682). The square root of this figure then represented the standard deviation from the mean (Portney & Watkins, p. 369). With this information a test statistic was found with the following formula:

\[
\text{t-test statistic} = \left| \frac{\text{average of the differences between "prosthesis-off" and "prosthesis-on" conditions}}{\text{standard deviation of the differences}} \right| / \sqrt{\text{square root of the sample size}}
\]

The t-test statistic was compared to the appropriate critical value for a paired, two-tailed t test with an alpha level of .05 as determined by reference to the "Critical Values of t" statistical table (Portney & Watkins, p. 615). The test statistic must be greater than or equal to the critical value to reject the null hypothesis. (Please refer to Figure 1 below.)

**Figure 1. Calculations for Data Analysis of FR Scores**

<table>
<thead>
<tr>
<th>Average difference</th>
<th>= ((0.0 + 1.0 + 5.0 + 1.0)/4 = 1.75)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Deviation of Differences</td>
<td>= (\sqrt{\left{((0.0 - 1.75)^2 + (1.0 - 1.75)^2 + (5.0 - 1.75)^2 + (1.0 - 1.75)^2) / (4 - 1)\right}} = 2.2174)</td>
</tr>
<tr>
<td>t-test Statistic</td>
<td>= (</td>
</tr>
<tr>
<td>Critical Value of t</td>
<td>= ((\alpha = .05) t(3) = 3.182)</td>
</tr>
</tbody>
</table>

The null hypothesis stated that no statistically significant difference would be found between subject use and non-use of an upper extremity prosthesis in children ages 5 to 15 with unilateral upper extremity amputation and resulting forward reach distance as
measured by the FR test. As indicated by the calculations and data presented in Table 2 and Figure 1, a t-test statistic of 1.578 was found. This value was less than the critical value of 3.182, indicating that the difference in values between “prosthesis-off” and “prosthesis-on” FR test measurements was not statistically significant.

The Statistical Package for the Social Sciences (SPSS) version 8.0 data analysis program was used to calculate other statistical parameters. The 95% confidence interval (CI) of the paired samples test was calculated (95% CI = -1.7783 to 5.2783). A 95% CI indicates a range of scores in which the researchers can be 95% confident that the true population mean will fall. The null hypothesis states that the difference between the means of “prosthesis-off” and “prosthesis-on” will be zero. Since the 95% CI contains zero, this confirms the results of the t-test statistic (Portney & Watkins, 1993, p. 372).

The t-test analysis resulted in a value of \( p = .213 \). The nonparametric Wilcoxon Signed Ranks Test which examines both the direction and relative amount of difference between scores was also performed resulting in a \( p \)-value of .102. This value being less than the t-test \( p \)-value suggests that the confidence to not reject the null hypothesis would be stronger if a larger sample size were attained. This larger sample size would be needed to detect a difference between the two conditions, if one exists (J. Ritchie, personal communication, April 2, 1999). Both \( p \)-values were greater than the alpha level set at \( \alpha = .05 \) for this study, and other statistics confirmed that differences were not statistically significant. Therefore, the null hypothesis was not rejected.
Findings of Interest

Trends in Distance Reached Under Two Conditions

Every subject who exhibited a change in distance reached between the two experimental conditions (subjects 2 through 4), reached farther when in the "prosthesis-off" condition. (Please see Figure 2 below.) The change in reach was not a statistically significant difference, and a larger sample size may have negated this trend. Still, this directional trend among the subjects in this study is noted here and discussed further in chapter 5.

Figure 2. Comparison of "Prosthesis-off" to "Prosthesis-on" Conditions

Functional Reach Data

Comparison to Donahoe et al. Data

An informal comparison was made between the data collected in this study and that collected by Donahoe et al. (1994). In the study by Donahoe et al., the researchers
identified trends in FR test values for children without disabilities in age related groups.

This data is summarized below. (Please refer to Table 3.)

Table 3. Mean Reach and 95% Confidence Intervals (CI) as found by Donahoe et al.

<table>
<thead>
<tr>
<th>Age</th>
<th>Number</th>
<th>Mean Reach (cm)</th>
<th>95% CI (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 6</td>
<td>n = 22</td>
<td>21.17</td>
<td>16.79 - 24.91</td>
</tr>
<tr>
<td>7 - 8</td>
<td>n = 36</td>
<td>24.21</td>
<td>20.56 - 27.96</td>
</tr>
<tr>
<td>9 - 10</td>
<td>n = 15</td>
<td>27.97</td>
<td>25.56 - 31.64</td>
</tr>
<tr>
<td>11 - 12</td>
<td>n = 34</td>
<td>32.79</td>
<td>29.68 - 36.18</td>
</tr>
<tr>
<td>13 - 15</td>
<td>n = 10</td>
<td>32.30</td>
<td>29.58 - 36.08</td>
</tr>
</tbody>
</table>

FR test values for two of the four subjects with UE amputations in the current study were found to be within the 95% confidence interval (CI) as calculated by Donahoe et al. (1994) under both conditions of "prosthesis-off" and "prosthesis-on". (Please compare Tables 2 and 3.) Subject #1 had a FR score below the 95% CI defined by Donahoe et al. for both the "prosthesis-off" and "prosthesis-on" conditions. Subject #3, conversely, demonstrated a reach distance above the 95% CI for both conditions. A discussion of this trend appears in chapter 5.
CHAPTER 5
DISCUSSION AND IMPLICATIONS

Discussion of Findings

The purpose of this study was to compare the forward reaching distance of children with unilateral upper extremity amputations while wearing and not wearing their prostheses. The null hypothesis: No statistically significant difference will be found between subject use and non-use of an upper extremity prosthesis in children ages 5 to 15 with unilateral upper extremity amputation and resulting forward reach distance as measured by the Functional Reach test. Additionally, trends were noted regarding reaching distance of children with unilateral upper extremity amputations compared to children without disabilities (Donahoe et al., 1994).

Comparison of “Prosthesis-off” to “Prosthesis-on” Conditions

This study found that there was no statistically significant difference in FR measurements between the “prosthesis-off” and “prosthesis-on” conditions. Therefore, the null hypothesis was not rejected. These results infer that UE prosthesis use or lack of use had no effect on maximal, voluntary forward reaching during the FR test for the subjects in this study.

There are several possible reasons for this result. Biomechanics publications consider both weight and position of head, arms, and trunk (HAT) whenever calculating
the forces acting on the trunk and the counterforce generated by the muscles of postural control (Le Veau, 1992; Smith et al., 1996; Ladin et al., 1989). Possibly, the change in weight distribution of HAT from the “prosthesis-off” to “prosthesis-on” condition was insufficient to effect noticeable change in the FR scores. Position also should be considered. During the FR test, the subjects kept the prosthetic limb in a resting position at the side of the body. Had this position been altered, the presence of the prosthesis may have exerted measurable effects on FR ability.

Another possibility exists. Because the subjects were physically high functioning, the FR test may not have been sensitive in detecting change in the reaching distance between the “prosthesis-off” and “prosthesis-on” conditions. In this case, the effect size or measurable change in reach may have been too small to be detected. The children who participated in this study were typically active at home, school, and play. Participants appeared well rested and interested. These factors may have enhanced performance. If the children were compromised in their functioning due to prolonged decreased activity, tiredness, lack of interest, or other reasons, the subjects may have exhibited measurable reaching differences due to being near a threshold of impairment.

Motor learning also may be implicated in the apparent lack of difference between reaching distance across the two conditions. Motor learning is “... the acquisition and or modification of movement... the search for a task solution that emerges from an interaction of the individual with the task and the environment” (Shumway-Cook & Wollacott, 1995, pp. 23-24). The design of this study gave subjects little opportunity for learning to occur. Only one practice reach and one test reach were performed for each
condition of “prosthesis-off” and “prosthesis-on”. Although motor learning is specific to environmental demands and no subject had prior experience with the FR test, the postural set needed for this new demand may have resembled the reaching demands of daily life allowing carryover of learning to occur. All subjects shortened limbs were present from birth or near birth, and all had been using a prosthesis for more than 4 years. Each child previously had many opportunities in that time to reach, both while wearing and not wearing a prosthesis. Even though 2 subjects had received a new prosthesis within an hour of performing the FR test, little difference was found between conditions. Indeed, Friedli et al. (1984) noted that adaptation to differing environmental task demands during upper extremity movement occurs rapidly. Regarding postural set for voluntary movement, “. . . initial changes could already be apparent with the first trial of a new condition, without any experience, just the knowledge of the condition” (Friedli et al., 1984, p. 620).

Though not statistically significant, a trend toward decreased maximal forward reach distance while wearing a prosthesis was noted. One possibility for this trend may involve the position and tightness of the prosthetic harness. All subjects sported a figure of eight harness design that wraps posteriorly across the subject’s back then anteriorly across the clavicle and into the axilla of the intact arm. The potential exists for a restriction of shoulder flexion due to friction of the harness on the skin or an alteration of the scapulohumeral rhythm due to restriction of scapular motion.

Although the null hypothesis was not rejected, it is highly possible that a Type II error exists. A Type II error occurs when no significant difference is found between sets
of data, but a difference really does exist (Portney & Watkins, 1993). An inadequate sample size, as in this study, increases the chance of a Type II error. Noting this, there is no certainty that the FR test results truly reflect a lack of significant difference between conditions.

Comparison of FR Scores to Subjects without Disabilities

As mentioned in chapter 4, the test values of 3 out of 4 subjects with unilateral UE amputations in both the "prosthesis-off" and "prosthesis-on" conditions were found to be within or exceed the 95% CI as calculated by Donahoe et al. (1994). The study by Donahoe et al. was chosen because the results provide an indication of the forward reaching ability of children without disabilities. Also, other researchers have used the study for comparison of children with disabilities to those without disabilities (Niznik et al., 1995; Pellegrino et al., 1995).

The decision to examine only trends rather than perform statistical analysis on the data to compare to the Donahoe et al. (1994) study was made when the researchers noted that although the total number of subjects was 116, Donahoe et al. broke results into age related categories. Each category contained 10 to 36 subjects. These numbers are relatively small for establishing normative values (Portney & Watkins, 1993, p. 334). The literature review revealed only one study replicating the research by Donahoe et al. on a 3 to 5 year old population without disabilities (Norton et al., 1999). As the groupings by age did not match in these two studies, the data was not cumulative. Therefore, statistical comparison to the data from the Donahoe et al. study was unwarranted.
A trend was found indicating that the majority of subjects with unilateral UE amputations had a maximal voluntary forward reach equal to or greater than age matched subjects without disabilities from the Donahoe et al. study (1994). The possible reasons for similarities between forward reaching in children with amputations and those without disabilities are closely matched with those reasons why a donned or doffed prosthesis had no observable effect on FR. When compared to the presence of two intact UEs, the weight and/or position of the residual limb with or without a prosthesis attached may not create enough difference in the weight of HAT to affect FR measurements. Likewise, motor learning over time or undetectable changes in the FR due to small effect size may have contributed to these results.

Functional Reach test scores for subject #1 were well below the 95% CI as determined by Donahoe et al. (1994). The researchers, Weber and Smith, noticed that this subject seemed unwilling to push toward her limits of stability during the FR test. Rather than bending at the waist to extend reach as most subjects did, this subject only protracted her shoulder from the original position, allowing limited reach. Certainly, postural control deficits could be a reason for this choice of strategies. Many other possibilities also exist including, but not limited to, a lack of understanding of the task, lack of motivation, fear of the researchers or environment, or fear of falling.

Applications to Clinical Physical Therapy Practice

Due to the small number of subjects in this study, no statistically significant inference can reasonably be made regarding the data collected in this study. Still, this
study contains preliminary data on children with unilateral UE amputations and their voluntary forward reaching limits while wearing and not wearing their prostheses. The trends suggest that for these subjects, a slight but not statistically significant advantage may exist in forward reaching ability while not wearing a prosthesis. An awareness of this trend may indicate a need for closer observation of children’s functional abilities involving reaching while wearing and not wearing a prosthesis to see if any differences are noted.

In the majority of these subjects, it appears that the postural control necessary to obtain a voluntary maximal forward reach has not been compromised due to the shortened arm nor the use of a prosthesis. These children appeared to adapt almost instantaneously upon donning or doffing their prostheses, thereby maintaining adequate postural control to attain similar results on the FR test in either condition. Generalization of these results to other children with unilateral UE amputations and prostheses is not warranted. Since no statistically conclusive results can be gleaned from the data from this study, clinical reasoning dictates that the current methods of assessing possible balance deficits in this population of children (i.e., parent report and clinician observation/screening) remain unaltered at this time.

**Limitations**

**Test Instrument**

The FR test was originally designed for use with the elderly population. Normative data has been established for adults ages 21 to 87 (Duncan et al., 1990). Researchers have begun to collect data with the pediatric population, Donahoe et al.
(1994) and Norton et al. (1999) being the most notable. However, as sample sizes for specific age groups were small for each of these studies, normed values have not been established at this time. Therefore, a statistical comparison of data between the studies by Donahoe et al. and/or Norton et al. and this study was not warranted. A discussion and informal comparison was made instead.

Similarly, the relationship between the FR test and risk of falls in the elderly population remains questionable. Regardless, the validity of the FR test to predict falls in the pediatric population has not been established. Therefore, no assumptions or predictions have been made regarding fall risk in children from the FR test results.

Test-retest reliability of the FR test has been variable across numerous studies with varying populations (Duncan et al., 1990; Smithson et al., 1998; Donahoe et al., 1994; Pellegrino et al., 1995). Although our subjects did not perform the FR test repeatedly, the variable test-retest reliability leaves a question as to the veracity of any particular FR score relating to the overall reaching performance of a subject. Therefore, any particular trial of the FR test only truthfully relates the reaching ability of the subject at that moment in time. The systems approach to postural control reiterates this idea by recognizing that many internal and external factors affect each instance of voluntary reach.

The FR test is limited to measuring only one aspect of dynamic standing balance. Other components of postural control, such as automatic postural control, static standing balance, or high measures of functional balance are not addressed by this test. Therefore, the FR test alone does not provide a complete balance profile.
The standardized version of the FR test instructions asks that the subject reach forward with the right and dominant hand while the left hand remains in a natural position (Duncan et al., 1990; Donahoe et al., 1994). Chesser, Werley, and Yeager (1998) tested the functional reach of 50 right hand dominant females over the age of 65 years using both their right and left arms. A paired t test determined that there was no statistically significant difference between FR scores for the right and left arms of these subjects. The FR test has been utilized by other researchers with subjects who had only one functional upper extremity. In this case, the subjects were asked to use their unaffected extremity to perform the reach regardless of sidedness or dominance (Fishman et al., 1997). For the purposes of this study, subjects were asked to reach with whichever arm was intact, the right or left. Since the FR test is not standardized for the left hand nor the non-dominant hand, the validity of its use for this study was compromised even though the test has been used this manner in other research.

Subject motivation had the potential of affecting results. Although subjects appeared generally cooperative, obtaining a maximal reach demands an eagerness to push the limits of stability. This may explain the results of subject #1 which were less than the age matched children without disabilities.

Study Design

Limitations were also present in the study design. All subjects were obtained from a single site, the Area Child Amputee Clinic at Mary Free Bed Hospital and Rehabilitation Center in Grand Rapids, Michigan, as a convenience sample. Criteria for inclusion
required that an UE amputation be present. Since the independent variable of UE amputation could not have been ethically manipulated, this study was without control subjects. Both these factors led to a considerable lack of randomization in this study.

Subject population was a limitation for two reasons. First, there was a low number of children with UE amputations available to the researchers. Upper extremity amputations are uncommon; therefore, acquiring a large sample size proved difficult. Second, the subject population was composed of only juveniles ages 5 to 8. Therefore, conclusions derived from the results of this study regarding other populations differing in age, geographic location, clinic association, or disability would not be valid.

Although the researchers excluded subjects with amputations more recent than 6 months, researchers chose not to account for the experience gained from overall duration of prosthesis wear as this would have further limited subject number and decreased the ability to generalize these results to other populations. It may be possible that subjects who had more experience utilizing their prostheses achieved a different level of overall performance on the FR test than those with less experience. Also, those individuals with more experience may have had varying differences in results between the “prosthesis-off” condition versus “prosthesis-on” condition as compared to subjects with less experience.

Several factors can account for duration of prosthesis wear and experience. First, one can consider the number of years that have passed since the initial fitting of the subject’s first prosthesis. A second factor in experience encompasses the time since the fitting of the currently worn prosthesis. Third, subjects’ duration of wear may be influenced by the number of hours the prosthesis is worn each day and whether it is worn
consistently across weeks and months. Lastly, the amount of manual tasks performed engaging the prosthesis may also influence experience. Some prostheses are strictly for cosmetic purposes. This multitude of factors led researchers to ignore this variable.

**Strengths**

A major strength of this study was the lack of environmental constraints. The room where the testing was performed was quiet, well lit, and adequate in size. The parents' presence seemed a comfort to the subjects since the researchers, equipment, and procedures were new to the children. The physical screen and FR test were easy and fun for the children and rarely took over 10 minutes. Generally, the clinic visit was viewed by most subjects as a pleasant experience with friendly doctors, prosthetists, and therapists the children knew from other visits, plenty of toys with which to play, and for some, time away from school. All these factors may have enhanced the overall well being, cooperation, and motivation of the subjects.

Another strength involved the relative ease of using the test instrument. The FR test equipment consisted of a meterstick, poster putty, a small level, and masking tape. Conversion of the treatment room into a research area demanded approximately two minutes by one researcher. The administration of the FR test was simple and quick. These assets combined to make a pleasant and relaxed experience for subjects, parents, and researchers.
Suggestions for Further Research and Possible Modifications to this Study

The researchers recommend that this study be repeated and the sample size increased. Before conducting this research, no studies existed that examined the effects of UE amputations and prosthesis use on forward reaching. Although this study found no statistically significant differences between prosthesis use and non-use, the conclusions cannot be strongly supported due to the relatively small sample size.

Recommendations for small changes in the data collection forms are also warranted. Even though the condition performed first was randomized, no place for recording that information appeared on the data collection sheet. That data could have been helpful to determine other reaching trends. Likewise, a place to record the length of the intact limb could have made data collection more efficient and orderly.

In repeating this study, the researchers also suggest that other measures which assess the differing aspects of postural control be added to gain a more complete view of the subject’s functional balance. A small battery of tests to screen for balance deficits needs to be determined and proven effective, as no one assessment examines all aspects of postural control.

In order to add strength to this study, a strong basis for comparison must exist. The researchers recommend that the Donahoe et al. (1994) study be replicated and the age range expanded to include ages 16 through 20, a group which has yet to be assessed for reaching distance using the FR test. These results could be added to the initial data to increase the power of the normative data already collected. Once valid norms have been established, diverse populations may be statistically compared to the normed population.
and conclusions drawn. Also, studies examining differences in reaching under varied conditions will have a basis for identifying and excluding outliers (data which falls outside an accepted range).

Most importantly, research needs to be completed and replicated that establishes construct, concurrent, and predictive validity and test-retest reliability of the FR test for the pediatric population. Clinically and in physical therapy textbooks, the FR test is touted as a measure of balance; a balance assessment tool for people of every age. The FR test possesses a face validity in that it logically assesses some aspects of postural control within specific environmental demands. Still, whether specific scores on the FR test can indicate anything about the functional postural control of a pediatric subject remains to be proven.

**Conclusion**

The researchers recommend that children with unilateral UE amputations continue to be informally screened for balance deficits through parent report and therapist observation. Until this study can be repeated with a larger sample size and varied tests of postural control, there is no mechanism to confirm or negate the need for routine, formal balance testing of children with unilateral UE amputations.
REFERENCES


December 1998

Dear Parents/Guardians:

Student researchers from Grand Valley State University will be conducting a research project through the Area Child Amputee Center (ACAC) beginning January 1999 and ending April 1, 1999, examining reaching balance in children who have an amputation on one arm, or one shortened arm. We believe the information from this study may benefit patients by helping our staff and others know more about balance in children.

If you agree to join us in this study, the researchers will need 30 minutes of your time during your next scheduled clinic visit. During that time you will be asked to fill out a one-page health questionnaire about your child and a consent form.

If you do not have a clinic visit scheduled between January and April and you would like to participate in this study, please call me to schedule a time convenient to your schedule.

Your child will be checked for full motion and strength of arms and legs. Your child will be asked to stand still in one place for 30 seconds and then asked to show how far he/she can reach with the unaffected arm along a ruler attached to the wall. A researcher will be present to be sure your child will not fall by trying to reach too far. For children with a prosthesis, the researchers will check reach with the prosthesis off and with it on.

We anticipate no risk to you or your child from this testing. Your child will not be identified by name in the study.

We hope you will join us in this study. Whether you choose to participate or not, your child will receive the same high standard of care from ACAC. You may withdraw from the study at anytime without risk to your involvement with ACAC.

Sincerely,

Char Greer, Manager
APPENDIX B

INFORMED CONSENT
The Effects of Prosthesis Use Versus Non-Use on Forward Reach Distance in Children Ages 5 to 15 with Unilateral Upper Extremity Amputations as Measured by the Functional Reach Test

Conducted in Cooperation with the Area Child Amputee Clinic at Mary Free Bed Hospital and the Physical Therapy program at Grand Valley State University

Informed Consent Form

I understand that this is a study examining balance in children who have a unilateral (one-sided) upper extremity (arm) amputation or a shortened limb. The information obtained from this study may help clinicians plan treatment for people with amputations and shortened limbs.

Description of the Research Procedure:

You or your child will first be asked to fill out a brief questionnaire regarding his/her general health. Following this, the researchers will check to see that your child has full motion and strength in his/her arms and legs. The researchers will also ask your child to stand in one place for 30 seconds to check his/her balance. The child will be asked to perform a different balance test in which he/she will stand with his/her toes touching a line and reach forward as far as possible without falling or taking a step. One of the investigators will physically monitor the child to prevent any falling while the other will record the reach measurement. This reach test will be repeated with the prosthesis off and on if your child wears a prosthesis.

I understand that:

1. participation in this study will involve one 30 minute session conducted during my child's scheduled clinic visit.

2. my child has been selected for participation because he/she has an amputation or shortened limb and fits the criteria for this study as detailed in the health history questionnaire provided with this consent form.

3. my child will be physically monitored during his/her reach to prevent falls.

4. the information obtained in this study will be kept confidential and the data will be coded so that my child's identity remains unknown to people not directly involved in the research.

5. a summary of results will be made available to me upon request.
I acknowledge that:

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. In giving my consent, I understand that the participation of my child in this study is voluntary. I may withdraw my child and/or my child may withdraw from this study at any time. Withdrawal will not affect the care my child receives from Mary Free Bed Child Amputee Clinic/Mary Free Bed Hospital.

3. The investigators, Scot Smith and Mary Weber, have my permission to review medical records regarding my child's amputation or shortened limb.

4. I authorize the investigators to release the information obtained from this study to scientific literature. I understand that neither my child nor others will be identified by name.

5. I have been given the phone numbers of the following people so that I may contact them at any time if I have questions about this study.

   Researcher: Scot Smith (616) 895-1363
   Researcher: Mary Weber (616) 527-3106
   Mary Free Bed Human Subjects and Ethics Committee Chairperson: Ellen M. Ballard (616) 242-9201
   GVSU Human Subjects Review Committee Chairperson: Paul Huizenga (616) 457-1028
   Research Committee Chairperson: Mary Green (616) 895-2680

I acknowledge that I have read and understand the above information and agree to have my child participate in this study.

________________________________________________________________________
(participant’s signature & date) (parent’s/guardian’s signature & date)

________________________________________________________________________
(witness’ signature & date) (investigators’ signatures & date)

________________________________________________________________________
I am interested in receiving a summary of the study results.

   (signature)
APPENDIX C

PARENT QUESTIONNAIRE
**Parent/Guardian Questionnaire**

Child’s birthdate_________________  **Gender:** Male  Female

**Answer the following questions by circling the correct answer:**

<table>
<thead>
<tr>
<th>Does your child have a history of:</th>
<th>If yes, date of diagnosis:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ankle, knee, or hip injury that required medical attention?</td>
<td>yes  no  unsure  _________</td>
</tr>
<tr>
<td>2. Neurological disorder or disease</td>
<td>yes  no  unsure  _________</td>
</tr>
<tr>
<td>3. Dizziness or hearing loss</td>
<td>yes  no  unsure  _________</td>
</tr>
<tr>
<td>4. Severe visual impairment</td>
<td>yes  no  unsure  _________</td>
</tr>
<tr>
<td>5. Unable to follow one step commands</td>
<td>yes  no  unsure  _________</td>
</tr>
<tr>
<td>6. Falling more than others his/her age</td>
<td>yes  no  unsure  _________</td>
</tr>
</tbody>
</table>

Please explain your child’s limb difference. Include date of amputation or surgery.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

**Thank you.**
APPENDIX D

PHYSICAL ASSESSMENT FORM
Subject Physical Assessment Form

**Active Range of Motion**

- Note the specific type of movement (in anatomical nomenclature) and range deficit (quantify goniometrically) at any affected joints. Otherwise, write "WNL."

- If possible, record causative factors for any range limitations (i.e.: pain, stiffness, etc.). Further investigate causative factors during PROM testing.

<table>
<thead>
<tr>
<th>Joint</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk (Gross)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cervical</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Passive Range of Motion

- Note the specific type of movement (in anatomical nomenclature) and range deficit (quantify goniometrically) at any affected joints. Otherwise, write "WNL."

- If possible, record causative factors for any range limitations (i.e.: muscle flexibility, joint contracture, etc.).

- Check at varying speeds for tone assessment. Note any abnormalities in the designated section for tone assessment.

<table>
<thead>
<tr>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle</td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td></td>
</tr>
<tr>
<td>Hip</td>
<td></td>
</tr>
<tr>
<td>Trunk (Gross)</td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td></td>
</tr>
<tr>
<td>Cervical</td>
<td></td>
</tr>
</tbody>
</table>
Muscle Tone/Spasticity

- To be checked simultaneously with PROM.

- Record any unusual results utilizing the Modified Ashworth Scale. Also specify the involved muscles (flexors, extensors, etc.) at each joint.

<table>
<thead>
<tr>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle</td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td></td>
</tr>
<tr>
<td>Hip</td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td></td>
</tr>
</tbody>
</table>
**Manual Muscle Test**

- Note specific direction of movement (in anatomic nomenclature) and MMT grade (Kendall Scale) in any joints displaying less than Good (grade = 4) strength. Otherwise, write "Good", "Good +", or "WNL".

<table>
<thead>
<tr>
<th></th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Static Standing Balance**

- Ask the subject to stand still with heels touching for 30 seconds.

- Below, record any incidence of loss of balance and duration of static standing.

Duration of Stand and Notes:
APPENDIX E

DIAGRAM OF THE FUNCTIONAL REACH TEST
Diagram of the Functional Reach Test
APPENDIX F

DATA COLLECTION SHEET
Data Collection Sheet

The following will be read prior to data collection:

"Make a fist and hold your arm out straight in front of you. Stay there until we say, 'stop'." Researcher will wait three seconds and record the starting position measurement. "Reach forward as far as you can without taking a step or losing your balance. Stay there until we say, 'stop'.” Researcher will wait three seconds and record the ending position measurement.

DOMINANT ARM: R  L  ARM USED FOR REACH: R  L

Length of shortened limb: __________  Date of amputation: __________

<table>
<thead>
<tr>
<th>Functional Reach test</th>
<th>Practice Trial (check)</th>
<th>Starting Position (cm)</th>
<th>Ending Position (cm)</th>
<th>Distance Reached (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOT wearing prosthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wearing prosthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
APPENDIX G

INTRARATER PILOT STUDY MATERIALS
Pilot Study Data, Formulae, and Calculations

Pilot Study Data with Average Reaching Distances and Sum of Squares Results

| Subject | Trial 1 (cm) | Trial 2 (cm) | Trial 3 (cm) | Trial 4 (cm) | Trial 5 (cm) | \( \Sigma x \) | \( \sum (\Sigma x_i)^2 \) \\n|---------|-------------|-------------|-------------|-------------|-------------|-------------|----------------|
| 1       | 31.0        | 29.0        | 31.0        | 28.0        | 27.0        | 146.0       | 4263.20       \\n| 2       | 28.0        | 24.0        | 20.0        | 24.0        | 24.0        | 120.0       | 2880.00       \\n| 3       | 30.0        | 27.5        | 24.0        | 25.0        | 22.0        | 128.5       | 3302.45       \\n| 4       | 36.0        | 35.0        | 37.0        | 38.0        | 35.0        | 181.0       | 6552.20       \\n| 5       | 34.0        | 34.0        | 33.5        | 29.0        | 33.0        | 163.5       | 5346.45       \\n| 6       | 45.0        | 46.0        | 44.0        | 44.0        | 44.0        | 223.0       | 9945.80       \\n| 7       | 37.0        | 35.0        | 35.5        | 33.5        | 33.5        | 174.5       | 6090.05       \\n| 8       | 45.0        | 31.5        | 41.0        | 43.0        | 36.5        | 197.0       | 7761.80       \\n| 9       | 23.5        | 21.5        | 22.5        | 23.5        | 23.5        | 115.5       | 2668.05       \\n| 10      | 44.5        | 34.0        | 44.0        | 43.0        | 42.5        | 218.0       | 9548.45       \\n| 11      | 42.0        | 39.0        | 37.0        | 40.0        | 41.0        | 199.0       | 7920.20       \\n| 12      | 33.5        | 29.0        | 24.5        | 26.0        | 27.0        | 140.0       | 3920.00       \\n| 13      | 24.5        | 21.5        | 22.5        | 23.5        | 23.5        | 115.5       | 2668.05       \\n| 14      | 31.0        | 29.0        | 26.5        | 29.0        | 28.0        | 143.5       | 4118.45       \\n| 15      | 40.5        | 41.5        | 39.5        | 39.5        | 36.0        | 197.0       | 7761.80       \\n| 16      | 20.5        | 20.0        | 18.0        | 18.5        | 19.0        | 96.0        | 1843.20       \\n| 17      | 34.5        | 34.0        | 36.0        | 34.0        | 34.0        | 172.5       | 5951.25       \\n| 18      | 34.5        | 31.0        | 33.0        | 34.5        | 33.0        | 166.0       | 5511.20       \\n
\[ \Sigma x = 3046.5 \]

\[ \sum (\Sigma x_i)^2/n = 103015.45 \]


\[
SS_t = \text{total sum of squares} = \Sigma x^2 - \left( \frac{\Sigma x}{n} \right)^2 \\
N
\]

\[ = 103395.75 - \left( \frac{(3046.5)^2}{95} \right) \]

\[ = 5699.315 \]

\[
SS_b = \text{between subjects sum of squares} = [ \Sigma (\Sigma x_i)^2 / n] - [(\Sigma x)^2 / N] \\
= 103015.45 - 97696.445 \]

\[ = 5319.0053 \]

\[
SS_e = \text{within subjects error effect} = \Sigma x^2 - \Sigma [(\Sigma x_i)^2 / n] \\
= 103395.75 - 103015.45 \]

\[ = 380.3 \]
\[ df_i = (N - 1) = (95 - 1) = 94 \]

\[ df_s = (k - 1) = (19 - 1) = 18 \text{ where } k = \# \text{ of subjects} \]

\[ df_e = (N - k) = (95 - 19) = 76 \]

\[ BMS = \frac{SS_b}{df_b} = \text{between subjects mean square} \]
\[ = \frac{5319.0053}{18} \]
\[ = 295.50029 \]

\[ EMS = \frac{SS_e}{df_e} = \text{Error mean square within subjects} \]
\[ = \frac{380.3}{76} \]
\[ = 5.0039434 \]


Model 3 - intrarater reliability of a therapist for one specific data collection
Form k - mean scores increase reliability estimates, reducing error variance

\[ ICC_{(3,k)} = \frac{(BMS - EMS)}{BMS} \]
\[ = \frac{(295.50059 - 5.0039434)}{295.50029} \]
\[ = 0.9830662 \]

\[ ICC = 0.98 \]
The Effects of Prosthesis Use Versus Non-Use on Forward Reach Distance in Children Ages 5 to 15 with Unilateral Upper Extremity Amputations as Measured by the Functional Reach Test

Conducted in Cooperation with the Area Child Amputee Clinic at Mary Free Bed Hospital and the Physical Therapy program at Grand Valley State University

Intra-rater Reliability Validation Pilot Study: Informed Consent Form

I understand that this is a study examining balance in children who have a unilateral (one-sided) upper extremity (arm) amputation or a shortened limb. The portion of the study I am participating in will be used to confirm that the researchers are competent and uniform in their ability to measure functional reach using the Functional reach Test. The information obtained from this study may help clinicians plan treatment for people with amputations and shortened limbs.

Description of the Research Procedure:

You will be asked to fill out a brief questionnaire regarding your health history. Following this you will be asked to perform a test in which you will stand with your toes touching a line and reach forward with your dominant hand (the one with which you write) as far as possible without falling or taking a step. You will be asked to repeat the test if you stagger or take a step.

I understand that:

1. participation in this study will involve one 20 minute session conducted at a time the researchers and I have agreed upon.

2. I have been selected for participation because I fit the criteria for this study as detailed in the health history questionnaire provided with this consent form.

3. it is not anticipated that this study will lead to physical or emotional risk to myself.

4. the information obtained in this study will be kept confidential and the data will be coded so that my identity remains unknown to people not directly involved in the research.

5. a summary of results will be made available to me upon request.

Subject's initials: _______
I acknowledge that:

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. In giving my consent, I understand that the participation of my child in this study is voluntary. I may withdraw from this study at any time without any penalty or harm to myself.

3. I authorize the investigators to release the information obtained from this study to scientific literature. I understand that neither I, nor any of the other participants, will be identified by name.

4. I have been given the phone numbers of the following people so that I may contact them at any time if I have questions about this study.

   Researcher: Scot Smith (248) 391-2582
   Researcher: Mary Weber (616) 527-3106

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

__________________________________________________________________________
(participant’s signature & date) (investigators’ signatures & date)

__________________________________________________________________________
(witness’ signature & date)

I am interested in receiving a summary of the study results.

__________________________ (signature)
Intra-rater Reliability Validation Pilot Study:  
Subject Questionnaire

Subject’s birthdate____________________  Gender:  Male  Female

Answer the following questions by circling the correct answer:

Do you have a history of:                              If yes, date of diagnosis:

1. Ankle, knee, or hip injury that required medical attention?  yes  no  unsure  ____________
2. Neurological disorder or disease                        yes  no  unsure  ____________
3. Dizziness or hearing loss                               yes  no  unsure  ____________
4. Severe visual impairment                                yes  no  unsure  ____________
5. Unable to follow one step commands                      yes  no  unsure  ____________
6. Falling more than others your age                       yes  no  unsure  ____________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

Thank you.
Intra-rater Reliability Validation Pilot Study:  
Data Collection Sheet

The following will be read prior to data collection:

"Make a fist and hold your arm out straight in front of you. Stay there until we say, 'stop'.” Researcher will wait three seconds and record the starting position measurement. “Reach forward as far as you can without taking a step or losing your balance. Stay there until we say, ‘stop’.” Researcher will wait three seconds and record the ending position measurement.

DOMINANT ARM:  R  L  
ARM USED FOR REACH:  R  L

<table>
<thead>
<tr>
<th>Functional Reach test</th>
<th>Practice Trial (check)</th>
<th>Starting Position (cm)</th>
<th>Ending Position (cm)</th>
<th>Distance Reached (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 3</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Trial 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
APPENDIX H

REQUEST FOR SUPERVISORY COMMITTEE and
THESIS COMMITTEE APPROVAL OF TOPIC
REQUEST FOR SUPERVISORY COMMITTEE

This is to be completed by the student and transmitted to the Director of your program.

Student’s Supervisory Committee: The Committee, consisting of a Chairman plus two members are to be identified by the student. Committee appointments are not final until approved by the Director of Occupational or Physical Therapy. PAS students need only the signature of their Research Advisor.

Student(s) Name(s) (print)

Topic area or tentative thesis title: UE Amputation Effects on Balance

COMMITTEE RECOMMENDATION:

Chairperson/Research Advisor: P.T. Signed: 10/22/97

Program/Department: Health Sciences Signed: 11-24-97

Member: Signed: 2-23-98

Program/Department:

Signature: Program Director

Date: 2-23-98

rh#2/request.com
MEMO: Mary Free Bed Research Committee

FROM: Research Committee Members

RE: Research Project:
The Study of Unilateral Upper Extremity Amputation and Balance

DATE: February 23, 1998

We have reviewed the Research Proposal for the above research project which was designed by Scot Smith and Mary Weber.

Based on this review and our input, we approve this topic for research. We feel this research is significant and the information gathered by this study may benefit the Area Child Amputee Center as well as the larger scientific community.

Mary E. Green, M.S., P.T.
(committee chair)

Theresa Bacon-Baguley, R.N., Ph.D.
(committee member)

Jennifer McWain, M.S., P.T.
(committee member)
APPENDIX I

LETTER OF COOPERATION
MEMO: Mary Free Bed Research Committee
FROM: Area Child Amputee Center
RE: Research Project:
The Study of Unilateral Upper Extremity Amputation and Balance
DATE: February 20, 1998

We have reviewed the Research Protocol Summary for the above research project which was designed by Scot Smith and Mary Weber.

Based on our review, we would like to collaborate with the researchers on this project. We feel the research questions posed in this project are important and information gathered throughout this project may benefit our patients.

Charles D. Bukrey, M.D.  Raymond J. Lovett, M.D.

Barb Kaniewski, OTR  Char Greer, MPH
APPENDIX J

GVSU HUMAN SUBJECTS
REVIEW BOARD MATERIALS
Principal Investigators: Scot G. Smith and Mary E. Weber

Department or School: Physical Therapy

Address and Telephone: 2378 Westover Drive, Ionia, MI 48846 (616) 527-3106

Title of the project:

The Effects of Prosthesis Use Versus Non-Use on Forward Reach Distance in Children Ages 5 to 15 with Unilateral Upper Extremity Amputation as Measured by the Functional Reach Test

Summary of the project:

A quasi-experimental design will be used. We intend to examine the differences in results of the Functional Reach (FR) Test as applied to a convenience sample of persons with unilateral upper extremity amputations. Comparison will be made between FR measures with the prosthesis on versus those made with the prosthesis off, and any observed trends will be discussed.

In what capacity does this project involve human subjects? (E.g., surveys, interviews, clinical trial, use of medical records, etc.)

Subjects and/or parent/guardian will fill out a questionnaire, may undergo a basic physical assessment, and may perform the FR Test. Subject's medical records may be reviewed.

Check one:

___ This is a report on research on human subjects which is exempted by 46.101 of the Federal Register 46(16):8336, January 26, 1981. (Refer to instructions on the reverse of this form.)

___ This is a request for expedited review as described in 46.110 of the Federal Register 46(16):8336, January 26, 1981. (Refer to instructions on the reverse of this form.)

___ This is a request for full review. (Refer to instructions on the reverse of this form.)

Principal Investigators

Department/Unit Chair and Advisor

Date

Date

Note: Proposals which do not include a summary of the project and which fail to respond to the requirements stated in the instructions for applicants (on the back of this form) will not be considered and will be sent back to the authors.

5/97
January 11, 1999

Scott Smith, Mary Weber
2378 Westover Drive
Ionia, MI 48846

Dear Scott and Mary:

The Human Research Review Committee of Grand Valley State University is charged to examine proposals with respect to protection of human subjects. The Committee has considered your proposal, "The Effects of Prosthesis Use Versus Non-Use on Forward Reach Distance in Children Ages 5 to 15 with Unilateral Upper Extremity Amputation as Measured by the Functional Reach Test", and is satisfied that you have complied with the intent of the regulations published in the Federal Register 46 (16): 8386-8392, January 26, 1981.

Sincerely,

[Signature]
Paul Huizenga, Chair
Human Research Review Committee
APPENDIX K

MARY FREE BED HOSPITAL AND
REHABILITATION CENTER
RESEARCH AND HUMAN SUBJECTS MATERIALS
Mary Free Bed Hospital and Rehabilitation Center

APPROVAL FORM FOR STUDIES INVOLVING HUMAN SUBJECTS

Instructions: This form and all accompanying materials, if any, should be presented to Human Subjects Review Committee. Retain a copy for your personal records.

When completed, this form should demonstrate how human subjects would be used in a proposed study, and in doing so, demonstrate that guidelines for human subject use in research are met.

Date submitted to Human Subjects Review Committee: April 14, 1998

Title of Proposal: The Effects of Prosthesis Use Versus Non-Use on Forward Reach Distance in Children Ages 5 to 15 with Unilateral Upper Extremity Amputation as Measured by the Functional Reach Test

Principal Investigator and Dept.: Scot G. Smith and Marv E. Weber, Grand Valley State University Physical Therapy students

If office is other than Mary Free Bed, include the address and phone number:
Scot Smith, 285 Manzana Ct., Apt 2-C, Walker, MI 49544, (616) 735-1514
Mary E. Weber, 2378 Westover Drive, Ionia, MI 48846, (616) 527-3106

Summary of research design:

A quasi-experimental repeated measures design will be used. We intend to examine the differences in results of the Functional Reach (FR) test as applied to a convenience sample of persons with unilateral upper-extremity amputations. Comparison will be made between FR measures with the prosthesis-on versus those made with the prosthesis-off, and any observed trends will be discussed.
How are the subjects to be recruited for this study?

Subjects for this study will be patients of the Area Child Amputee Center ages 5 to 15 years. Following a review of patient records by the ACAC staff, subjects who meet research design criteria will be contacted by letter.

Does this study involve any of the following procedures?

Yes  No

- _X_ Deception
- _X_ Punishment
- _X_ Use of Drugs
- _X_ Covert Observation
- _X_ Interviewing of children
- _X_ Induction of mental and/or physical stress
- _X_ Procedures which risk physical harm to the subject
- _X_ Materials commonly regarded as socially unacceptable
- _X_ Procedures that might be regarded as invasion of privacy

In the case of any items checked “yes” above, explain the procedure in detail.

Subjects (ages 5 to 15) will undergo a minimal physical examination. This exam will include range of motion, strength, muscle tone, and static standing balance measures. These are standard physical therapy evaluation tools. Subjects who meet the inclusion criteria will then be asked to perform the FR test. During all of these procedures verbal instructions will be given to the child regarding testing procedures.

The child will be asked to, “Reach forward as far as you can without taking a step or without losing your balance.” The subject will be guarded during reaching. As stated in the informed consent, we do not expect any risk to the subject during these procedures.

Please indicate the theoretical and/or methodological necessity for employing any procedure(s) checked “Yes”.

Physical examination procedures are necessary to determine if the subjects meet the inclusion criteria. The FR test is the balance measure being used for this study. During this test subjects must complete a maximal forward reach to accurately determine their forward limits of stability. Although this allows for the possibility of a child losing his/her balance, a researcher will be guarding the child during reaching.
If the study involves deception, when and how will the subjects be debriefed? (Generally, the nature of the deception and its necessity should be explained to the subjects.)

Not applicable

If the study involves induction of mental and/or physical stress, how will the subjects be brought back to their original state?

After the child has performed a maximal reach, holding position for 3 seconds, the child will be instructed to relax and stand normally. Researchers will observe the child for any signs of physical stress after the completed reach.

Will any data be gathered through photographic or sound-recording devices?  
Yes ___ No ___ X ___  If “Yes”, how will the confidentiality of the materials be produced by such devices be protected?

Will names of subjects be recorded? Yes ___ X ___ No ____ (strictly anonymous). If “Yes”, answer questions 1-4 below.

1. Where will names be recorded (e.g., on test protocols, on a separate list with code numbers, etc.)?

Subjects’ names will be recorded on a master list with corresponding code number designations. All other documents containing subject information will use the designated code number only.

2. For what purpose(s) will names be recorded?

Names will be recorded to allow referencing to subjects’ ACAC charts.

3. Will access to names be under your exclusive control? Yes ___ X ___ No ____

If “No”, what will be done to protect the confidentiality of the subjects?

4. Will names of subjects be included in any publication based on this study?

Yes ___ ___ X ___ No ___ X ___  If “Yes”, for what reason(s)?

Sometimes research findings are presented in a manner which permits knowledgeable readers to infer the identity of a person used as a subject, even if names are omitted. Do you expect to present findings which may possibly provide such clues?

Yes ___ ___ No ___ X ___  If “Yes”, explain.
Will information be obtained pertaining to persons other than immediate subjects (e.g., their friends)? Yes ____ No ___X____ If "Yes", how will the confidentiality of such persons be protected?

Attach to this form a copy of the informed consent form you propose to use. The following considerations must be used when designing an informed consent form:

1. Style and language must be chosen so that it is readily understood by a layperson.
2. The form must include in its title the hospital name and the title of the project.
3. The form must include the researcher's name and the means by which the researcher may be contacted.
4. The explanation section must include:
   a. a statement that the subject agrees that he or she is a volunteer and that in no way would nonparticipation or withdrawal effect treatment while at Mary Free Bed.
   b. a description of the procedure, estimation of duration, and any information about attendant discomfort, risk, or drug use.
   c. an assurance of anonymity and confidentiality.
5. The response section must include:
   a. indication by signature that the patient has read and received a proper explanation.
   b. indication by signature whether or not the patient wishes to receive project results.
   c. if the patient is mentally incompetent or a minor, signature of a guardian.
   d. investigator's signature.
   e. witness' signature.

4/87
TO: Researcher
FROM: Human Subjects and Ethics Committee

Congratulations on approval from the Research Committee. The attached packet includes the paperwork that you need to complete for the Human Subjects and Ethics Committee. Please complete this, attach a copy of your proposal (including consent form), and return it to:

Mary Free Bed Hospital and Rehabilitation Center
Ellen M. Ballard, Ph.D., Psychology Department
235 Wealthy Street, S.E.
Grand Rapids, MI 49503

You will be contacted by the committee concerning an appointment for you to meet with the committee.

Please review your Informed Consent Form carefully, to insure you have included all necessary elements (see Page 4 of the packet). Please add my name, position as Chairperson, and phone number (616) 242-9201 to the consent form as a contact person for subjects.

Thank you.

Ellen M. Ballard, Ph.D.
Chairperson, Human Subjects Review Committee
April 27, 1997

Mr. Scot G. Smith  
Ms. Mary E. Weber  
Grand Valley State University Physical Therapy  
1 Campus Drive  
Allendale, Michigan 49401

Dear Mr. Smith and Ms. Weber:

Your study, "The Effects of Prosthesis Use Versus Non-Use on Forward Reach Distance in Children Ages 5 to 15 with Unilateral Upper Extremity Amputation as Measured by the Functional Reach Test" has been approved by the Human Subjects Review Committee, pending the following changes as recommended by the Committee and discussed with you at our April 22 meeting:

1. Add Grand Valley name to top of page.

2. On Page 2 of Study change "Health History" wording to "Parent/Guardian Questionnaire."

3. On Consent Form, #3 change "guard" to "physically monitored."

4. On Consent Form, add Paul Huizenga, GVSU Chairperson  
   Human Subjects Review Committee  
   Mary Green, Chairperson

Sincerely,

[Signature]

Ellen M. Ballard, Ph.D.  
Human Subjects Review committee Chairperson

cc: Barbara White

Mary Free Bed Hospital & Rehabilitation Center  
235 Wealthy, S.E., Grand Rapids, MI 49503-5299, Phone (616)242-0300, FAX (616)454-3939  
Accredited by: Joint Commission on Accreditation of Hospitals, Commission on Accreditation of Rehabilitation Facilities.