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The Effects of a Heel Lift on Gait Parameters during Ambulation for People with Hemipareses

Bryan Avery
University of North Dakota

Lindsay Riley
University of North Dakota

Shannon Webster
University of North Dakota

THE EFFECTS OF A HEEL LIFT ON GAIT PARAMETERS DURING AMBULATION FOR PEOPLE WITH HEMIPARESIS

by

Bryan Avery
Bachelor of Science in Physical Therapy
University of North Dakota, 2006

Lindsay Riley
Bachelor of Arts in Biology
Concordia College, 2005

Shannon Webster
Bachelor of Arts in Biology
Bemidji State University, 2005

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This scholarly project, submitted by Bryan Avery, Lindsay Riley, and Shannon Webster in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Faculty Advisor under whom the work has been done and is hereby approved.

Graduate Advisor

Chairperson

PERMISSION

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Lindsay Riley

Date 12/14/07

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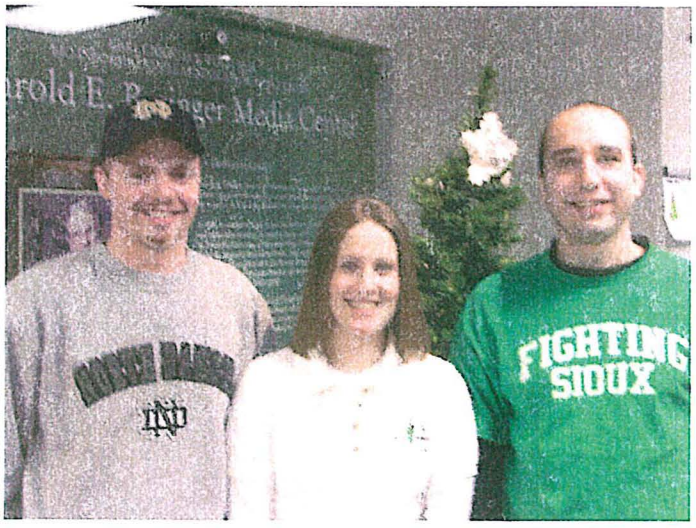

Bryan Avery, Lindsay Riley, Shannon Webster

ABSTRACT

People with hemiparesis can have difficulty weight-bearing through their involved lower extremity. This can lead to asymmetry during static standing and dynamic activities including gait. Previous research has shown improved symmetry in static standing when a heel lift is inserted under the non-paretic lower extremity. The purpose of this study is to determine if a heel lift can improve symmetry during dynamic gait in people with hemiparesis.

Five subjects (1 female, 4 male) with unilateral hemiparesis were recruited from the community. All demonstrated greater than 55% of weight-bearing on the non-paretic limb in static standing. Hemiparesis resulted from either a stroke or a brain tumor. Gait parameters were measured using the GAITRite® walkway system. Subjects ambulated a minimum of 20 steps both with and without a 9.5 mm heel lift inserted. Gait velocity, step length, single limb support time, and swing time were analyzed for each test condition.

Subjects could not be compared due to the variation between them. A series of five case studies are presented based on individual findings as measured by percent change. A heel lift under the non-paretic limb showed greater weight shifting onto the paretic limb for one subject. Improved gait velocity and symmetry in step length were noted for this subject. Another subject subjectively reported that the heel lift insert made ambulation easier for him,

even though analysis of the gait parameters showed little change in his gait symmetry. Use of the heel lift successfully improved gait symmetry in one subject and was subjectively beneficial to another subject. No definite conclusion can be made overall, but it does appear that use of a 9.5 mm heel lift may improve weight -bearing onto the paretic lower extremity and subsequently lead to greater symmetry during dynamic gait activities in certain subjects with hemiparesis.

CHAPTER I

INTRODUCTION

People with hemiparesis often have problems with putting weight through their involved extremity. This may be a confidence issue or a learned response during the rehabilitation period after the incident. People with hemiparesis have weakness, sensation, and proprioception deficits and may have spatial relation syndrome on their affected side.[1]

Problem Statement/Purpose of Study

People with hemiparesis may have asymmetry during static and dynamic activities that may diminish their function and abilities. The purpose of this research study is to determine the effect a heel lift has when it is inserted in the uninvolved shoe of a person with hemiparesis. The research questions for this study are:

1. Does wearing a heel lift on the uninvolved side improve ambulation for people with hemiparesis?

2. Does wearing a heel lift improve symmetry of gait?

Significance of the Study

Previous research has shown that a heel lift inserted under the uninvolved side improves weight-bearing symmetry in static balance for individuals with hemiparesis.[2-4] Individuals with hemiparesis can have a deficit in symmetry to

the involved side during dynamic activities, such as gait, and they may have diminished function if an asymmetry is present. Currently, there is little research describing the effects of a heel lift involving dynamic walking with this patient population.

CHAPTER II

LITERATURE REVIEW

The central nervous system (CNS) controls and regulates all mental and physical functions.[1] Disease or trauma of the CNS may cause damage to several types of tissues in a local area, or it may cause dysfunction in one type of tissue throughout many areas of the CNS. Damage to cells to a local point in the brain can result in hemiplegia. Hemiplegia is the paralysis of one side of the body from damage to the corticospinal tracts of the CNS.[5] The most common cause of hemiplegia is from a stroke caused by a thrombosis, brain hemorrhage, or cerebral embolism. Tumors can also be responsible for hemiplegia but are less common. With such an injury to the brain tissue, hemiparesis contributes to impairments in balance, walking difficulties, and increase risk of falls.[6]

There have been consistent gait differences that have been found with individuals who have hemiparesis. Gait in individuals with post-stroke hemiparesis is characterized by reduced speed, cadence, stride length, increased step width, and asymmetrical step length.[7] Gait differences found in post-stroke hemiparesis include impaired swing initiation of the paretic limb, inadequate propulsion of the leg during pre-swing, increased percentage swing time, reduced knee flexion at toe-off, shortened limb support on the paretic limb, and exaggerated propulsion of the non-paretic limb during pre-swing.

Hemiparetic gait is also affected by compensatory strategies and motor behaviors that include pelvic hiking and wing-phase propulsion along with circumduction of the paretic limb. All of these deviations in gait increase energy use during ambulation which can cause fatigue in the individual. According to Bohannon,[8] the major deviations noted for asymmetry of gait are appearance, temporal measures, and distance measures. Temporal asymmetry includes relative time spent on the involved versus uninvolved limb as measured in percent of total gait cycle. A commonality noted for people with hemiparesis is increased time spent on the uninvolved limb during stance phase of gait.

Distance asymmetry from hemiparesis results in a decrease in stride length. Step length is a more reliable determinant of gait since stride length is not as sensitive to change. Step length is highly correlated with temporal parameters such as gait velocity, double limb support time, and stance time.[8]

Standing balance of individuals with hemiparesis is characterized by increase postural sway and by a shift in the average position of the center of pressure toward the uninvolved limb during static standing.[9,10] People without hemiparesis have relatively equal weight-bearing when the feet are parallel in the same place. With the feet positioned astride, tests revealed deficiencies in shifting weight posterior laterally over both the affected and non-affected legs with hemiparetic individuals. There was more of a deficiency toward the affected leg in diagonal position. All of the weight shifting limitations discussed were significantly below the values for normal individuals without hemiparesis.

Walking aids have been introduced to people with hemiparesis to try to reduce the postural sway. Walking aids have been proven to increase postural stability, improve muscle action, and to reduce the load on the involved weight-bearing leg.[9] After a CNS lesion occurs that results in hemiparesis, people will often times use a walking aid, such as a standard cane or quad cane, to increase their walking ability. Giving a walking aid, like a cane, can encourage people with hemiparesis to walk with a more normal gait pattern. The use of a cane does not improve the asymmetrical weight-bearing pattern during stance that is a characteristic of people.

Physical therapy has looked at improving gait patterns by using an ankle foot orthosis (AFO) on patients with hemiparesis. According to Pohl et al,[6] the AFO can improve spatio-temporal parameters of gait and lower the energy costs of walking. The use of an in-shoe AFO improved weight-bearing on the paretic leg and improved postural sway in stance. Wang et al[11] reported that weight bearing was more evenly distributed when the subject wore the AFO on the paretic leg. The AFO works by providing ankle stability by keeping the ankle joint in a good alignment and giving external support. Subjects with hemiparesis of less than six months duration found that the AFO improved the symmetry in quiet standing and the dynamic standing balance as measured by the Balance Master®. The AFO also improves gait speed and cadence with an onset of less than six months. Subjects that were greater than 12 months post-incident did not have as good results on balance and gait with AFO use.

Extensive research has been conducted to determine effective treatments for individuals with hemiparesis. This is due to the fact that hemiparesis, with its potential for significant weakness and sensation deficits, can alter functional gait parameters as well as other weight-bearing activities related to balance. The majority of research has been in the area of static balance symmetry.[2-4]

Individuals experiencing unilateral hemiparesis can develop misuse of the involved limb if there is a weight-bearing asymmetry present.[2,3] There is evidence supporting forced-use interventions as well as programs designed to re-train the involved limb for improved gait parameters, including but not limited to the Bobath method, harness lifts, and treadmill training.[3]

The use of a heel lift or shoe wedge under the uninvolved limb in individuals with hemiparesis has also been demonstrated to be an effective intervention to improve weight-bearing asymmetry in stance.[2-4] It is believed that increasing the length of the uninvolved limb forces the body to shift weight onto the involved limb and in effect provide input and force the use of the limb. Different types of shoe lifts or wedges have been used to test this theory.

Chaudhuri et al[4] demonstrated improved weight-bearing symmetry with the use of a 6 mm and 9 mm shoe lift. Subjects were measured using the NeuroCom Balance Master-Equitest device for both symmetry and dynamic balance perturbations. Two of the subjects wore an AFO but no other assistive device was used. Each of the ten subjects was within the range of 2.3 to 22.1 weeks post-stroke at the time of the study. They all had resultant unilateral hemiparesis. The researchers found that use of either the 6 mm or 9 mm shoe

lifts approached near 50/50 weight-bearing on the involved and uninvolved hemiparetic limbs. They concluded that shifting weight to the involved limb with the shoe lift leads to greater control through muscle activity stimulation.

Rodriguez et al[3] investigated the effects of a shoe lift as well as a shoe wedge on weight-bearing symmetry. Nine subjects with unilateral hemiparesis that were 2 to 8 weeks post-stroke were assessed in static standing using the Balance Master to determine weight-bearing ratios. In order to meet inclusion criteria, the subjects had to stand independently without an AFO or other assistive device for 5 minutes. The most effective intervention (closest to 50/50 ratio) was the 5° shoe wedge. The 12 mm shoe lift was the most effective height for its category. The use of a 12.5° shoe wedge showed reversed weight-bearing asymmetry where there was a greater weight-bearing on the involved limb. Both the shoe lift and wedge showed carryover of symmetry gains towards the involved limb when the subjects' final measurement was taken without any shoe insert. Although the wedge showed the greatest effect, there was concern that it increased the potential for injury since it promoted foot eversion. However, the researchers concluded that up to a 7° shoe wedge angle could be safe for clinical use.

Ariun et al[2] tested a shoe lift in individuals with unilateral hemiparesis that presented with diminished weight-bearing on the involved lower extremity. All eight of the subjects had a stroke resulting in hemiparesis 0.16 to 5 years prior to the study. Five of the subjects wore an AFO. There was no mention if the added height of the ankle-foot orthosis was taken into account when applying the

heel lift to the non-involved limb. Subjects' weight-bearing was assessed using the Balance Master in static standing, but the article did not specify what weight-bearing test was used. The results showed an almost 50/50 weight-bearing ratio with a 10 mm shoe lift. One of the subjects was given a 10 mm shoe lift to use while completing a six-week physical therapy program as well as during any daily leisure activities. The subject was assessed wearing the shoe lift while ambulating on a 10 meter walkway with optoelectronic sensors to determine velocity and the step print technique to measure stride length. The Balance Master® weight-bearing test was used to determine static standing symmetry. Results under these conditions showed improved weight-bearing symmetry 4 days after completing the program. Carryover of symmetry was seen even after 10 weeks without using the shoe lift, although it was not as high as the measurement taken 4 days post-completion. In addition, the subject's gait was assessed with improvements shown in gait velocity and stride length after completion of the therapy program. Gait velocity has been shown to be a valid determinant of hemiparesis functional recovery. Fugl-Meyer Lower Extremity Assessment and Balance Scale post-test scores showed improvement compared to pre-test. Aruin et al[2] concluded that shoe lifts would be beneficial in balance re-training programs for individuals with hemiparesis.

CHAPTER III

METHODOLOGY

The research design was reviewed and approved by the UND Institutional Review Board (Approval #IRB-200704-325). (See Appendix A.) Subjects read and signed an approved consent form (Appendix B) prior to beginning the study and were given a copy of this form. A copy of the approved medical questionnaire (Appendix C) and subject data collection form (Appendix D) are provided.

Subjects

Five subjects (1 female, 4 male) were included in the study with a mean age of 68 ± 11.47 years (range of 52 to 79 years). Two subjects had left hemiparesis and 3 subjects had right hemiparesis. One subject's hemiparesis was the result of a post-brain tumor resection, while the 4 other subjects had post-stroke hemiparesis. Time since hemiparetic incident ranged from 2 years to 11 years. Subjects in this study were recruited from the community (Table 1).

Subjects completed a medical questionnaire to screen for any serious medical conditions that may limit full participation in the study. This included other neurological disorders, unstable medical conditions, severe visual or vestibular deficits, recent trauma, or other orthopedic problems directly affecting balance and ability to ambulate. Inclusion criteria included a diagnosis of left or

Table 1. Subject Demographics

Subject	Age	Gender	Hemiparesis (L or R)	Lesion	Time Since Incident	AFO Use	Assistive Device
1	79	Female	Left	Stroke	11 years	Left	Cane (SPC)
2	52	Male	Left	Brain Tumor	2 years	Left	Cane (SPC)
3	75	Male	Right	Stroke	6 years	None	Cane (SPC)
4	60	Male	Right	Stroke	2.5 years	Right	None
5	74	Male	Right	Stroke	2 years	None	None

SPC = single point cane

right hemiparesis, having this diagnosis for 6 or more months, and age 18 years or older, ability to be able to follow two-step directions, walk independently for at least 50 feet with or without an assistive device, have an asymmetric static posture exhibiting more than 55% of body weight dispersed on the uninvolved limb as shown on the Balance Master, and own laced shoes that do not have more than a half-inch heel.

Assessment included gait analysis both with and without the heel lift insert. Randomization was completed by having the subjects pick a card designating no heel lift during the first trial; if the second card was chosen, the subject would walk with the heel lift during the first trial. Gait analysis was performed under the first randomized condition and repeated with the other condition.

Instrumentation

The Balance Master® (NeuroCom International, Inc., Clackamas, Ore.) was used to obtain static standing weight-bearing ratios. This instrument is designed to assess and treat balance deficits. The system uses dual force plates to analyze the vertical forces exerted on it, and a computer output can be generated.[12] The assessment completed was the Weight-Bearing Squat (WBS) test with 0° knee flexion. Liston et al[13] demonstrated that the Balance Master® had good test-retest reliability among patients with stroke.

The GAITRite® (CIR Systems, Inc., Havertown, Pa.) was used to measure the spatial and temporal parameters of gait. This instrument is an electronic walkway that is connected to a PC that analyzes an individual's gait. The walkway is 16 ft. long x 3 ft. wide and has 18 432 pressure-sensitive sensors that determine data. It has been proven to be a valid and reliable tool for assessing gait parameters in both a normal population as well as populations that have dysfunction.[14-16]

Webster et al[14] compared the GAITRite® walkway system to the Vicon 5-12®, a three-dimensional motion analysis device. This study compared the validity of the spatial and temporal aspects of gait between the two systems. The subjects wore the Vicon 5-12® system as they walked down the GAITRite® walkway. This allowed for simultaneous data collection from both systems. Both systems looked at velocity, cadence, step length, and step time during the same walking trial. Paired t-tests revealed that there was excellent agreement between the two systems.

McDonough et al[15] tested one healthy woman subject with video analysis while walking on a GAITRite® and simultaneously walking on paper placed over the talking surface. This allowed for comparison of three methods of measurement at the same time. This article also supported the validity of the GAITRite® walkway system when looking at gait parameters.

Bilney et al[16] compared the GAITRite® system to the Clinical Stride Analyzer®. The study looked at the concurrent validity as well as the test-retest reliability of the GAITRite® system. The results found good concurrent validity between the systems. Uden et al[17] also assessed the test-retest reliability of the GAITRite® walkway system on subjects initially and then a week later to see if the same results would be achieved. The GAITRite® walkway system proved to be very reliable for test-retest reliability a week apart.

A pilot study was completed with the use of both the GAITRite® and Balance Master® Weight-Bearing Squat test. The testers of this study were trained in the use of the equipment and demonstrated intra-rater reliability in all measurements prior to the start of the study.

Three Adjust-a-lift (UCOheal®, Wheeling, Ill.) heel lifts, size small, medium, and large, were used. These rubber lifts are adjustable height from 9.5 mm to 6.4 mm to 3.2 mm. For the purpose of this study, the 9.5 mm height was used. (See Figures 1 and 2.)

Procedure

The Balance Master® was set-up before the subject data collection process. After completion of the medical questionnaire and signature of

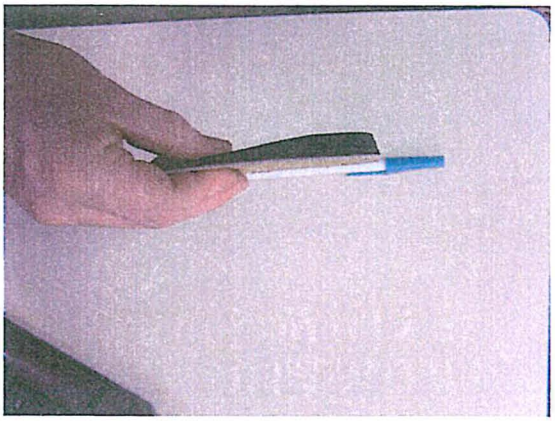

Figure 1. Size width comparison of the 9.5 mm heel lift to a Bic© pen.

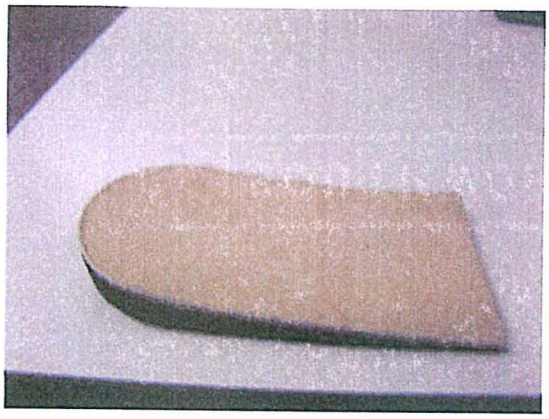

Figure 2. Top view of the medium-sized 9.5 mm heel lift used in the study.

informed consent, subject eligibility was determined. Subjects' height was measured in feet and inches with shoes on and input into the Balance Master®. Subjects stood with both feet within the blue marked box on the force plates (Figure 4). They were then asked to march in place three times and then stand comfortably while the weight-bearing ratio measurement was recorded. Weight-bearing ratio left to right was measured in three trials and averaged. See Table 2.

Table 2. Lower Extremity Weight-bearing Percentages Using the Balance Master®

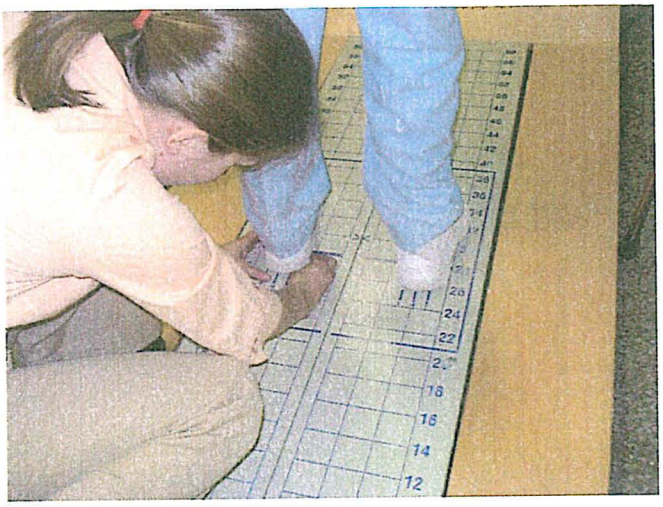

Figure 3. The subject's feet are being centered on the Balance Master©.

Table 2. Lower Extremity Weight-bearing Percentages Using the Balance Master®

	Trial 1		Trial 2		Trial 3		Average of 3 Trials	
	Left	Right	Left	Right	Left	Right	Left	Right
Subject 1	46	54	38	62	38	62	40.7	59.3
Subject 2	53	47	30	70	40	60	42.8	57.2
Subject 3	73	27	78	22	81	19	77.3	22.7
Subject 4	77	23	75	25	68	32	73.3	26.7
Subject 5	62	38	59	41	60	40	60.3	39.6

Baseline measurements for light touch sensation were performed in sitting and following the dermatome patterns for L_5 through S_2 nerve roots. Sensation

was recorded as absent, diminished, or normal for both the right and left lower extremities. Active ankle dorsiflexion range of motion was measured in sitting with knees bent with a goniometer and documented for both left and right ankle (Figure 4). Leg length measurements were taken from the top of the greater trochanter to the floor through the lateral malleolus and with shoes on. Leg length was documented in centimeters to input into the GAITRite® computer program. Leg length was required to calculate gait parameters.

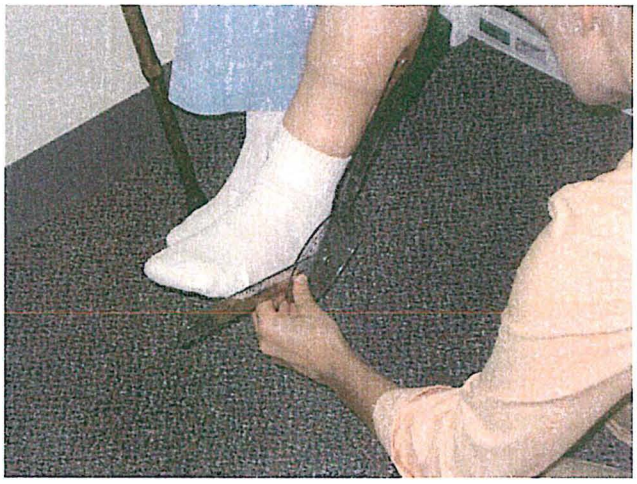

Figure 4. The subject's ankle dorsiflexion is being measured with a goniometer.

Randomization was completed following baseline measurements. As subjects were randomized, the researchers inspected the subjects shoes to verify heel height and whether a heel lift could be properly inserted.

The GAITRite® was set up in the Department of Physical Therapy. Two large Xs of tape were placed on opposite walls to remind the subjects to keep their heads up during testing. On both ends of the GAITRite®, an additional 6-foot walking distance was marked with a tape line on the floor. This was to ensure that the subjects did not improperly accelerate or decelerate as they

walked on the instrument. With the additional walking distance, the total length of the walkway was 28 feet (Figure 5).

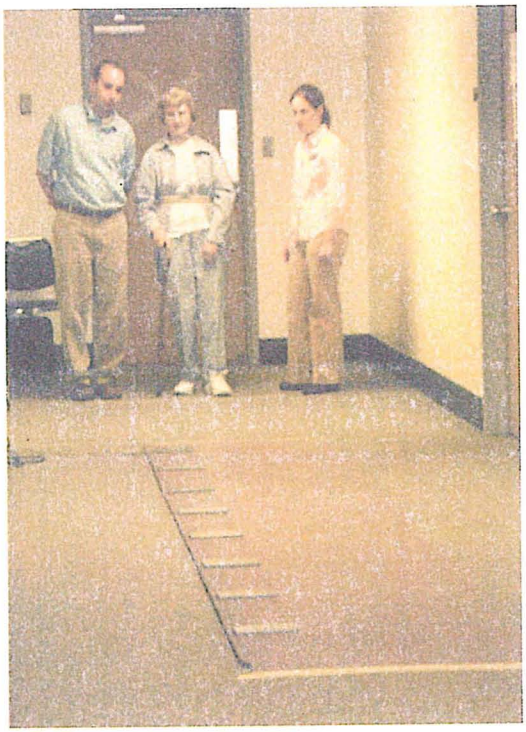

Figure 5. The subject is getting instructions before walking down the GAITRite©.

After data collection, subjects provided written consent to be videotaped while ambulating on the GAITRite®. The patients were instructed to walk at a normal pace. Under the first randomized condition, subjects ambulated until 20 step were obtained which equaled approximately three to four walks. Subjects then ambulated under the second randomized condition until 20 steps were obtained. Subjects were provided adequate rest time between trials as needed. Assistive devices or AFOs were permitted during ambulation (see Table 1). All of the subjects wore a gait belt during the trials and a spotter provided contact guard assistance while walking next to the individual.

Data Analysis

Due to the wide variation of the subject demographics, statistical analysis was not possible on the chosen gait parameters. Results are presented in a series of case studies outlining individual findings comparing heel lift to no heel lift. Gait velocity, step length, single limb support time, and swing time were analyzed to determine if the subjects gait improved with the use of a heel lift on the non-paretic limb.

CHAPTER IV

RESULTS AND DISCUSSION

The following chapter will outline the case descriptions and outcomes of the five subjects that participated in this study. The information provided in each case study will include subject history, objective measurements, data analysis, observational gait, and discussion. To view the GAITRite® footfall patterns of each case study, refer to Appendix E. For each subject, it was expected that using a heel lift would increase gait velocity, improve step length symmetry, increase single limb support time of the paretic limb, and increase swing time of the non-paretic limb.

Case Study 1

Subject 1 was a 79-year-old female, 5 feet 3¾ inches, who had left hemiparesis resulting from a stroke 11 years ago. Past medical history included atrial fibrillation, hypertension, and right ankle triple arthrodesis. Subject reported that she currently wore glasses, utilized a single point cane on the right and an AFO on her left foot, and was able to walk 200 meters independently. Activity level included independence in ADLs with no history of falls. Motivation level was high to try any new treatments or surgeries to decrease her impairments including participation in physical therapy sessions two times a week for several weeks. Subject reported that a heel lift was previously used to

compensate for a leg length difference attributed to wearing an AFO. Subject continued to wear an AFO even after a successful ankle fusion, but no longer uses heel lift on non-paretic side (Figure 6A).

Figure 6A. Subject 1 has just finished walking down the GAITRite©.

Objective Measures

Sensation to dermatomes L_4-S_2 were normal to light touch, and sitting active ankle dorsiflexion range of motion on the paretic limb measured 2° and non-paretic limb measured 13°. Leg length measurement with shoes on for the paretic limb was 89 centimeters and for the non-paretic limb was 90 centimeters. Heel height measured 2 centimeters on either shoe. Weight-bearing ratio was 40.7% on the paretic limb and 59.3% on the non-paretic limb.

Data Analysis

This subject's velocity increased from 25.26 m/min to 25.86 m/min while wearing the 9.5 centimeter heel lift. The percent change was a 2.4% increase with the heel lift (Figure 6B).

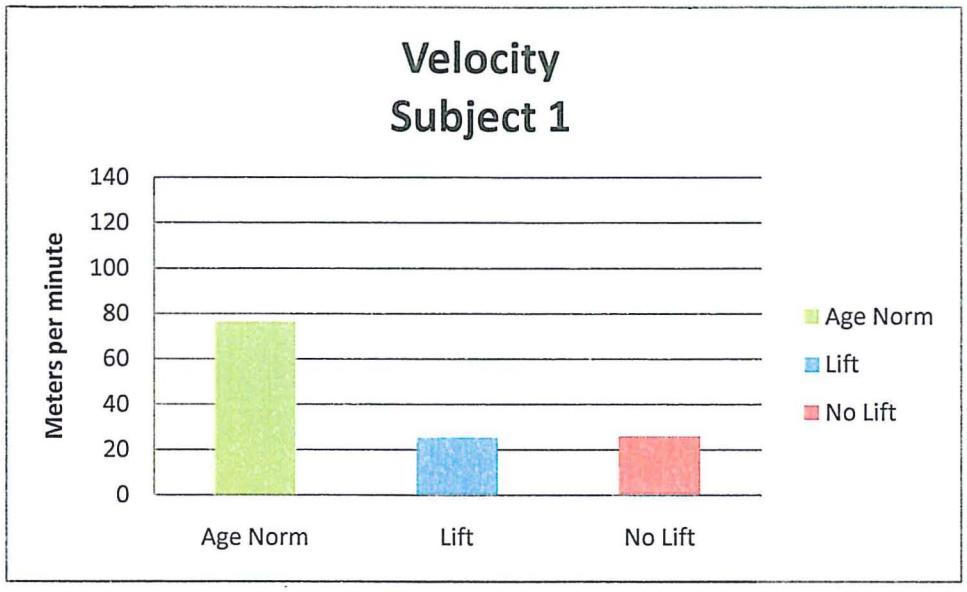

Figure 6B. Velocity - Subject 1.

Step length on the paretic limb increased with the heel lift inserted from 41 cm to 48.5 cm. Percent change for the paretic limb was 18.3%. Non-paretic step length decreased from 31.8 cm to 22.9 cm for a percent change of -28.0% with the heel lift insert (Figure 6C).

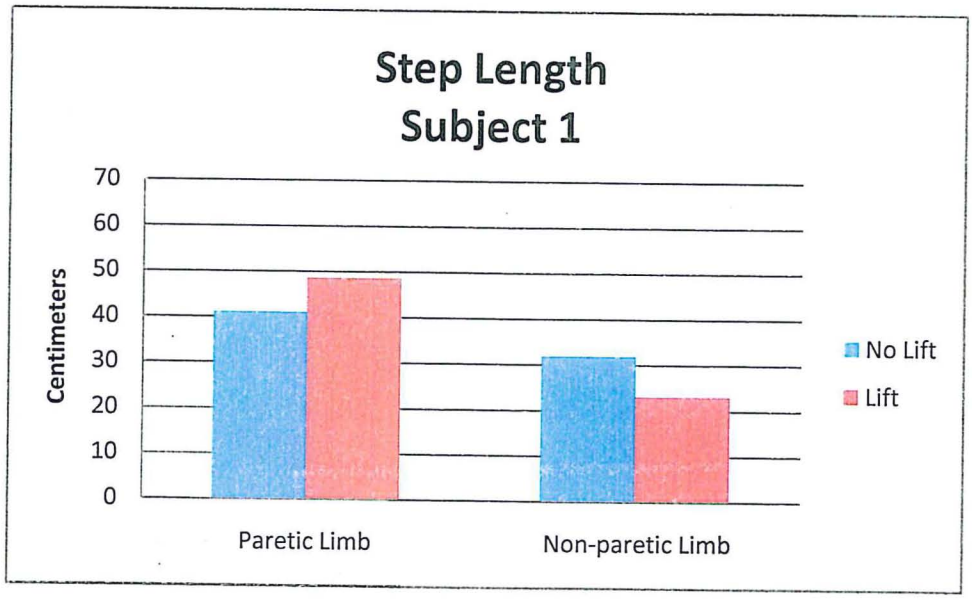

Figure 6C. Step Length - Subject 1

Single limb support on the paretic limb was 29.3% without the heel lift and decreased to 24.1% with the heel lift. The non-paretic limb single support was 32% without the heel lift and increased to 35.8% with the heel lift. Percent change for the paretic limb was -21.6% and 11.9% for the non-paretic limb with the heel lift (Figure 6D).

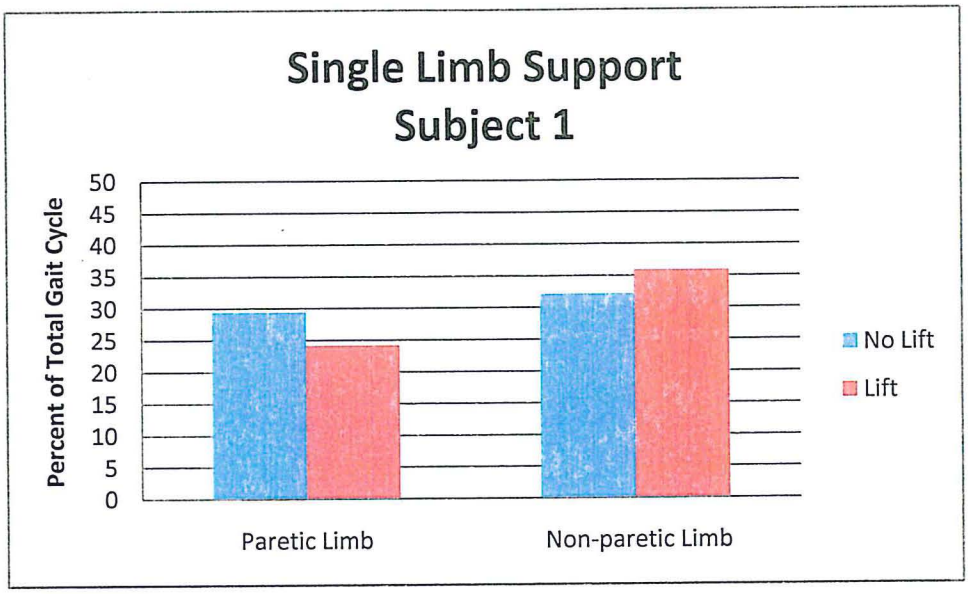

Figure 6D. Single Limb Support - Subject 1

Swing percentage of the paretic limb without a heel lift was 31.9% and increased to 35.9% with a heel lift. The non-paretic limb swing percentage was 29.3% without a heel lift and decreased to 24% with the heel lift inserted. Percent change for the paretic limb was 12.5% and for the non-paretic limb was -22.1% with the heel lift inserted (Figure 6E).

Observational Gait

Through video observation, an asymmetry was noted with more weight-bearing transferred through the uninvolved limb. The left arm did not swing during any part of the gait cycle and showed increased tone while ambulating.

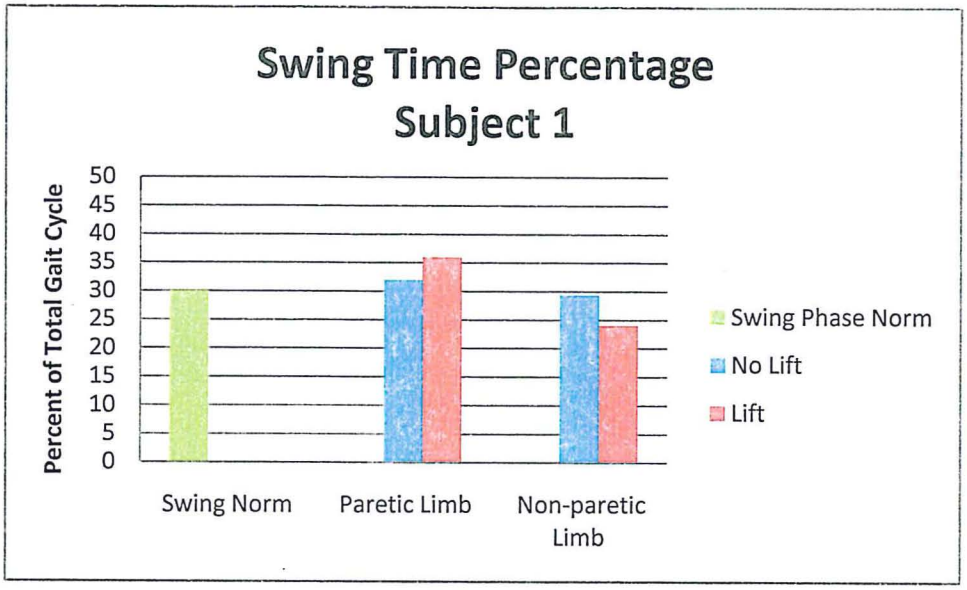

Figure 6E. Swing Time Percentage - Subject 1

Backward lean strategy and hip hiking on the right occurred to advance the involved limb. Increased tone as evident in the involved limb and limited knee flexion, making it difficult to advance the right leg. There was no ankle dorsiflexion due to the triple arthrodesis and use of an AFO on her left side. See Appendix F for DVD of subject walking.

Discussion

While reviewing the subject's data from the GAITRite®, no noticeable gait change in improved symmetry was observed under the testing parameters. Subject continued to incorporate a backward lean technique to advance the involved limb during swing phase. The subject did not subjectively report any improvements in her ability to ambulate with the 9.5 mm heel lift inserted. Walking velocity has been shown to be a good determinant of hemiparesis functional recovery.[2] Velocity for this subject was well below the normal for her age group. The normal comfortable velocity for a healthy adult in the 70th

decade is 76.3 m/min.[18] The heel lift did increase her velocity by 0.60 m/min (2.4% change). Step length for the paretic limb increased with the use of the heel lift (18.3%) and the non-paretic limb step length decreased by 28%. It was expected that step length for the non-paretic limb would increase but was not the case for subject 1. These findings may have been due to the increased amount of clearance provided by the heel lift for the paretic limb.

The normal percentage of single limb support for the reference leg for older adults in the total gait cycle is 40%. In comparison, the normal percentage of swing phase for the reference leg in the healthy older population is 30%.[19] Subject 1's single limb support and swing phase percentage findings in the gait cycle were consistent with the step length results. In order to have an increased step length on the paretic limb, more time must be spent in single limb support on the non-paretic limb with a longer swing phase on the paretic side.

The participant has been living with hemiparesis for 11 years and has developed many strategies to compensate for her impairments. It may be unlikely that a single session of using a heel lift under the uninvolved limb would have much effect on these strategies.

Case Study 2

Subject 2 as a 52-year-old male, 5 feet 11 inches, with left hemiparesis due to a brain tumor resection 2 years ago. His past medical history included radiation therapy and ringing in ears. He wore a 6.5 mm heel lift for his right shoe from a physical therapist previously, but it was unknown how long he has utilized it. This heel lift was used to compensate for a leg length discrepancy

caused by the use of an AFO on the left ankle. The subject was currently using his AFO. He reported being able to ambulate 2 blocks independently with the use of a single point cane. Falls were common the first 15 months after brain surgery, but he has not fallen in the past 10 months (Figure 7A).

Figure 7A. Subject 2 just completed a walk down the GAITRite©.

Objective Measurements

Sensation was intact for dermatomes L_4-S_2 to light touch. Sitting active ankle dorsiflexion range of motion measured 0° on the paretic limb and 13° on the non-paretic limb. Leg length measurement with shoes on for the paretic limb was 96 cm. Three different measurements of leg length were taken on the non-paretic limb due to the subject's prior use of a heel lift. Measurements for leg length with shoes on was 95.5 cm without any heel lift, 98 cm with his own heel lift, and 99 cm with the researchers' 9.5 mm heel lift. For this study, the measurement of 95.5 cm as used to remain consistent with other subjects. Heel height measured 2.5 cm on either shoe. Weight-bearing ratio was 42.8% on the paretic and 57.2% on the non-paretic. For this study, the subject's own heel lift

was removed from his right shoe and a 9.5 mm heel lift was placed in the right shoe.

Data Analysis

Gait velocity increased from 26.76 m/min to 28.74 m/min when wearing the new 9.5 mm heel lift. Percent change for velocity was 7.4% with the heel lift (Figure 7B).

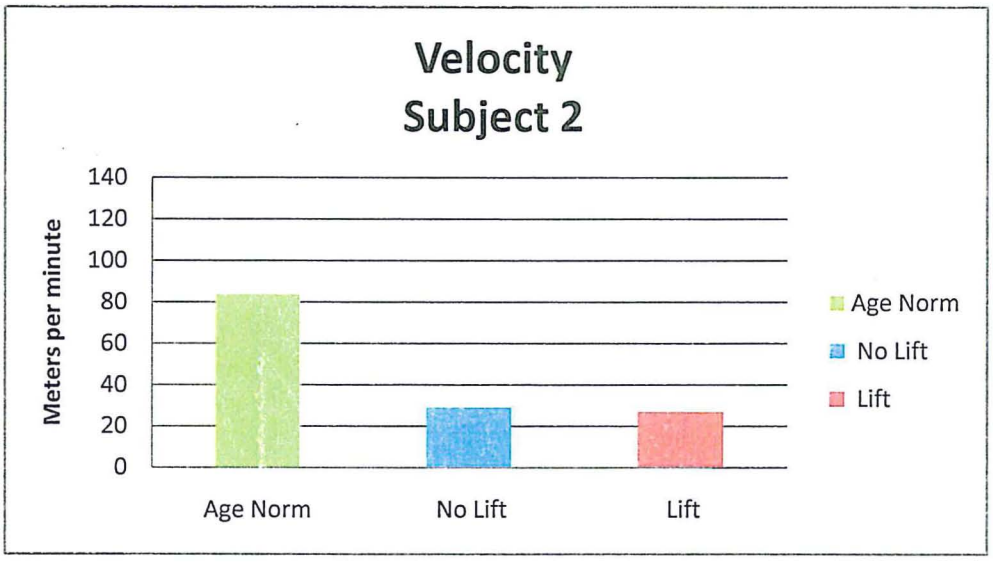

Figure 7B. Velocity - Subject 2

With the heel lift, the step length increased on the paretic limb from 44.9 cm to 45.5 cm for a percent change of 1.3%. Step length increased on the non-paretic limb from 36.1 cm to 42.5 cm for a percent change of 17.7% with the heel lift (Figure 7C).

Single limb support percentage for the paretic limb without a heel lift was 24.2% and decreased to 23.8% with the addition of the heel lift insert. The non-paretic limb single limb support was 33.2% without the heel lift and increased to

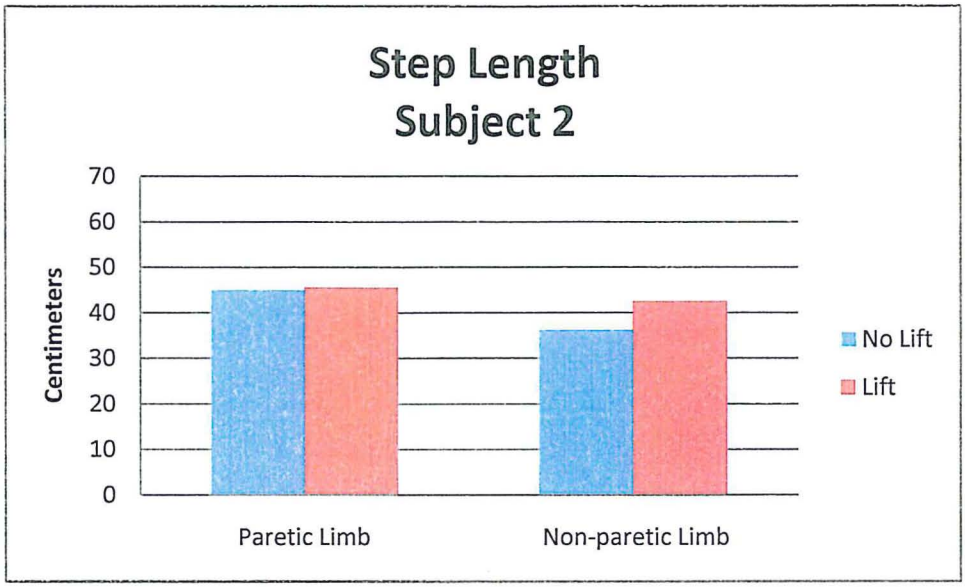

Figure 7C. Step Length - Subject 2

34.4% with a heel lift. Percent change for the paretic limb was -1.7% and for the non-paretic limb was 3.6% with the heel lift (Figure 7D).

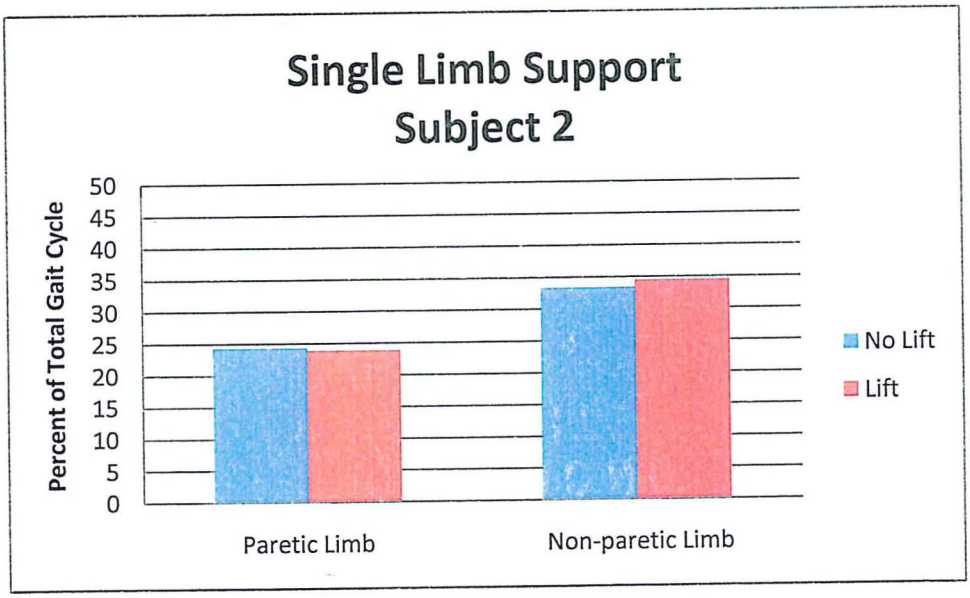

Figure 7D. Single Limb Support - Subject 2

Swing phase percentage of the paretic limb without a heel lift was 32.9% and increased to 34.5% with a heel lift. Non-paretic limb swing phase percentage without a heel lift was 24.5% and decreased to 23.8% with a heel lift.

Percent change for the paretic limb as 4.9% and -2.9% for the non-paretic limb with the heel lift (Figure 7E).

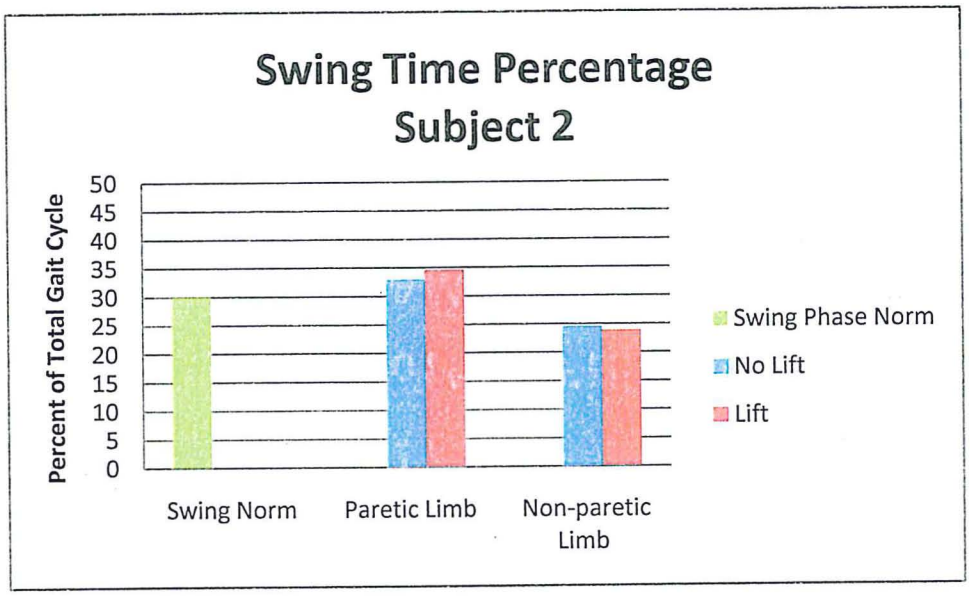

Figure 7E. Swing Time Percentage - Subject 2

Observational Gait

Through video observation, subject used a hip hike and limb circumduction strategy to advance his involved limb due to minimal left knee flexion and ankle dorsiflexion. There was an audible left foot drag with each step and left foot placement was supinated which forced the subject to walk on the latter aspect of his shoe. This was evident by the wear pattern on his shoe. This substitution pattern gave his ankle a varus appearance. Due to left hemiparesis in the upper extremity, left arm swing did not occur normally during the gait cycle. Refer to Appendix F for DVD of subject walking.

Discussion

Subject 2 was unique from the other study participants since he was the only subject who had unilateral hemiparesis as a result of a brain tumor

resection. His heel lift had been worn for an undetermined amount of time and showed obvious wear from use, since it measured about 3 mm less than the 9.5 mm lift used in this study. At this time, the subject's personal heel lift was removed and data collection continued for this subject with no heel lift in the right shoe. The 9.5 mm heel lift was then inserted into the right shoe and data collection was completed for this condition.

No obvious observable changes in symmetry or gait pattern were seen with the new heel lift under the non-paretic limb after viewing video recording. Swing phase compensations continued to show a slight foot drag, hip hiking, and lim circumduction on the paretic side. It is possible that due to his previous experience with a heel lift under the non-paretic limb, this subject had already established compensatory strategies.

Normal comfortable velocity for a healthy adult in the 50th decade is 83.6 m/min.[18] Measured gait velocity for this subject increased by 1.98 m/min (7.4% change). The use of a heel lift improved symmetrical step length to within 3 cm paretic compared to non-paretic. The subject was able to achieve a 6.4 cm greater increase in step length on the non-paretic side allowing for a more normalized step pattern bilaterally.

The heel lift was expected to cause weight shifting and weight acceptance to the paretic limb for longer single limb support time. The heel lift insert did not affect single limb support percentage in this subject. Non-paretic single limb support remained greater compared to the paretic, but both values were below the normal percentage for the total gait cycle. This is common in individuals with

hemiparesis, since they are more stable during ambulation by limiting single limb support time and increasing time in double limb support.

Swing phase findings were consistent with the single limb support results. Since the subject spent less time on the left leg compared to the right during single limb support, it was expected that swing phase would also be limited on the right side. Inability to properly weight shift and accept that weight on the involved limb led to a decrease in swing time for the uninvolved limb. Ambulating with the heel lift did not affect the ratio of left to right swing phase percent.

Use of a heel lift insert on the uninvolved side showed improvement in both gait velocity and step length. Single limb support and swing phase percentages did not show improved symmetry. Symmetrical step length was the most notable change when using the heel lift.

Case Study 3

Subject 3 was a 76-year-old male, 4 feet 11 inches, with right hemiparesis from a stroke 6 years ago. His past medical history included heart disease, hypertension, and coronary artery bypass surgery. He currently wore glasses. He stated he used a single point cane within his home and a walker for ambulation in the community. Subject reported that he could ambulate 50 feet at one time. He reported no history of falls within the home or community (Figure 8A).

Figure 8A. Subject 3 has just finished walking down the GAITRite©.

Objective Measurements

Light touch sensation to dermatomes L_4-S_2 were normal, and sitting active ankle dorsiflexion range of motion measured 10° on the non-paretic limb and 9° on the paretic limb. Leg length measurement with shoes on for the non-paretic limb was 80 cm. and for the paretic limb was 79 cm. Shoe heel height measured 2 cm. for each shoe. Average weight-bearing ratio was 77.3% on the non-paretic limb and 22.7% on the paretic limb which was more asymmetrical than the other subjects in this study.

Data Analysis

Velocity with this subject without the heel lift was 28.08 m/min. and with the heel lift decreased to 27.48 m/min. Percent change for velocity was -2.1% with a heel lift (Figure 8B).

Step length increased on the paretic limb from 17.9 cm. without the heel lift to 18.9 cm. with the heel lift inserted. The non-paretic limb step length was 36.2 cm. without the heel lift and decreased to 35.7 cm. with the heel lift.

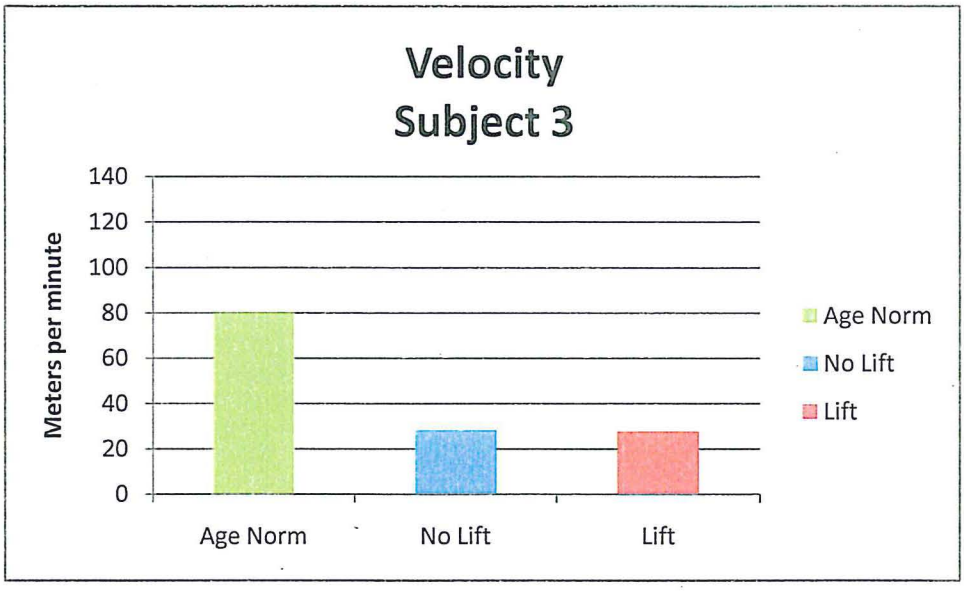

Figure 8B. Velocity - Subject 3

Percent change for the paretic limb was 5.6% and for the non-paretic limb was -1.4% with a heel lift (Figure 8C).

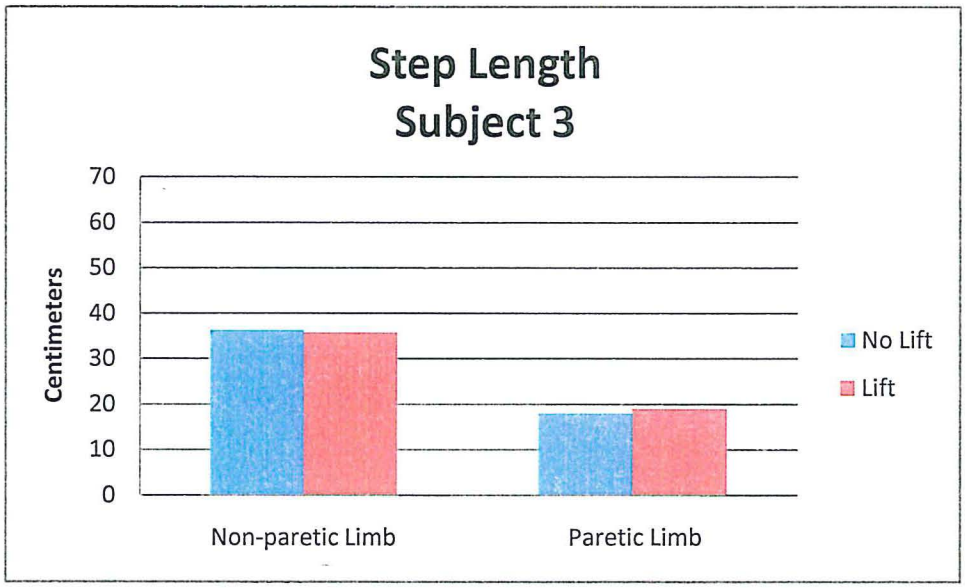

Figure 8C. Step Length - Subject 3.

Single limb support percentage for the paretic limb without the heel lift inserted was 28.4% and decreased to 27.9% with the heel lift. The non-paretic limb single limb support was 38% without a heel lift and increased to 39.4% with

the heel lift. Percent change for the paretic limb was -1.8% and 3.7% for the non-paretic limb with a heel lift (Figure 8D).

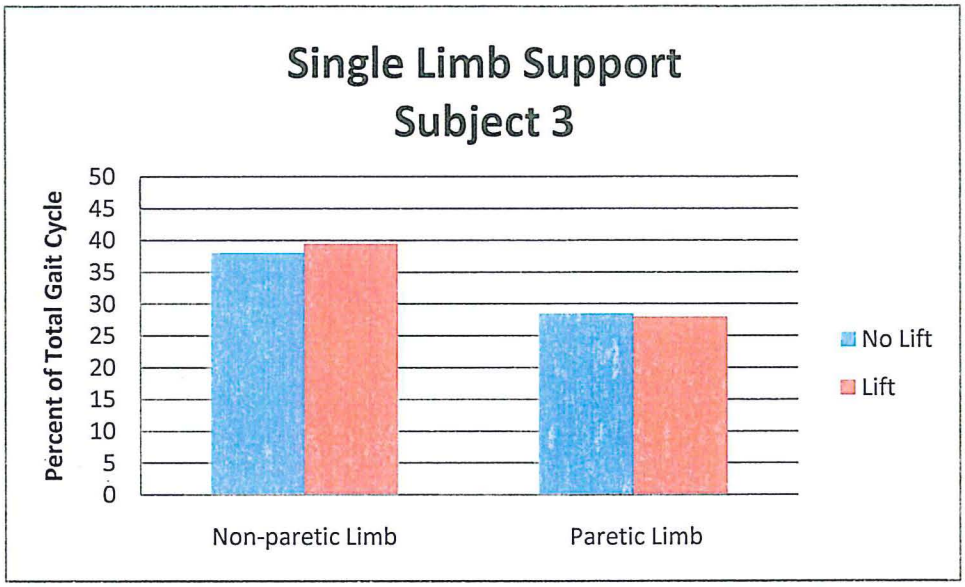

Figure 8D. Single Limb Support - Subject 3

Swing time percentage for the paretic limb without a heel lift insert was 38.3% and increased to 39.7% with the heel lift. The non-paretic limb swing time was 28.2% without the heel lift and decreased to 27.7% with the heel lift. Percent change for the paretic limb in swing time was 3.7% and was -1.8% for the non-paretic limb with a heel lift (Figure 8E).

Observational Gait

Through video observation, the subject ambulated by using a single point cane in the left hand. Subject had a flexed overall body posture, ambulated with short quick asymmetrical steps, and dragged the paretic toe at the beginning of swing phase of the paretic leg due to limited dorsiflexion of the ankle. There was a noticeable hip hiking and circumduction of the paretic lower extremity through

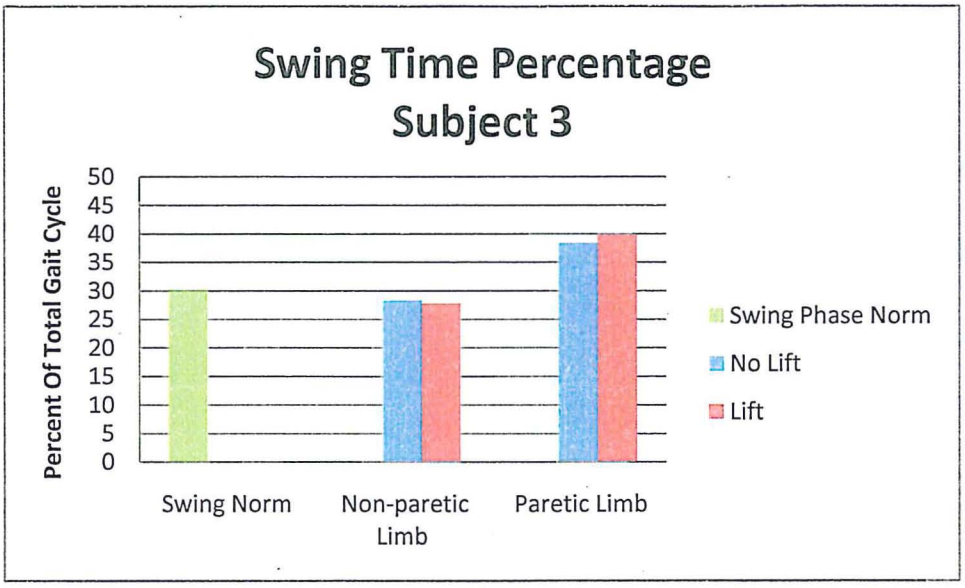

Figure 8E. Swing Time Percentage - Subject 3.

phase of gait. The subject's paretic foot contacted the floor in a foot-flat position during initial contact of the gait cycle.

The paretic upper extremity was held in a flexion synergy pattern with the arm internally rotated, abducted, elbow flexed, supinated forearm, wrist flexed, and fingers flexed with a closed fist. The arm was held stiff and did not appear to move. The non-paretic upper extremity was very ridged looking during and was held in a stable position with the shoulder neutral at the side of the trunk with slight elbow flexion, and a neutral wrist position. The elbow was flexed slightly to advance the cane. Subject also appears to have the ability to weight shift with small steps throughout gait on both lower extremities. See Appendix F for DVD of subject walking.

Discussion

This subject had a flexed posture, shortened step length, limb circumduction, and pelvic hiking as major compensations during ambulation.

Ambulation velocity did not improve for this subject when the 9.5 mm heel lift was inserted. Normal velocity for a healthy adult with no health impairments in the 70th decade is 79.8 m/min.[18] The subject actually had a slower velocity (27.48 m/min) with the lift in.

Step length on the paretic lower extremity increased when the heel lift was used (5.6% change). These findings may have been due to the increased amount of clearance as a result of the 9.5 mm heel lift height on the non-paretic limb.

Single limb support for the subject decreased on the paretic limb and swing phase decreased on the non-paretic lower extremity with the 9.5 mm heel lift in the shoe. In addition, step length decreased on the non-paretic limb with the heel lift because he spent less time in stance phase of the gait cycle on the paretic lower extremity. It was expected that the subject would have increased single limb support on the paretic side, increased swing time on the non-paretic side, and an increased step length with the non-paretic leg.

Overall, the use of the heel lift with this subject did not considerably change his gait parameters. This could be due to his marked asymmetry in weight-bearing through the lower limbs in static standing (77% non-paretic and 23% paretic).

Case Study 4

Subject 4 was a 61-year-old male, 5 feet 9¼ inches, who had right hemiparesis resulting from a stroke 2.5 years ago. Past medical history included a loss of sensation on the right side due to the stroke. He wore an older AFO on

the right and used a single point cane occasionally for ambulation. Subject reported that he could ambulate 40 to 50 feet. Verbal expression as limited but auditory comprehension was functional with cues and demonstrations. He relied on his wife for most activities, including driving and answering questions. The subject stated that he had a history of falls as well as has difficulty navigating curbs in the community (Figure 9A).

Subject 9A. Subject 4 completing a walk across the GAITRite®.

Objective Measurements

Sensation to light touch following dermatomes L_4-S_2 was normal on the non-paretic and absent on the paretic limb. Sitting active range of motion for active ankle dorsiflexion measured -2° on the non-paretic and foot held in 30° of plantarflexion on the paretic limb. Leg length measurement with shoes on for the non-paretic limb was 98 centimeters and the paretic limb was 96 centimeters. Heel height measured 2.5 centimeters on both shoes. Using the Balance Master® weight bearing ratio was 73.3% on the non-paretic limb and 26.7% on the paretic limb.

Data Analysis

Gait velocity without heel lift was 17.16 m/min decreased to 16.53 m/min with the heel lift. Percent change for velocity in this subject was -3.7% with the heel lift (Figure 9B).

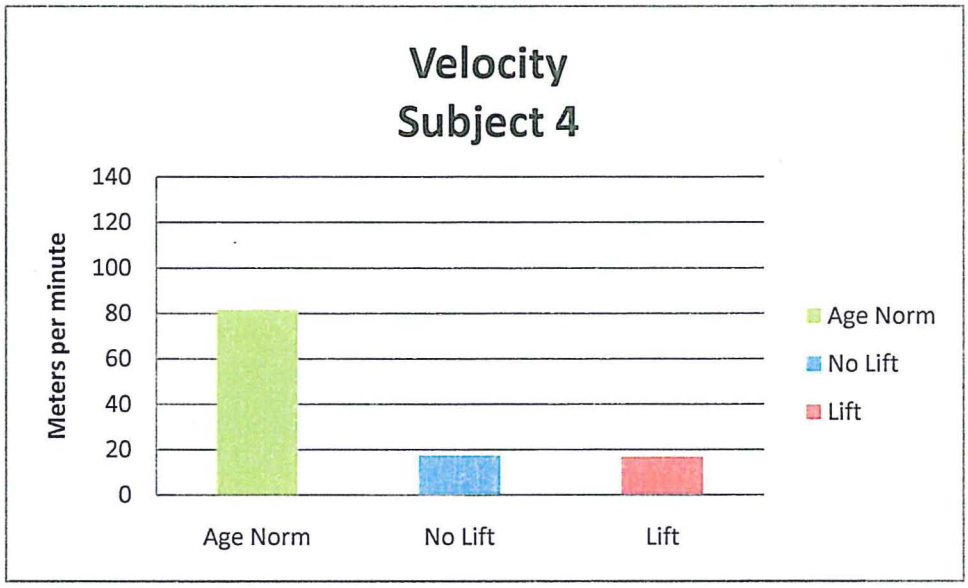

Figure 9B. Velocity - Subject 4.

The step length on the non-paretic limb decreased from -1.5 cm to -2.8 cm with lift inserted. When looking at the individual step lengths during the two conditions, it is evident that the subject varies from a positive to a negative with his non-paretic step length. This variation indicates that the subject does not necessarily have a negative step length but rather that the overall average was negative. A negative step length is indicated when the non-paretic heel did not pass the paretic heel (Table 3).

Table 3. Comparison of Step Length for Subject 4.

	Non-Paretic Step Length	
Step Number	Lift	No Lift
1	-2.695 cm	5.393 cm
2	-8.699 cm	-0.102 cm
3	3.976 cm	0.805 cm
4	-11.288 cm	-4.956 cm
5	4.692 cm	1.918 cm
6	3.168 cm	-2.749 cm
7	1.054 cm	0.333 cm
8	0.278 cm	-6.101 cm
9	2.548 cm	-9.397 cm

The paretic limb had an increase in step length with the heel lift inserted from 41.1 cm to 41.5 cm. This indicates a percent change of 1.0% with the heel lift (Figure 9C).

Single limb support for the paretic limb was 13.3% without the heel lift and decreased to 13.1% with the heel lift. The non-paretic limb had a single limb support of 46.8% without the heel lift and decreased to 44.5% with the heel lift. Percent change for the paretic limb was -1.5% and for the non-paretic limb was -4.9% with the heel lift (Figure 9D).

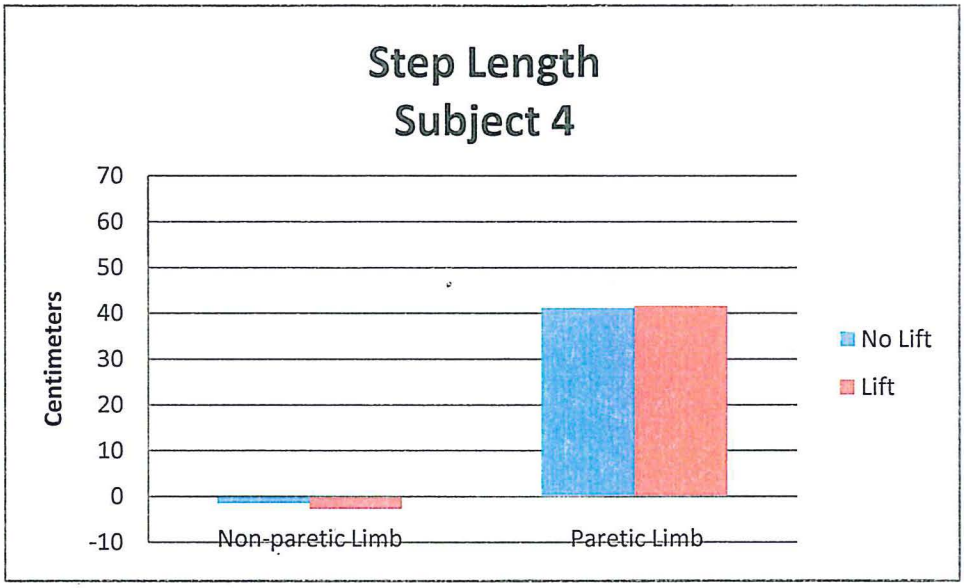

Figure 9C. Step Length - Subject 4.

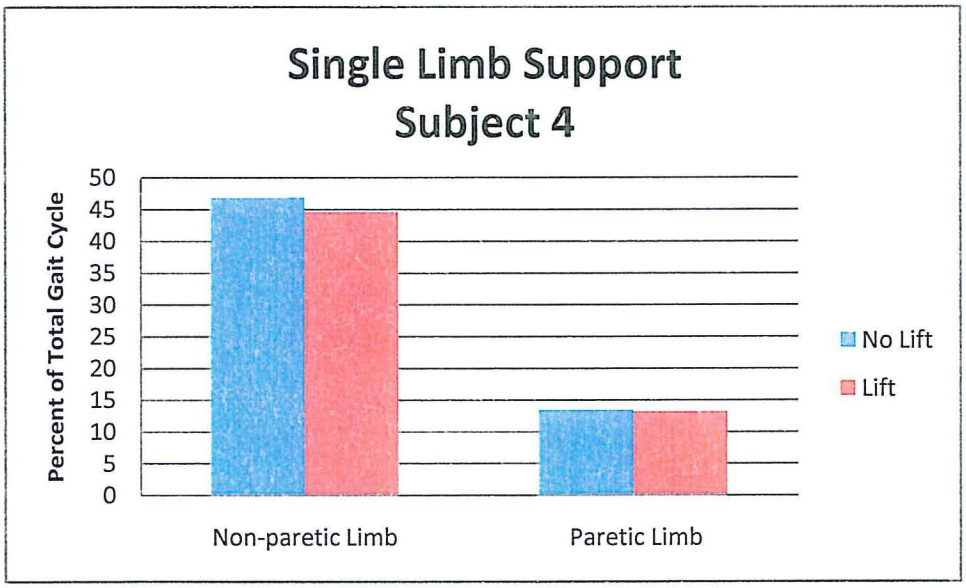

Figure 9D. Single Limb Support - Subject 4.

Swing time for the paretic limb was 46.8% without the heel lift and decreased to 44.6% with the heel lift. The non-paretic limb had a swing time percentage of 13.3% without the heel lift and decreased to 13.1% with the heel

lift inserted. Percent change for the paretic limb was -4.7% and for the non-paretic limb was -1.5% with the heel lift (Figure 9E).

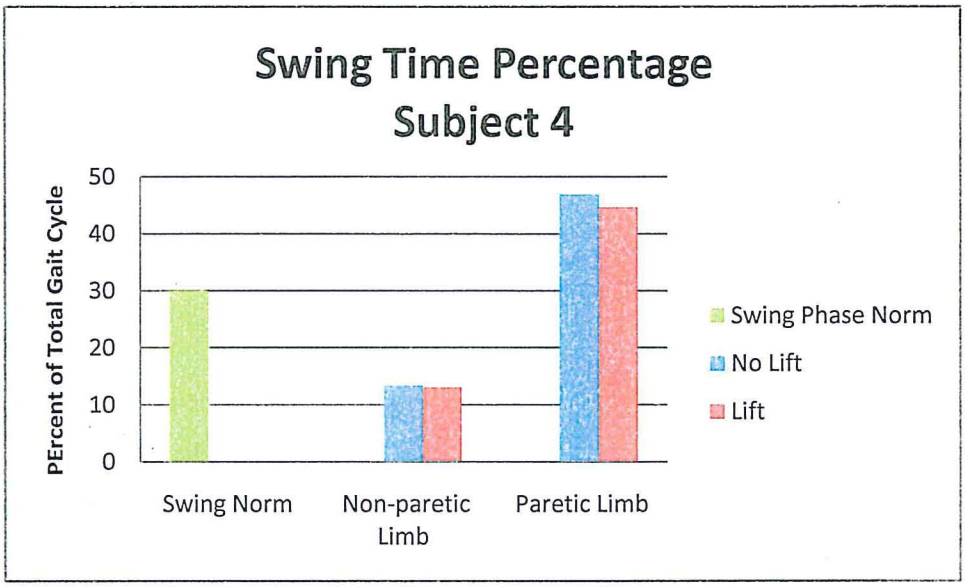

Figure 9E. Swing Time Percentage - Subject 4.

Observational Gait

Through video observation, this subject showed obvious lower extremity extensor synergy pattern on the right as well as a wide base of support. There was no hip, knee, or ankle movement during the whole gait cycle for the right limb. The non-paretic limb was externally rotated to compensate for the internally rotated extensor pattern on the paretic limb. During paretic step, the subject maintained a plantarflexed and supinated position of the paretic foot and never achieved right heel strike. He utilized a step-to-gait with advancement of the paretic foot forward followed by stepping to with the non-paretic foot which resulted in a negative step length. Due to increased tone in the right upper

extremity, arm swing was not observed during any part of the gait cycle. See Appendix F for DVD of subject walking.

Discussion

Normal velocity for a 60th decade old is 81.5 m/min.[18] This subject was significantly below the norm for his age and gender, which would be expected due to the extent of his hemiparesis and tone. Balance was a concern due to the high amount of instability that this subject portrayed with weight-bearing on the paretic limb, and the structural stability of his AFO was a concern. The subject should maintain a plantarflexed and supinated position of the paretic foot if the AFO was working properly.

This subject was very interesting in the fact that he did not have a positive step length on the non-paretic limb. When observing the video, it became apparent that the subject used a step-to pattern, he would advance the paretic leg and step up to but not past the non-paretic leg. He may have compensated due to the lack of balance or an unstable AFO. Step length is the distance between successive heel contacts of the two different feet. The negative values that were obtained from the GAITRite® can be explained by the large amount of lower extremity tone. This tone inhibited the subject from stepping through on the swing phase of the left.

The other aspects of gait did not have a significant change and it seems that the heel lift did not have any effect on his gait parameters. Wearing an AFO may have limited his ability to walk successfully with the trial heel lift. He wore his AFO on the right foot and the heel lift was inserted in the left shoe. The AFO

does provide added height in the shoe similar to a heel lift. It seems that a heel lift may not be a suitable solution for all hemiparetic subjects and that she may have to be selective when incorporating this intervention. The high amounts of tone as well as the negative step length seemed to be limiting factors for the effectiveness of this intervention.

Case Study 5

Subject 5 was a 74-year-old male, 6 feet 3¾ inches, who had right hemiparesis resulting from a stroke 2 years ago. Past medical history included diabetes, asthma, prostate tumor, low blood pressure, dizziness when arising from lying too quickly, and arthritis in left shoulder. At the time of the study, subject did not wear any glasses but normally does at home. He does not use any assistive device or orthotic during ambulation. The farthest distance the subject stated he could walk was approximately ¼ mile independently. He has a history of occasionally falling when the ground in uneven (Figure 10A).

Objective Measurement

Sensation to dermatomes L_4-S_2 bilaterally were normal to light touch, and sitting active ankle dorsiflexion range of motion on the non-paretic was 12 degrees and 5 degrees of the paretic. Leg length measurement with the shoes on was 106 cm of the non-paretic limb and 106 cm on the paretic limb. The heel height of the shoes was 2.5 cm on the left and right. Weight-bearing ratio was 60.3% on the non-paretic limb and 39.6% on the paretic limb.

Figure 10A. Subject 5 completing a walk across the GAITRite®.

Data Analysis

Gait velocity without the heel lift was 60.85 m/min and decreased to 54.48 m/min with the heel lift. Percent change was -10.5% with the heel lift (Figure 10B).

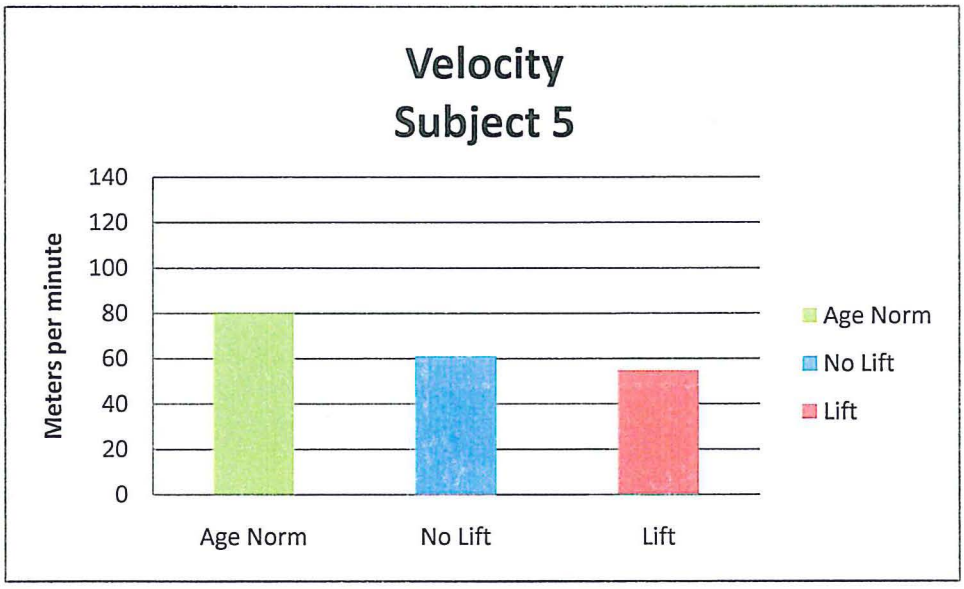

Figure 10B. Velocity - Subject 5.

Step length for the paretic limb without a heel lift was 52.78 cm and decreased to 49.76 cm with the heel lift inserted. Step length for the non-paretic

limb without a heel lift was 64.97 cm and decreased to 61.35 cm with the heel lift. Percent change for the paretic limb was -5.7% and for the non-paretic limb was -5.6% with the heel lift (Figure 10C).

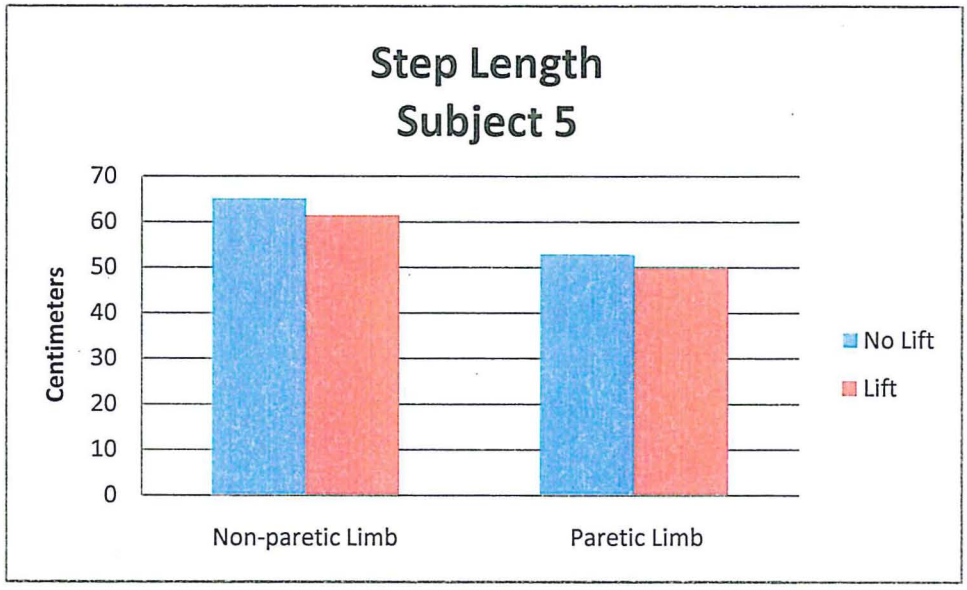

Figure 10C. Step Length - Subject 5.

Single limb support for the paretic limb without the heel lift was 33.4% and decreased to 31.4% with the heel lift. The non-paretic limb single limb support without a heel lift was 32.7% and increased to 34.1% with the heel lift inserted. Percent change for the paretic limb in single limb support was -6.0% and for the non-paretic limb was 4.3% with the heel lift (Figure 10D).

Swing time percentage for the paretic limb without a heel lift was 33% and increased to 33.7% with the heel lift inserted. The non-paretic limb had a swing time of 33.1% without the heel lift and that decreased to 31.8% with the heel lift. Percent change for the paretic limb was 2.1% and for the non-paretic limb was -3.9% with the heel lift (Figure 10E).

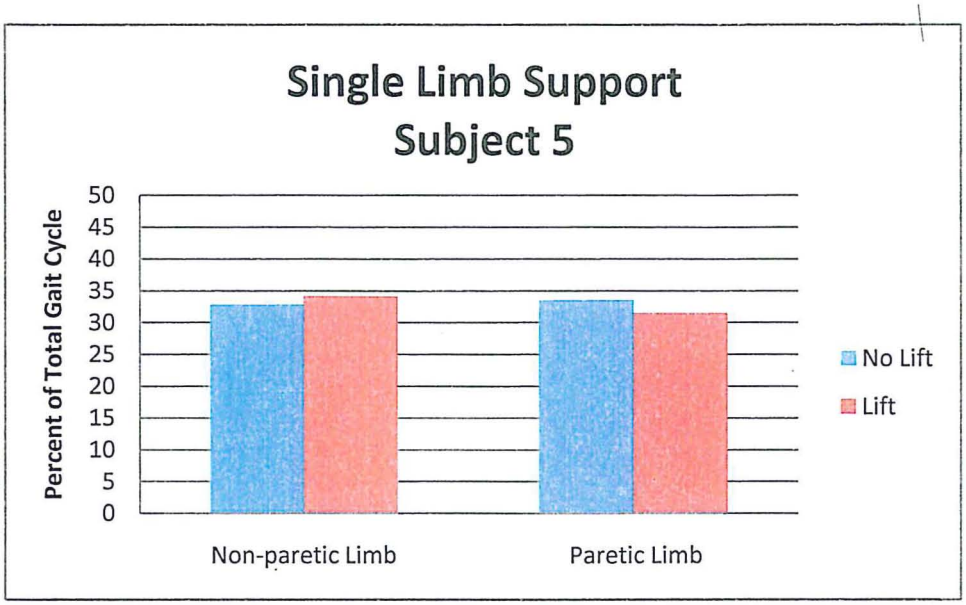

Figure 10D. Single Limb Support - Subject 5.

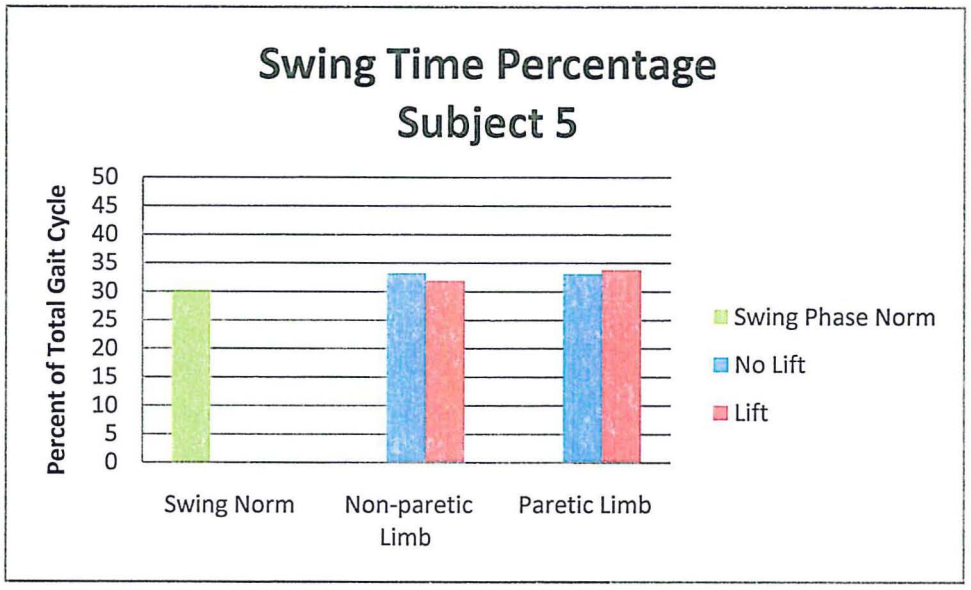

Figure 10E. Swing Time Percentage - Subject 5.

Observational Gait

Through video observation, a flexed posture was apparent throughout the gait cycle. The subject had some subtle asymmetry in his gait pattern as

compared to the other subjects that had more involved hemiparesis. There was no arm movement on paretic involved arm and only slight elbow flexion on the non-paretic arm during gait. The non-paretic shoulder was depressed slightly and the trunk appeared to sway to the left side during swing phase of the paretic leg. The non-paretic foot toed out and the paretic foot remained in a neutral forward position. There was less hip flexion during initial swing phase on the paretic limb of the gait cycle. The subject took a slower step with the paretic leg and a quicker step on the non-paretic leg. See Appendix F for DVD of subject walking.

Discussion

When observing the subject walking, the symmetry of the subject ambulating on the GAITRite® showed some slight changes under the testing parameters with the use of the 9.5 mm heel lift. The normal velocity for his age group was 79.8 m/min without any pathological impairment.[18] Walking velocity did decrease when the heel lift was used. This may be due to the more stance time on the non-paretic leg when the heel lift was in the shoe. Step length for the paretic limb and the non-paretic limb decreased when the heel lift was used. This may be due to the alteration of both the right and left stance limb when the heel lift was used. Fatigue may have affected his gait parameter results since his stride was large and required more walking trials than the other subjects to get 20 steps.

Single limb support decreased on the paretic when the heel lift was used. On the non-paretic leg, the single limb support increased with the use of the heel

lift. These results are not expected findings when the heel lift is used. These results may be because of the decreased velocity of ambulation with the use of the heel lift. The subject may spend more time on the non-paretic leg because he tended to say to the left during stance phase on the non-paretic leg.

Swing phase for the paretic leg during gait increased with the use of the heel lift. The subject's velocity decreased and he spent more time on the non-paretic leg during stance phase with the heel lift. It was expected that using the heel lift would have the opposite effect and he would spend more time on the paretic limb in single limb support allowing for longer swing time on the non-paretic limb. He subjectively reported that he felt wearing the heel lift improved his ability to walk and decreased toe drag. As a result of these positive findings, the subject was given a 9.5mm heel lift to use on a trial basis.

CHAPTER V

SUMMARY AND CONCLUSION

Each individual case was looked at and analyzed for specific gait deviations. There were some similarities and notable differences between each case. The research questions that were addressed include: Does wearing a heel lift on the non-involved side improve ambulation for people with hemiparesis and does wearing a heel lift improve symmetry of gait? The overall outcome for heel lift use in this case series will be addressed.

All of the individuals in this study had decreased velocity, cadence, stride length, and asymmetrical step length which are all typical of a hemiparetic gait pattern.[2] Another distinctive gait deviation was the increased time spent on the uninvolved limb during stance phase. When looking at velocity for the five participants in this study, two subjects had an increase in velocity with the heel lift inserted. Subject one had a 2.4% increase in velocity and subject two had a 7.4% increase in velocity. Aruin et al[2] has identified gait velocity to be a determinant of functional return in people with hemiparesis. Although these subjects had an increase, they were still well below normal velocity for their age.

Step length improved in one of the five subjects when ambulating with the heel lift insert. Contrary to Aruin et al's[2] work, this study chose to look at step length instead of stride length when analyzing gait. If there is an asymmetry with

step length, this discrepancy will not necessarily show up in stride length. Stride length can appear normal or unchanged even if an asymmetry is present. According to the results of Ariun's[2] study, gait velocity was correlated with stride length. As gait velocity increases, stride length increased and gait velocity decreased, stride length decreased.

Single limb support did not increase on the paretic lower extremity using the heel lift on any of the subjects in this study. As stated by Bohannon,[8] it is common for people with hemiparesis to have difficulty supporting weight on their paretic limb. The heel lift in studies measuring static weight bearing showed increased weight acceptance on the paretic side.[2-4] Non-paretic swing phase did not improve in any of the subjects in this study. The subject spent more time on their non-paretic leg during swing phase. Swing phase for the non-paretic limb cannot improve if there is decreased weight acceptance on the paretic side.

Limitations/Recommendation of Study

One of the limitations of the study is that the 9.5 mm heel lift was only administered for a very short length of time. It is not known that if the subjects were to wear the heel lift for a greater time period and be tested again if there would be more notable changes in the gait parameters. In future studies, the heel lift should be given for a greater period of time to each individual to use so he/she can learn to walk with it. The results should be compared to initial use and again after the lift has been used for a given time frame, as demonstrated by Aruin et al,[2] when a single subject participated in walking trials after wearing the

heel lift for six weeks. There and used may be changes in gait parameters after the subject has used the heel lift for an extended period of time.

The small sample size of adults with hemiparesis is another limitation of the study. This study became a case study series due to the limited number of subject and used only descriptive statistics. A larger sample size of individuals with hemiparesis would be recommended to be able to run statistics to get significant results of the gait parameters.

Some subjects in the study wore an AFO during the walking trials and some did not. The use of an AFO may have an effect on the outcome of a heel lift insertion. In order to compensate for the AFO, a larger heel lift might be needed. It is also not known if the heel lift adjusted enough to the AFO height itself. It does not appear that the height of the AFO played any significant factor in any gait parameters when used with the heel lift. Only three subjects in the study wore AFOs and no significant changes were apparent in their results. Two leg length measurements should have been taken, the first with shoes on without the lift and the second with the lift inserted. This would have allowed for comparison of the effects of an AFO. More research is needed to find out whether the use of an AFO will alter the effects of a heel lift.

Another limitation is the length of time the subject has had hemiparesis. Previous studies from Chaudhuri et al[4] and Rodriguez et al[3] used a heel lift to improve weight-bearing symmetry in subjects with more acute hemiparesis. Work by Aruin et al[2] used subjects in the acute, sub-acute, and chronic stages. Each of our subjects had hemiparesis ranging from 2 years to 11 years which

more closely resembled the demographics of the study by Aruin et al.[2] Each individual has learned compensatory strategies for his/her hemiparesis and a onetime use of a heel lift may not affect gait parameters. Some subjects were currently trying or had already tried a heel lift as an intervention. The height of the heel lift, reason for use, or the length of time used was not known for subjects who had worn heel lifts in the past. What would be the effects of a heel lift after a more acute episode of hemiparesis or more long-term hemiparesis? The amount of time the individual has hemiparesis should be more standardized to get accurate results. Aruin et al's[2] subjects ranged from 0.16 years to 5 years post-hemiparesis from a unilateral stroke. The subjects should not have already tried the heel lift for an intervention prior to the study. This may account for some unwanted limitations.

Additional limitations of the study are stated below. There was a high variability in each of the subjective and objective measurements including side of hemiparesis, degree of sensation loss, ankle dorsiflexion ROM, and degree of asymmetry in static weight-bearing. If the dominant hemisphere is involved for the individual in our study, then this could make a difference on learned use of the heel lift. These variables could be better controlled by setting stricter limitations for inclusion into the study.

The individuals in this study were not measured during static weight-bearing after the heel lift was inserted. Measuring static weight-bearing on the Balance Master® would have allowed comparison of weight-earing ratios with and without the heel lift. This information would then determine whether wearing

a heel lift promoted weight shifting onto the paretic limb in quiet standing as reported by Aruin et al.[2]

Assistive devices were used for the subjects that normally used them for ambulation. Assistive devices were allowed but not required, and three subjects used a single point cane. The use of an assistive device could have altered the heel lift effects on gait parameters. It is unclear what effects the use of an assistive device had on the gait parameter results.

Single limb support time for the paretic limb and swing time for the non-paretic limb are measurements of the same gait parameters. This was evident in the results of this study when calculating percent change for these parameters. It would have been more beneficial to look at another gait parameter, such as stride length.

Clinical Implications

The findings of this study are limited and may not be appropriate for every individual with hemiparesis. The use of a heel lift should always be individualized to the patient when attempting to use it for physical intervention to improve gait in clinical setting. By observing the characteristic gait pattern of a subject with hemiparesis, it should be apparent whether a heel lift would benefit the individual or not. It is much easier to observe changes in gait with the use of a computerized walkway, such as the GAITRite® compared to observation alone. The use of the heel lift can improve the clearance of the involved leg during swing phase of gait when the patient has a difficult time clearing the foot. Velocity has been shown to increase in one subject post stroke after wearing the

heel lift for 6 weeks y Aruin et al.[2] Slower walking requires greater energy consumption and greater balance. If the heel lift improves weight shifting and gait velocity after 6 weeks of use, this may help patients with hemiplegia improve their functional ambulation. Short-term results of the heel lift according to this study do not indicate that the use of a heel lift improves gait velocity immediately. This would be a fairly inexpensive intervention treatment option to improve foot clearance of the involved leg and gait velocity with long-term use.

Conclusion

A heel lift under the non-paretic limb improves weight-bearing on the paretic limb during static stance.[2-4] This study looked at how a heel lift affected gait parameters (velocity, step length, swing/SLS) in five subjects with unilateral hemiparesis. No definite conclusions can be made from this study. A heel lift under the non-paretic limb improved gait velocity and symmetrical step length in one subject. A second subject reported subjective benefits of wearing a heel lift. A heel lift may be an affordable option to improve gait in certain individuals with less hemiparetic involvement and a more symmetrical weight-bearing ratio. The individuals with a greater degree of hemiparesis in this study did not benefit from the use of the heel lift. Further research is needed to determine if a heel lift is more effective after a longer duration of use.

APPENDIX A

REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW

University of North Dakota Institutional Review Board

Date: 4/26/2007 Project Number: IRB-200704-325

Principal Investigator: Danks, Meridee; Avery, Bryan; Riley, Lindsay; Webster, Shannon

Department: Physical Therapy

Project Title: The Effects of a Heel Lift on Gait Parameters During Ambulation for People with Hemiparesis

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on April 27, 2007 and the following action was taken:

☑ Project approved. **Expedited Review** Category No. 4
Next scheduled review must be before: April 26, 2008

☒ **Copies of the attached consent form with the IRB approval stamp dated April 27, 2007 must be used in obtaining consent for this study.**

☐ Project approved. **Exempt Review** Category No. _____
This approval is valid until _____ as long as approved procedures are followed. No periodic review scheduled unless so stated in the Remarks Section.

☐ **Copies of the attached consent form with the IRB approval stamp dated _____ must be used in obtaining consent for this study.**

☐ Minor modifications required. The required corrections/additions must be submitted to RDC for review and approval. **This study may NOT be started UNTIL final IRB approval has been received.**

☐ Project approval deferred. **This study may not be started until final IRB approval has been received.**
(See Remarks Section for further information.)

☐ Disapproved claim of exemption. This project requires Expedited or Full Board review. The Human Subjects Review Form must be filled out and submitted to the IRB for review.

☐ Proposed project is not human subject research and does not require IRB review.
☐ Not Research ☐ Not Human Subject

PLEASE NOTE: Requested revisions for student proposals MUST include adviser's signature. All revisions MUST be highlighted.

☒ Education Requirements Completed. (Project cannot be started until IRB education requirements are met.)

cc: ✓ Chair, Physical Therapy

Alan J. Ree 4/27/07
Signature of Designated IRB Member Date
UND's Institutional Review Board

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact RDC to obtain the required documents.

(Revised 10/2006)

University of North Dakota Human Subjects Review Form

All research with human participants conducted by faculty, staff, and students associated with the University of North Dakota, must be reviewed and approved as prescribed by the University's policies and procedures governing the use of human subjects. It is the intent of the University of North Dakota (UND), through the Institutional Review Board (IRB) and Research Development and Compliance (RD&C), to assist investigators engaged in human subject research to conduct their research along ethical guidelines reflecting professional as well as community standards. The University has an obligation to ensure that all research involving human subjects meets regulations established by the United States Code of Federal Regulations (CFR). When completing the Human Subjects Review Form, use the "IRB Checklist" for additional guidance.

Please provide the information requested below:

Principal Investigator: Meridee Danks, Bryan Avery, Lindsay Riley, Shannon Webster

Telephone: 701-777-3861 E-mail Address: mgreen@medicine.nodak.edu

Complete Mailing Address: Department of Physical Therapy
University of North Dakota
School of Medicine and Health Sciences
PO Box 9037
501 N. Columbia Road
Grand Forks, ND 58203

School/College: University of North Dakota Department: Physical Therapy

Student Adviser (if applicable): Meridee Danks

Telephone: 701-777-3861 E-mail Address:

Address or Box #:

School/College: Department:

Project Title: The effects of a heel lift on gait parameters during ambulation for people with hemiparesis.

Proposed Project Dates: Beginning Date: May 2007 Completion Date: May 2008
(Including data analysis)

Funding agencies supporting this research: UND PT Department

Did the contract with the funding entity go through UND Grants and Contracts Administration? ☐ YES or ☐ NO
Attach a copy of the contact. Do not include the any budgetary information. The IRB will not be able to review the study without a copy of the contract with the funding agency.

☐ YES or ☒ NO Does any researcher associated with this project have an economic interest in the research, or act as an officer or a director of any outside entity whose financial interests would reasonably appear to be affected by the research? If yes, submit on a separate piece of paper an additional explanation of the financial interest. The Principal Investigator and any researcher associated with this project should have a Financial Interests Disclosure Document on file with their department.

☐ YES or ☒ NO Will research subjects be recruited at another organization (e.g., hospitals, schools, YMCA) or will assistance with the data collection be obtained from another organization?

If yes, list all institutions:

Letters from each organization must accompany this proposal. Each letter must illustrate that the organization understands their involvement in that study, and agrees to participate in the study. Letters must include the name and title of the individual signing the letter and should be printed on letterhead.

Does any external site where the research will be conducted have its own IRB? ☐ YES ☐ NO ☒ N/A

If yes, does the external site plan to rely on UND's IRB for approval of this study? ☐ YES ☐ NO ☐ N/A
(If yes, contact the UND IRB at 701 777-4279 for additional requirements)

If your project has been or will be submitted to other IRBs, list those Boards below, along with the status of each proposal.

_____ Date submitted: _____ Status: ☐ Approved ☐ Pending

_____ Date submitted: _____ Status: ☐ Approved ☐ Pending

(include the name and address of the IRB, contact person at the IRB, and a phone number for that person)

Type of Project: Check "Yes" or "No" for each of the following.

☒ YES or ☐ NO New Project

☐ YES or ☒ NO Dissertation/Thesis/Independent Study

☐ YES or ☒ NO Continuation/Renewal

☒ YES or ☐ NO Student Research Project

☐ YES or ☒ NO Is this a Protocol Change for previously approved project? If yes, submit a signed copy of this form with the changes bolded or highlighted.

☐ YES or ☒ NO Does your project involve abstracting medical record information? If yes, complete the HIPAA Compliance Application and submit it with this form.

☐ YES or ☒ NO Does your project include Genetic Research?

☐ YES or ☒ NO Does your project include Internet Research?

Subject Classification: This study will involve subjects who are in the following special populations: Check all that apply.

☐ Children (< 18 years)
☐ UND Students
☐ Prisoners
☐ Pregnant Women/Fetuses
☐ Persons with impaired ability to understand their involvement and/or consequences of participation in this research
☒ Other Persons with hemiparesis from the community

Please use appropriate checklist when children, prisoners, pregnant women, or people who are unable to consent will be involved in the research.

This study will involve: Check all that apply.

☐ Deception (Attach Waiver or Alteration of Informed Consent Requirements)
☐ Radiation
☐ New Drugs (IND) IND # ___Attach Approval
☐ Investigational Device Exemption (IDE) # ___Attach Approval
☐ Non-approved Use of Drug(s)
☒ None of the above will be involved in this study
☐ Stem Cells
☐ Discarded Tissue
☐ Fetal Tissue
☐ Human Blood or Fluids
☐ Other

I. Project Overview

Please provide a brief explanation (limit to 200 words or less) of the rationale and purpose of the study, introduction of any sponsor(s) of the study, and justification for use of human subjects and/or special populations (e.g., vulnerable populations such as children, prisoners, pregnant women/fetuses).

1. The purpose of this research study is to determine the effect of a heel lift insert under the non involved leg on walking parameters in people with hemiparesis. Previous research has shown how a heel lift insert improves weight bearing symmetry in static balance for those people with hemiparesis. People with hemiparesis can have a deficit to varying degrees in symmetry to the involved side during dynamic activities such as gait, and may have diminished function if an asymmetry is present. Currently, there is little research describing the effects of a heel lift involving dynamic walking with this patient population. Human subjects with hemiparesis are required in the current research proposal in order to generate new data on this patient population relative to dynamic walking.

II. Protocol Description

Please provide a succinct description of the procedures to be used by addressing the instructions under each of the following categories.

1. **Subject Selection.**

a) Describe recruitment procedures (i.e., how subjects will be recruited, who will recruit them, where and when they will be recruited and for how long) and include copies of any advertisements, fliers, etc., that will be used to recruit subjects.

Human subjects will be recruited to participate in this study through personal phone calls, email, and/or mail. The principal investigator and student researchers will recruit subjects during summer 2007. Recruitment will take place within the Physical Therapy Department at the UND Medical School. For this study, advertisements and/or flyers will not be utilized.

b) Describe your subject selection procedures and criteria, paying special attention to the rationale for including subjects from any of the categories listed in the "Subject Classification" section above.

Human subjects will be selected based on their diagnosis of either left or right hemiparesis, having the diagnosis 6 plus months post-injury/incident leading to hemiparesis, age 18 years or older, and male or female gender. Subjects will be able to, follow two-step directions, walk independently for at least 80 feet, have an asymmetric static posture exhibiting more than 55% of body weight dispersed on the non involved leg, and own laced shoes that do not have more than a half inch heel.

c) Describe your exclusionary criteria and provide a rationale for excluding subject categories.

Subjects will be excluded by the following criteria: any unstable medical condition, other neurological diseases, severe visual or vestibular deficits, trauma, other orthopedic problems directly affecting walking/balance, and any other factors that would prevent full participation within this study.

d) Describe the estimated number of subjects that will participate and the rationale for using that number of subjects.

We plan to utilize up to 30 subjects for this study. Due to time constraints the number of subjects will be limited.

e) Specify the potential for valid results. If you have used a power analysis to determine the number of subjects, describe your method.

2. **Description of Methodology.**

a) Describe the procedures used to obtain informed consent.

The subject will read the consent form and provide a signature. They will also receive a copy of this document. This document will contain a detailed description of the procedures, inherent risks to the subjects through participation, and privacy issues regarding the collection of personal data.

b) Describe where the research will be conducted. Document the resources and facilities to be used to carry out the proposed research. Please note staffing, funding, and space available to conduct this research.

This project will be conducted within the Physical Therapy Department located at the UND School of Medicine and Health Sciences. All equipment and instrumentation, as listed in the research protocol, are available within the department. There is ample space to perform the research within this department.

c) Indicate who will carry out the research procedures.

The research will be conducted by Bryan Avery, SPT, Lindsay Riley, SPT, and Shannon Webster, SPT. This project will be supervised by Dr. Meridee Danks.

d) Briefly describe the procedures and techniques to be used and the amount of time that is required by the subjects to complete them.

1. The subject will read the consent form and provide a signature.

2. The participant will complete a health history questionnaire to provide some insight and determine eligibility in the study. Both the consent form and questionnaire will take five minutes to read and complete.
3. If the participants do not meet the inclusion criteria as listed above, they will be thanked for their time and dismissed from the study but will be given the option to complete the GAITRite component if they so wish. Data for these subjects will not be included in the study.
4. The participants' height will be measured in centimeters with shoes on. A pencil mark will be made on the wall and the researcher will measure the height from the ground to the pencil mark.
5. The participant will stand on the Balance Master® (an instrument that determines body weight distribution) to determine if an asymmetry is present for inclusion into the study. If the participant does not have an asymmetry present they will be thanked for their time and dismissed from the study. Set up and data collection is expected to take 1-2 minutes. The data will be saved on the computer and recorded on an individual data collection form.
6. The areas being assessed are:
    i. Sensation testing will be performed in sitting.
    ii. Range of motion of the ankle joint will be measured using a goniometer in sitting with the knee bent.
    iii. Both of these measurements will take a total of 5 minutes to measure and record.
7. The participants will randomly select a number out of a can to determine the order in which they wear the heel lift.
8. Leg length will be measured in standing with shoes on.
9. The participants will be instructed to walk at a comfortable rate along the GAITRite® walkway (a computerized carpet that measures walking parameters). An X will be placed on the far wall for the participants to focus on while walking to encourage the subject to look up. The subject will walk an extra 6ft at both ends to allow for acceleration and deceleration of gait. The participants will be given the opportunity to "practice" one time walking down and back on the on the computerized carpet. The participants will walk up and down the computerized carpet with and without a heel lift. Twenty steps will be obtained for each treatment condition. The participants will then be given a maximum of 5 minutes to recuperate, then asked to repeat the procedure under the second randomly assigned condition. It should take four or five walks along the computerized carpet to obtain twenty steps. The data will be saved on the Balance Master® and GAITRite® for later analysis.

e) Describe audio/visual procedures and proper disposal of tapes.
N/A

f) Describe the qualifications of the individuals conducting all procedures used in the study.

All researchers have been instructed in the proper technique for performing the above tests as outlined in question 2d. The researchers are currently second year students in the Doctorate of Physical Therapy program at UND. Dr. Meridee Danks is an Assistant Professor of Physical Therapy and Doctor of Physical Therapy at UND and has worked as a PT for twenty five years.

g) Describe compensation procedures (payment or class credit for the subjects, etc.).

The subjects will not receive monetary compensation for their participation. Individuals that do not meet inclusion criteria will still be able to walk on the computerized carpet and will receive a free copy of the data collected.

Attachments Necessary: Copies of all instruments (such as survey/interview questions, data collection forms completed by subjects, etc.) must be attached to this proposal.

3. Risk Identification.

a) Clearly describe the anticipated risks to the subject/others including any physical, emotional, and financial risks that might result from this study.

There is minimal risk involved with participating in this study. This includes fatigue and a miniscule risk of falling. During the testing on the Balance Master® and GAITRite® , a researcher will be available to supervise the subject in order to minimize the risk of falling. There is no apparent emotional or financial risk involved.

b) Indicate whether there will be a way to link subject responses and/or data sheets to consent forms, and if so, what the justification is for having that link.

There will be no link between the consent form and the participants data collected in this study.

c) Provide a description of the data monitoring plan for all research that involves greater than minimal risk.
N/A

d) If the PI will be the lead-investigator for a multi-center study, or if the PI's organization will be the lead site in a multi-center study, include information about the management of information obtained in multi-site research that might be relevant to the protection of research participants, such as unanticipated problems involving risks to participants or others, interim results, or protocol modifications.
N/A

4. **Subject Protection.**

a) Describe precautions you will take to minimize potential risks to the subjects (e.g., sterile conditions, informing subjects that some individuals may have strong emotional reactions to the procedures, debriefing, etc.).

There is minimal risk because the subjects are independent in walking. A spotter and gait belt will be provided during data collection to ensure the safety of the participants.

b) Describe procedures you will implement to protect confidentiality and privacy of participants (such as coding subject data, removing identifying information, reporting data in aggregate form, not violating a participants space, not intruding where one is not welcome or trusted, not observing or recording what people expect not to be public, etc.). If participants who are likely to be vulnerable to coercion and undue influence are to be included in the research, define provisions to protect the privacy and interests of these participants and additional safeguards implemented to protect the rights and welfare of these participants.

All information that is collected during this study will remain confidential and there will not be a link from the consent forms to the data collected. In order to ensure subject confidentially, subjects will be assigned a number at the commencement of the study. This number will be the primary identifier for that subject through the remainder of the study.

c) Indicate that the subject will be provided with a copy of the consent form and how this will be done.

Subjects will receive a copy of the consent form after they have signed the consent form that will stay within the department.

d) Describe the protocol regarding record retention. Please indicate that research data from this study and consent forms will both be retained in separate locked locations for a minimum of three years following the completion of the study.
Describe: 1) the storage location of the research data (separate from consent forms and subject personal data)
2) who will have access to the data
3) how the data will be destroyed
4) the storage location of consent forms and personal data (separate from research data)
5) how the consent forms will be destroyed

1) The data will be located in a locked file cabinet within the Physical Therapy Department (separate from consent forms).
2) The PI, student researchers and officials that may audit research documents.
3) Data will be shredded after 3 years.
4) The consent forms will be in a locked file cabinet within the Physical Therapy Department (separate from research data).
5) Forms will be shredded after 3 years.

e) Describe procedures to deal with adverse reactions (referrals to helping agencies, procedures for dealing with trauma, etc.).

If a fall or other adverse events occur medical personnel will be contacted.

f) Include an explanation of medical treatment available if injury or adverse reaction occurs and responsibility for costs involved.

UND and the Physical Therapy Department will not be held liable for medical costs associated with the incident.

III. Benefits of the Study

Clearly describe the benefits to the subject and to society resulting from this study (such as learning experiences, services received, etc.). Please note: extra credit and/or payment are not benefits and should be listed in the Protocol Description section

under Methodology.

The subjects may not benefit personally from being in this study. However, in the future other people might benefit from this study by having results that may lead to a new approach to treating people with hemiparesis. Upon request, subjects will be given a copy of the results from this study.

IV. Consent Form

A copy of the consent form must be attached to this proposal. If no consent form is to be used, document the procedures to be used to protect human subjects, and complete the Application for Waiver or Alteration of Informed Consent Requirements. Refer to form IC 701-A, Informed Consent Checklist, and make sure that all the required elements are included. **Please note:** All records attained must be retained for a period of time sufficient to meet federal, state, and local regulations; sponsor requirements; and organizational policies. The consent form must be written in language that can easily be read by the subject population and any use of jargon or technical language should be avoided. **The consent form should be written at no higher than an 8th grade reading level,** and it is recommended that it be written in the third person (please see the example on the RD&C website). A two inch by two inch blank space must be left on the bottom of each page of the consent form for the IRB approval stamp.

Necessary attachments:

- ☐ Signed Student Consent to Release of Educational Record Form (students only);
- ☐ Investigator Letter of Assurance of Compliance;
- ☐ Consent form, or Waiver or Alteration of Informed Consent Requirements (Form IC 702-B)
- ☐ Surveys, interview questions, etc. (if applicable);
- ☐ Printed web screens (if survey is over the Internet); and
- ☐ Advertisements.

By signing below, you are verifying that the information provided in the Human Subjects Review Form and attached information is accurate and that the project will be completed as indicated.

Signatures:

Lindsay Riley — 4-23-07

(Principal Investigator) Date:

Linda Dunn — 4-23-07

(Student Adviser) Date:

Requirements for submitting proposals:

Additional information can be found on the IRB web site at www.und.nodak.edu/dept/orpd/regucomm/IRB/index.html.

Original Proposals and all attachments should be submitted to Research Development and Compliance, P.O. Box 7134, Grand Forks, ND 58202-7134, or brought to Room 105, Twamley Hall.

Prior to receiving IRB approval, researchers must complete the required IRB human subjects' education. Please go to http:// http://www.und.edu/dept/rdc/regucomm/IRB/IRBEducation.htm for more information.

The criteria for determining what category your proposal will be reviewed under is listed on page 3 of the IRB Checklist. Your reviewer will assign a review category to your proposal. Should your protocol require full Board review, you will need to provide additional copies. Further information can be found on the RD&C website regarding required copies and IRB review categories, or you may call the RD&C office at 701 777-4279.

In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency (agreement/contract if there is no proposal) must be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 7 copies if the proposal is clinical-medical. If the proposed work is being conducted for a pharmaceutical company, 7 copies of the company's protocol must be provided.

INVESTIGATOR LETTER OF ASSURANCE OF COMPLIANCE WITH ALL APPLICABLE FEDERAL REGULATIONS FOR THE PROTECTION OF THE RIGHTS OF HUMAN SUBJECTS

I Bryan Avery, Lindsay Riley, Shannon Webster, Andee Dwyer
(Name of Investigator)

agree that, in conducting research under the approval of the University of North Dakota Institutional Review Board, I will fully comply and assume responsibility for the enforcement of compliance with all applicable federal regulations and University policies for the protection of the rights of human subjects engaged in research. Specific regulations include the Federal Common Rule for Protection of the Rights of Human Subjects 45 CFR 46. I will also assure compliance to the ethical principles set forth in the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research document, The Belmont Report.

I understand the University's policies concerning research involving human subjects and agree to the following:

1. Should I wish to make changes in the approved protocol for this project, I will submit them for review PRIOR to initiating the changes. (A proposal may be changed without prior IRB approval where necessary to eliminate apparent immediate hazards to the subjects or others. However, the IRB must be notified in writing within 72 hours of any change, and IRB review is required at the next regularly scheduled meeting of the full IRB.)

2. If any problems involving human subjects occur, I will immediately notify the Chair of the IRB, or the IRB Coordinator.

3. I will cooperate with the UND IRB by submitting Research Project Review and Progress Reports in a timely manner.

I understand the failure to do so may result in the suspension or termination of proposed research and possible reporting to federal agencies.

Bryan Avery, Lindsay Riley, Shannon Webster, Andee Dwyer 4/23/07
Investigator Signature Date

STUDENT RESEARCHERS: As of June 4, 1997 (based on the recommendation of UND Legal Counsel) the University of North Dakota IRB is unable to approve your project unless the following "Student Consent to Release of Educational Record" is signed and included with your "Human Subjects Review Form."

STUDENT CONSENT TO RELEASE OF EDUCATIONAL RECORD[1]

Pursuant to the Family Educational Rights and Privacy Act of 1974, I hereby consent to the Institutional Review Board's access to those portions of my educational record which involve research that I wish to conduct under the Board's auspices. I understand that the Board may need to review my study data based on a question from a participant or under a random audit. The study to which this release pertains is

The effects of a heel lift on gait parameters during ambulation for people with hemiparesis.

.

I understand that such information concerning my educational record will not be released except on the condition that the Institutional Review Board will not permit any other party to have access to such information without my written consent. I also understand that this policy will be explained to those persons requesting any educational information and that this release will be kept with the study documentation.

0596993, 0441012, 0479943
NAID #

Bryan Avery, Lindsay Riley,
Printed Name

4/23/07
Date

, Lindsay Riley,
Signature of Student Researcher

[1]Consent required by 20 U.S.C. 1232g.

APPENDIX B

Title: The effects of heel lift on gait parameters during ambulation for people with hemiparesis.

Any persons participating in research must give informed consent to take part in the study. You must understand the risks involved in research. This document provides information that will be important to understand to be involved in the research. Research studies include only subjects who choose to participate. Please take your time in making your decision as to whether to take part in this research study. If you have any questions, please ask at any time.

You are invited to be in a research study conducted by Dr. Meridee Danks (UND faculty), Bryan Avery, Lindsay Riley, and Shannon Webster (UND physical therapy graduate students), about the effects of a heel lift on gait parameters during walking for people with hemiparesis. You have been chosen as a potential candidate because of your history of hemiparesis. It is known that hemiparesis involves changes in hip and leg movement during walking.

Up to 30 people will take part in this study at the University of North Dakota School of Medicine and Health Sciences Physical Therapy Department. Your participation will last approximately one hour if you meet the research criteria to be included in the study.

After this document has been read, you will be asked to sign it if you agree to take part in the study. You will then be asked to fill out a health questionnaire. Following this, your height will be measured and you will stand on the Balance Master system® (an instrument that determines the amount of weight on each leg during standing). If you do not meet the study requirements to this point, we will simply thank you for coming. No further testing will be administered. If you meet the requirements to this point you will proceed through the rest of the study process. Sensation will be tested in your legs. Then range of motion of your ankles and the length of your legs will be measured. You will be asked to pick a number from a can to determine the order you will be tested. The final task of the procedure is to walk on the computerized carpet several times to analyze walking. A safety belt will be place on you and a spotter will walk next to you while on the computer carpet for safety. Upon completion of the walking the study will be over.

You may not benefit personally from being in this study. However, we hope that in the future other people might benefit from this study by having results that may lead to a new approach to treating people with hemiparesis. Upon request, we will give you a copy of the results from this study. You will not be paid for being a participant in this research.

In any report about this study that might be published, you will not be identified. Confidentially will be maintained by assigning you a number at the beginning of the study and this information will only be shared with the individuals conducting the study. The information will be locked in a file cabinet to further protect from outside threats. Your study record may be reviewed by government agencies, the University of North Dakota Research Development and Compliance office, and the University of North Dakota Institutional Review Board.

In the event of an injury, medical personnel will be contacted. Payment for any such treatment is to be provided by you or your third-party payer. No funds have been set aside to compensate you in the event of injury.

Your participation is voluntary. You may choose not to participate or you may discontinue you participation at any time without penalty or loss of benefits to which you are otherwise entitled. Your decision whether or not to participate will not affect your current or future relations with the University of North Dakota.

If you later have questions, concerns, or complaints about the research please contact Dr. Meridee Danks at (701-777-3861). If you have questions regarding your rights as a research subject, or if you have any concerns or complaints about the research, you may contact the University of North Dakota Institutional Review Board at (701-777-4279).

Your signature indicates that you read and understand the research process, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Subjects Name_____

_____ _____

Signature of Subject Date

APPENDIX C

Health Questionnaire

Identification number:_____

Birth date:_____ Contact number:_____

Sex: Male/Female

What condition caused your hemiparesis?
Which side is involved?
When did the incident occur?

Circle if you have or ever have had any of the following

Anemia Yes/No
Diabetes Yes/No
Thyroid Disorder Yes/No
Rheumatic Fever Yes/No
Heart Disease Yes/No
Heart Attack Yes/No
Stroke Yes/No
Epilepsy Yes/No
Asthma Yes/No
Glaucoma Yes/No
Tumors Yes/No
Cancer Yes/No
Radiation Yes/No
High/Low Blood Pressure Yes/No
Dizziness Yes/No
Headaches Yes/No
Emphysema Yes/No
Loss of Sensation Yes/No
Kidney Disease Yes/No
Pace Maker Yes/No
Heart Surgery Yes/No
Arthritis Yes/No
Joint Replacement Yes/No
Ringing in Ears Yes/No
Orthotics Yes/No
Broken bones Yes/No
Vision Yes/No

Do you use an assistive device for walking? Yes/No
(if yes, what type?)_____

Please list medications:

What types of shoes do you normally where?

What is the farthest distance you can walk by yourself?

Do you have a history of falls? If yes, explain.

APPENDIX D

Subject Data Collection Form

Patient Number _____

Height (cm) (Shoes on) _____

Balance Master	Left	Right
Weight Bearing Percent:	_____	_____

Sensation of feet
Light Touch
Fill in: Absent/impaired/normal
Use examiners finger

LEFT	L4____	L5____	S1____	S2____
RIGHT	L4____	L5____	S1____	S2____

ROM (degrees)
Sitting
Ankle Dorsiflexion _____ _____

Leg Length (cm) (Shoes on) _____ _____
Greater trochanter to floor

Random Grouping Assignment for GAITRite

_____ No Heel Lift

_____ Heel Lift

Heel Height of Shoes
Left_____
Right_____

APPENDIX E

Tested on: 6/28/2007 10:48:25 AM

UND
501 N Columbia Rd
P. O. Box 9037
Grand Forks ND 58203

Tel# 7017772831

Age	Gender	Left LEG	Right	Height	Weight
75	M	96	98	0	0

Subject 1

Parameters

Distance (cm)	371.4
Ambulation Time (sec)	8.59
Velocity (cm/sec)	43.2
Mean Normalized Velocity	.45

Functional Ambulation Profile: 47

Cadence (Steps/Min)	76.8
Step Time Differential (sec)	.38
Step Length Differential (cm)	25.97
Cycle Time Differential (sec)	.00

Walk # / Footfall #	L/R	Mean(%CV)	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1/10	1/11	1/12
Step Time (sec)	L	.990 (8)			1.013		1.113		.925		.988		.912	
	R	.606 (3)		.625		.612		.612		.575		.600		.613
Cycle Time (sec)	L	1.595 (5)			1.638		1.725		1.537		1.563		1.512	
	R	1.593 (6)				1.625		1.725		1.500		1.588		1.525
Swing Time (sec)	L	.538 (48) /33.7			.638		.775		.100		.638		.537	
/ %GC	R	.365 (4) /22.9				.387		.362		.350		.375		.350
Stance (sec)	L	1.057 (20) /66.3	1.000		.950		1.437		.925		.975			
/ %GC	R	1.228 (7) /77.1		1.238		1.363		1.150		1.213		1.175		
Single Support (sec)	L	.365 (4) /22.9			.387		.362		.350		.375		.350	
/ %GC	R	.538 (48) /33.8		.638		.775		.100		.638		.537		
Double Support (sec)	L	.693 (31) /43.4			.563		1.075		.575		.600		.650	
/ %GC	R	.691 (29) /43.4		.601		.589		1.050		.575		.638		
Step Length (cm)	L	47.926 (3)			48.115		49.785		46.603		48.227		46.901	
	R	21.961 (13)		19.277		25.410		20.613		25.452		21.542		19.473
Stride Length (cm)	L	70.391 (5)			67.414		75.198		67.217		73.684		68.444	
	R	70.566 (4)				73.663		70.615		72.231		69.788		68.531
Base of Support (cm)	L	13.47 (10)			12.965		12.850		13.210		12.397		15.912	
	R	13.00 (17)		14.361		10.399		15.672		11.129		13.428		
Toe In / Out (deg)	L	4 (61)			3		3		0		5		7	
	R	12 (7)		13		12		11		13		13		

2st trial, lift R

Heel Lift (R)

Tested on: 6/28/2007 10:51:47 AM

UND
501 N Columbia Rd
P. O. Box 9037
Grand Forks ND 58203

Tel# 7017772831

Age	Gender	Left LEG	Right	Height	Weight
75	M	80	79	0	0

Subject 1

Parameters

Distance (cm)	251.1
Ambulation Time (sec)	5.69
Velocity (cm/sec)	44.1
Mean Normalized Velocity	.55

Functional Ambulation Profile: 48

Cadence (Steps/Min)	73.8
Step Time Differential (sec)	.37
Step Length Differential (cm)	27.78
Cycle Time Differential (sec)	.01

Walk # / Footfall #	L/R	Mean(%CV)	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8
Step Time (sec)	L	1.021 (4)			.988		1.013		1.063	
	R	.656 (2)		.637		.662		.662		.662
Cycle Time (sec)	L	1.675 (3)			1.625		1.675		1.725	
	R	1.683 (2)				1.650		1.675		1.725
Swing Time (sec)	L	.613 (9) /36.6			.550		.650		.638	
/ %GC	R	.400 (3) /23.8				.400		.412		.387
Stance (sec)	L	1.062 (3) /63.4	1.075		1.025		1.087			
/ %GC	R	1.284 (4) /76.3		1.250		1.263		1.338		
Single Support (sec)	L	.400 (3) /23.9			.400		.412		.387	
/ %GC	R	.613 (9) /36.4		.550		.650		.638		
Double Support (sec)	L	.654 (4) /39.0			.625		.675		.663	
/ %GC	R	.671 (8) /39.9		.701		.613		.700		
Step Length (cm)	L	51.743 (2)			52.354		52.055		50.821	
	R	23.968 (11)		23.634		26.474		25.379		20.384
Stride Length (cm)	L	76.910 (2)			75.988		78.543		76.200	
	R	75.852 (5)				78.829		77.447		71.279
Base of Support (cm)	L	12.19 (9)			12.158		11.129		13.268	
	R	11.78 (5)		12.437		11.184		11.747		
Toe In / Out (deg)	L	2 (34)			2		2		1	
	R	14 (6)		13		13		15		

4th trial, no lift

No Heel Lift

Tested on: 6/28/2007 12:07:14 PM

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P. O. Box 9037
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Tel# 7017772831

Age	Gender	Left LEG	Right	Height	Weight
75	M	80	79	0	0

Subject 2

Parameters

Distance (cm)	322.2
Ambulation Time (sec)	6.20
Velocity (cm/sec)	52.0
Mean Normalized Velocity	.65

Functional Ambulation Profile: 60

Cadence (Steps/Min)	67.7
Step Time Differential (sec)	.30
Step Length Differential (cm)	5.20
Cycle Time Differential (sec)	.01

Walk # / Footfall #	L/R	Mean(%CV)	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8
Step Time (sec)	L	1.058 (10)			1.025		.975		1.175	
	R	.756 (7)		.775		.667		.813		.750
Cycle Time (sec)	L	1.817 (9)			1.800		1.662		1.988	
	R	1.806 (6)				1.712		1.788		1.925
Swing Time (sec)	L	.642 (6) /35.3			.663		.600		.663	
/ %GC	R	.454 (7) /25.1				.425		.486		.450
Stance (sec)	L	1.175 (12) /64.7	1.137		1.062		1.325			
/ %GC	R	1.354 (8) /74.9		1.287		1.300		1.475		
Single Support (sec)	L	.454 (7) /25.0			.425		.486		.450	
/ %GC	R	.642 (6) /35.5		.663		.600		.663		
Double Support (sec)	L	.737 (14) /40.6			.637		.837		.737	
/ %GC	R	.712 (13) /39.4		.624		.700		.813		
Step Length (cm)	L	49.005 (4)			47.241		48.732		51.041	
	R	43.804 (10)		41.456		38.822		46.129		46.808
Stride Length (cm)	L	91.831 (7)			88.705		87.600		99.188	
	R	93.647 (7)				86.109		98.976		97.854
Base of Support (cm)	L	18.32 (3)			18.956		18.010		17.979	
	R	18.44 (9)		19.781		18.973		16.564		
Toe In / Out (deg)	L	6 (44)			7		3		8	
	R	13 (11)		15		13		12		

2 trial, lift 3/8

Heel Lift (R)

Tested on: 6/28/2007 11:56:44 AM

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501 N Columbia Rd
P. O. Box 9037
Grand Forks ND 58203

Tel# 7017772831

Subject 2

Age	Gender	Left LEG	Right	Height	Weight
75	M	80	79	0	0

Parameters

Distance (cm)	286.0
Ambulation Time (sec)	6.35
Velocity (cm/sec)	45.0
Mean Normalized Velocity	.57

Functional Ambulation Profile: 58

Cadence (Steps/Min)	66.1
Step Time Differential (sec)	.26
Step Length Differential (cm)	4.28
Cycle Time Differential (sec)	.03

Walk # / Footfall #	L/R	Mean(%CV)	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8
Step Time (sec)	L	1.054 (5)			1.038		1.012		1.112	
	R	.797 (5)		.850		.775		.813		.750
Cycle Time (sec)	L	1.867 (4)			1.888		1.787		1.925	
	R	1.833 (1)				1.813		1.825		1.862
Swing Time (sec)	L	.629 (5) /33.7			.600		.625		.662	
/ %GC	R	.417 (2) /22.7				.413		.413		.425
Stance (sec)	L	1.238 (5) /66.3	1.288		1.162		1.263			
/ %GC	R	1.416 (1) /77.3		1.400		1.412		1.437		
Single Support (sec)	L	.417 (2) /22.3			.413		.413		.425	
/ %GC	R	.629 (5) /34.3		.600		.625		.662		
Double Support (sec)	L	.767 (10) /41.1			.749		.851		.700	
/ %GC	R	.787 (2) /42.9		.800		.787		.775		
Step Length (cm)	L	43.299 (6)			43.273		40.862		45.762	
	R	39.015 (10)		34.367		40.272		37.855		43.465
Stride Length (cm)	L	80.856 (4)			77.687		81.135		83.746	
	R	83.872 (6)				83.569		78.818		89.229
Base of Support (cm)	L	18.34 (7)			17.804		17.485		19.721	
	R	17.77 (5)		17.471		17.016		18.809		
Toe In / Out (deg)	L	6 (17)			7		5		6	
	R	12 (12)		14		11		12		

2 trial, no lift in shoe now

No Heel Lift

Tested on: 6/28/2007 1:30:17 PM

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501 N Columbia Rd
P. O. Box 9037
Grand Forks ND 58203

Tel# 7017772831

Subject 3

Age	Gender	Left LEG	Right	Height	Weight
75	M	80	79	0	0

Parameters

Distance (cm)	351.8
Ambulation Time (sec)	7.90
Velocity (cm/sec)	44.5
Mean Normalized Velocity	.56

Functional Ambulation Profile: 59

Cadence (Steps/Min)	98.7
Step Time Differential (sec)	.20
Step Length Differential (cm)	15.50
Cycle Time Differential (sec)	.01

Walk # / Footfall #	L/R	Mean(%CV)	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1/10	1/11	1/12	1/13
Step Time (sec)	L	.498 (11)			.525		.475		.437		.587		.512		.450
	R	.702 (12)		.788		.712		.613		.588		.663		.800	
Cycle Time (sec)	L	1.192 (7)			1.313		1.187		1.050		1.175		1.175		1.250
	R	1.185 (9)				1.237		1.088		1.025		1.250		1.312	
Swing Time (sec)	L	.325 (7) /27.3			.338		.325		.300		.325		.362		.300
/ %GC	R	.463 (18) /39.1				.487		.413		.363		.413		.600	
Stance (sec)	L	.867 (10) /72.7	.975		.862		.750		.850		.813		.950		
/ %GC	R	.723 (9) /61.0		.750		.675		.662		.637		.712		.700	
Single Support (sec)	L	.463 (18) /38.8			.487		.413		.363		.413		.600		.500
/ %GC	R	.325 (7) /27.4		.338		.325		.300		.325		.362		.300	
Double Support (sec)	L	.396 (14) /33.2			.375		.338		.488		.400		.350		.425
/ %GC	R	.398 (16) /33.6		.412		.350		.362		.512		.350		.400	
Step Length (cm)	L	35.407 (6)			35.566		37.027		37.399		35.919		34.679		31.854
	R	19.906 (6)		17.985		21.393		19.963		19.749		19.931		21.409	
Stride Length (cm)	L	55.487 (4)			53.556		58.420		57.363		55.670		54.612		53.299
	R	55.650 (4)				56.997		56.994		57.149		55.851		56.089	
Base of Support (cm)	L	11.38 (5)			11.293		10.736		11.574		11.014		11.402		12.282
	R	11.43 (7)		11.932		10.313		11.275		11.461		11.060		12.458	
Toe In / Out (deg)	L	2 (55)			1		3		3		1		3		1
	R	10 (11)		10		6		11		10		11		11	

2 trial, no lift

No Heel Lift

Tested on: 6/28/2007 1:37:33 PM

UND
501 N Columbia Rd
P. O. Box 9037
Grand Forks ND 58203

Tel# 7017772831

Subject 3

Age	Gender	Left LEG	Right	Height	Weight
75	M	80	79	0	0

Parameters

Distance (cm)	340.3
Ambulation Time (sec)	7.58
Velocity (cm/sec)	44.9
Mean Normalized Velocity	.56

Functional Ambulation Profile: 59

Cadence (Steps/Min)	102.9
Step Time Differential (sec)	.20
Step Length Differential (cm)	16.78
Cycle Time Differential (sec)	.00

Walk # / Footfall #	L/R	Mean(%CV)	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1/10	1/11	1/12	1/13
Step Time (sec)	L	.473 (4)			.488		.462		.438		.487		.487		.475
	R	.677 (6)		.662		.675		.625		.750		.713		.650	
Cycle Time (sec)	L	1.152 (5)			1.150		1.137		1.063		1.237		1.200		1.125
	R	1.152 (4)				1.163		1.087		1.188		1.200		1.137	
Swing Time (sec)	L	.319 (6) /27.7			.325		.312		.288		.337		.337		.312
/ %GC	R	.465 (12) /40.4				.488		.387		.525		.513		.450	
Stance (sec)	L	.833 (5) /72.3	.825		.825		.775		.900		.863		.813		
/ %GC	R	.688 (3) /59.7		.675		.700		.663		.687		.687		.713	
Single Support (sec)	L	.465 (12) /40.4			.488		.387		.525		.513		.450		.425
/ %GC	R	.319 (6) /27.7		.325		.312		.288		.337		.337		.312	
Double Support (sec)	L	.372 (7) /32.3			.338		.388		.376		.351		.363		.413
/ %GC	R	.369 (6) /32.0		.351		.388		.375		.350		.350		.401	
Step Length (cm)	L	35.211 (5)			33.380		34.585		33.453		35.763		37.242		36.845
	R	18.431 (11)		17.215		18.199		17.261		22.586		19.632		17.557	
Stride Length (cm)	L	53.958 (6)			50.595		52.786		50.733		58.360		56.874		54.403
	R	53.854 (3)				51.596		51.846		56.050		55.396		54.805	
Base of Support (cm)	L	11.54 (7)			12.615		12.358		10.434		10.928		11.356		11.524
	R	11.74 (8)		13.258		12.147		11.695		10.432		10.895		12.001	
Toe In / Out (deg)	L	3 (97)			3		2		1		6		4		-1
	R	10 (11)		10		10		12		10		9		9	

2 trial, heel lift

Heel Lift (L)

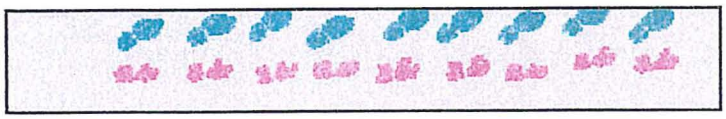
Tested on: 7/11/2007 1:39:03 PM

UND
501 N Columbia Rd
P. O. Box 9037
Grand Forks ND 58203

Tel# 7017772831

Age	Gender	Left LEG	Right	Height	Weight
74	M	106	106	0	0

Subject 4



Parameters

Distance (cm)	308.3
Ambulation Time (sec)	10.86
Velocity (cm/sec)	28.4
Mean Normalized Velocity	.27

Functional Ambulation Profile: 45

Cadence (Steps/Min)	93.9
Step Time Differential (sec)	.52
Step Length Differential (cm)	41.69
Cycle Time Differential (sec)	.00

Walk # / Footfall #	L/R	Mean(%CV)	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1/10	1/11	1/12	1/13
Step Time (sec)	L	.393 (7)		.400		.400		.362		.388		.388		.438	
	R	.916 (9)			.688		1.075		.875		.887		.767		.912
Cycle Time (sec)	L	1.308 (5)				1.288		1.437		1.263		1.275		1.225	
	R	1.308 (7)			1.288		1.475		1.237		1.275		1.175		1.350
Swing Time (sec)	L	.167 (11) /12.8				.200		.137		.175		.163		.163	
/ %GC	R	.628 (19) /48.0			.550		.650		.662		.500		.487		.600
Stance (sec)	L	1.141 (7) /87.2		1.088		1.300		1.088		1.112		1.062		1.162	
/ %GC	R	.680 (11) /52.0	.738		.625		.575		.775		.688		.750		.675
Single Support (sec)	L	.628 (19) /48.0		.550		.850		.662		.500		.487		.600	
/ %GC	R	.167 (11) /12.8			.200		.137		.175		.163		.163		.163
Double Support (sec)	L	.513 (14) /39.2		.539		.450		.426		.612		.575		.562	
/ %GC	R	.513 (14) /39.2			.425		.438		.600		.526		.587		.513
Step Length (cm)	L	-1.480 (>100)		2.070		.621		-4.521		-6.180		5.784		-4.949	
	R	40.206 (7)			41.824		40.767		42.158		39.682		36.658		35.384
Stride Length (cm)	L	38.408 (11)				42.617		36.301		36.222		45.633		31.719	
	R	38.907 (13)			44.004		41.421		37.713		33.600		42.480		30.776
Base of Support (cm)	L	21.16 (12)		19.657		22.498		24.122		20.002		24.285		20.307	
	R	21.05 (11)			20.432		24.325		20.822		23.228		22.994		17.552
Toe In / Out (deg)	L	27 (7)		25		28		27		29		27		23	
	R	-7 (>100)			-4		-7		-6		-9		-11		-2

no lift

No Heel Lift

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Age	Gender	Left LEG	Right	Height	Weight
74	M	106	106	0	0

Subject 4

Parameters

Distance (cm)	308.7
Ambulation Time (sec)	11.41
Velocity (cm/sec)	27.1
Mean Normalized Velocity	.26

Functional Ambulation Profile: 45

Cadence (Steps/Min)	89.4
Step Time Differential (sec)	.56
Step Length Differential (cm)	48.65
Cycle Time Differential (sec)	.00

Walk # / Footfall #	L/R	Mean(%CV)	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1/10	1/11	1/12	1/13
Step Time (sec)	L	.407 (11)		.437		.412		.413		.438		.425		.362	
	R	.969 (10)			.913		.950		.962		.962		1.088		.988
Cycle Time (sec)	L	1.372 (5)				1.325		1.363		1.400		1.387		1.450	
	R	1.372 (10)			1.350		1.362		1.375		1.400		1.513		1.350
Swing Time (sec)	L	.183 (12) /13.3				.200		.188		.200		.200		.162	
/ %GC	R	.653 (14) /47.6			.588		.625		.662		.575		.813		.613
Stance (sec)	L	1.189 (6) /86.7		1.125		1.175		1.200		1.187		1.288		1.225	
/ %GC	R	.719 (13) /52.4	.762		.737		.713		.825		.700		.737		.775
Single Support (sec)	L	.653 (14) /47.6		.588		.625		.662		.575		.813		.613	
/ %GC	R	.183 (12) /13.3			.200		.188		.200		.200		.162		.200
Double Support (sec)	L	.536 (10) /39.1		.538		.550		.538		.612		.476		.612	
/ %GC	R	.538 (16) /39.2			.537		.525		.625		.500		.575		.575
Step Length (cm)	L	-4.732 (>100)		-6.027		6.421		-7.562		3.448		-19.633		-2.221	
	R	43.915 (17)			38.955		41.795		38.628		61.642		42.567		39.876
Stride Length (cm)	L	39.580 (12)				45.377		34.253		42.369		42.021		40.371	
	R	39.974 (31)			32.932		48.284		31.266		65.344		25.000		37.818
Base of Support (cm)	L	20.93 (15)		22.353		20.999		18.551		24.254		21.166		19.387	
	R	20.88 (16)			22.444		19.124		19.970		26.638		16.910		18.607
Toe In / Out (deg)	L	28 (34)		26		25		32		33		7		33	
	R	-9 (>100)			-2		-3		-10		0		-12		-18

Heel Lift (L)

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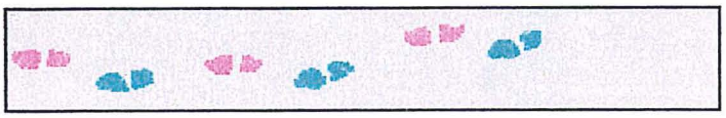
Subject 5

Age	Gender	Left LEG	Right	Height	Weight
74	M	106	106	0	0



Parameters

Distance (cm)	282.8
Ambulation Time (sec)	2.66
Velocity (cm/sec)	106.3
Mean Normalized Velocity	1.00

Functional Ambulation Profile: 80

Cadence (Steps/Min)	112.8
Step Time Differential (sec)	.04
Step Length Differential (cm)	16.15
Cycle Time Differential (sec)	.02

Walk # / Footfall #	L/R	Mean(%CV)	1/1	1/2	1/3	1/4	1/5	1/6
Step Time (sec)	L	.556 (2)			.550		.562	
	R	.517 (5)		.487		.538		.525
Cycle Time (sec)	L	1.069 (4)			1.037		1.100	
	R	1.088 (0)				1.088		1.037
Swing Time (sec)	L	.331 (8) /31.0			.312		.350	
/ %GC	R	.375 (5) /34.5				.388		.362
Stance (sec)	L	.738 (2) /69.0	.725		.750			
/ %GC	R	.713 (2) /65.5		.700		.725		
Single Support (sec)	L	.375 (5) /35.1			.388		.362	
/ %GC	R	.331 (8) /30.4		.312		.350		
Double Support (sec)	L	.375 (5) /35.1			.362		.388	
/ %GC	R	.362 (2) /35.1		.388		.375		
Step Length (cm)	L	66.244 (1)			66.696		65.791	
	R	50.095 (8)		46.451		54.281		49.552
Stride Length (cm)	L	117.313 (3)			114.439		120.187	
	R	118.845 (4)				122.290		115.400
Base of Support (cm)	L	10.81 (12)			11.753		9.868	
	R	8.78 (54)		12.115		5.437		
Toe In / Out (deg)	L	9 (8)			9		8	
	R	1 (>100)		3		-2		

no lift

No Heel Lift

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Age	Gender	Left LEG	Right	Height	Weight
74	M	106	106	0	0

Subject 5

Parameters

Distance (cm)	340.4
Ambulation Time (sec)	3.53
Velocity (cm/sec)	96.4
Mean Normalized Velocity	.91

Functional Ambulation Profile: 79

Cadence (Steps/Min)	102.0
Step Time Differential (sec)	.00
Step Length Differential (cm)	15.46
Cycle Time Differential (sec)	.03

Walk # / Footfall #	L/R	Mean(%CV)	1/1	1/2	1/3	1/4	1/5	1/6	1/7
Step Time (sec)	L	.587 (4)		.612		.575		.575	
	R	.588 (6)			.550		.600		.613
Cycle Time (sec)	L	1.150 (3)				1.125		1.175	
	R	1.175 (1)			1.162		1.175		1.188
Swing Time (sec)	L	.356 (17) /31.0				.312		.400	
/ %GC	R	.400 (6) /34.0			.362		.425		.413
Stance (sec)	L	.794 (3) /69.0		.613		.775			
/ %GC	R	.775 (3) /65.0	.800		.750		.775		
Single Support (sec)	L	.400 (8) /34.8		.362		.425		.413	
/ %GC	R	.356 (17) /30.3			.312		.400		
Double Support (sec)	L	.409 (13) /35.6		.451		.350		.426	
/ %GC	R	.406 (11) /34.6			.438		.375		
Step Length (cm)	L	64.461 (5)		63.490		67.767		62.125	
	R	49.000 (12)			42.326		53.881		50.793
Stride Length (cm)	L	113.105 (4)				110.127		116.082	
	R	113.499 (7)			105.838		121.681		112.998
Base of Support (cm)	L	9.68 (17)		8.718		11.614		8.654	
	R	9.88 (18)			11.140		8.627		
Toe In / Out (deg)	L	11 (16)		12		9		12	
	R	-1 (>100)			-4		3		

lift

Heel Lift (L)

APPENDIX F

DVD is attached to the back cover.

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