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The Effectiveness of Balance Training Exercises in Post-Stroke Individuals Using the Neurocom Balance Master® System

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THE EFFECTIVENESS OF BALANCE TRAINING EXERCISES
IN POST-STROKE INDIVIDUALS USING THE
NEUROCOM BALANCE MASTER® SYSTEM

by

Joseph Brenner
Bachelor of Science in Physical Therapy
University of North Dakota, 1998

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1999
This Independent Study, submitted by Joseph Brenner in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title  The Effectiveness of Balance Training Exercises in Post-Stroke Individuals Using the NeuroCom® Balance Master System

Department  Physical Therapy

Degree  Master of Physical Therapy

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Signature  Joseph E. Brenner

Date  12-17-98
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ABSTRACT

A case study was completed on a 70-year-old female who had suffered a right cerebral vascular accident and left hemiparesis on June 25, 1996. She exhibited left upper and lower abnormal synergy patterns that disrupted her gait cycle. The subject volunteered for the study to improve her ambulation efficiency. Individuals suffering a stroke often times exhibit deficits in balance due to weakness, sensory loss, impaired righting reflexes, and visuospatial distortion. Force platforms, such as the NeuroCom Balance Master®, have become useful pieces of equipment in the field of physical therapy. The technological advancements in force platforms have allowed clinicians to objectively assess and rehabilitate patients with abnormal balance limitations. The purpose of this case study was to determine if individuals who were at least six months post-stroke could effectively improve their balance using the NeuroCom Balance Master®. After a six-week training regimen on the NeuroCom Balance Master®, the subject showed significant improvements in limits of stability, symmetric weight bearing, and walking abilities.
CHAPTER I
INTRODUCTION/LITERATURE REVIEW

Strokes are the third leading cause of death in the United States.\textsuperscript{1} According to the American Heart Association, there are approximately three million stroke survivors and 500,000 new strokes that occur annually. Mortality rates for stroke victims have been on the decline since the early 1900s. Since 1969, mortality rates have decreased 5\% each year, especially in the older age groupings. After the age of 65, the incidents of strokes rise exponentially with each decade of age categories. Gender comparisons are close to being equal with regard to stroke rates, but African-American men and woman comprise a significantly higher number of incidents within the U.S.\textsuperscript{2}

Of the four subtypes of strokes, ischemic strokes account for almost 80\% of all cerebral vascular accidents.\textsuperscript{1-3} Age, hypertension, and cardiac disease are the three main risk factors for stroke occurrence. Associated with cardiac disease, an estimated one million Americans are affected by atrial fibrillations which are known to increase the chance of stroke by a factor of five. Other risk factors include diabetes, obesity, smoking, serum lipids, hemoglobin concentration, oral contraceptives, and other environmental factors.\textsuperscript{1,2}

The main disabling physical effect of strokes tends to be asymmetric weight bearing toward the uninvolved side during static standing and dynamic
movements.\textsuperscript{4,6} It has been estimated that stroke patients transfer up to 70\% of their body weight to their uninvolved side.\textsuperscript{7,8} An increase in postural sway and a decrease in limits of stability have been observed in post-stroke and older populations. Decreased maximal excursions for postural control for anterior/posterior and medial/lateral positioning have also been noted.\textsuperscript{9} Sensory loss, lack of proprioceptive accuracy, difficulty with coordination of lower limb movement, and increased attentional demands are added factors that make simple movements challenging.\textsuperscript{4,6,10,11}

Post-stroke victims often times have neurologic limb spasticity, trunk damage, and abnormal synergy patterns that inhibit their ability to ambulate normally.\textsuperscript{4,11,12} The effects and residual symptoms associated with strokes disrupt gait patterns, limit functional capabilities, increase fall potential, and decrease activities of daily living.\textsuperscript{10} The major common denominator among all the disabling physical effects of strokes is balance. Without the ability to balance, functional activities become difficult and inefficient. Increasing the ability to balance is one of the most important determinants for a successful reeducation program for stroke patients.\textsuperscript{11-15}

Balance is a complex, interrelated system of sensory information, feedback, and somatic adjustment to the changing environment. Visual input, somatosensory feedback and vestibular systems are the main components within the balance triad scheme. The three components can be combined or used as individual sensory reference points. The vestibular system uses gravity as its medium for reference. The visual system uses feedback from the
environment for orientation. The somatosensory system uses tactile stimulation to register the body's spatial relationship. Somatosensory components include proprioceptive, cutaneous, and joint receptors. Studies indicate that during disturbed surface perturbations, somatosensory systems are the dominant balance receptor. During slower oscillations, all three components offer simultaneous feedback.

Postural control is a complex relationship between musculoskeletal and neural pathways to promote stability and orientation. Sensory and motor systems both respond to changing environmental situations for needed adaptive postural control. All activities, including quiet stance or sitting, demand perpetual feedback for orientation. Stretch receptors in the muscle fibers resist being lengthened and create a tonic reflex feedback mechanism during postural stance. Anti-gravity muscles help to maintain postural tone. The anti-gravity muscles include the soleus, gastrocnemius, tibialis anterior, gluteus medius, gluteus maximus, tensor fascia latae, iliopsoas, thoracic erector spinae, and the abdominals. The trunk musculature during postural tone is thought to be the key element with regard to postural stability. Stroke victims often suffer from one or more of the balance related sensory mechanisms. A combination of disabling effects on balance makes therapy more difficult and extends the recovery time.

Patterns for postural stability involvement are referred to as ankle, hip, and stepping strategies. During postural challenges, muscle synergy groups are recruited and act as coupling units to maintain posture control. Muscles acting
as units are thought to simplify the demands on the central nervous system.⁷,¹⁵,²⁰,²¹

Ankle strategies are usually the first mechanism to engage to limit sway during upright postural stance. Ankle strategies restore the body's center of mass predominantly on firm surfaces where one's equilibrium is challenged with small perturbations. The forward sway ankle strategy uses the paraspinal, hamstring, and gastrocnemius muscles for stabilization. The backward sway uses the abdominals, quadriceps, and tibialis anterior muscles for postural control.¹⁵,²¹

Hip strategies control the center of mass with larger and rapid movements with ankle anti-phase rotations. They are engaged in the control of the forward sway and use the abdominal and quadriceps muscles to maintain the body's center of gravity. Proximal trunk strategies for backward sway use the paraspinal and hamstring muscles to preserve balance.¹⁵,²¹

Stepping strategies are accessed when the body's center of mass goes outside its limits of support. A step, reach, or a hop is used to control the body's center of force, center of mass, and center of gravity.¹⁵,²¹

Varying strategies are incorporated depending upon the environmental demands that occur from moment to moment. Studies have indicated that through repeated exposure to a given postural task subjects have increased their response time and decreased their postural sway ranges.⁵,¹⁰,²¹ Equilibrium strategies inherently choose the appropriate sensing devices for each individual
task. How we respond to the challenge depends on age, type of task, type of environment, and the ability level of the individual.\textsuperscript{11,13-15}

The NeuroCom Balance Master\textsuperscript{®} (NBM\textsuperscript{®}) system uses force plate analysis, visual and auditory feedback to monitor balance abilities for participants.\textsuperscript{9,22} The NBM\textsuperscript{®} program has been shown to be highly reliable with regard to limits of stability and center of gravity testing.\textsuperscript{5,21} Studies have indicated significant gains with hemiplegic patients in areas of weight bearing with increased symmetry, reducing abnormal lateral displacements, and increased functional outcomes in standing mobility and transfer tasks.\textsuperscript{5,9,12} The NBM\textsuperscript{®} was chosen for this case study due to its transferability of functional tasks and rehabilitation potentials. The measures most commonly used on the NBM\textsuperscript{®} are the postural sway feedback, symmetry, and limits of stability programs.\textsuperscript{12} The Berg Balance Scale was selected for the initial and final balance assessments because of its high reliability and validity as an indicator for functional balance abilities.\textsuperscript{23}

Problem Statement

Stroke rehabilitation has historically focused on the first six months of recovery. There have been limited studies and programs to help stroke patients recover past this six-month plateau.\textsuperscript{13} There is no conclusive research that indicates that stroke patients can continue to reeducate their involved hemiparetic musculature or retrack damaged neurologic tissue.
Purpose of Study

The purpose of the case study was to determine if a training protocol on the NBM® with a stroke patient, who was a minimum of six months post-stroke, could achieve a significant increase in symmetry, balance, and functional abilities. The results will be of benefit to health care providers to assist in designing training protocols used to address balance problems for post-stroke survivors.

Research Questions

Can the patient increase her symmetric weight bearing levels to within normal standards? Can affected gait patterns, due to increased tone and spasticity, become more efficient and controlled? Will an 18-session training regimen on the NeuroCom Balance Master® help facilitate functional abilities and expand the instrumental activities of daily living for this case study participant?
CHAPTER II

METHODOLOGY

The subject of this case study was a former patient at the Altru Health Institute and had expressed an interest in participating in balance studies undertaken by students at the University of North Dakota. Final approval of the project was given by the Altru Health Institute and the University of North Dakota Institutional Review Board. An information and consent form was signed by the participant acknowledging her willingness to participate in the study and informing her of any risk factors that may be involved (see Appendix A).

Subjects

Three post-stroke subjects between the ages of 40 to 80 years old were recruited to participate in a balance training program at the Altru Health Institute utilizing the NBM® system. An initial and final assessment on the NBM® and Berg Balance Scale was performed on each subject to determine if the training protocol was effective in improving each of the subjects' balance. The subjects recruited are former physical therapy patients at the Altru Health Institute in Grand Forks, North Dakota. All subjects were screened to ensure they could understand instructions, ambulate independently, demonstrate the ability to see characters on the computer screen, and were at least six months post from their cerebral vascular accident. Subjects wore a gait belt during the sessions and,
for her safety, there were always two students standing by. Each participant worked independently with a member of the research team and separate case studies were conducted on each of the participants.

Instrumentation

The NBM® system (NeuroCom International, Inc., 9570 SE Lawnfield Road, Clackamas, OR 97015) with software version 6.1 was used for this study. The system operates on two 9-inch by 60-inch force plates that determine the amount of force being exerted by each foot. The total vertical force information is transferred to the computer system where calculations are performed to determine the test subject's center of gravity. The computer screen is equipped with a cursor to provide visual feedback on the location of his/her center of gravity. The computerized measurement and feedback system is what makes the system unique and beneficial to both the subject and researcher. The system is unique in that the subject receives instantaneous visual and auditory feedback on body positions during his/her training. The feedback allows the subject the opportunity to increase sensory appreciation and reeducate neuromuscular pathways that have been affected from the stroke.

Validity of the Balance Master system has been established through its ability to generate computerized printouts of objective, quantifiable data. Published literature also supports the scientific efficacy and clinical use of the Balance Master and acknowledges it as a reliable and valid tool for assessing and retraining balance deficits.
The Berg Balance Scale assessment (see Appendix B) was performed on the initial and final evaluations. The Berg Balance Scale rates performances from zero (cannot perform) to four (normal performance) on 14 different tasks. The tasks include ability to: 1) sit, 2) stand, 3) reach, 4) lean over, 5) turn and look over each shoulder, 6) turn in a complete circle, and 7) step. The total possible score is 56 which indicates excellent balance. A score of 45 indicates that a person can function independently and safely. Any score under 45 identifies a person as having a balance deficit. The Berg Balance Scale assessments are a functional representation of movements related to activities of daily living.23

Procedure

The study format involved an initial and final evaluation that included a motor control assessment and questionnaire. An initial and final assessment on the NBM® and Berg Balance Scale assessment were also completed. Training sessions were for 30-minute time periods three times per week. Each subject participated in a six-week training program using the Balance Master® system.

The initial and final NBM® assessments included symmetrical weight bearing/squat test, modified clinical test for sensory interaction on balance, limits of stability, rhythmic weight shifting, sit to stand test, walking, step up/over, or step/quick turn. Collectively, these tests quantify: 1) the patient's ability to move the center of gravity (COG) through the limits of stability; 2) sway velocity defined as the distance in degrees traveled by the COG multiplied by the time of the trial; 3) limits of stability (LOS) defined as the maximum distance a person can lean
without losing balance, reaching, or stepping; 4) weight bearing, which is defined as the percentage of weight born by both legs; 5) reaction time; and 6) directional control. The assessments were individualized and dependent on each subject's ability level. Each member of the research team chose the types and levels of assessment protocols according to their subject's ability level.

The training protocols included activities for symmetric weight bearing and LOS. The four main categories to choose from the NBM® menu (see NBM® manual) are: 1) weight shifting, 2) mobility, 3) closed chain, and 4) seated. Graduated levels of difficulty allowed for customization of programs per individual sessions. On a scale of one through six, level one is considered to be the least challenging and levels five and six the most challenging. The training exercises allow the subjects to learn how to control their COG while maintaining either a dynamic or static posture. The participant's movements on the force plates cause a displacement in the COG. The change in COG controls the direction of the cursor on the screen to move accordingly. The subjects were instructed to move as quickly and accurately as possible to the highlighted target on the computer screen. Due to the high learning curve associated with this machine, the subjects were allowed to perform several trial sessions before any results were collected.

The types and levels of training protocols were chosen by each member of the research team to target individual areas of deficits. Final evaluations and assessments replicated the initial data collection on the NBM® and the functional balance assessment scales.
Assessment Protocol

The testing of subjects was conducted using the standardized assessment protocols on the NBM® and the administration of the Berg Balance System. Due to the high learning curve associated with the NBM®, the subject was allowed to perform several trial sessions before any results were collected. Final assessments replicated the initial data collection on the NBM® system and Berg Balance Scale. The description of each assessment test is stated in the Appendix B or NBM® manual, along with the performance measures of each test. Independent team members chose individualized assessment programs for their assigned subjects.

Data Analysis

All results were calculated by a percent change from the initial results in relation to the final results. The percent change is calculated by subtracting the final from the initial and dividing it by the initial times one hundred. The subject and researcher's observations are also included in result/discussion section.

Reporting of Results

Upon completion of this study, a summary of the results will be completed and sent to each subject and to Altru Health Institute. A copy of this independent case study will be given to the University of North Dakota Department of Physical Therapy. This study was completed to fulfill the requirements for the University of North Dakota School of Medicine and Health Sciences Physical Therapy Program.
CHAPTER III

DISCUSSION/RESULTS

This section includes the subject profile and the past to present information regarding the evaluation questions. The Berg Balance Scale results are discussed along with the specific percent changes. The NBM® initial and final individual assessment results are depicted in a chart and the changes are compared to normative data. The participant’s and researcher’s comments and opinions were reported with regard to the functional outcomes that occurred during the study.

Subject Profile

The patient is a 70-year-old female who had suffered a right cerebral vascular accident and left hemiparesis on June 25, 1996. During the acute phase of her stroke, she had significant left upper extremity hypertonicity and was initially treated with Zanaflex, Phenol, and Botox injections. She was intermittently involved in outpatient physical therapy since her CVA, but formally discharged on September 15, 1997. She is currently taking Lonoxin for an irregular heartbeat and aspirin for blood thinning.

Presently, she exhibits a moderate left upper extremity flexor synergy pattern that is continuous, unless manually altered. She displays a moderate left lower extremity extension synergy pattern, especially with weight bearing
activities. Her increased left lower extremity hypertonicity causes her to lock her knee into extension, hip hike, and retract her pelvis during ambulation. She wears a left ankle foot orthosis and walks with a single point cane. The cane is used mostly for safeguarding purposes and tactile feedback. She unable to actively dorsiflex and/or evert her foot. The combined lower extremity abnormalities cause her to circumduct her left leg during the swing phase of her gait cycle. She also displays a lack of upper body rotation that results in a stiff and inefficient gait pattern.

Manual muscle tests (MMT) on December 30, 1997, at the Dakota Clinic indicated that zero grades for left extensor hallucis longus and her everters. This researcher described her left pre-tibials and peroneals muscle activity at trace levels. She was tested in the short sitting position to decrease her extensor spasticity and give a more accurate indication of her active movement pattern. The accuracy of the MMT may have been altered due to her abnormal tone. All other muscles tested were within functional limits. The patient states that she has full intact sensations and denies having any pain. She is fully oriented to person, place, and time. The patient denies any visual disturbances.

She was motivated to start the study and verbalized that she would like to make functional gains. The patient exercises for one hour three to five times per week on isotonic exercise equipment. The patient reported that she had difficulty with her walking because of her stiff legged lower extremity. She ambulates with a cane independently in the community, although her walking
abnormality was her chief complaint. The main goal that she chose focused on regaining a normal walking pattern.

Questionnaire

The patient answered ten evaluation questions during the initial and final evaluation (see Appendix D). Out of the ten questions asked, two of the answers to the questions changed during the progression of the study. One of the questions focused on the use of assistive devices. She reported on the initial questioning that she always uses her cane at home. On the final evaluation, she indicated that she did not feel the need to use it to ambulate around her house anymore. The other question asked about numbness or sensory losses on her involved side. Initially, she stated that she had no numbness, sensory loss, or "pain." On the final evaluation, she reported that she had "pain" in her left hip with an increase of feeling. The area of pain was located at the anterior superior iliac spine. She also stated that before her stroke, she had parasomnic episodes of a syndrome labeled "restless legs" (akathisia). This is a common disorder that affects people mostly over 50 years old. The symptoms include vague uncomfortable sensations in the legs and associated spontaneous, uncomfortable jerking movements. This was not reported on the initial evaluation questions. In the two years since her stroke, she had had no episodes or symptoms. Towards the end of the study, she was experiencing the restless leg syndrome again. She expressed the opinion that this was a positive indication that her increased weight bearing on her involved side was conditioning atrophied musculature.
Training Sessions

The NBM® training sessions between the initial and final evaluations focused on components of gait with associated trunk rotation, diagonal weight shifting and balance exercises. The training format targeted proximal trunk stability first and then moved toward more distally challenging exercises. Walking, turning, and one-legged stance exercises were added as ability levels progressed. Each session attempted to start with training modes that were achievable and that transferred over from the last session. More challenging balancing exercises were chosen in the mid-session to allow her the opportunity to extend beyond her usual limits of stability. The challenging exercises were effective for increasing her ability to reeducate inherent balance strategies. The sessions ended with training activities that were successful and reinforced the positive gains.

On the training menu, the left side weight bearing was emphasized throughout the study to challenge her involved side. She used her AFO during all training activities to restrict her plantarflexion and inversion tone. Foam was sometimes used under her right foot or both feet to decrease surface stability. A theraband dorsiflexion wrap was occasionally used to assist her left foot dorsiflexion, knee flexion, and hip flexion. This was effective with assisting her quality of movement during ambulation. The dorsiflexion wrap gave her lower extremity a sensory reminder of what a more normalized gait pattern is like. Tactile facilitation was used to break her synergy pattern, which increased her knee and hip flexion during the exercises.
Berg Balance Scale Assessments and Results

A licensed physical therapist and this researcher performed and scored independent Berg assessments on the subject. The inter-related reliability of the scoring indicated a one-point discrepancy. The subject was tested wearing her AFO. On the initial test, the subject scored a total of 44, which indicates a balance deficit. She scored a 50 on the final test, which indicates a safe balance level. The percent increase was 14%.

The major areas of improvement were: 1) standing unsupported with one foot in front of the other; initially she scored a zero; zero indicated that she was not capable of stepping one foot in front of the other for any length of time. On the final assessment, her score was a three out of four. She was capable of placing her foot ahead of the other independently and maintaining the position for 30 seconds. To score a three, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride length. 2) The placing of alternate feet on a stool while standing unsupported. The subject is asked to place each foot on the stool four times or eight total. On the initial testing, she scored a two out of four. A two indicates that she is capable of only completing four steps with supervision. She scored a four out of four on her final test with stepping. A four indicated that she could stand independently and complete eight steps in less than 20 seconds.

NeuroCom Balance Master® Assessment Results

The NBM® assessment tests were chosen according to her functional ability level and targeted programs that would be advantageous towards
reaching her goal of achieving a normal walking pattern. The balance components chosen for the evaluation sequences were: 1) weight bearing, 2) limits of stability, and 3) rhythmic weight shift.

The activities of daily living evaluations chosen for this participant focused on: 1) walking and 2) the step/quick turn. These tests are directly related to the desired functional outcome of increased efficiency with walking. The normative data used to compare subject results are based off the NBM® findings according to age and height of the individual. The chart below describes the results of the initial and final evaluations. (See Appendix E for complete analysis.)

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<th>EVALUATIONS</th>
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<th>FINAL 10/16/98</th>
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| WALK              | Abnormal range: 1) width of the step  
2) speed of the step | Abnormal range: 1) width of step                      |
| STEP/QUICK TURN   | Abnormal range: 1) time required to turn  
2) amount of sway during turn | ALL Normal                                           |
| WEIGHT BEARING    | ALL Normal                                           | Abnormal range: 1) weight bearing not equally distributed |
| RHYTHMIC WEIGHT SHIFT | Abnormal range: 1) inability to coordinate movement | ALL Normal                                           |
| LIMITS OF STABILITY | Abnormal range: 1) time required to react to the stimuli | ALL Normal                                           |

Walk Test

The initial walk test showed her speed to be abnormal, but the final test indicated that the speed had increased to within normal limits. She increased her
walking by total of 22% and her end sway improved by 33% margin. Her width of step remained abnormal throughout the study and did not improve. She may have inherently kept her step width the same throughout the study for safety concerns.

Step/Quick Turn Test

The step/quick turn assessment was initially abnormal in the time required to turn and the amount of sway during the turn. The final test indicated that she was within normal limits for all categories within this testing phase. There was significant improvements in this assessment overall. The left side time to turn in seconds improved by 76% and degrees to turn improved by 73%. The turn time difference between right and left and the turn sway difference percentage improved astronomically. The major change was probably due to a lack of understanding of the required initial test movement. Her right side time to turn in seconds improved by 46% and the degrees to turn improved by 52%. Her turn time during the final Berg test also improved, but did not score any higher.

Weight Bearing Test

The weight bearing assessment initially recorded that she was approximately 50% left and 50% right symmetric in standing. The final test registered her weight bearing at a 60% left and 40% right in standing. The emphasis during the training sessions focused on left leg stance and challenged her left sided balance. This may have resulted in an over compensation to stand on her left side rather than symmetrically weight bearing. Typical stroke patients normally weight bear more on their non-involved. Even though the results
showed an increase in asymmetry in standing, it still fell on the cusp for abnormal/normal limits for weight bearing.

Rhythmic Weight Shifting Test

The initial assessment results for rhythmic weight shifting registered that she was in the abnormal range for her ability to coordinate movement. The final test indicated that she had improved her ability to coordinate movement to within normal limits. She improved her left to right shifting by 32% with degrees per second. The forward and backward directional control improved by 14%. All other attributes for rhythmic weight shifting were found to be normal. Stroke patients usually have a decrease in maximal for postural control for anterior/posterior and medial/lateral positioning.8

Limits of Stability Test

The initial test for limits of stability data recorded that she reacted abnormally with the time required in relation to the stimulus. The final assessment indicated that all attributes for limits of stability were normal. These results are significant and are directly related to postural sway and fall prevention.15 Her end point excursion rate improved by 43% and the maximum excursion rate improved by 29%. Reaction time for 1) back direction improved 57%, 2) right direction improved 60%, and 3) left direction improved 62%. Her movement velocity for: 1) forward direction improved 107%, 2) back direction improved 71%, 3) right direction improved 132%, and 4) left direction improved 37%. Reaction time and movement velocity increases act as fall prevention safeguards.10
Post-Training Observations

The NBM® results indicated that she made notable gains for quality, efficiency, and accuracy of movement from the initial assessment to the final. It is not fully understood if the improvements were due to learned motor planning, improved balance strategies, heightened proprioception, or a combination of each one. The results showed improvements that were directly related to the assessments and trainings on the NBM® system, but are these changes transferable and meaningful for her functional activities of daily living?

The subject reported an increase of capabilities at her house and in the community. She stated that her left leg felt like “dead weight” before the study, but that towards the end, she had an increase of feeling and was able to sense herself weight bearing more on the left side. This information seems contradictory with regard to her statements during the initial evaluation as she denied any sensation deficits. Approximately two years prior, pinprick testing at her initial hospital evaluation indicated that she had fully intact dermatome patterns and had only a minor vibratory loss in her left foot. She may have had a loss of proprioception in her leg without being aware of it. Her increased weight bearing on the left leg apparently increased her sensory appreciation. She also observed that she did not favor the right leg as much and felt that she used both legs equally.

The subject noted that she could pick up her left upper leg higher, which increased her ability to flex the knee. She stated that her overall walking pattern
had become more efficient, but it did not reach the level of normalcy that she had envisioned.

By the time of the final evaluation, this researcher observed that the subject’s gait pattern had become more normalized with increased hip flexion, knee flexion, and a decrease in hip hiking. She was making efforts to flex her knee and hip, which caused her hip to drop and protract more. Due to an increase of active knee flexion, she had more clearance room for proper swing through and less circumduction. The subject continued to wear her AFO throughout the study; therefore, her dorsiflexion status was not a factor. A clonus reaction occurred when she initiated an increase in knee flexion with proper swing through during her gait cycle. The extensor tone in her left leg partially subsided with the activation of her knee flexion. It is questionable if the clonus will diminish with continued practice or if her muscles will begin to adapt to the new demands.

The subject’s ability levels and task learning on the NBM® had increased significantly during the study. She had improved her balance performance with more difficult one-legged stance exercises and/or standing on foam. She exhibited an increased ability to maneuver and pivot during the more complex walking exercises. Her quality of movement became more automatic and she began to anticipate the timing of the cursor. Classical music was used occasionally to assist her with rhythmic weight shifting. The music acted as a catalyst to transform her quality of movement from a cognitive/associative level type of motion to a more proficient automatic/autonomic level. During the
walking exercises, the music assisted with her timing and accuracy. The repeated movements and walking exercises were similar to dance steps. The random patterns were not as effective with the supplementary music.

She would occasionally experience performance anxiety when she would be trying to actualize her best recorded performances. It seemed that when she attempted to try her hardest, a paradoxical intended event would occur. Her actions seemed to be more on a cognitive or mechanical level. Conversely, when she performed without any thought inhibition, her inherent feedforward abilities exhibited a greater effectiveness with performance.

The participant was highly motivated to work at achieving her personal goal of normalizing her gait pattern. She was consistently on time for every session and asked many questions with regard to how she might progress. Her cooperation made it easy to suggest new training strategies to improve the components of her gait cycle. On the other hand, her expectations about attaining her goal were sometimes unrealistic, with regard to time lines and immediate recovery. Sometimes she would create a self-defeating dialogue and become fixated on her physical deficits. These incidents were usually redirected once she was reminded of the progress she had made and the goal she wished to attain.

Limitations of Study

The NBM® force plates are sensitive and efficient. Consistent, correct placement of the participant's feet is crucial for accurate weight bearing recorded data. Due to human error or inattentive monitoring by the researcher, the feet of
the participant have the possibility of being misplaced and therefore can give a false reading. This was observed several times during the training sessions and monitored closely once it was discovered.

The Berg Balance Scale is a valid and reliable measure for balance ability levels. Although it is valid and reliable for balance, it does not measure the functional capabilities of walking, instrumental activities of daily living (IADLs), or home functions. An adjunct functional independence measure evaluation would have assisted this researcher with measuring her functional abilities. All conclusions with regard to her IADLs were subjective observations that were reported by the participant.

The NBM® is a fairly new device for improving balance and functional outcomes. There is a substantial learning curve for individual operators. The researcher must coordinate the remote control, give verbal cues and instructions, watch for subject foot placement, offer tactile facilitation, and be on guard for safety concerns. Lack of experience with the NBM® limits the quality of training and assessment accuracy. Before the study, this researcher trained with normal functioning students on the NBM® and not with anyone with a balance deficit.

The student researchers who have limited experience with stroke patients may compromise the possible therapeutic outcomes of the subjects in the study. The students' knowledge base might confine the progress with training of the subjects.

For this study, the 18-session training regimen was an effective time period for functional changes to occur for the participants in the study. Were the
changes temporary or were they more permanent? A follow-up assessment for a set period after the study would give a true indication to see if the participants' changes remained intact. Future studies on the NBM® may wish to include a follow-up assessment to examine and see if the results of the study are permanent or only short term gains.

The six-week study format seemed to be the appropriate time period for functional results. Some studies have suggested four week formats, but this researcher found that significant functional results only began to show up after the four-week time period.

One of the inconsistencies of the study was the warm-up time period for the initial and final NeuroCom® Balance Master assessments. The initial assessment warm-up time period consisted of several sessions of learning and practice. The final assessment was completed with only a limited number of minutes for warm-up or trials. Future studies on the NBM® may wish to include a standardized time period for initial and final evaluation warm-ups. The warm-up time period would depend upon the subject's endurance level. Acclimation and task learning time periods should remain separate from the standardized warm-up periods.

Clinical Implications

The NBM® was an effective tool for increasing balance capabilities. The participant in the study became more aware of the sensing and proprioception qualities of her involved lower extremity. Her increased sensory appreciation transferred into her everyday IADLs. Even though her physical
ability levels had plateaued since her stroke, she made notable functional gains and increased her balance capabilities. A transfer of learning was evident and the participant’s quality of life was heightened. Continued research is needed to confirm the effectiveness of the NBM® with patients who are six months post-stroke.

The NBM® study was an excellent tool for a physical therapy student to learn about post-stroke patients and balance disorders. The hands-on approach to learning gave this researcher experience that will transfer over to clinical applications.

Conclusion

The NBM® system was an effective mechanism for re-training post-stroke patients with balance deficits. The subject adapted quickly to the visual feedback modes and increased her balance ability levels through continued practice. The participant increased her symmetric weight bearing capabilities and began to predominantly focus more of her weight on her involved side. This researcher observed that the efficiency of her gait pattern increased along with her quality of movement. The NeuroCom® Balance Master results, Berg Balance Scale results, and the participant’s personal testimonials all indicated that she increased her functional balance capabilities and overall quality of life.
APPENDIX A
**Human Subjects Review Form**

For new projects or procedural revisions to approved projects involving human subjects.

**Kelly Adams,**
**Joe Brenner, Jim Sillanpaa**

**Institution:** University of North Dakota
**Department:** Physical Therapy

**Research Coordinator:** Meridee Green

**Proposed Project Dates:**

**Project Title:** The Effectiveness of Balance Training Exercises in Post-Stroke Individuals Using the NeuroCom Balance Master System

Funding Agencies (if applicable):

<table>
<thead>
<tr>
<th>Type of Project</th>
<th>□ New Project</th>
<th>□ Continuation</th>
<th>□ Renewal</th>
<th>□ Student Research Project</th>
<th>□ Dissertation or Thesis Research</th>
<th>□ Completed Project</th>
<th>□ Reports (Adverse events, deaths, complications)</th>
<th>□ Amendments or change in project</th>
</tr>
</thead>
</table>

**Dissertation/Thesis Adviser, or Student Advisor:** Meridee Green

**Proposed Project:**

<table>
<thead>
<tr>
<th>□ Involves New Drugs (IND)</th>
<th>□ Involves Non-Approved Use of Drug</th>
<th>□ Involves a Cooperating Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ None of the Above</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If any of your subjects fall in any of the following classifications, please indicate the classification:

<table>
<thead>
<tr>
<th>□ Minors (&lt; 18 Years)</th>
<th>□ Pregnant Women</th>
<th>□ Mentally Disabled</th>
<th>□ Fetuses</th>
<th>□ Mentally Retarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Prisoners</td>
<td>□ Students</td>
<td>□ Abortuses</td>
<td>□ Control Group</td>
<td></td>
</tr>
</tbody>
</table>

If your project involves any human tissue, body fluids, pathological specimens, donated organs, fetal material, or placental materials, check here ______:

X Expedited Review requested under item 3, 8 (number) of HHS Regulations (see attached explanation)

Exempt Review requested under item ______ (number) of HHS Regulations (see attached explanation)

---

**ABSTRACT** (Limit to 200 words or less and include justification or necessity for using human subjects. Attach additional sheet if necessary.)

Balance is an integral part of daily activities. The ability to maintain balance is a result of a highly complex system in the central nervous system. Individuals suffering a stroke often times exhibit deficits in balance due to weakness, sensory loss, impaired righting reflexes, and visuospatial distortion. Force platforms, such as the Balance Master, have become a useful piece of equipment in the field of physical therapy. The technological advancements in force platforms have allowed clinicians to objectively assess and rehabilitate patients with balance impairments. The purpose of this study is to determine if the training protocol on the NeuroCom Balance Master is effective in improving balance for individuals suffering a stroke.
2. PROTOCOL: (Describe procedures to which humans will be subjected.)

Background and Objectives
Balance is critical for optimal function in activities of daily living. Deficits in balance are common among post-stroke patients and can result in decreased functional capability. The Balance Master will be used to assess the balance of post-stroke individuals and help determine areas of limitation in regard to functional activities. The Balance Master system is designed to provide visual feedback to the patients regarding their center of gravity as well as training protocols to enhance equal weight distribution in upright positions, stability, and overall functional balance. The objective of this study is to determine if the training protocol performed on the NeuroCom Balance Master is effective in improving balance for post-stroke individuals in a six-week period.

Subjects
It is anticipated that four post-stroke subjects between the ages of 40-80 years will be recruited to participate in this study. Each participant will work independently with a member of the research team and separate case studies will be conducted on each of the participants. The subjects being recruited will be former physical therapy patients at the Rehab Clinic of Altru Hospital in Grand Forks, North Dakota. All subjects will be screened to ensure they can understand instructions, ambulate independently, able to see the characters on the computer screen, and are at least six months post from their cerebral vascular accident. Subjects with history of musculoskeletal disease, lower extremity orthopedic problems, or neurological or vestibular impairments other than stroke are excluded from the study.

Instrumentation
The NeuroCom Balance Master system will be used for this study. The system operates on two 9-inch by 60-inch forceplates that determine the amount of force being exerted by each foot. The total vertical force information is transferred to the computer system where calculations are performed to determine the test subjects' centers of gravity. The computer screen is equipped with a cursor to provide visual feedback on the location of his/her center of gravity. The computerized measurement and feedback systems are what make the system unique and beneficial to both the subject and researcher. Inter- and intra-reliability were established between researchers using the Balance Master prior to the start of the study. Three individuals were instructed and tested on two assessment exercises by each member of the research team. Two trials were conducted within three days of each other. Validity of the Balance Master system has been established through its ability to generate computerized printouts of objective, quantifiable data. Published literature also supports the scientific efficacy and clinical use of the Balance Master and acknowledges it as a reliable and valid tool for assessing and retraining balance deficits.

Procedure
Each subject will begin the six-week program by performing a warm-up training session. During this session, the subject will familiarize him/herself with the Balance Master machine and how it works. It allows the subjects to learn how to control his/her center of gravity. It also allows the researcher to determine what level of difficulty is appropriate for the subject. The high learning curve associated with this machine requires the subject to perform a trial session before any results are recorded. The warm-up session will last about 15 minutes and will involve recording several movement characteristics while the subject voluntarily moves to various locations indicated by the cursor on the computer screen. The subjects are encouraged to move as quickly and accurately as possible. After matching the level of difficulty with the ability level of the subject, an assessment using the Balance Master will be conducted to identify deficiencies in performance of daily life tasks. The assessment itself will take

--- Continued on separate sheet ---
2. **PROTOCOL:**
   **Procedure (Cont.)**  
   approximately 30 minutes. Areas of deficiency will fluctuate depending on the subject and the severity of the stroke. Upon identifying the deficiencies, a training protocol will be implemented and carried out by the subject three times a week for six weeks. The training sessions will last approximately 30-45 minutes.

   Statistical analysis of the data will consist of descriptive and analytical statistics. The data gathered for each test subject will be analyzed using a related samples t-test. All data and consent forms will be kept in a confidential file by Meridee Green, MPT, in the Department of Physical Therapy at the University of North Dakota. Here they will remain for a two-year period.
3. **BENEFITS:** (Describe the benefits to the individual or society.)

The goal of the individuals participating in the study, who are affected with balance deficits secondary to a stroke, is to increase their functional balance capabilities and indirectly improve their postural alignment through improved strategies for sensory reeducation. Patients will gain confidence in their balance abilities while performing activities of daily living. Expanding their activity levels will enable patients to improve their quality of living. Data results from participating subjects in the Balance Master study would help educate individuals with balance deficits and health care providers who seek to improve treatment effects. Verification of efficient treatment effects on the Balance Master could decrease the time required for patient rehabilitation and act as a cost saving measure for insurance providers and their members. Health care providers, insurance providers, and patients with balance deficits will all benefit from this study through an increased knowledge and understanding of balance.

4. **RISKS:** (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

The risks to subjects participating in this study are minimal, but those that exist will be controlled by the use of a spotter throughout the training program. The assessment portion of the Balance Master testing consists of three levels of difficulty that allow the researcher to establish a baseline level of function of the participant. The components of each level consist of movement patterns that are performed in everyday life, such as standing weight bearing, weight shifting, sit-to-stand movements, and walking. Training protocols will be designed by the researcher and will consist of similar movement patterns of varying degrees of difficulty. The conditions under which the testing will be performed occur in everyday life. Because of this, the risk to participants is decreased. In the event the subject should lose his/her balance, the researcher will be standing in close proximity to guard against a fall. In addition, each subject will be wearing a waist gait belt to provide the researcher a handhold in the event a subject should lose his/her balance. Subjects will be given a warm-up period on the Balance Master to familiarize them with the equipment before any assessment or training is initiated. Verbal and visual instructions will be provided in addition to a demonstration prior to any testing. The subjects are voluntary participants who will be chosen based on their health status and willingness to participate as indicated by a signed consent form. Participants dignity, self respect, and privacy will be protected in the following ways: 1) all testing will be done in a private, controlled environment, 2) subjects will be scheduled and tested independently, 3) giving subjects complete instructions regarding their role in the research project, 4) subjects will be informed that this is a voluntary exercise and they may withdraw at any time from the testing without fear of retribution or prejudice.
5. **CONSENT FORM**: A copy of the CONSENT FORM to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no CONSENT FORM is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe who will be obtaining consent, where signed consent forms will be kept, and for what period of time.

All consent forms and data reports will be kept in the Department of Physical Therapy, Room 1518, of the UND School of Medicine and Health Sciences. Data and information obtained from the study will be kept in Room 1518 for two years following the completion of this study. Please see attached consent form.

6. For FULL IRB REVIEW, forward the signed original of this completed form and, copies as outlined in the attached instructions to:

For EXEMPT or EXPEDITED REVIEW forward a signed original and a copy of the consent form, questionnaires, etc., and any supporting documentation to:

Eleanor Tveit, IRB Secretary  
1000 South Columbia Road  
Grand Forks, ND 58201  
701-780-6161

The policies and procedures on Use of Human Subjects in Medical Park Institutions apply to all activities involving use of Human Subjects performed by personnel conducting such activities. No activities are to be initiated without prior review and approval of the Medical Park Institutional Review Board.

Signatures:

Principal Investigator: [Signature]  
Date: 7/14/98

Project Director: [Signature]  
Date: 7/15/98

Student Advisor (where applicable): [Signature]  
Date: 7/15/98
Information and Consent Form

Title: The Effectiveness of Balance Training Exercises in Post Stroke Individuals Using the NeuroCom Balance Master System.

You are invited to participate in a study conducted by Kelly Adams, Joe Brenner, and Jim Sillanpaa, physical therapy students at the University of North Dakota. The purpose of this study is to determine if the balance training program on the NeuroCom® Balance Master is effective in improving balance for individuals suffering a stroke. Only subjects who have suffered a stroke and are otherwise healthy will be asked to participate in the study.

The NeuroCom® Balance Master is a machine commonly used in the physical therapy field and is a clinically accepted assessment and training tool for balance training.

You will be asked to report to the Physical Therapy Department at the Altru Health Institute Rehabilitation Hospital where a general assessment will be conducted by a member of the research team. We ask that you wear loose, comfortable clothing, and flat walking shoes when participating in this study. It is important you wear the same pair of shoes throughout the study. The general assessment will include a training session to familiarize yourself with the Balance Master equipment and will take approximately 15 minutes to complete. Following this, a trial test will be conducted and you will be asked to perform a series of tests on the Balance Master to evaluate what type of exercises is deemed most appropriate. This portion of the assessment will last approximately 30 minutes.

Your participation in the this study will involve performing a 30 minute exercise program on the NeuroCom® Balance Master three days a week for 6 weeks. At the end of the six weeks you will be re-tested on the Balance Master to determine the effects of the balance program.

Although the process of physical performance testing may involve some degree of risk, the researchers of this study feel the risk of injury or discomfort is minimal. Any risks will be lessened by providing an assistant to safeguard you from possible loss of balance.

The results of this study will be confidential and your data will be identified by a
number known only by your investigators. If you decide to participate, you are free to discontinue participation at any time. You may stop the experiment at any time if you are experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to your health. Your decision not to participate in this study will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. In addition, “I understand that my medical records and study records are confidential. However, representatives of the study sponsor, the U.S. Food and Drug Administration (FDA), or the Institutional Review Board may need to inspect my medical records and/or study records. By signing this consent, I am allowing this inspection.”

The investigators involved are available to answer any questions you have concerning this study. If you have any questions about your rights as a research subject contact the IRB chairperson at (701) 780-6161. Questions may also be answered by calling Kelly at (701) 780-8817, Joe at (701) 777-9188, or Jim at (701) 775-4103. A copy of this consent form is available to all participants in the study.

In the event that this research activity results in physical injury, medical treatment, including first-aid, emergency treatment and follow-up care as it is to members of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payor, if any.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all the above and willingly agree to participate in this study explained to me by Kelly Adams, Joe Brenner, and Jim Sillanpaa.

<table>
<thead>
<tr>
<th>Participant’s Signature</th>
<th>Date</th>
</tr>
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<tbody>
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</table>

<table>
<thead>
<tr>
<th>Witness(not the scientist)</th>
<th>Date</th>
</tr>
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<tbody>
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<td></td>
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</table>
Institutional Review Board
Research Project Action Report

Date: August 12, 1998
IRB#: PT-008

Principal Investigator: Kelly Adams, Joe Brenner, Jim Sillanpaa
Department: Physical Therapy

Address to which notice of approval should be sent: ___________________________
Research Coordinator: Meridee Green
Phone #: 777-2831

Project Title: The Effectiveness of Balance Training Exercises in Post-Stroke Individuals
Using the NeuroCom Balance Master System

The above referenced project protocol and informed consent was reviewed by the Altru Health System Institutional Review Board on ____________ and the following action was taken:

☐ Project approved. Next Scheduled review is on ________________________
   If no date is given, then review will be required in 12 months. (See REMARKS SECTION for any special condition.)

☒ Project approved. EXPEDITED REVIEW NO. 3, 8
   Next scheduled review is on ________________________

☐ Project approved. EXEMPT CATEGORY NO. __________________________
   No periodic review scheduled unless so stated in REMARKS SECTION.

☐ Project approval deferred. (See REMARKS SECTION for further information.)

☐ Project denied. (See REMARKS SECTION for further information.)

☐ Amendment approved

☐ Administrative change approved

☐ Protocol revision approved

☐ Revised consent form approved

☐ Adverse event reviewed - Date of event ______________________

☐ Other ____________________________________

REMARKS:

Any changes in protocol, adverse occurrences or deaths in the course of the research project must be reported immediately to the IRB chairperson or the IRB office (780-6161).

Signature of Chairperson or Designated IRB Member
Altru Health System Institutional Review Board

12th of August 1998

If the proposed project is to be part of a research activity funded by a federal agency, a special assurance statement or a completed 596 Form may be required. Contact IRB office to obtain the required documents.
APPENDIX B
BALANCE SCALE

Name__________________________ Date_________________
Location_________________________ Rater_________________

ITEM DESCRIPTION  SCORE (0-4)

1. Sitting to standing
2. Standing unsupported
3. Sitting unsupported
4. Standing to sitting
5. Transfers
6. Standing with eyes closed
7. Standing with feet together
8. Reaching forward with outstretched arm
9. Retrieving object from floor
10. Turning to look behind
11. Turning to 360 degrees
12. Placing alternate foot on stool
13. Standing with one foot in front
14. Standing on one foot

TOTAL ______

GENERAL INSTRUCTIONS

Please demonstrate each task and/or give instruction as written. When scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for specific time. Progressively more points are deducted if the time or distance requirements are not met, if the subject’s performance warrants supervision, or if the subject touches an external support or receives assistance from the examiner. Subjects should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for testing are a stopwatch or watch with a second hand, and a ruler or other indicator of 2.5 and 10 inches. Chairs used during testing should be of reasonable height. Either a step or a stool (of average step height) may be used for item #12.
1. SITTING TO STANDING
INSTRUCTIONS: Please stand up. Try not to use your hands for support.
( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or to stabilize
( ) 0 needs moderate or maximal assist to stand

2. STANDING UNSUPPORTED
INSTRUCTIONS: Please stand for two minutes without holding.
( ) 4 able to stand safely 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

3. SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
( ) 4 able to sit safely and securely 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

4. STANDING TO SITTING
INSTRUCTIONS: Please sit down.
( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assistance to sit

5. TRANSFERS
INSTRUCTIONS: Arrange chair(s) for a pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.
( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cueing and/or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

6. STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

7. STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand for 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds

8. REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the finger reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
( ) 4 can reach forward confidently 25 cm (10 inches)
( ) 3 can reach forward 12 cm safely (5 inches)
( ) 2 can reach forward 5 cm safely (2 inches)
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support
9. **PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION**

**INSTRUCTIONS:** Pick up the shoe/slipper which is placed in front of your foot.

- ( ) 4 able to pick up slipper safely and easily
- ( ) 3 able to pick up slipper but needs supervision
- ( ) 2 unable to pick up but reaches 2-5 cm (1-2 inches) from slipper and keeps balance independently
- ( ) 1 unable to pick up and needs supervision while trying
- ( ) 0 unable to try/needs assist to keep from losing balance or falling

10. **TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING**

**INSTRUCTIONS:** Turn to look directly behind you over toward left shoulder. Repeat to the right. Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.

- ( ) 4 looks behind from both sides and weight shifts well
- ( ) 3 looks behind one side only other side shows less weight shift
- ( ) 2 turns sideways only but maintains balance
- ( ) 1 needs supervision when turning
- ( ) 0 needs assist to keep from losing balance or falling

11. **TURN 360 DEGREES**

**INSTRUCTIONS:** Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.

- ( ) 4 able to turn 360 degrees safely in 4 seconds or less
- ( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
- ( ) 2 able to turn 360 degrees safely but slowly
- ( ) 1 needs close supervision or verbal cues
- ( ) 0 needs assistance while turning

12. **PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED**

**INSTRUCTIONS:** Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.

- ( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
- ( ) 3 able to stand independently and complete 8 steps > 20 seconds
- ( ) 2 able to complete 4 steps without aid with supervision
- ( ) 1 able to complete > 2 steps needs minimal assist
- ( ) 0 needs assistance to keep from falling/unable to try

13. **STANDING UNSUPPORTED ONE FOOT IN FRONT**

**INSTRUCTIONS: (DEMONSTRATE TO SUBJECT)** Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width

- ( ) 4 able to place foot tandem independently and hold 30 seconds
- ( ) 3 able to place foot ahead of other independently and hold 30 seconds
- ( ) 2 able to take small step independently and hold 30 seconds
- ( ) 1 needs help to step but can hold 15 seconds
- ( ) 0 loses balance while stepping or standing

14. **STANDING ON ONE LEG**

**INSTRUCTIONS:** Stand on one leg as long as you can without holding.

- ( ) 4 able to lift leg independently and hold > 10 seconds
- ( ) 3 able to lift leg independently and hold 5-10 seconds
- ( ) 2 able to lift leg independently and hold = or > 3 seconds
- ( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently
- ( ) 0 unable to try or needs assist to prevent fall

( ) TOTAL SCORE (Maximum = 56)
APPENDIX C
ASSESSMENT PROTOCOL

Sit-to-Stand

The subject assumes a comfortable seated position on wooden boxes with the feet placed on designated areas of the force plate. The subject is then asked to rise on command to a standing position as quickly and as comfortably as possible and to maintain the erect position for five seconds. The sit-to-stand maneuver is repeated three times and the results are averaged to obtain the following performance measures:

1) **Weight Transfer** - the time in seconds required to voluntarily shift the center of gravity forward beginning in the seated position and ending with full weight-bearing on the feet.

2) **Rising Index** - documents the maximum vertical force exerted by the legs during the rise phase. This force is expressed as a percentage of the patient's body weight.

3) **COG Sway Velocity** - documents control over the base of support during the rising phase of the maneuver and for five seconds thereafter. Sway is expressed as mean velocity of COG sway in degrees per second.

4) **Left/Right Weight Symmetry** - documents deficiencies in the percentage of body weight borne by the left and right legs during active rising phase.

**Walk and Tandem Walk**

The subject is instructed to stand at one end of the force plate and upon command initiates gait, walking as quickly and comfortably as possible to the
other end, stops and holds a static upright posture until the test terminates. The test is repeated three times with the results averaged to obtain the following values:

1) **Step Width** - lateral distance between successive steps measured in centimeters.

2) **Step Length** - longitudinal distance between successive steps measured in centimeters.

3) **Speed** - forward progression measured in meters/sec.

4) **End Sway** - mean velocity in degrees per second of antero-posterior component of COG sway after the subject terminates walking.

**Rhythmic Weight Shift**

The subject is instructed to stand in place with feet positioned on a designated area of the force plate while viewing the COG position cursor on the computer screen. The subject is then instructed to move rhythmically such that the COG cursor moves back and forth between two boundaries spaced in opposite directions from center at 50% of the distance to the LOS perimeter. The required rhythm of the back and forth movement is demonstrated by a pacing target. The task is repeated with rhythmic movements between antero-posterior and lateral boundaries. To accommodate different functional levels, the test includes three different pacing speeds. The following parameters were calculated from the COG cursor:
1) **On-Axis Velocity** - quantifies the average velocity of the rhythmic movement in degrees per second along the specified movement direction.

2) **Directional Control** - quantifies the straightness of the movement trajectory to the target. The average velocity of the on-axis component of the movement trajectory is expressed as a percentage of the total (on-axis and off-axis velocity) movements.

**Limits of Stability Test**

The subject is instructed to stand and view the computer screen on which a cursor represents their COG position relative to their base of support. The screen shows eight targets spaced at 45° intervals around the center target to form an oval. The center target represents the COG position of the subject during static standing. The eight peripheral targets represent 100% of the distance from the center position to the theoretical limits of stability. The subjects are instructed to stand as still as possible while maintaining the COG cursor within the highlighted center target. The subjects are then instructed to move as quickly and accurately as possible to the highlighted peripheral target, hold the position until the end of the trial, and then return the cursor to the center target. To minimize anticipation, highlighting of the designated target is delayed randomly relative to the start of each trial. The sequence is repeated until each subject can move successfully to each of the eight LOS targets, beginning with the forward target and progressing in a clockwise direction.
During movement to each of the eight targets, COG is recorded based on the following parameters:

1) **Reaction Time (RT)** - time in seconds between highlighting of the LOS target and the first change in COG position significantly greater than observed during a period of time prior to the target highlighting.

2) **Mean Velocity (MVL)** - the mean COG velocity over the time interval beginning with the point at which the subject moves 5% of the distance to the target and ending with the point at which the subject moves to within 95% of endpoint excursion. Mean COG velocity is expressed in degrees per second.

3) **Endpoint Excursion (EPE)** - the distance the COG is displaced toward the target during the subject's primary movement. This movement segment ends when the COG movement first ceases progression toward the target. Endpoint excursion is expressed as a percentage of the distance to the target. Therefore, a subject whose initial movement ends precisely at the target has an endpoint excursion of 100%.

4) **Maximum Excursion (MXE)** - the maximum distance the COG is displaced toward the target over the entire duration of the trial. MXE is also expressed as a percentage of the distance of the target.

5) **Directional Control (DCL)** - this parameter quantifies the extent to which the subject moves along a straight-line path from the center target to each LOS target. The result is a percentage value between 100%, representing a
perfect straight-line path toward the target, and the minimum value of 0%, representing a path deviating substantially from the straight-line.

**Weight Bearing Test**

The subject is instructed to maintain an erect, centered stance with feet placed on the designated areas of the force plate. The following score was recorded:

1) **Percentage Weight Bearing** - the fraction of the total body weight placed on each foot and expressed as a percentage.

**Step and Quick Turn Test**

This test challenges the balance and stepping for subjects during walking and turning. The assessment encompasses coordination of body movement and head rotation, which produces changing visual and vestibular inputs. The test quantifies two movement characteristics as the patient takes two forward steps, quickly turns 180°, and steps back to the original location. The test measures turn-time and turn-sway velocity as the patient turns toward the end forceplate.
APPENDIX D
1) Do you need to use assistive devices for ambulation or activities of daily living?

2) What activities or movements do you find most difficult to perform?

3) Are you currently on any medications?

4) How much alcohol do you consume per day, week, or month?

5) Do you have any numbness or sensory losses due to your stroke involvement?

6) Do you have any inner ear problems with associated dizziness or lightheadedness?

7) Have you fallen at any time in the week, month, or year? How often?

8) Are you currently involved with a regular exercise program?

9) When was the last time you were involved with therapy?

10) Do you have any health problems that may preclude you from doing this study?
Name: GREEN, THREE
ID: ATID00137
DOB: 5/9/1928
Height: 5'5"

File: HBM137.QBM
Diagnosis: LEFT HEMI
Operator: Not Specified
Test Date: 9/2/1998

Referral Source:
DOB: 5/9/1928
Height: 5'5"
Comments:

SUMMARY REPORT (LEVEL ONE ASSESSMENT)

Weight Bearing
(Left Side)

Sit To Stand
(Rising Index)

Limits Of Stability
(Movement Velocity)

Walk (Level One)
(Step Width)

Limits Of Stability
(Endpoint & Maximum Excursions)

Walk (Level One)
(Speed)

Evaluation Date: 9/2/1998
Patient Name: GREEN, THREE
Age: 70
Diagnosis: LEFT HEMI

ACTIVITY OF DAILY LIVING EVALUATION

WALK---The following attributes were in the abnormal range:
(1) The width of the step;
(2) The speed of the step;

STEP/QUICK TURN---The following attributes were in the abnormal range:
(1) The time required to turn;
(2) The amount of sway during the turn;

BALANCE COMPONENTS EVALUATION

WEIGHT BEARING---All attributes were in the normal range.

LIMITS OF STABILITY---The following attributes were in the abnormal range:
(1) The time required to react to the stimuli;

RHYTHMIC WEIGHT SHIFT---The following attributes were in the abnormal range:
(1) The ability to coordinate movement.
WALK TEST (Level One)

Data Range Note:
NeuroCom Data Range: 70–79

Name: GREEN, THREE  Diagnosis: LEFT HEMI
ID: ATID00137  Operator: Not,Specified
DOB: 5/9/1928  Referral Source: 
Height: 5'5"  Comments: 

STEP/QUICK TURN TEST

Data Range Note: NeuroCom Data Range: 70–79

Post Test Comments:
WEIGHT BEARING TEST

% Body WT

% Body WT

0° 52 48

Data Range Note:
NeuroCom Data Range: 70–79

Post Test Comments:
RHYTHMIC WEIGHT SHIFT TEST

Left/Right

Front/Back

SLOW (3 sec per transition)

deg/sec
On-Axis Velocity

%  
Directional Control

Data Range Note: NeuroCom Data Range: 70–79

Post Test Comments:

**Name:** GREEN, THREE  
**ID:** ATID00137  
**DOB:** 5/9/1928  
**Referral Source:** Not Specified

**Diagnosis:** LEFT HEMI  
**Operator:** Not Specified  
**File:** HBM137.QBM  
**Test Date:** 9/2/1998  
**Test Time:** 10:53:25 AM

### LIMITS OF STABILITY TEST

<table>
<thead>
<tr>
<th>Transition</th>
<th>RT (sec)</th>
<th>MVL (deg/sec)</th>
<th>EPE (%)</th>
<th>MXE (%)</th>
<th>DCL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (F)</td>
<td>1.09</td>
<td>3.0</td>
<td>71</td>
<td>73</td>
<td>79</td>
</tr>
<tr>
<td>2 (RF)</td>
<td>1.60</td>
<td>2.5</td>
<td>82</td>
<td>101</td>
<td>83</td>
</tr>
<tr>
<td>3 (R)</td>
<td>1.92</td>
<td>3.2</td>
<td>64</td>
<td>86</td>
<td>76</td>
</tr>
<tr>
<td>4 (RB)</td>
<td>1.32</td>
<td>2.5</td>
<td>68</td>
<td>89</td>
<td>77</td>
</tr>
<tr>
<td>5 (B)</td>
<td>1.08</td>
<td>1.7</td>
<td>65</td>
<td>74</td>
<td>84</td>
</tr>
<tr>
<td>6 (LB)</td>
<td>2.41</td>
<td>2.4</td>
<td>60</td>
<td>97</td>
<td>74</td>
</tr>
<tr>
<td>7 (L)</td>
<td>1.58</td>
<td>2.7</td>
<td>80</td>
<td>90</td>
<td>91</td>
</tr>
<tr>
<td>8 (LF)</td>
<td>0.62</td>
<td>2.5</td>
<td>66</td>
<td>79</td>
<td>77</td>
</tr>
</tbody>
</table>

100% LOS

### Data Range Note:
NeuroCom Data Range: 70–79

Post Test Comments:
Name: GREEN, THREE
Diagnosis: LEFT HEMI
ID: ATID00137
DOB: 5/9/1928
Height: 5'5"
Referral Source:

**SUMMARY REPORT (LEVEL ONE ASSESSMENT)**

**Weight Bearing**

(Left Side)

<table>
<thead>
<tr>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
</tr>
<tr>
<td>80</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>0 deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

**Modified CTSIB**

(deg/sec) (Mean COG Sway Velocity)

<table>
<thead>
<tr>
<th>(deg/sec)</th>
<th>Fi-EO</th>
<th>Fi-EC</th>
<th>Fo-EO</th>
<th>Fo-EC</th>
<th>Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>3.2</td>
<td>2.4</td>
<td>1.6</td>
<td>0.8</td>
<td>NS</td>
</tr>
</tbody>
</table>

**Limits Of Stability**

(deg/sec) (Movement Velocity)

<table>
<thead>
<tr>
<th>(deg/sec)</th>
<th>Forward</th>
<th>Back</th>
<th>Right</th>
<th>Left</th>
<th>Comp</th>
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</thead>
<tbody>
<tr>
<td>5.8</td>
<td>2.9</td>
<td>6.5</td>
<td>3.7</td>
<td>4.7</td>
<td></td>
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</tbody>
</table>

**Walk (Level One)**

(cm)

<table>
<thead>
<tr>
<th>(cm)</th>
</tr>
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<tbody>
<tr>
<td>50</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

| 24.7     |

**Rhythmic Weight Shift (Slow)**

(deg/sec) (On-Axis Velocity)

<table>
<thead>
<tr>
<th>(deg/sec)</th>
<th>L/R</th>
<th>F/B</th>
<th>Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.7</td>
<td>1.8</td>
<td>2.8</td>
<td></td>
</tr>
</tbody>
</table>

**Limits Of Stability**

(%) (Endpoint & Maximum Excursions)

<table>
<thead>
<tr>
<th>(%)</th>
<th>Forward</th>
<th>Back</th>
<th>Right</th>
<th>Left</th>
<th>Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td>109±10</td>
<td>54</td>
<td>73</td>
<td>54</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>83</td>
<td>83</td>
<td>83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>100</td>
<td>85</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>54</td>
<td>73</td>
<td>54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Sit To Stand**

(Rising Index)

Mean

<table>
<thead>
<tr>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
</tr>
<tr>
<td>80</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

**Walk (Level One)**

(cm/sec)

<table>
<thead>
<tr>
<th>(cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
</tr>
<tr>
<td>80</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

Mean

---

Evaluation Date: 10/16/1998
Patient Name: GREEN, THREE
Age: 70
Diagnosis: LEFT HEMI

ACTIVITY OF DAILY LIVING EVALUATION

WALK---The following attributes were in the abnormal range:
(1) The width of the step;

STEP/QUICK TURN---All attributes were in the normal range.

BALANCE COMPONENTS EVALUATION

WEIGHT BEARING---The following attributes were in the abnormal range:
(1) Weight bearings were not equally distributed.

LIMITS OF STABILITY---All attributes were in the normal range.

RHYTHMIC WEIGHT SHIFT---All attributes were in the normal range.
WALK TEST (Level One)

Trial 1

Trial 2

Trial 3

Data Range Note:

NeuroCom Data Range: 70–79

Post Test Comments:

final

Name: GREEN, THREE  
ID: ATID00137  
DOB: 5/9/1928  
Height: 5'5"  
Diagnosis: LEFT HEMI  
Operator: Not Specified  
Referral Source:  
Comments:  
File: HBM137.QBM  
Test Date: 10/16/1998  
Test Time: 12:42:05 PM

**STEP/QUICK TURN TEST**

**Turn Time**

<table>
<thead>
<tr>
<th>Turn Time</th>
<th>% Difference</th>
<th>sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2</td>
<td>41% (51%)</td>
<td>3.2</td>
</tr>
<tr>
<td>2.4</td>
<td></td>
<td>2.4</td>
</tr>
<tr>
<td>1.6</td>
<td></td>
<td>1.6</td>
</tr>
<tr>
<td>0.8</td>
<td></td>
<td>0.8</td>
</tr>
<tr>
<td>0.0</td>
<td>Mean</td>
<td></td>
</tr>
</tbody>
</table>

**Turn Sway**

<table>
<thead>
<tr>
<th>Turn Sway</th>
<th>% Difference</th>
<th>deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.5</td>
<td>31% (44%)</td>
<td>16.5</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>29.1</td>
<td>Mean</td>
<td>29.1</td>
</tr>
</tbody>
</table>

**Data Range Note:**

NeuroCom Data Range: 70–79

Post Test Comments:

final
final
WEIGHT BEARING TEST

% Body WT

LEFT SIDE

RIGHT SIDE

Percentage Weight Bearing:

<table>
<thead>
<tr>
<th>Angle</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>62</td>
<td>38</td>
</tr>
</tbody>
</table>

Data Range Note:
NeuroCom Data Range: 70–79

Post Test Comments:
final
Name: GREEN, THREE  
ID: ATID00137  
DOB: 5/9/1928  
Height: 5'5"  

Diagnosis: LEFT HEMI  
Operator: Not,Specified  
Referral Source:  
Comments:  

File: HBM137.QBM  
Test Date: 10/16/1998  
Test Time: 12:16:07 PM  

RHYTHMIC WEIGHT SHIFT TEST

Left/Right

SLOW (3 sec per transition)

Front/Back

SLOW (3 sec per transition)

deg/sec  On-Axis Velocity

<table>
<thead>
<tr>
<th></th>
<th>L/R</th>
<th>F/B</th>
<th>Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.7</td>
<td>1.8</td>
<td>2.8</td>
<td></td>
</tr>
</tbody>
</table>

%  Directional Control

<table>
<thead>
<tr>
<th></th>
<th>L/R</th>
<th>F/B</th>
<th>Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>65</td>
<td>72</td>
<td></td>
</tr>
</tbody>
</table>

Data Range Note: NeuroCom Data Range: 70–79

Post Test Comments:

final  
final

**Name:** GREEN, THREE  
**ID:** ATID00137  
**DOB:** 5/9/1928  
**Height:** 5'5"  
**Referral Source:**  

**Diagnosis:** LEFT HEMI  
**Operator:** Not Specified  
**File:** HBM137.QBM  
**Test Date:** 10/16/1998  
**Test Time:** 12:16:07 PM

### LIMITS OF STABILITY TEST

<table>
<thead>
<tr>
<th>Transition</th>
<th>RT (sec)</th>
<th>MVL (deg/sec)</th>
<th>EPE (%)</th>
<th>MXE (%)</th>
<th>DCL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (F)</td>
<td>1.70</td>
<td>5.5</td>
<td>117</td>
<td>117</td>
<td>78</td>
</tr>
<tr>
<td>2 (RF)</td>
<td>0.97</td>
<td>7.3</td>
<td>99</td>
<td>104</td>
<td>88</td>
</tr>
<tr>
<td>3 (R)</td>
<td>0.69</td>
<td>5.9</td>
<td>85</td>
<td>103</td>
<td>88</td>
</tr>
<tr>
<td>4 (RB)</td>
<td>0.31</td>
<td>5.6</td>
<td>57</td>
<td>77</td>
<td>51</td>
</tr>
<tr>
<td>5 (B)</td>
<td>0.84</td>
<td>3.4</td>
<td>69</td>
<td>102</td>
<td>78</td>
</tr>
<tr>
<td>6 (LB)</td>
<td>0.43</td>
<td>3.0</td>
<td>67</td>
<td>79</td>
<td>65</td>
</tr>
<tr>
<td>7 (L)</td>
<td>0.81</td>
<td>3.8</td>
<td>87</td>
<td>101</td>
<td>89</td>
</tr>
<tr>
<td>8 (LF)</td>
<td>0.68</td>
<td>4.1</td>
<td>99</td>
<td>104</td>
<td>91</td>
</tr>
</tbody>
</table>

**100% LOS**

**Reaction Time (RT)**

**Movement Velocity (MVL)**

**Endpoint & Max Excursions (EPE & MXE)**

**Directional Control (DCL)**

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REFERENCES


