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Natasha A. Creaser
Grand Valley State University

Michael W. Jones
Grand Valley State University

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The Effects of Partial Unweighting on Hemiplegic Gait

by

Natasha A. Creaser
Michael W. Jones

THESIS

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

MASTER OF SCIENCE IN PHYSICAL THERAPY

1995
THE EFFECTS OF PARTIAL UNWEIGHTING ON HEMIPLEGIC GAIT

NATASHA A. CREASER
MICHAEL W. JONES

ABSTRACT

This study investigated the effects of 30% body weight support on gait in two individuals with hemiplegia secondary to stroke. Two subjects with right hemiplegia were tested. Each completed four trials, two full weight bearing and two unweighted 30%, in random order. Each trial consisted of walking six meters on a treadmill at the subjects' self-selected speed. Temporal distance data were collected via Stride Analyzer footswitches. Subjects were also videotaped from the side during all trials. We expected velocity, cadence, stride length, uninvolved limb swing time, and involved limb stance time to increase with unweighting. Subjects 1's results agreed only in stride length and uninvolved limb swing time. However, Subject 2’s results agreed in all variables but one: involved limb stance time. Possible reasons for the differences are discussed. Videotape gait analysis revealed increased symmetry between limbs and decreased biomechanical variation at hip, knee and ankle for both subjects.
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CHAPTER 1

INTRODUCTION

Every year approximately 500,000 Americans have new or recurrent strokes, of which 350,000 survive (American Heart Association, 1992). Cerebrovascular accidents (CVAs) can happen to young people, even children, but are most prevalent in the elderly. Disability after a stroke ranges from mild to severe. Statistics on amount of disability are difficult to gather due to several factors such as pre-existing conditions of the patient, type of stroke, age, and the fact that most CVA survivors referred for rehabilitation are moderately to severely affected, which necessarily excludes the mildly affected from being accurately represented (Duncan, 1994).

Stroke patients present in many different ways and each patient is unique (Finch & Barbeau, 1986). There are some characteristics, though, which occur frequently enough to give a generally "typical" stroke patient. The most common impairment is hemiplegia, which is a unilateral weakness that affects almost all functional activities, including dressing, eating, and walking. Motor deficits occurring with a CVA include muscle weakness and diminished or absent coordination (Davies, 1993). A patient can also have perceptual deficits such as neglect of limbs on the affected side and loss of correct midline perception. Cognitive deficits, such as speech and language problems, or memory problems, may occur as well. A person who has had a CVA can present with any combination of the above problems, and each at different levels of involvement.
The ability to walk is a basic skill that is commonly impaired after stroke, which very much affects quality of life. Walking is a complex task. It is, therefore, very challenging to retrain gait, especially in patients who have neurological impairments. The incidence of stroke is high, the survival rate is always increasing (Duncan, 1994), and a main goal of stroke patients is to improve their walking (Bohannon, 1986). Therefore, a great deal of the physical therapy treatment program is dedicated to gait training. Because of the complexity of walking, and that it is affected differently in every hemiplegic patient (Finch & Barbeau, 1986), choosing the optimum method of treatment is often difficult. New strategies for gait retraining are continuously being investigated (Waagfjord, Levangie, & Certo, 1990). Therapists must rehabilitate patients as effectively and as quickly as possible, yet patients respond differently to various training methods. Clearly, although several effective methods exist, the ideal hemiplegic gait retraining method has not yet emerged.

It is our intention to help continue this search for new methods in gait rehabilitation. We propose a pilot study to begin investigation into a system of body weight support in combination with treadmill walking for retraining hemiplegic gait. We will analyze gait patterns of hemiplegic patients in full weight bearing and at 30 percent unweighted while walking on a treadmill at self-selected speed. We hope this will provide useful data which will lend credence to the use of the body weight support system for gait retraining of individuals with hemiplegia.
CHAPTER 2

LITERATURE REVIEW

I. Hemiplegic Gait

Functional gait has five characteristics: 1) safety, so as not to endanger the person; 2) efficiency, so as not to waste energy which could be used for other activities; 3) aesthetically pleasing, so that one does not feel self-conscious; 4) absence of assistive devices, so that one can use the hands and arms freely; and 5) automaticity, so as to leave one free to concentrate on other activities (Davies, 1993). A person suffering a cerebrovascular accident (CVA) resulting in hemiplegia may present with alterations in some or in all of these characteristics. The combination of deficits is unique to each patient, but there are several deficits which tend to be characteristic of hemiplegic gait. Typically, individuals with hemiplegia ambulate slowly, inefficiently, and bear their weight asymmetrically between limbs. Biomechanical, temporal distance, or metabolic alterations in gait characteristics may occur secondary to muscle weakness, hypertonus, lack of coordination, altered perception, or impaired balance in individuals with hemiplegia.

Hemiplegic gait may show biomechanical abnormalities at any or all joints of the trunk or lower extremities. Limitations in trunk, hip, knee, and ankle motion are common abnormalities in the hemiplegic patient (Chin, Rosie, Irving, & Smith, 1982). Individuals with hemiplegia typically walk with their center of gravity posterior to normal; that is, flexed to some degree at the hips, which forces them to actively step forward instead of letting the advancing leg
swing to "catch" the body as it "falls" forward (Davies, 1993). Many stroke patients feel off balance, as if they will fall, which adds to the tendency to move the center of gravity posteriorly (Davies, 1993). Abnormal hip and trunk movements cause altered steps, affecting the uninvolved foot as well. At the foot, heelstrike and forefoot contact with the ground may not be separate and the knee may remain flexed. Movement of the hips may be altered as well, with the hip joint actually moving backwards with each step forward (Davies, 1993).

Temporal distance characteristics of gait include velocity, cadence, stride length, step length, and time spent in the various portions of the gait cycle. Brandstater, de Bruin, Gowland, & Clark (1983) found that hemiplegic subjects walked more slowly than normals, and that speed decreased as the severity of the lesion increased. Pinzur, Sherman, DiMonte-Levine, & Trimble (1987) also concluded that the extent of deviation in gait is positively related to the extent of the involvement of the central nervous system. Ozgirgin, Bolukbasi, Beyazora, & Orkun (1993) studied velocity in individuals with hemiplegia and in normals. They reported an average speed of 0.42m/s in hemiplegic subjects, compared to the average in normals of between 1.2 and 1.5m/s. Individuals with hemiplegia also have decreased cadence and stride length compared to normals (Brandstater et al., 1983). Pinzur et al. (1987) found changes in the gait cycle to be an increased proportion of the cycle spent in stance and double limb support phases for both the affected and the unaffected limb. Proportion of weight bearing between the two limbs was also altered: the uninvolved limb bore more of the weight (Gruendal, 1992). The greater the ratio of asymmetry was, the poorer their ambulatory status (Gruendal, 1992).
The asymmetrical gait of hemiplegic subjects was found to be less efficient metabolically than normal gait (Bard, 1963), and there are mechanical costs due in part to the energy changed in the HAT (head-arms-trunk) segment (Olney, Monga, & Costigan, 1986). Olney et al. suggested that hemiplegics are not able to walk quickly enough to benefit from "the energy-conserving exchange between potential and kinetic energy of body segment and trunk segment."

For all these different presentations of hemiplegic gait, there are many methods which can be used for re-education.

II. Neurorehabilitative Gait Training Methods

A. Theoretical Aspects

There are several methods of neurorehabilitation for hemiplegia, each with its own theory for recovery of function (Davies, 1993; Brunnstrom, 1970; Morris and Sharpe, 1993). There are differences in their approaches to gait retraining, as well as common elements. The most widely used methods will be discussed, and then a method that has recently been introduced will be discussed.

One currently utilized treatment is Neurodevelopmental Treatment, (NDT). NDT emphasizes two main areas: 1) inhibition of abnormal postural tone and movement, and 2) facilitation of normal postural tone, reactions, and movement (Davies, 1993). Inhibition and facilitation are achieved by handling the patient at key points of control, using reflex inhibiting patterns, and proprioceptive and tactile stimulation. The NDT method promotes working on several prerequisites to gait before actually beginning to walk. Some of these
prerequisites are orientation of body in space and to midline, balance reactions, the ability to transfer weight, the ability to control knee flexion, selective control of the affected limb, and the ability to perform rotational components needed for walking (Davies, 1993).

Brunnstrom's approach for treating stroke patients is another method of rehabilitation that is often used. This method is based on the belief that there are a six sequential stages through which a stroke patient progresses during recovery, although an individual patient may or may not experience each stage, and recovery may plateau at any stage (Brunnstrom, 1970). The appearance of flexor and extensor synergies in stage two is regarded as a positive sign, and these synergies are facilitated by the therapist. The patient independently and actively producing the synergistic movement pattern is the therapeutic goal. The synergies are subsequently broken down and component parts are combined to restore active functional movements independent of synergy patterns. The goal is movement selectivity, free from stereotypic patterns (Brunnstrom, 1970).

Brunnstrom's view of gait retraining is similar to NDT's. Brunnstrom promotes that preparation for gait involves having the ability to balance the trunk in the upright position, to selectively produce movement in the lower extremities, and to alternate muscle responses for the reciprocal motions necessary for walking (Brunnstrom, 1970). As these goals are being met, the patient is increasing the amount of weight bearing while working on reciprocal movements. Eventually the patient begins walking as a part of the exercise session.
Proprioceptive neuromuscular facilitation (PNF) is an approach to rehabilitation which uses total patterns of movement, and promotes the response of the neuromuscular mechanism by the stimulation of proprioceptors. The goal of this method is a balance of power between muscular antagonists and coordination, which enables a patient to perform functional skills. PNF uses the developmental sequence to progress a patient to functional postures, including lower extremity weight bearing in preparation for gait. Progressive upright positioning (prone on elbows, quadruped, kneeling and half-kneeling) is used in therapy to get the patient to standing and then to walking. In PNF, reflex activity is used to promote and reinforce good patterns, with the goal of volitional control, having integrated the reflexes. Motor learning concepts are also used in PNF: the performance of many repetitions and visual limb tracking, for example, provide patient feedback for motor learning. Repetition also improves strength, endurance, and coordination (Voss, Ionta, & Myers, 1985). Treatment principles include optimal resistance, manual contacts, overflow, stretch reflex, visual and verbal commands, and reversing movements (Sullivan, Markos, & Minor, 1982).

The motor learning approach was developed by Carr and Shepherd (1983) as a way to treat stroke patients which incorporated the most recent neurophysiologic research in the area of motor learning. The treatment principles for this method include task-specific training, manipulation of environmental factors, active involvement of the patient in problem-solving, therapist's manual guidance, repetition with faded feedback, and early intervention (Carr, Shepherd, Gordon, Gentile, & Held, 1987). The importance of task-specific training was based on research of muscle action, postural adjustments, and reaching, which showed that, "people learn what they
practice" (Carr et al., 1987). The patient can work in a quiet secluded area if too much external stimulation would interfere with practice and analysis of the task at hand. Alternatively, external stimulation can be utilized to challenge the patient to perform previously learned tasks in a more "real world" environment. The recovery process and the problems encountered following a stroke are based on the assumption that the experiences to which the patient is exposed will affect his recovery, either positively or negatively. Motor learning practitioners hold that early intervention may provide experiences that positively affect the patient's outcome. Involving the patient in problem-solving is key to his learning or relearning a skill. The process involves several steps: 1) analysis of the task to be performed, 2) practice of missing components, 3) practice the whole task, and 4) transference of training, with the opportunity to practice in context (Carr and Shepherd, 1983).

B. Clinical Aspects

1. In-Water Training

Gait re-education in water has been used in neurorehabilitation for several years as a method of treatment. Water has several therapeutic effects. Warm water aids pain relief and relaxation. In addition, water's buoyancy supports a patient's body weight and reduces the effects of gravity (Duffield, 1969). A graded exercise program can be designed using buoyancy first to assist, then to support, and ultimately as resistance to movements. Additionally, water improves circulation, gives patients increased confidence in their ability to perform functional activities (Duffield, 1969), and allows the therapist to handle the patient more easily (Smith, 1990). Duffield (1969) asserts that pool therapy is helpful for gait retraining in hemiplegics.
to her, dragging of the leg and swinging through with circumduction can be eliminated in the pool because the buoyancy of the water helps flex the hip and knee, and counteracts dragging the leg. Morris (1992), working with hemiplegics in water, noted some additional benefits of pool therapy: weight reduction, thereby giving the patient improved independent control over his upright stability and a longer period of time to compensate for lateral displacement; and ease of movement which prepares them for gait training on land sooner in their course of rehabilitation.

Taylor, Morris, Shaddeau, Groomes, & Dupuy (1993) studied the effects of pool therapy on the velocity, cadence and stride length in hemiplegic gait. The subjects were two males, one with right hemiparesis, the other with left hemiparesis. The study lasted twelve weeks, with a single case ABAB design used, each phase lasting three weeks. During the A phases, gait data was collected and analyzed on land with a Footswitch Stride Analyzer while subjects walked on a level floor for ten meters. In-pool gait training took place during each B phase. Patients walked in waist-deep water, and received verbal encouragement to increase velocity and improve symmetry.

One subject showed significant increases in velocity, cadence, and stride length, while subject two significantly improved in cadence only. Although not all results were statistically significant, there was a trend toward improvement in both subjects in all three parameters studied. They concluded that water walking had a positive effect on all three variables. They expressed caution, however, in generalizing these results to all hemiplegics because these particular subjects were highly functional and more than a year post CVA. They suggested further study with a greater number of subjects with varying levels of involvement before generalizing to all hemiplegic patients.
2. Treadmill Training

Treadmill training as a means for re-educating gait in stroke patients has been investigated by Waagfjord et al. (1990). These investigators studied stride length, step length, base of support, cadence, and velocity on a single hemiplegic patient who had left hemiparesis, using an inked footprint method for data collection. Treatment consisted of ten minutes of walking on a level treadmill at the patient's self-chosen pace. Baseline and treatment data were collected three times per week for three weeks. The findings for this case study showed a small but statistically significant improvement in base of support and right step length, with increased symmetry in right and left step length. The authors suggested that increased symmetry resulted in improved gait parameters because an increase in right step length must be accompanied by an increase in stance time on the affected left limb. They concluded that their findings support treadmill training as a means of treatment for this particular hemiplegic patient, and that further research is needed before it can be generalized to all hemiplegics.

Two separate studies have shown that walking on a treadmill does not vary significantly from floor walking. Arsenault, Winter, & Martenuik (1986) studied treadmill and floor walking on normals. Electromyographic data was collected from five muscles: soleus, rectus femoris, biceps femoris, vastus medialis and tibialis anterior. Subjects walked twenty strides over both a level walkway and a treadmill. Cadence was kept constant for each subject via a metronome in each case. EMG activity throughout the walking cycle was recorded. Comparison of the EMG profiles during floor walking and treadmill walking revealed no statistically significant differences for most muscles. The biceps femoris only exhibited increased activity. The treadmill EMGs had higher
amplitude (though not significant) but lower variation than the floor walking data. The authors concluded that EMG activity is similar on each surface, and that the treadmill is a valid tool for gait studies.

Murray, Spurr, Sepic, Gardner, & Mollinger (1985) measured kinematics, EMG and heart rate in normal subjects on a treadmill and on the floor. They found that there were no statistically significant differences at a given speed between floor and treadmill walking for velocity, step length, cadence, stance, swing, and double limb support. They did find a trend at all speeds for shorter step lengths, faster cadences, shorter swing phases and longer double limb support times on the treadmill. No significant differences were found in patterns of knee flexion or extension, shoulder and elbow flexion or extension, or in vertical pathways of the heel and toe. The pelvis was slightly anterior throughout the cycle on the treadmill, but this was also not statistically significant. Significant differences were found in hip extension, ankle dorsiflexion, and vertical excursion of the head. Hip extension was increased while walking on the floor at all speeds (slow, free, fast); ankle dorsiflexion was greater during stance at slow and free speeds on the floor; and vertical excursion of the head was reduced on the treadmill. EMG studies were done on the erector spinae, gluteus maximus, hip abductors and adductors, hamstrings, quadriceps, and the calf and pretibial muscles. Variances in repeated cycles were significantly increased only in the hamstrings on the treadmill. Normalized EMG activity was increased only in the quadriceps on the treadmill at slow and fast speeds. Average EMG activity was greater on the treadmill at every speed for all muscles studied except two: hip abductors and erector spinae, at free speed only. They also found that heart rate was significantly higher with fast treadmill walking, but was not significantly higher
for comfortable walking speed, and was the same for walking at a slow speed. They concluded that walking on a treadmill was not notably different from walking on the floor.

III. Treadmill Training and Unweighting

A. Theoretical Aspects

In a 1986 article, Finch and Barbeau suggested a new method of gait retraining for hemiplegics. They proposed a system of training in which a patient walks on a treadmill while supported by a harness. This harness would reduce the patient's weight bearing by a predetermined percentage. Neurological patients have difficulty in gait with lower extremity weight acceptance and weightshifting or advancing on the limbs while weight bearing (Chin et al., 1982). This body weight support (BWS) system would reduce some of the input of weight, allowing energy to be focused on posture, balance, and the stepping mechanism (Barbeau, Wainberg, & Finch, 1987).

This theory is based on research done on "spinalized" cats (Barbeau & Rossignol, 1987; Visintin & Barbeau, 1989). Sherrington (see Pearson, 1976) first demonstrated that cats with severed spinal cords showed rhythmic, stepping-type movements from their hind limbs several weeks post-surgery. T. Graham Brown (Pearson, 1976; Horak, 1991) furthered this research by severing the dorsal roots of similarly spinalized cats. These deafferrented animals also showed the ability to ambulate with a reciprocating gait. Thus, no sensory input from the weight-bearing extremities was necessary for reciprocating hind-leg motion. This ability was enhanced by stimulating hindlimb extension with the use of a treadmill, and was particularly effective if the animal was gait re-trained with the hind-end weight partially supported with
the use of a tail sling (Barbeau & Rossignol, 1987). Training to the adult deafferented cats consisted of partial weight bearing while walking on a treadmill with the tail supported, with training sessions lasting at least thirty minutes for 2-3 times per week. Over the course of the experiment, the weight borne by the hind limbs was progressively increased, to the animal's tolerance. After 3 weeks to 3 months of this training, the cats were able to ambulate with a normal reciprocating gait pattern bearing all of their hind-end weight.

Central pattern generators (CPGs) extant in the spinal cord of both cats and man have been hypothesized to create reciprocating movements in the lower extremities (Delcomyn, 1980; Vilensky, 1987; Morris, Summers, Matyas, & Ia nsek, 1994). Thelan, Bradshaw, & Ward (1981) have proposed that evidence exists in one month old human infants for the presence of CPGs in the form of spontaneous kicking. They speculate that this alternating lower extremity movement is the precursor to bipedal ambulation. The neuromuscular pattern for bipedal ambulation is generated in the spinal cord. Another group, working with spinalized Macaque monkeys, showed that these animals, contrary to studies on cats, do not show stepping movements under the same conditions which produce these movements in cats (Eidelberg, Walden, & Nguyen, 1981). These researchers hypothesized that, even though CPGs may be present in primates, their influence on gait may be superseded in the adult primate by tonic descending neurons.

The influence that descending neurons have on the spinal cord, and CPGs in particular, cannot be disregarded, especially in the pathologic state. These pathways, some of which were "hard wired" during development, and some of which were influenced by movement patterns after birth, are clearly affected by disease states such as CVA. Coordinating the CPGs and
remaining descending influences to produce useful, functional, bipedal ambulation is the goal of the many therapeutic approaches discussed here. The literature on animal studies supports the current approach of treadmill ambulation with weight reduction in the gait retraining of patients with hemiplegia.

Finch and Barbeau (1986) discussed some reasons for abnormal gait in patients with hemiplegia: hyperactive stretch reflexes (especially in the triceps surae), muscle weakness or poor activation of muscle groups, and intrinsic ankle joint problems. With the BWS system, the load on the triceps surae would be reduced, thereby decreasing the amount of stretch on those muscles. Theoretically, the patient's weight could be supported to the point where the stretch reflex could be eliminated or maintained at a level which would be manageable for the patient (Finch & Barbeau, 1986). The patient could then work on other aspects of gait such as balance, posture, weight acceptance, and the stepping mechanism. A system of partial weight bearing can allow for control of the load put on weak or poorly controlled lower extremities, which would also be beneficial to gait retraining. The limbs would fatigue less quickly, thereby lengthening the exercise session. In patients with spasticity the amount of weight bearing may be limited to the subthreshold of the hyperactive stretch reflex in the ankle (Finch & Barbeau, 1986). These researchers stated that BWS training would be beneficial to posture and balance training in hemiplegics. Presumably, reducing the weight to be supported and moved by the body in turn reduces the number of motor units which need to be recruited and coordinated, which is controlled in complex movements by the central nervous system. They also suggest that graded body weight support can be supplemented with such things as cutaneous
stimulation, stretching, electrical stimulation, biofeedback and orthotics. They recommend early intervention with a combination of body weight support and modalities, as individually required for each patient, as a method to produce improved results in gait re-training.

Several methods of neurorehabilitation, such as NDT, PNF, and Brunnstrom, approach gait training by first working on isolated components, and progressing the amount of weight bearing as the patient improves. This can be difficult if a patient has high tone, because weight bearing can induce stretch reflexes which then make controlling the limbs difficult (Finch & Barbeau, 1986), even if the patient is ready to start walking. Carr and Shepherd (1987) question the carryover of isolated tasks to a functional tasks. Finch and Barbeau (1986) suggest that body weight support while standing and walking on a treadmill would allow these patients to work on posture, balance, and the stepping mechanism while in the natural position for bipedal ambulation. Carr and Shepherd (1987) state that motor control is context specific, which lends additional support to the idea of putting patients in the natural position for walking. Also, the absence of assistive devices, which cause patients to lean away from the midline, encourages a more symmetrical balance of body weight on the legs, which would provide sensory feedback of a more natural position (Finch, Barbeau, & Arsenault, 1991). This, plus the removal of body weight, may facilitate the expression of more normal gait patterns (Finch et al., 1991). It would follow that carryover from training on this apparatus to functional walking on land might occur with more success. Finch and Barbeau (1986) submit that early intervention for gait retraining using the BWS system with other stimulation or facilitation can be beneficial to returning normal walking ability in patients with hemiplegia.
B. Gait Studies Using Body Weight Support (BWS)

Finch et al., (1991) developed a BWS device that consists of an overhead harness, hanging from the ceiling, which is secured around the patients' pelvis and lower rib cage. This apparatus was used to study the effects of BWS on the gait of normal males (Finch et al., 1991). The effects of BWS on EMG, kinematic, and temporal distance characteristics were studied. Data were collected with the subjects unweighted 0%, 30%, 50%, and 70% of full body weight. The subjects were unable to maintain their 0% unweighted speed at any of the remaining levels of unweighting. An average of their speeds at each level was calculated, and speeds were assigned as follows: at 0%, speed was 1.36 m/s; at 30%, 0.97 m/s; at 50%, 0.85 m/s; and at 70%, 0.70 m/s. The subjects performed two trials at a single session. In the first trial subjects walked with full weight bearing (FWB) at each speed to collect data for comparison. In the second trial, the subjects were unweighted.

Results of this study revealed no significant difference in cycle time between FWB and BWS trials. The percentage of stance time was significantly reduced over the BWS trials (at FWB stance comprised 60% of the cycle, at 30%, 50% and 70% BWS stance comprised 57%, 55.6%, and 52% of the gait cycle, respectively). The data for total double limb support also showed significant decreases as the percentage BWS increased: 21.7% at FWB, 17.1% at 30% BWS, 13.4% at 50% BWS, and 8.6% at 70% BWS. Kinematic variables that were significantly affected by all levels of BWS were hip and knee angle displacements. The maximum swing angles of hip and knee exhibited during the BWS trials were significantly smaller than during FWB.
The major EMG changes in gait with BWS in Finch's (1991) study were reduced mean burst amplitude in those muscles used for weight acceptance and push off, and an increase in mean burst amplitude in tibialis anterior. In addition, the percentage of stance was decreased, the percentage of total double limb support decreased, hip and knee angular displacement decreased, single limb support time increased, and the center of gravity was raised (an effect of the BWS itself). The authors suggested that the reduction in percentage stance and total double limb support time may be due to BWS alone, or to the combined effect of BWS and decreased walking speed. They stated that further study was needed on the relationship between BWS and walking speed. The investigators concluded that any BWS level less than 70% could be beneficial for training, and that the BWS system they used "did not produce abnormal gait." Based on these results, the authors developed a gait training regimen which addressed strength, coordination, and balance concurrently using a BWS system. The amount of weight bearing and walking speed they proposed should increase as the patient progresses.

Another group of researchers (Harburn, Hill, Kramer, Noh, Vandervoort, & Matheson, 1993) published an article describing the design and use of a harness system which would provide for the safety of the patient during gait assessment and training. They focused on safety and efficiency of using this system during gait training. The clinician can be less concerned that the patient will fall, and instead spend the time and energy on rehabilitating the patient. The use of the harness would also allow a therapist to handle a patient alone, thereby enabling other staff to attend to other work. The authors also pointed out that with the rise in legal actions, the harness can provide a measure of protection against litigation.
The effects of body weight support on the gait of spastic paretic patients was investigated (Visintin & Barbeau, 1989). They focused on the effects of BWS on EMG activity, joint angular displacement and temporal distance parameters in seven neurologically impaired subjects, six of whom had incomplete spinal cord injuries, and the final subject with progressive spastic paraparesis. The trials were videotaped, with reflective joint markers on the shoulder, hip, knee, ankle, heel, fifth metatarsal head, and the toe area of the lateral border of the shoe. Temporal distance parameters were collected with footswitches. Gait was analyzed at 0% supported and at 40% BWS, while patients walked at maximum comfortable walking speed, on a treadmill. Data was also collected from ten normal subjects for comparison.

The results revealed high variability between subjects in EMG, joint angular displacement, and temporal distance data. Therefore, each subject was treated as an individual case study and analyzed separately. One generalized effect noted was a decrease in mean burst EMG amplitude for most muscles when unweighted 40%. Four subjects who walked with a flexed posture at 0% unweighted were straighter at 40% unweighted. Four subjects who had knee flexion at initial contact at 0% unweighted exhibited an increase in knee extension at 40% unweighted; and two who had excessive knee flexion at midstance at 0% showed increased extension at 40%. Six of the seven subjects qualitatively demonstrated "smoother, freer movements of the lower limbs at 40% BWS," according to these researchers. Subjects reported that walking while unweighted was easier and that they did not tire as quickly.

Temporal distance factors also were affected by the change in body weight. Generally, at 40% BWS there was an increase in cycle duration, which led to an increase in stride length. Single limb support time increased as the
total double support time decreased. Improvement was also noted in comfortable walking speed: five subjects were able to walk faster when unweighted (Visintin & Barbeau, 1989).

Overall, this study demonstrated that in subjects with spastic paresis secondary to spinal cord injury, certain variables in gait were improved when the subjects were 40% unweighted. The authors did not conduct a training program in this project, but suggested further research into this new method of gait retraining.

A case study was done by Betti-Gardner, Holden, & Leikauskas (1994) on the effects of gait training with the BWS system on a treadmill for an incomplete spinal cord injured patient. The patient was trained at 30% BWS, at three different speeds (walking, fast walking, and running), for 20 minutes three times a week for six weeks. Researchers progressed the subject from 1.5 mph to 4.0 mph by the end of the study.

Gait performance was measured once a week throughout the experiment using a Stride Analyzer at comfortable walking speed, fast walking and running. Velocity, cadence, stance and swing times and stride length were analyzed. These variables were measured off the treadmill to ascertain whether treadmill training would transfer to over-ground walking. Increases were noted in velocity, cadence, swing time, and stride length, while stance time decreased. These improvements lasted for at least three weeks. The authors assert that their results show that using graded weight bearing with the treadmill "holds promise" for gait retraining of neurologically impaired patients (Betti-Gardner et al., 1994).
Visintin et al. (1988) also investigated progressive weight bearing with a patient with chronic right hemiplegia. The patient began his training unweighted 60%, and through the course of the four month study unweighting was reduced to 40% and finally 20%. Proper postural alignment was stressed, which resulted in improved alignment and knee control to near normal at 20% BWS. The patient also showed improvement in comfortable walking speed, which increased from 0.26 m/s to 0.40 m/s. The authors postulated that partial body weight support facilitated the expression of the locomotor pattern and that balance, stepping, and weight bearing can be trained concurrently. Therefore, they supported the use of BWS with treadmill training in recovery of walking in hemiplegic patients.

Given that each hemiplegic patient is unique in terms of his or her deficits, an individual treatment program is optimal for a patient's progress in rehabilitation. As a result of individuality, not every patient responds to a particular modality, exercise or treatment program. For this reason it is important for physical therapists to continually search for new and efficacious methods of gait retraining. For example, if a patient with hemiplegia is not responding to treatment with the Brunnstrom method, the therapist could add pool therapy to the patient's rehabilitation program. In instances where a patient cannot tolerate water exercise, or being in a pool is contraindicated, but would still benefit from reduced weight bearing during walking, the body weight support system can be used.

Using a treadmill, which is part of the BWS regimen, has been shown to have minimal effects on the gait of normals, and has improved the gait of a hemiplegic patient. Therefore, treadmill training may be a useful tool in both evaluating and retraining gait. The BWS system has been shown to produce
only insignificant changes in the gait of normal males; yet training with this system has improved the gait of patients with incomplete spinal cord injuries and a small group of patients with hemiplegia. This research lends support to further investigation of the BWS system as a means of gait retraining for neurologically impaired patients.

Our literature review revealed only one case study of the effects of BWS in hemiplegic patient. Further study therefore is warranted. As a pilot study, we propose to evaluate temporal distance gait characteristics and do a visual gait analysis via videotape on patients with hemiplegia while partially unweighted. We hypothesize that with unweighting, velocity, cadence, stride length, uninvolved limb swing time, and involved limb stance time will increase. We also expect to see improved symmetry between limbs upon qualitative visual analysis of the videotape. We intend to illustrate that BWS can be an effective method of gait retraining for patients with hemiplegia.
Chapter 3

Methods

Exclusion Criteria

Exclusion criteria included the following:

1. Subjects must have survived a cerebrovascular accident resulting in unilateral hemiparesis at any time prior to their participation in the study.

2. Subjects must score at least a 4 on the Adult FIM Locomotion scale (i.e., minimal contact assistance-subject performs 75% or more of locomotion effort to go a minimum of 150 feet or 50 meters).

3. Subjects must not have neurologic or orthopedic complications (such as receptive aphasia) which would preclude them from understanding their part in the research study, or which would interfere with their free and informed consent to the procedures.

4. Medical clearance must be acquired from the patient’s physician before participation in the study. (Appendix A)

5. Subjects must be willing to sign an informed consent to participate in the study. (Appendix B)

Pre-Trial Patient Data

The following patient data was collected: age, sex, height, weight, leg length, date of CVA onset, and side of residual hemiplegia. In addition, the lower extremity portion of the Fugl-Meyer (Fugl-Meyer et al., 1975) assessment of motor performance was administered to the subjects to determine their level
of recovery. This evaluation tool is comprised of a 3-point rating system for lower extremity reflexes, motor function, coordination, range of motion. The tool has been judged to be a reliable and valid measure of lower extremity recovery by researchers (Duncan, Probst, & Nelson, 1983; Fugl-Meyer et al., 1975). The Fugl-Meyer evaluation will be used to compare subjects' level of recovery with the changes in their gait characteristics during weighted and unweighted treadmill walking.

Study participants were briefed with regards to certain subjective experiences the subject's might have, including a feeling of fatigue or an unusual sensation from walking on the treadmill for the first time. The participants may also feel some constriction wearing the unweighting belt which will be donned during both testing phases. They were informed that these feelings should be expected, and that if any of these feelings are unduly uncomfortable they may terminate their participation in the investigation at any time.

Instrumentation

The subjects walked on a Challenger Mach 1.75 treadmill (Model # 4002-2), a variable speed treadmill capable of velocities from 0.0 M/sec to over 4.0 M/sec. This treadmill could be brought to an immediate stop, if necessary, with a front panel switch designed expressly for this purpose. The Mach 1.75 also had hand rails on three sides, to the left, right, and front of the subject, which the subject was allowed to grasp if desired. The subject self-selected their own comfortable treadmill velocity during all of the trials, and were allowed to terminate any trial at any point.

The unweighting harness (Vigor Equipment Company "Unweighting Station", Model #2001-F) was attached around the mid-waist area of the
subject. Of necessity, the fit was quite snug in order to allow the unweighting of 30% of the subject's body weight without harness slippage. The subject was forewarned of this and an adjustment period was allowed before data collection began. The amount of unweighting was determined using the following formula:

\[
\frac{(\text{Subject's Body Weight}) \times (0.30)}{2} = \text{Weight added to pulley}
\]

This formula is accurate because the rope attached to the harness runs through a single block-and-tackle pulley before terminating. This arrangement effectively halves the amount of weight which must be added to the end of the rope to achieve a 30% patient weight reduction.

Gait temporal-distance measurements were collected with the use of the Stride Analyzer (B & L Engineering, Santa Fe Springs, CA), a device which utilizes footswitches placed in the sole of the subject's shoes for data collection. This data was downloaded to an IBM-compatible personal computer (PC) and analyzed using the Stride Analyzer software. The Stride Analyzer records a number of gait temporal-distance measurements, including the following: velocity, cadence, stride length, gait cycle time, duration of stance and swing phases, and single- and double-limb support time as a percentage of the gait cycle time.

Similar footswitch devices for the analysis of gait have been used in normal subjects (Finch et al., 1991), in patients with "spastic paretic gait" secondary to spinal cord injury (Visintin & Barbeau, 1989; Stewart, Barbeau, and Gauthier, 1991; Betti-Gardner et al., 1994) and in patients with hemiplegia (Taylor et al., 1993). These researchers report acceptable levels of reliability and validity with the use of this device.
**Preliminary Study**

A preliminary study was undertaken utilizing the Stride Analyzer to determine if the data collected by the Principle Investigators (PI) had adequate intra- and inter-tester reliability. Ten normal volunteers were tested using the Stride Analyzer. No unweighting was used in these trials. Each researcher tested each subject at their self-chosen treadmill walking speed, and collected temporal-distance data on subsequent days. The PIs alternated the order in which the Stride Analyzer manual switch was operated on each day of testing to rule out any possibility of operator error.

The correlation coefficient was calculated to verify inter- and intra-tester reliability. The results indicated that the correlation coefficients of same-day inter-tester reliability on all stride analyzer data were greater than 0.9. Comparison of data collected on different days, either of inter- or intra-tester reliability, showed a correlational coefficient varying between 0.2 and 0.7 depending on the parameter measured. This lack of correlational strength was most likely due to the allowance of research subjects to self-choose their treadmill velocity on each of the four trials (two on day one, two on day two). It was noted in the data that the subjects' tendency was to choose similar velocities on the same day, while choosing somewhat different velocities on the following day. This certainly would influence all other measured parameters. Such a problem was not encountered on the research subjects with hemiplegia, as this data was all collected on one trial date and by the same PI on each occasion.
**Procedure**

Research participants ambulated at full weight-bearing status on the treadmill with the unweighting harness in place for a warm-up period not exceeding 5 minutes to acclimate to treadmill walking. Upper extremity support was allowed during this and subsequent phases. Two experimental design protocols were utilized, and the one applied to a particular subject was determined by a random drawing by the subject. The "A-B-B-A" protocol consisted of a six meter trial of full weight bearing treadmill ambulation ("A"), followed by a similar distance with 30% unweighting ("B"). This order was reversed after a five minute rest period to eliminate the possibility of ordering effects. The "B-A-A-B" protocol was the reverse of the above protocol.

The research subjects were allowed to use the treadmill hand rails during all trials. Although this might have hindered data analysis due to the unknown amount of weight bearing on their upper extremities, it was reasoned that the subjects might have felt more stable and comfortable, and therefore ambulated in a style more like their ground walking. This point is not trivial, in that this research may lend credence to a new rehabilitation technique for patients with hemiplegia. Benefits gained by the use of this rehabilitation technique may translate into improved ground walking.

**Data Analysis**

Data was collected using the Stride Analyzer during the four ambulation trials. The data was collected from the Stride Analyzer printout, and has been represented in graphical form in the Results section. Due to the small sample size, data analysis consisted of qualitative trend analysis. Where appropriate,
comparisons of the research subjects were made, as well as comparisons between the demographic data and that collected with the stride analyzer.

Further data was collected with the use of a videocamera placed on the patient's right side, at a 90° angle to the subject, approximately 10 feet from the treadmill. The intent of the videotaping procedure was to gather subjective data regarding the changes, if any, between ambulation full weight bearing versus partially unweighted. Eastlack and associates (1991) reported that without standardization of the evaluation procedures, objective inter-rater videotape analysis may not be statistically valid. Therefore, we propose to use the videotape data in a purely qualitative manner regarding the overall appearance of the subject in the two test states. Several areas of gait were evaluated with the videotape, including apparent symmetry of weight distribution, trunk position, hip retraction, knee position during stance and swing phases, and ankle function during the gait cycle.
CHAPTER 4

Results

Case 1

Demographic data regarding subject 1 can be found in Table 1. He was a 41 year old male with a left-sided cerebral infarct resulting in residual right-sided hemiplegia. This subject was tested eight years after his cerebrovascular accident (CVA). The subject formerly used a right ankle-foot orthosis (AFO) along with a straight cane for ambulation. He reports discontinuing both of these devices approximately two years after his CVA. He is currently a community ambulator without assistive devices.

Figures 1 through 5 exhibit this subject’s temporal-distance measures of gait changes as recorded by the Stride Analyzer. The parameters of velocity (fig. 1), cadence and gait cycle time (fig. 2) exhibited no correlation with the weighting status of the subject, although each of these parameters either decreased or increased across all the trials. Velocity and cadence progressively decreased, and gait cycle time increased, possibly indicating progressive fatigue, although the subject denied this.

Stride length (fig. 1), right and left swing times, right and left stance times (figs. 3 and 4), and single and double limb support times (fig. 5) all were noted to correspond to the subject's weighting status. Stride length increased from an average of 0.60 meters to 0.63 meters with 30% unweighting, a 5%
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Table 1: Demographic data of volunteers tested in the study.

¹ Subject #2 uses a small base quad cane for household ambulation.
² Subject #2 uses a wheelchair for community ambulation.
³ "A" denotes trials with full weight bearing. "B" denotes trials with 30% unweighting.
Figure 1: Velocity and stride length as a function of the type of intervention applied to subject #1. "A" refers to the subject walking full weight bearing, while in "B" trials the subject is 30% unweighted.
Figure 2: Cadence and gait cycle as a function of the type of intervention applied to subject 1.
Figure 3: Right (involved) swing time and left (uninvolved) stance time (as a percentage of the gait cycle) as a function of the type of intervention applied to subject 1. Note the decreased left stance time and concomitant increased right swing time with unweighting (1B and 2B).
Figure 4: Left swing time and right stance time (as a percentage of the gait cycle) as a function of the type of intervention applied to subject #1. Note the decreased right stance time and concomitant increased left swing time with unweighting (1B and 2B).
Figure 5: Single- and double-limb support times as a percentage of the gait cycle during the trials in subject 1. Note the increase in both right and left single limb support times with unweighting ("B" trials). There is a concomitant decrease in double limb support time with unweighting.
increase. This correlates with, but is somewhat less than, the studies of Visintin and Barbeau (1989), who saw increases of 13.7 to 42.9% with so-called "spastic paretic" subjects.

Unexpectedly, both right and left swing times increased, and both right and left stance times decreased as a percentage of the gait cycle during 30% unweighted trials (figs. 3 and 4). While these changes amounted to no more than 2-3% of the total gait cycle, it is paradoxical to note that right stance time (i.e., the involved limb) decreased, while left swing time increased during the unweighting trials with this subject. These findings are difficult to explain because one would expect, as weightbearing decreases on one extremity, it must of necessity increase on the other.

Analysis of the videotaped trials revealed that during full weight bearing ambulation trials, the subject was slightly forward flexed, exhibited trunk rotation which coincided with lower extremity motions, hiked and circumducted the involved hip, and showed a severe knee hyperextension moment at mid-stance of the involved extremity. Unweighting reduced this subject's hip hiking and leg circumduction used to clear his involved limb during swing phase. Unweighting also appeared to reduce involved limb knee hyperextension that is apparent with full weight bearing.

The subject appeared also to more equally distribute his weight over his lower extremities while unweighted according to the videotape, although this subjective analysis is not borne out by the Stride Analyzer data. Figure 5 shows the breakdown of right and left single limb support (as a percentage of the gait cycle) as well as double limb support. While it is apparent that unweighting increases single limb support time bilaterally ("B" trials), it is also apparent that each limb is taking up approximately equal amounts of increased single limb support time. Therefore, the involved lower extremity
was not accepting as large a share of the support burden as we hoped unweighting would allow in this subject.

**Case 2**

Demographic data regarding subject 2 can be found in Table 1. He was a 72 year old male with a left-sided cerebral infarct resulting in residual right-sided hemiplegia. This subject was tested one year, 2 months after his cerebrovascular accident (CVA). The subject uses a small base quad cane for walking, but his primary mode of ambulation is via wheelchair propelled mainly by his spouse. His other health problems include coronary artery disease, hypertension, and diabetes mellitus. Complications secondary to these ailments have limited his participation in rehabilitation programs.

Figures 6 through 10 exhibit subject 2’s temporal-distance measures of gait changes as recorded by the Stride Analyzer. Velocity, cadence, and stride length increased 27%, 19%, and 5%, respectively (figs. 6 and 7), with unweighting. Gait cycle time decreased an average 4.3%. These figures indicate a net positive influence of unweighting on the temporal-distance measures of gait. These figures revert to baseline values or beyond upon returning to full weight bearing status, indicating no training effect with a limited test protocol such as that utilized in the present study.
Figure 6: Velocity and stride length as a function of the type of intervention applied to subject 2.
Figure 7: Cadence and gait cycle as a function of the type of intervention applied to subject #2. Note the increased cadence with concomitant decreased gait cycle time during unweighting.
Figure 8: Right (involved) swing time and left (uninvolved) stance time (as a percentage of the gait cycle) as a function of the type of intervention applied to subject #2. Note the decreased left stance time and concomitant increased right swing time with unweighting (1B and 2B).
Figure 9: Right (involved) stance time and left (uninvolved) swing time (as a percentage of the gait cycle) as a function of the type of intervention applied to subject 2. Note the decreased right stance time and concomitant increased left swing time with unweighting (1B and 2B).
Figure 10: Single- and double-limb support times as a percentage of the gait cycle during the trials of subject 2. Note the increase in both right and left single limb support times with unweighting ("B" trials). There is a concomitant decrease in double limb support time with unweighting.
As in Case 1, both right and left swing times increased, and both right and left stance times decreased as a percentage of the gait cycle during 30% unweighted trials (figs. 8 and 9). This, again, appears paradoxical, as a decrease in the stance time of one limb should be accompanied by an decrease in swing time of the contralateral extremity. Such is not the case as reported by the Stride Analyzer.

Figure 10 indicates the inverse relationship of double limb to single limb support times, with the former decreasing 25% and the latter increasing (on both right and left legs) 25% each with body weight support (BWS). The left extremity accepted more weight bearing load with the BWS trial. This may have been due to the increased proprioceptive feedback from the uninvolved extremity.

Analysis of the videotaped trials revealed that during full weight bearing ambulation trials, subject 2 exhibited an external rotation of the involved extremity which worsened as each walking trial progressed, probably secondary to fatigue. He also hiked and circumducted the involved hip, and showed a moderate knee hyperextension moment upon weight acceptance. Foot clearance and toe drag were problems particular to this subject during swing-through of the right limb. The lower extremity Fugl-Meyer examination indicated that dorsiflexion of the involved foot was minimal in standing, and this was evident in the walking trials as well.

Unweighting reduced this subject's hip hiking and leg circumduction used to clear his involved limb during swing phase. Unweighting also appeared to reduce involved limb knee hyperextension that was apparent with full weight bearing. To a lesser extent, 30% BWS also reduced his toe drag, although this problem became more apparent as the trials progressed, indicating fatigue.
The subject appeared also to more equally distribute his weight over his lower extremities while unweighted according to the videotape, a view supported by the temporal-distance measures. As mentioned previously, this subject clearly supported a greater share of even his unweighted body weight on the uninvolved limb. However, a greater portion of his weight was supported with his involved extremity in the unweighted state than in full weight bearing as extrapolated from Figure 10.
Chapter 5

Discussion

1 Discussion of results

Case 1 vs. Case 2

Although such a small sample size does not permit broad generalities to be drawn from the current study, some interesting inferences become apparent upon comparison of the two cases. The most predictive measure of the response of these two subjects to unweighted treadmill ambulation may be their lower extremity Fugl-Meyer scores. Clearly, subject 1 has recovered a greater degree of function (as measured by the Fugl-Meyer) than subject 2 (Table 1). Many factors influence the degree and rate of recovery from stroke, including those found in Table 1. Because of subject 1’s increased recovery status, he may not have been as “susceptible” to the changes in his gait while unweighted. He mentioned several times, “I’m not sure if I like this feeling [of BWS] or not.” It is not out of the question that, given his level of recovery and his questionable feelings toward the protocol, he was able to physically resist some of the gait changes that the test put him through. Subject 2, with his more recent onset and reduced level of recovery, in addition to his other debilitating health problems, may have succumbed to the effects of unweighting more readily.

Related to the level of recovery is the fact that subject 1 was eight years postinjury, and subject 2 was only 14 months postinjury. In addition, subject 1 was a community ambulator who used no assistive devices, whereas subject
2 used a wheelchair for community ambulation, and a small-based quad cane for short distances. Subject 1 has had a greater opportunity to ingrain his gait pattern and it is unlikely that this pattern would be significantly affected by a single data collection session. Perhaps the method used in this protocol is not appropriate for patients who have a high level of function or compensatory patterns in the involved limb.

Based on previous literature (Visintin & Barbeau, 1989; Waagford et al., 1990; Betti-Gardner et al., 1994) we expected changes in velocity, stride length, cadence, and bilateral stance and swing times. In general, subject 2’s responses more closely correlated with these studies and our hypothesized outcomes as to the effect that unweighting should have on temporal-distance measures of gait. His velocity, cadence, stride length and uninvolved (left) swing time all increased with unweighting. We hypothesized that with an increase in uninvolved limb swing would come an increase in involved limb stance time, but this did not bear out with either subject.

Videotape analysis revealed improvements in gait for both subjects with unweighting. Subject 1 had more symmetrical weightshifting between limbs, and much less severe hyperextension of the right (involved) knee at midstance on that limb. Subject 2 had a decreased forward lean at the trunk while unweighted, reduced retraction of the right side of the pelvis throughout the gait cycle, and also had much less severe hyperextension of the right (involved) knee at midstance on that limb. Subject 2 also had less difficulty advancing his right limb with unweighting, and had more symmetrical weightshifting between limbs.

Betti-Gardner and colleagues (1994) report that changes seen using a long-term unweighting protocol on a spinal cord injured subject remained in effect for at least 3 weeks beyond the end of the unweighting training. The
current study showed no lasting benefits of a single unweighting data collection session. Ideally, long-term training with early post-stroke intervention would enhance the functional carry-over utilizing a similar protocol. Studies with unweighting on spinalized cats (Barbeau & Rossignol, 1987) evidence the utility of progressively decreased unweighting, combined with treadmill training, in stimulating a normal gait pattern. One may conclude from this study, as well, that early intervention may indeed result in enhanced benefits from a similar protocol used in human post-stroke rehabilitation.

2 Limitations

The number of participants limits the ability to generalize the results of this study. We have attempted to describe our research as case studies, but at the time of collection it was unclear how many participants we would have, and therefore did not collect the large amount of data necessary for doing a true case study.

While it was interesting to compare someone eight years postinjury to someone with a more recent CVA, we would have preferred to have both subjects with a year or less since their injuries. It appears that the amount of time since the CVA could affect the applicability of unweighting as a technique for rehabilitation, but in order to discern this, we would need to study a larger number of subjects who had recent strokes. A further study suggests itself based on our results. Two groups of patients with hemiplegia, one group under one year postinjury, and one over one year, could be analyzed as attempted in the current work. That study could provide interesting data regarding time postinjury, level of recovery, and treadmill unweighting effects on temporal-distance gait parameters.
3 Recommendations

Based on the results of our study, we feel that further research is warranted for using unweighting as a method for gait retraining of patients with hemiplegia. A study replicating ours with a large number of subjects could confirm this method as having beneficial effects on gait of stroke patients. It would then be interesting to do a training protocol with stroke patients using unweighting.

In addition, we would recommend conducting a study like this at a facility with a large population of stroke patients. This would make recruitment of subjects much easier.
REFERENCES


**Data Collection Sheet**

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</tbody>
</table>

**Subject Comments:**

**Protocol Order:**

| ABBA | BAAB |

**Hand Placement:**

| R   | Front / Side Rail |
| L   | Front / Side Rail |

**Other:**

**Start Video**

**Stop Video**

<table>
<thead>
<tr>
<th>Notes</th>
<th></th>
</tr>
</thead>
</table>
### Fugl-Meyer Measurement of Physical Performance—Lower Extremity Evaluation—Page 1

<table>
<thead>
<tr>
<th>Area/Position</th>
<th>Test</th>
<th>Scoring Criteria</th>
<th>Maximum Score</th>
<th>Attained Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supine</strong></td>
<td>I. Reflex Activity-Tested in Supine</td>
<td>0-No reflex activity 2-Reflex activity</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Achilles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Patellar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>II. A. Flexor Synergy</td>
<td>0-Cannot be performed 1-Partial motion 2-full motion</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hip Flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knee Flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ankle DF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>II. B. Extensor Synergy</td>
<td>0-No motion 1-Weak motion 2-Almost full strength compared to normal</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hip Extension</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Adduction</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Knee Extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ankle PF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sitting (Knees free of chair)</strong></td>
<td>III. Movement combining synergies</td>
<td>0-No active motion 1-From slightly extended position, knee can be flexed, but not beyond 90° 2-Knee flexion beyond 90°</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Knee flexion beyond 90°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. Ankle DF</td>
<td>0-No active flexion 1-Incomplete active flexion 2-Normal DF</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>
Supine

Vi. Coordination/speed- Heel to opposite knee (5 reps in rapid succession)

A. Tremor________
   0-Marked tremor
   1-Slight Tremor
   2-No tremor

B. Dysmetria_______
   0-Pronounced or asymmetric
   1-Slight or systematic
   2-No dysmetria

C. Speed__________
   0-6 seconds slower than unaffected side
   1-2-5 seconds slower
   2-Less than 2 seconds diff

TOTAL (Total Max LE Score) 34
Fugl-Meyer Measurement of Physical Performance

Lower Extremity Evaluation-Page 2

**Standing**

IV. Movement out of Synergy (Hip @ 0°)
   
   A. Knee Flexion

   B. Ankle DF

**Sitting**

V. Normal Reflexes
   
   Knee flexors
   
   Patellar
   
   Achilles

0-Knee cannot flex w/o hip flexion
1-Knee begins flexion w/o hip flexion, but does not reach to 90°, or hip flexes during motion
2-Full motion as described
   
0-No active motion
1-Partial motion
2-Full motion

0-2 Of the 3 are markedly hyperactive
1-1 reflex is hyperactive, or 2 reflexes are lively
2-No more than 1 reflex lively
APPENDIX C

PATIENT INFORMED CONSENT FORM

Project Title  The Effects of Partial Unweighting on Hemi-plegic Gait

Purpose: I understand that this is a study which will investigate the effects of unweighting on stroke patients' walking ability. The results of this study will help determine if unweighting will be useful for rehabilitation of walking for stroke patients. This study is being conducted by Mike Jones (616-846-5177) and Tasha Greaser under the supervision of Barb Baker (616-895-3356).

Procedures: I understand that participation in this study will take one to one and a half hours of my time. I understand that a standardized evaluation will be performed by the investigators on the function of my legs. I understand that I will walk on a treadmill while wearing the unweighting harness, and will be given time to get used to walking on the treadmill. Then I will be required to walk a distance of six yards, four times. Two times I will be partially unweighted, and two times I will not be unweighted. I will be required to have inserts placed in my shoes which will take measurements on how I walk. I understand that I will be videotaped while I am walking on the treadmill. I understand that I will always choose the speed at which I walk. I understand that I have a scheduled break after two trials, but that I will be allowed to rest at any time if needed.

Risk of Discomfort: I understand that my doctor has given permission for me to participate in this study. I understand that it is not anticipated that this study will lead to any risk of physical harm. I understand that the unweighting harness may be tight around my chest, but will not interfere with my breathing or any other physical function.
Confidentiality: I understand that the information collected about me will be kept strictly confidential and the data will be coded so that the identification of individual participants will not be possible. I understand that the results of this study may be published in a journal without disclosure of my identity. I am aware that a summary of the results will be made available to me upon my request.

Participation: I understand that my participation in this study is voluntary and that I may withdraw at any time. I acknowledge that I have been given an opportunity to ask questions regarding this research study, and that these questions have been answered to my satisfaction.

Consent: I acknowledge that I have read and understood the above information and that I voluntarily agree to participate in this study.

______________________________
Subject’s signature

______________________________
Witness’ signature

______________________________
Investigator’s signature

______________________________
Date

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

Title of Project: The Effects of Partial Unweighting on Hemiplegic Gait

Principal Investigators: Mike Jones and Tasha Creaser, student physical therapists from Grand Valley State University, under the supervision of Barb Baker, PT, and Cathy Harro, PT.

Brief Summary:
Hemiplegics have a distinctive gait pattern often typified by an imbalance of stance time and of weight bearing between limbs. A new method of gait retraining for neurologically impaired patients has recently been introduced. It consists of a patient unweighting apparatus to be used in conjunction with a treadmill. This method may help hemiplegics improve walking ability by retraining the CNS while the patient ambulates in a biomechanically correct position. Partially unweighting the patient may reduce the number of motor units needed to carry out the activity, and it is theorized that this reduced number of motor units will be more easily controlled by the patient's damaged CNS, producing more normal gait patterns. As the patient gains motor control, the amount of weight bearing is increased until the person can ambulate normally while full weight bearing.

This study will compare stroke patients' gait patterns while full weight bearing to their gait patterns while partially unweighted. Up to fifteen subjects who have had a CVA and who can walk will be chosen for this study. After giving informed consent and being screened for lower limb function (using the lower extremity Fugl-Meyer examination) and heart rate, subjects will put on the unweighting harness and begin walking on the treadmill for a warm-up period of up to three minutes. Each subject will complete four trials, each six meters long. In two trials subjects will be partially unweighted; in the other two they will be full Weight bearing. The order of weight bearing will be randomly determined. Data will be collected via footswitches which will have been inserted in the subjects' shoes, and analyzed using a special computer program which gives temporal-distance gait data. Subjects will also be videotaped from the side during the trials for a subjective visual analysis of any changes in gait patterns with unweighting. Data gathered will be compared within each subject for changes in gait while full weight bearing vs. partially unweighted. It is hoped that this data will help determine whether the unweighting apparatus will be beneficial to the rehabilitation of gait for neurologically impaired patients and lay the groundwork for future studies.
MEDICAL CONSENT FORM

I have read the enclosed description of this research study, which is designed to investigate the effects of partial unweighting on the gait of hemiplegic subjects. I understand that the subjects will be required to complete four walking trials, each at a comfortable, self-chosen speed with rest periods between trials. This is not an aerobic test. Subjects will self-select the speeds at which they will ambulate during the trials. Individual trial distance will not exceed six meters. A warm-up period of three minutes or less will allow subjects to get used to the treadmill before data is collected. I understand that a physical therapist or physician will be standing by for maximum safety.

As the personal physician of ____________________________, I give this individual medical clearance to participate in this study.

Patient’s name ________________________________

______________________________ Physician’s signature

________________________ Date