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

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

by

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An Independent Study Submitted to the Graduate Faculty of the
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for the degree of
Master of Physical Therapy

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This Independent Study, submitted by James D. Sillanpaa 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.

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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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ABSTRACT

A case study was completed on a 51-year-old female who suffered a stroke in 1996 and exhibited left-sided hemiplegia. The case study examined the effects of a six-week balance training program on an individual at least six months post stroke using a force platform system called the NeuroCom Balance Master®. Individuals suffering a stroke often times exhibit deficits in balance due to weakness, sensory loss, impaired righting reflexes, and visuospatial distortion.

The goal of the training program was to improve the subject’s balance deficits by focusing on areas of symmetrical weight bearing, weight shifting, and coordination of movement. Initial and final assessments were conducted using the NeuroCom Balance Master® and the Tinetti Assessment Tool to assess any change in the subject’s balance.

At the conclusion of the six-week training program, the subject improved in areas of static and dynamic balance and the ability to weight shift in the anterior direction and to her hemiparetic left side. The subject’s gait pattern also improved in terms of step length, step width, and step speed. Therefore, the results of this study seem to indicate that post stroke individuals of at least six months may have the ability to improve their overall balance with continued postural training. However, further research is necessary to determine the...
functional outcomes of postural feedback training and the reasons for improvement seen on the NeuroCom Balance Master.®
CHAPTER I
INTRODUCTION/LITERATURE REVIEW

Stroke is the third leading cause of death and the number one disability for men and women of all ages, classes, and ethnic origins in the United States.\textsuperscript{1-3} Over 500,000 new strokes occur each year resulting in 150,000 deaths. The actual number of strokes appears to be increasing each year. However, improvements in medical care have resulted in a decline in the stroke death rate over the past 20 years. Stroke frequently increases dramatically with increasing age, doubling with every decade after 55 years of age.\textsuperscript{3} Nearly three million Americans have some degree of disability from strokes, and the estimated annual economic burden is more than $30 billion.

What is a stroke? A stroke (cerebral vascular accident, or CVA) occurs when there is a decreased amount of blood flow in the brain tissue (ischemia) or when there is cellular injury secondary to the rupture of a blood vessel in the brain (hemorrhage).\textsuperscript{2} Ischemic strokes can be divided into either thrombotic or embolic types depending on the pathophysiologic mechanism involved. Thrombotic strokes, which are more common, develop in narrowed cerebral blood vessels and embolic strokes are caused by a migration of material to the central nervous system blood vessels causing vascular occlusion and ischemia.
of brain tissue. Thrombotic strokes are more commonly associated with modifiable risk factors like high blood pressure, diabetes mellitus, and high cholesterol, and tend to have a more indolent onset. Embolic strokes are commonly associated with cardiac disease, or myocardial infarctions, and tend to occur more suddenly.

Strokes occurring secondary to intracranial hemorrhage are often more dramatic in nature. Hemorrhagic strokes present with sudden neurologic deficits and can also cause vomiting, elevated blood pressure, and decreased consciousness. Fluctuations in symptoms are rarely seen with hemorrhagic strokes, and the patients are often times critically ill.

Following a stroke, a variety of deficits are possible, including impairments of sensory, motor, mental, perceptual, and language functions.\textsuperscript{1-3} Stroke patients typically exhibit numerous deficits in motor control.\textsuperscript{1} Motor deficits are characterized by weakness (hemiparesis) or paralysis (hemiplegia) on the side of the body opposite of the brain lesion. During the early stages of a stroke, there may be a decrease or absence of muscle tone. The absence of muscle tone is referred to as flaccidity. As recovery begins, tone increases and the resistance of the muscles, called spasticity, causes stiff awkward movements. Primitive movement patterns called synergies are associated with the presence of spasticity. Abnormal synergy patterns of the extremities may be elicited reflexively or voluntarily. There are two synergy patterns for the upper and lower extremity: a flexion synergy and an extension synergy. The synergy pattern
typically seen in stroke patients is an upper extremity flexion pattern and a lower extremity extension pattern. The upper extremity flexion pattern consists of scapular retraction/elevation, shoulder abduction and external rotation, elbow flexion, forearm supination, and wrist and finger flexion. The lower extension synergy pattern includes hip extension, adduction, and internal rotation; knee extension; ankle plantarflexion/inversion; and toe plantarflexion. As the patient gains more voluntary control of the movement synergies, spasticity may increase and become more severe. Movement patterns not associated with the synergy pattern are more difficult to perform, but as spasticity declines these movements become less difficult to perform.

Reflexes can also change according to the stage of recovery. Initially, the stroke victim may not exhibit reflexes. As spasticity and synergies develop in the middle stages of recovery, excessive reflexes (hyperreflexia) emerge. Primitive reflexes or tonic reflex patterns may also appear following a stroke.

Sensation is another area frequently impaired on the hemiparetic side of a stroke patient. The extent of impairment is again dependent upon location and severity of the lesion. Proprioceptive losses, along with the loss of superficial touch and pain and temperature sensation, can lead to further dysfunction.

A term commonly confused with sensation is perception. Perception is the ability of an individual to select, integrate, and interpret stimuli from the body and the surrounding environment. Stroke patients with perceptual deficits often time have difficulty performing simple tasks, initiating and completing tasks,
switching tasks, and visually locating or identifying objects necessary to complete a task. Stroke patients with left hemiplegia have been known to perform more poorly on measures of visual-perceptual dysfunction than patients with right hemiplegia. Perceptual disorders are generally divided into four categories: disorders of body scheme or body image, spatial relations syndrome, agnosia, and apraxia.

Disorders in body scheme and body image may result in a stroke patient being unaware of his/her hemiplegic side (unilateral neglect), unaware of body parts and their relationship to one another and to the environment (somatagnosia), and unaware of the severity of one’s own paralysis (anosognosia). A stroke patient may also be unable to discriminate between the left and right sides of one’s own body (right-left discrimination) and between individual fingers (finger agnosia).

Spatial relations syndrome is a type of perceptual deficit that may also affect stroke patients. Spatial relation deficits cause the patient to have difficulty perceiving relationships between objects in space or the relationship between themselves and two or more objects. Deficits in visuospatial relations may also include depth and distance perception and vertical disorientation.

Agnosias are the third category of perceptual deficits and are referred to as a patient’s inability to recognize familiar objects using one or more sensory modalities. The most common form of agnosia is visual object agnosia. Visual
object agnosia is the inability to recognize people, objects, or possessions despite the normal function of the eyes and optic tracts.

The last category of perceptual deficits is a disorder of voluntary learned movement called apraxia.\textsuperscript{1} Apraxia is the inability to perform purposeful movements. A stroke patient suffering from apraxia may not be able to complete a movement or task despite understanding instructions.

Visual disturbances also occur among stroke victims and should not be confused with the visual perceptual disturbances stated above.\textsuperscript{1} Visual field deficits are one of the most common forms of sensory loss affecting the hemiplegic patient.\textsuperscript{4} The deficit is referred to as homonymous hemianopsia because it produces a loss of the outer visual field in one eye and the inner half of the visual field in the other eye. The patient is usually unaware of the condition and it can inhibit the performance of many daily activities.

Diplopia, or double vision, is another visual disturbance that occurs among stroke victims.\textsuperscript{1} The deficit is usually attributed to the decreased motion of one eye. Range of motion exercises for the eye muscles is one way to treat the condition. However, if the condition continues, an optometrist may prescribe prisms.

Due to the variety of deficits associated with a cerebral vascular accident, stroke rehabilitation can be very challenging for both the patient and the physical therapist. A principal construct within physical therapy is the reestablishment of balance function of patients following a stroke.\textsuperscript{5} Balance itself 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 (CNS). The basic task of balance is to position the body’s center of gravity (COG) over some portion of the support base.\textsuperscript{1,6} The support base can be the feet while standing upright or the buttocks while seated.

The CNS organizes information from sensory receptors throughout the body via a balance control system. Sensory elements help individuals determine their relationship to the support surface, surrounding environment, and gravity.\textsuperscript{1} Sensory interaction enables the CNS to be flexible and maintain balance through different sensory inputs.\textsuperscript{1}

The different sensory elements that provide the CNS with specific information about the position and motion of the body are the visual, somatosensory, and vestibular systems.\textsuperscript{1,6,7} The visual system reports information regarding the relative orientation of the body parts with reference to the environment.\textsuperscript{1,7} Visual inputs are important to maintaining postural control and balance, but they are not necessary.\textsuperscript{7} This is evident by being able to maintain one’s balance in a dark room. Somatosensory inputs provide the CNS with information regarding the orientation of the body with the support surface. The inputs include muscle and joint proprioceptors, cutaneous, and pressure receptors. The somatosensory inputs also provide information regarding the relationship of body parts to one another. The vestibular system detects the relationship of the head relative to gravity, along with acceleration and
deceleration forces acting on the head. Its primary motor functions include the stabilization of gaze during head movements; righting reactions of the head, trunk, and limbs; and regulation of muscle tone and postural muscle activity.¹

The visual system and somatosensory systems primarily use external references to determine the position of the body’s COG. In contrast, the vestibular system located in the inner ear is an internal system using an inertial-gravitational reference to determine the orientation of the head in space.⁶ At any time, information from one or more inputs is utilized to determine what is orientationally accurate and inaccurate. This process is referred to as sensory organization. The brain does not use a fixed combination of the three inputs. The combination of senses depends on the conditions in which a person is performing.⁶,⁷

The somatosensory and visual systems are predominantly used in most circumstances to maintain postural control and balance.⁶,⁷ During quiet stance, somatosensory inputs from all parts of the body contribute to balance control. The visual system also plays a very active role in postural control and balance during quiet stance. This is evident by measuring the amount of sway with eyes open versus eyes closed. A significant increase in sway takes place when eyes are closed and the visual system is not intact.

An experiment performed by Lee and colleagues⁸ demonstrated that visual cues are used differently depending on whether a person is standing quietly or responding to an unexpected threat to balance. Placing an individual
in a room where the ceiling and walls were moving forward to backward with the floor fixed created an illusion of sway in the opposite direction. If the walls and ceiling moved in slow oscillations, the individual would sway with these oscillations. However, if the ceilings and walls moved abruptly, the individuals would perceive a loss of balance. This loss of balance relates to the misinterpretation of the visual system and brain of determining exocentric motion (object motion) and egocentric motion (self motion). Somatosensory inputs appear to be more influential with postural control in response to abrupt surface perturbations. Somatosensory responses to support surface translations appear to be faster than those triggered by the visual system. Therefore, researchers suggest “the nervous system relies primarily on somatosensory inputs for controlling body sway when the imbalance is caused by rapid displacements of the supporting surface.” In contrast, the vestibular system has only a minor role in controlling posture when the support surface is displaced horizontally.

In addition to the sensory inputs necessary to maintain postural control, alignment, muscle tone, and postural tone are also required for the ability to stand upright. Ideal alignment is essential in maintaining an upright position. It allows the body to maintain equilibrium with the least amount of energy expenditure.

Muscle tone refers to the force with which a muscle resists stretching. It offsets the pull of gravity and keeps the body from collapsing. Muscle tone is
made up of both neural and non-neural components. The non-neural components are associated with the amount of muscle tone present in a normal relaxed person. The tone is present due to small amounts of free calcium in the muscle fibers. The neural component is associated with the activation of the stretch reflex. The stretch reflex resists the lengthening of the muscle and assists in keeping the muscle length at a set value. How the stretch reflex aides in controlling upright posture is not well understood, but one theory suggests as the ankle musculature is stretched by forward and backward sway, the stretch reflex is activated.

Postural tone refers to the activation of antigravity muscles during stance. Some clinicians suggest that postural tone in the trunk muscles is key to maintaining postural stability in an upright position. Other studies suggest that muscles throughout the body, not just the trunk musculature, are tonically active during stance. In situations where the center of mass (COM) moves outside the ideal alignment, more effort is required and compensatory postural strategies are implemented.

The compensatory postural strategies are derived from the three joints (hip, knee, and ankle) between the COG and the support base during erect standing. A variety of postures can be used to return the COG to ideal alignment following a perturbation. Horak and Nashner found specific muscle patterns called “muscle synergies” that are the basis of different movement strategies for balance. The “muscle synergies” are groups of muscles acting
together as a unit. The postural strategies for moving the COG are the ankle, hip, and stepping strategies.\textsuperscript{6,7,9} The ankle strategy restores the COG to a position of stability through movement around the ankle joint.\textsuperscript{6,7,9} It is the primary strategy used when the perturbation is small and the support surface is firm.\textsuperscript{7} The muscle synergies associated with ankle strategy are comprised of the gastrocnemius, hamstrings, and paraspinals during forward sway and tibialis anterior, quadriceps, and abdominals during backward sway.

The hip strategy restores equilibrium in response to larger, faster perturbations or when standing on a narrow support surface like a beam.\textsuperscript{9} The muscle synergies associated with the hip strategy are the abdominals and quadriceps to control forward sway and the paraspinals and hamstrings to control backward sway.

In response to stronger perturbations where the COG is displaced outside the base of support of the feet, a stepping strategy is used to bring the base of support under the COG.\textsuperscript{6,7,9} The maximum angle from the vertical that can be tolerated without loss of balance is referred to as the limits of stability (LOS). When a person exceeds his/her LOS, a stepping strategy must be implemented to prevent a fall. In a seated position, the hip strategy is the only compensatory postural strategy used to regain balance without using the arms.\textsuperscript{6}

Balance itself can be broken down into three aspects: steadiness, symmetry, and dynamic stability.\textsuperscript{5} Steadiness refers to the ability to maintain a
given posture with minimal extraneous movement (sway). The term “symmetry” refers to the equality of weight distribution between weight bearing components. Dynamic stability is the ability to move within a given posture without loss of balance.¹⁰

All three aspects of balance are disturbed following a stroke.¹⁰ A greater amount of postural sway, asymmetry of weight distribution, and decreased ability to move in a weight bearing position without loss of balance is typically seen with hemiparetic stroke patients.¹¹ In fact, asymmetrical stance is one of the most common features of change in standing posture after stroke. Stroke patients tend to put more weight on their unaffected leg in weight bearing positions.¹² During the stance portion of the walking cycle, the hemiparetic patient demonstrates deficits in the ability to shift body weight onto the paretic leg.¹³ Dettman and associates¹⁴ suggest the inability of proper weight shifting towards the paretic side may underlie many of the observed gait disturbances in stroke patients. Patients who experience difficulty with weight shifting also overestimate and underestimate the amount of weight shifting necessary to adjust to perturbations. Other patients may know the proper amount of weight shifting necessary, but they may not be able to execute the movements with the proper timing and coordination to be effective.¹⁵

The most common form of treatment for asymmetrical weight bearing and poor postural control is using both passive and active weight shifting.¹⁵ The underlying assumption is that practicing repetition of postural adjustments will
result in long term improvements in balance during ambulation and functional activities.

Postural sway is the term used to describe the movement of the body during standing. Overstall et al\(^{16}\) found a relationship between the reported history of falls and an increase in sway. A study conducted by Sackley\(^{12}\) looked at the relationship between falls, sway, and symmetry of weight-bearing after stroke. This study revealed that falls were a common occurrence among stroke patients. Nearly three-quarters of the subjects experienced at least one fall in the period between admission and six months post stroke. The number of falls in the study period correlated significantly with the sway values determined during the subjects' first assessment at two months post stroke. The study showed that increased sway was associated with increased risk of falling. It was also shown that sway values improved over time as the subjects recovered from their stroke. Impairment of postural control following a stroke involves changes in the motor and sensory systems. The sensory-motor changes are what leads to the increased postural sway and increased risk of falling.

In order to improve any physiological function, a challenging or overloading stimulus must be provided to the system responsible for that function. Specifically, to improve balance, exercises must be administered to challenge the visual, vestibular, somatosensory, and motor systems.\(^1,7\) An individual must be stimulated to move the COG through progressively greater
distances from the base of support. The neuromotor system must respond to repeated challenges and balance may eventually adapt.

Recent advances in technology have resulted in the availability of numerous force platform systems for balance retraining in individuals with balance deficits, including stroke patients. Force platform systems, like the NeuroCom Balance Master®, are designed to provide visual or audio feedback to the patients regarding their COG. The NeuroCom Balance Master® training protocols have been shown to enhance equal weight distribution in upright and seated positions, increase stability, and improve dynamic movement. Hamman and coworkers19 trained subjects with hemiplegia using visual feedback of COG movement during dynamic tasks. Their findings revealed improved performance in dynamic balance ability, but no change in postural sway. A study performed by Winstein et al13 identified increases in gait speed, cadence, stride length, and cycle time following visual biofeedback training. Another study has been inconclusive regarding the effects of postural feedback on ambulation.20 The need for further research on the effectiveness of force platforms for improving balance and functional mobility is considerable. Force platform systems like the NeuroCom Balance Master® may be utilized as an effective assessment tool to identify specific problems in postural control and as a training tool to improve overall balance.
Purpose of Study

The purpose of this case study is to determine the effectiveness of the NeuroCom Balance Master® system in improving balance of a stroke individual who is at least six months post stroke. Each of the various training exercises used during the study will be analyzed at the completion of the study to determine their effectiveness.

Significance of Study

Stroke rehabilitation has historically focused on the first six months of recovery. There is limited research to indicate if stroke patients can continue to improve their postural control and balance with training past the six-month period. Finding an effective way to treat balance deficits among stroke patients and other individuals with balance disorders is of increasing importance as the population grows older. Health care providers, third party payors, and patients with balance deficits may all benefit from this study through an increased knowledge and understanding of balance and balance training devices like the NeuroCom Balance Master®.

Research Questions

Can six weeks of postural feedback training increase the limits of stability and coordination of movement in stroke patients? Will improved performance in training exercises translate into improved functional mobility in terms of the Tinnetti Assessment Tool? Is the NeuroCom Balance Master® system an
effective means of improving the balance in stroke patients who are at least six months post stroke?
CHAPTER II

METHODOLOGY

The subject of this case study was a former patient at the Altru Health Institute who had expressed an interest in participating in the balance study undertaken by students at the University of North Dakota. The Altru Health Institute and the University of North Dakota Institutional Review Board gave final approval of the project. 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 NeuroCom Balance Master® system. An initial and final assessment of the NeuroCom Balance Master® and Berg Balance Scale or Tinetti Assessment Tool were performed on each subject to determine if the training protocol was effective in improving each of the subject’s balance. The subjects recruited were 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 are at least six months post from their cerebral vascular accident. Subjects wore a gait belt during the training sessions and there were always two assistants standing by for patient safety. Each participant worked independently with a member of the research team and separate case studies were conducted on each of the participants.

Instrumentation

The NeuroCom Balance Master® system (NeuroCom International, Inc., 9570 SE Lawnfield Road, Clackamas, Ore. 97015) with software version 6.1 was 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’ 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 receive instantaneous visual and auditory feedback on his/her body positions during training. The feedback allows the subject the opportunity to increase sensory appreciation and reeducate neuromuscular pathways that have been affected by the stroke.

Validity of the NeuroCom Balance Master® system has been established through its ability to generate computerized printouts of objective, quantifiable
data. Published literature also supports the scientific efficacy, clinical use of the NeuroCom Balance Master® and acknowledges it as a reliable and valid tool for assessing and retraining balance deficits.

Procedure

The study format involved an initial and final evaluation that included an assessment using the NeuroCom Balance Master® system and a functional balance test; in this case, the Tinnetti Assessment Tool (see Appendix B). The initial evaluation also included lower extremity manual muscle testing. Training sessions were for 30-minute time periods, three time per week. Each subject participated in a six-week training program using the NeuroCom Balance Master® system.

The initial and final assessments included symmetrical weight bearing, limits of stability, rhythmic weight shifting, sit to stand test, walking, and the step up/over test. Collectively, these tests quantified: 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 NeuroCom Balance Master® menu (see NeuroCom Balance Master® manual\textsuperscript{21}) are: 1) weight shifting, 2) mobility, 3) closed chain, and 4) seated. Graduated levels of difficulty allowed for customization of programs per individual session. 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 subject is allowed to perform several trial sessions before any results are 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 NeuroCom Balance Master® system and the functional balance assessment scales.

Assessment Protocol

The testing of subjects was conducted using the standardized assessment protocols on the NeuroCom Balance Master®. The description of each assessment test is stated in Appendix C or the NeuroCom Balance Master®.
manual, along with the performance measures of each test. Independent team members chose individualized assessment programs for their assigned subjects.

Data Analysis

Results from the initial and final assessment were analyzed and a percent change was calculated for different test parameters. The percent change was calculated by subtracting the final results from the initial, dividing it by the initial, and then multiplying it by 100. The results were compared to normative data that have been collected at Oregon State University and the Ruby Gerontology Center at Cal-State Fullerton on clinically asymptomatic subjects using the NeuroCom Balance Master® system (see NeuroCom Balance Master® manual).}

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 study will also 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

The following case study will include information on the subjects’ past medical history, initial evaluation, training protocol, results from initial and final NeuroCom Balance Master® assessment. There will also be a discussion on outcome of results.

Case Study

The subject is a 51-year-old female who was admitted to United Hospital (presently Altru Hospital) in Grand Forks, North Dakota, on April 17, 1996, after suffering a cerebral vascular accident. At the time of admission, the subject exhibited left-sided weakness and a computerized transaxial tomography (CAT) scan later revealed an intercerebral hemorrhage involving the right basal ganglia. During the hospital stay, the subject developed a hypersensitivity vasculitis syndrome which required further treatment at Mayo Clinic in Rochester, Minnesota. She was then transferred from the Mayo Clinic to the Rehab Hospital (Altru Health Institute) in Grand Forks where she began a comprehensive inpatient stroke rehabilitation program for approximately four weeks. After being discharged from the Rehab Hospital, the subject received physical therapy treatments periodically on an outpatient basis. In addition, the
subject was performing a weight-lifting program three times a week at the Rehab Fitness Center and an independent home exercise program. Currently, the patient ambulates using a single point cane and an athletic style ankle brace on the left foot due to ankle instability and is independent with activities of daily living.

An initial evaluation was performed on the subject on August 31, 1998. At this time, the subject was ambulating independently using a single point cane in the right upper extremity. The subject displayed increased hip flexion on the left side when initiating the swing phase of the gait cycle and increased ankle inversion on the left throughout the gait cycle. The subject’s right lower extremity strength was generally a 4+/5 to 5/5 throughout. Left knee flexion and extension were approximated at 3/5, ankle dorsiflexion 4/5, ankle plantar flexion and inversion 3/5, and ankle eversion 1/5. The subject also exhibited increased tone in the left upper and lower extremity.

A functional balance scale assessment was also administered during the initial evaluation of the subject. In this case, the Tinnetti Assessment Tool was used to determine the subject’s risk of falling based on certain balance tests and gait observations. The Tinnetti Assessment Tool has been regarded as reliable and valid as a predictor of falls and fall related injuries in elderly community dwellers.\textsuperscript{14,15} The subject demonstrated good sitting and standing balance, independent sit-to-stand transfers, and the ability to maintain balance with small perturbations. Areas of deficit were standing with a wide stance, using
discontinuous steps to turn 360°, and requiring right arm support while sitting down. The gait portion of the Tinnetti Assessment Tool consisted of analyzing the subject's gait pattern. Without using a cane, the subject exhibited decreased step length on the left, a wide base of support, and arms in a spread out position while walking. By allowing the subject to use a cane, she was able to maintain step symmetry and decrease the width of her steps. However, the improvements in the gait pattern are not necessarily reflected in the final score of the test. The use of a walking aid elicited a deduction in points. Therefore, the subject could only attain a certain level of scoring when using a cane. The subject's total score for the Tinnetti test was 22 out of 28 when using a cane versus 21 out of 28 without the cane. Based on these scores, it is determined the subject is at a greater risk to fall than a normal individual. However, the subject reported no incidence of falling during the previous year.

The last portion of the evaluation consisted of an assessment using the NeuroCom Balance Master® system. Prior to this assessment, the subject was allowed to familiarize herself with the machine by participating in several warm-up sessions. The warm-up sessions were performed to account for the high learning curve of the machine and to provide a more accurate assessment of the subject's balance at the time of initial assessment. The subject performed all tests during the initial and final assessment without using a cane. The initial and final NeuroCom Balance Master® assessments were performed on September 4, 1998, and October 19, 1998, respectively. The subject performed all tests
during the initial and final assessment wearing an ankle brace on the left foot and without the use of a cane. The assessment tests used during the initial and final NeuroCom Balance Master® assessments were weight bearing, limits of stability, rhythmic weight shifting, walk test, step up and over, and the sit to stand test. (See Appendix C or refer to the NeuroCom Balance Master® 6.1 manual for more specific information regarding protocol and normative data.)

Training Protocol

A training program was implemented to address the areas of deficit indicated by the assessment tests. The training protocol focused on symmetry, weight shifting, coordination of movement, and reactions to stimuli.

Training during the first several weeks centered towards weight shifting and mobility exercises. Weight shifting was predominantly performed to the left and to the front of the subject. The subject had tremendous difficulty weight shifting in the anterior direction. Level one exercises had to be used for this direction of movement. The inability of the subject to properly weight shift forward was evident by a protective reaction response. As she would lean forward, her arms would extend in front of her and a stepping strategy was used to regain balance. After a few weeks, the subject became more proficient at performing the weight shifting exercises. She demonstrated different strategies to reach the desired targets. Initially, she predominantly used an ankle and stepping strategy. As time passed, she learned how to use a hip strategy to reach targets farther in front of her. The occurrence of protective reactions and
stepping strategies diminished as she became more comfortable displacing her center of gravity. At the end of the six weeks, the subject was able to perform the weight shifting exercises at the highest level of difficulty and was able to reach the targets in front of her and to the left of her consistently.

The mobility training exercises focused on moving to designated areas on command. The subject would have to step in different directions as indicated by the computer screen. The subject initially had difficulty moving in a diagonal direction and was unable to reach the designated areas. Stepping forward and backward with the left foot was uncoordinated and difficult to perform. Additional diagonal movement exercises were incorporated into the training protocol to enhance the subject’s ability to move diagonally (i.e., weight shifting to the right followed by forward stepping to the left). After several training sessions, the subject made improvement with diagonal movements. However, she continued to have problems with stepping back to the left.

Closed chain exercises were incorporated into the training regime after a couple of weeks. The goals of the training exercises are designed to enhance proprioception, improve strength, and reeducate neuromuscular components of the left lower extremity. An emphasis was placed on diagonal movements with the subject’s knees bent. The exercise promoted increased weight bearing and strength on the left lower extremity, weight shifting in a diagonal direction, and coordination through reciprocal movements. The subject enjoyed this activity because it reminded her of downhill skiing. The subject’s enthusiasm for the
exercise quickly translated into improved performance. She progressed rather quickly with this exercise and was able to perform the movement at an increased pace and greater degree of displacement. Anterior-posterior and straight lateral movements were also performed with knees bent.

Side lunge exercises to the left were the next closed chain exercise to be introduced. The side lunge movement is a rather difficult exercise to perform because it requires greater eccentric control in the lower extremity. The subject was required to shift her weight almost entirely onto the left side and maintain control to prevent the knee from buckling.

During the last few weeks of the study, the subject progressed to more advanced mobility skills. The exercises required a significant amount of coordination and became cumbersome for the subject to complete. Exercises such as cross over step, step up/step down, and step over were implemented to enhance functional mobility skills. The subject’s progress was not as pronounced with the advanced mobility skills.

NeuroCom Balance Master® Assessment and Results

The results for the initial and final assessments are stated below for each administered test, including a brief discussion on the subject’s performance. Refer to Appendix D for specific results.

Weight Bearing Test

The initial weight-bearing test revealed an uneven weight distribution while the subject was in a standing position (46% on the left lower extremity
versus 54% on the right lower extremity). However, the degree of asymmetry between the left and right lower extremities was minimal and the results were within the normal range of the test. The subject’s equal weight distribution during stance is conflicting to findings in research. Literature indicates asymmetrical stance is one of the most common features of a stroke patient during stance.\textsuperscript{5,11}

Although the initial weight-bearing test depicted no abnormalities in weight distribution, improvement was noted during the final assessment. The final weight-bearing test revealed an equal distribution of weight during stance (50% on the left versus 50% on the right).

Limits of Stability Test

The subject exhibited several deficits during the limits of stability test. The time required to react to the stimuli (reaction time), the distance of the movement (endpoint excursion), the movement overshoot distance (maximum excursion), and the coordination of movement (directional control) all fell within the abnormal range of the test. The movement velocity was also diminished but the test results were not considered abnormal. Reaction time delays and movement velocities are indicative of high-level central nervous system deficits, and the functional consequences of these deficits is that the subject is at a greater risk to falls.\textsuperscript{13}

The subject’s greatest deficits during this test were related to motor control abnormalities. The subject was unable to reach targets in a single movement and the subject exhibited some difficulty with directional control. The
areas that gave the subject the most difficulty was moving in the forward
direction, towards her hemiparetic left side, and the combination of the two
movements (10 and 11 position on a clock). The subject was only able to reach
52% of the limits of stability in the forward direction, 80% limits of stability to the
left, and 59% limits of stability forward and to the left. The subject’s forward
directional control was also markedly decreased and fell within the abnormal
range.

The final limits of stability test unveiled the most significant results of the
entire study. The subject improved in areas of endpoint excursion, maximum
excursion, and directional control. Each area initially was considered abnormal,
but over the course of the study, each area improved enough to fall within the
normal range of the test. The most noticeable improvement was related to
movements in the forward direction, to the left, and the combination of the two
movements. A percent change of 123% and 98% was obtained for the endpoint
and maximum excursions for movement in the forward direction respectively.
Directional control for forward movement increased by 51% and forward
movement velocity doubled achieving a percent change of 104%. The subject’s
final results for forward movement were similar to normative data for all areas
except reaction time. During the final assessment, the subject reacted less
quickly to test stimuli in the forward direction and exhibited increased reaction
times. In fact, the reaction time increased by 142%.
Movements to the left also improved, but not as drastically. Endpoint and maximum excursion to the left achieved a percent change of 51% and 43% respectively, and reaction time towards the left went from being in the abnormal range (.98 sec) to the normal range (.64 sec), resulting in a percent change of 35%.

The combined movement of forward/left demonstrated the most noticeable improvement. Endpoint and maximum excursion in this diagonal resulted in a percent change of 168% and 110% respectively.

**Rhythmic Weight Shift Test**

This test revealed the continued difficulty the subject has with coordinated movement, but it must be noted the subject was tested at the highest level of difficulty during this test (Level III). Both the speed and coordination of the movement were considered abnormal during this initial test. The subject's inability to maintain postural control while changing directions was evident in both the forward/backward direction and the left/right direction. The inability to move the center of gravity reciprocally (accelerate, decelerate, and then change direction) may cause problems for the subject when walking in crowded places, stepping onto or off an escalator, or any functional activity that requires a quick change of direction.

The final results of the rhythmic weight shift test revealed a slight improvement in coordination of movement in both the anterior-posterior direction and lateral direction. Directional control for both planes of movement only
increased by 9%, but the final outcome reflected a progression of abnormal to normal test results. On axis velocity improved by 7% in the lateral direction and 20% in the anterior-posterior direction. However, the anterior-posterior on axis velocity was still considered abnormal.

Walking Test

This particular test gave a good indication of the subject’s gait pattern and the abnormalities that exist with a hemiplegic patient. Asymmetry in dynamic posture and movement is the most common locomotor deficit in the hemiplegic individual. The subject tended to lean towards the non-affected side during ambulation and exhibited a decreased step length on the left compared to the right. The decreased step length on the affected side is contradictory to a study conducted by Detman et al14 which showed step length of hemiplegic subjects to be greater on their affected side.

The decreased step length, increased step width, and decreased step speed were all considered abnormal. The decreased step length on the left lower extremity and the increased step width was consistent with the results stated earlier in the Tinnetti gait assessment. The decreased step speed exhibited by the subject is also a familiar gait characteristic among hemiplegic individuals. Detman et al14 found the speed of walking to be slower among hemiplegic individuals due to loss of function, decreased step length, and fear of falling. The decreased step speed also leads to a greater expenditure of energy and increases the balance requirements while walking.
The improvements made by the subject between the initial and final walk test appear to be quite drastic. The subject improved to the normal range in all categories; step width, step length, and speed of walking. However, the percent change in the different variables is not so pronounced. The percent change for step width was only about 7%. The percent change for step length was almost 20% and is consistent with the final results of the Tinnetti gait assessment that will be discussed shortly. Walking speed also increased, resulting in a percent change of 28%. Another noticeable different in the subject's gait pattern was that she maintained a midline position while walking instead of leaning toward the non-affected side.

Tinnetti Assessment Tool

The re-testing of the subject using the Tinnetti Assessment Tool revealed an improvement with the subject's step length and step symmetry. Initially, the subject was unable to bring the left swing foot in front of the right stance foot without the use of a cane during gait. The step length between the left and right lower extremity was also asymmetrical. At the end of the six weeks, the subject was able to bring the left swing foot past the right stance foot, and the step length between left and right appeared to be symmetrical. The final scores of the Tinnetti test were interesting since the subject scored better without the use of a cane (23) versus with the cane (22). Initially, she scored better using the cane. However, as previously stated, the use of a walking aid results in an
automatic deduction of points and the subject was unable to increase her total score.

The subject's increased score on the gait portion of the Tinnetti Assessment Tool was not enough for her to be categorized as "a low risk to fall" (test score 25-28). However, the improvement was significant enough to realize the patient made progress and the results were consistent with the final outcome of the NeuroCom Balance Master® walk test.

Sit to Stand Test

The subject did not exhibit the typical hemiplegic pattern of unequal weight distribution when performing this initial test. The subject was able to load weight evenly onto the affected and non-affected leg when rising from a sitting position. The subject was also able to transfer her center of gravity over her feet in an acceptable amount of time. However, the subject did have difficulty with producing sufficient force when rising to an upright position and limiting the amount of sway while rising. Insufficient force production may have been due to several factors: lower extremity weakness and/or motor control problems. The inability of the subject to perform the sit to stand transfer in one fluid movement was evident by the subject's arms actively coming forward as she would stand up. The subject would also need to regain her balance when she reached the full upright position.

The final results of the sit to stand test revealed no change in any of the test results. The absence of improvement may be attributed to the training
The step up and over test was the test the subject had the most difficulty performing. The test revealed incoordination problems, inequality of force production between lower extremities, and lack of control as the maneuver was performed. The subject demonstrated greater instability while stepping up with the left lower extremity than on the right. The force of the step up (lift-up index) was diminished bilaterally, but the degree of deficit was greater on the left. Concentric strength of the quadriceps, adequate range of dorsiflexion, single limb balance, and coordination of foot placement are all required to effectively perform this portion of the test. The subject seemed to have the most difficulty with coordination of movement and balancing on the affected extremity. The subject appeared unstable as she placed the left foot on the step and unweighted the right lower extremity. As the subject swung her right foot over the top of the step, the left knee locked into extension and then unlocked as her foot went into further dorsiflexion during step down.

The subject also exhibited a greater impact force on the left lower extremity when stepping down. The greater impact force on the left indicates less eccentric control of the non-involved lower extremity. However, the increased impact force may be attributed to the subject’s lack of coordination or sensory loss when placing the left foot on the platform. Despite the difference in impact
force between extremities, the results did fall within the normal range of the test bilaterally.

The results from the step up and over final assessment were not as significant as the previous tests. Movement time improved by 24% on the left side and 19% on the right side. The impact force (impact index) improved by 20% on the left side and stayed the same on the right side. The force of the step up did not show any change on either side.

Limitations of Study

The limitations of the study are predominantly due to the researcher's inexperience in working with stroke patients. The researcher had no prior clinical experience in stroke rehabilitation and was not able to apply previous experience and/or knowledge to enhance the training program. The lack of experience became very relevant when determining the type of exercises to incorporate into the training protocol. Being able to decide what exercises are the most appropriate is difficult when it is the researcher's first time working with a stroke patient on the NeuroCom Balance Master® system.

The inexperience in working with the NeuroCom Balance Master® is another limiting factor. Operating the system is relatively straight forward and user friendly; however, learning all the intricacies of the machine takes time. The correct placement of the feet on the platform can have drastic effects on the results. The tester must pay close attention to the position of the subject's feet and establish consistency with placement of the feet. The tester's ability to give
proper, consistent directions to the participant is also important. Unfamiliarity with the machine can lead to improper instructions and invalid results. The tester must be familiar with how to operate the machine and on how to perform all the tests and exercises.

An additional factor that may have placed limitations on the study is the subject's overall health. The subject developed radicular symptoms into her right lower extremity during the last few weeks of the study. At the time, the symptoms appeared to be consistent with sciatica and the subject was prescribed with medication to alleviate the symptoms. The subject was unable to participate in one of the training sessions due to the side effects from the medication - nausea and dizziness. The final NeuroCom Balance Master® assessment was also postponed one day due to the subject not feeling well. The subject was still taking medication at the time of the final assessment and the results may have been altered. The subject was eventually diagnosed with spinal stenosis and a bone spur is what elicited the symptomology.

Clinical Implications

Limited research has been conducted using the NeuroCom Balance Master® as a training tool for post stroke individuals and on the rehabilitation outcomes in general for patients greater than six months post stroke. Further testing may justify the use of the NeuroCom Balance Master® as an effective treatment alternative in long-term stroke rehabilitation.
The ability to provide effective treatment for post stroke individuals can result in a higher quality of life among stroke survivors and their families, reduced costs for health care providers and third party payors, and greater understanding and knowledge among health care professionals.
CHAPTER IV

CONCLUSION

The NeuroCom Balance Master® has been shown to be a viable tool for improving the limits of stability, coordination of movement, and speed of movement for the various test conditions. The areas of greatest improvement were related to the specificity of the training protocols, weight shifting in the forward direction and to the subject's hemiparetic side. Therefore, proper assessment of abnormalities in movement is essential to effectively treat balance deficits using the NeuroCom Balance Master® system.

Improvement in static and dynamic balance were documented in five of the six NeuroCom Balance Master® assessment tests. The subject improved in six balance components of the six test conditions: movement distance, movement overshoot distance, coordination of movement, width of step, length of step, and speed of step. The postural feedback training using the NeuroCom Balance Master® system also translated into functional improvements on the Tinnetti Assessment Tool. The subject improved her gait symmetry through increased step length and achieved a two-point increase on the total score of the test. This research seems to indicate that post stroke individuals of at least six months may have the ability to improve their overall balance with continued
postural training. Future research is necessary to determine if the progress exhibited by the subject over the six-week period is due to the improvement in balance of the individual, high learning curve of the NeuroCom Balance Master®, or a combination of both.
Institutional Review Board  
Research Project Action Report

Date: August 12, 1998  
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. EXPEDEIED REVIEW NO. ________________
   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

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.
Human Subjects Review Form

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

Kelly Adams, Joe Brenner, Jim Sillanpaa

Phone #: Jim - 775-4103 Date: 7/14/98

Institution: University of North Dakota Department: Physical Therapy

Research Coordinator: Meridee Green

Proposal Project Dates:

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

Funding Agencies (if applicable):

Type of Project: ☐ New Project ☐ Continuation ☐ Renewal ☐ Student Research Project

☐ Dissertation or Thesis Research ☐ Completed Project

☐ Reports (Adverse events, deaths, complications)

☐ Amendments or change in project

Dissertation/Thesis Adviser, or Student Advisor: Meridee Green

Proposed Project: ☐ Involves New Drugs (IND) ☐ Involves Non-Approved Use of Drug ☐ Involves a Cooperating Institution

☐ None of the Above

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

☐ Minors (< 18 Years) ☐ Pregnant Women ☐ Mentally Disabled ☐ Fetuses ☐ Mentally Retarded

☐ Prisoners ☐ Students ☐ Abortuses ☐ Control Group

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

☐ Expeditied 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)

1. 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.
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
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: ________________________________  Date: __________

Project Director: ________________________________  Date: __________

Student Advisor (where applicable): ________________________________  Date: __________
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. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be answered by calling the Altru Health System IRB Secretary at (701) 780-6161, or 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.

Participant’s Signature           Date

Witness(not the scientist)          Date
Balance Tests

Initial Instructions: Subject is seated in hard, armless chair. The following maneuvers are tested.

1. Sitting balance
   - Leans or slides in chair =0
   - Steady, safe =1

2. Arises
   - Unable without help =0
   - Able, uses arms to help =1
   - Able to arise, 1 attempt =2

3. Attempts to arise
   - Unable without help =0
   - Able, requires >1 attempt =1
   - Able to arise, 1 attempt =2

4. Immediate standing balance (first five seconds)
   - Unsteady (swaggers, moves feet, trunk sway) =0
   - Steady but uses walker or other support =1
   - Steady without walker or other support =2

5. Standing balance
   - Unsteady =0
   - Steady but wide stance (medial heels > 4 in. apart) and uses cane or other support =1
   - Narrow stance without support =2

6. Nudged (subject at maximum position with feet as close together as possible, examiner pushes lightly on subject’s sternum with palm of hand 3 times)
   - Begins to fall =0
   - Staggers, grabs, catches self =1
   - Steady =2

7. Eyes closed (at maximum position No.6)
   - Unsteady =0
   - Steady =1

8. Turning 360 degrees
   - Discontinuous steps =0
   - Continuous =1
   - Unsteady (grabs, staggers) =2
   - Safe, smooth motion

9. Sitting down
   - Unsafe (misjudged distance, falls into chair) =0
   - Uses arms or not a smooth motion =1
   - Safe, smooth motion =2

Balance Score: 13/16

Risk of falling based on gait and balance:
- Low Risk 25 - 28
- Greater Chance 19 - 24
- High Risk 0 - 18

Gait Tests

Initial Instructions: Subject stands with examiner, walks down hallway or across room, first at “usual” pace, then back at “rapid, but safe” pace (using usual walking aids)

10. Initiation of gait (immediately after told to “go”)
    - Any hesitancy or multiple attempts to start =0
    - No hesitancy =1

11. Step length and height
    a. Right swing foot
       - Does not pass left stance foot with step =0
       - Right foot does not clear floor completely with step =0
       - Right foot completely clears floor =1
    b. Left swing foot
       - Does not pass right stance foot with step =0
       - Left foot does not clear floor completely with step =0
       - Left foot completely clears floor =1

12. Step Symmetry
    - Right and left step not equal (estimate) =0
    - Right and left step appear equal =1

13. Step continuity
    - Stopping or discontinuity between steps =0
    - Steps appear continuous =1

14. Path (estimated in relation to floor tiles, 12-inch diameter; observe excursion of 1 foot over about 10 ft. of the course.)
    - Marked deviation =0
    - Mild/moderate deviation or uses walking aid =1
    - Straight without walking aid =2

15. Trunk
    - Marked sway or uses walking aid =0
    - No sway but flexion of knees or back or spreads arms out while walking =0
    - No sway, no flexion, no use of arms, and no use of walking aid =2

16. Walking time
    - Heels apart =0
    - Heels almost touching while walking =1

Gait Score:

Balance + Gait Score:

Source: The Journal of the American Geriatric Society

Tinetti Assessment Tool

Altru

Date 8/31/98

Physical Therapist

7091-0103-PRO SEPT 95
### Balance Tests

**Initial Instructions:** Subject is seated in hard, armless chair. The following maneuvers are tested.

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sitting balance</td>
<td></td>
</tr>
<tr>
<td>Leans or slides in chair</td>
<td>=0</td>
</tr>
<tr>
<td>Steady, safe</td>
<td>=1</td>
</tr>
<tr>
<td>2. Arises</td>
<td></td>
</tr>
<tr>
<td>Unable without help</td>
<td>=0</td>
</tr>
<tr>
<td>Able, uses arms to help</td>
<td>=1</td>
</tr>
<tr>
<td>Able to arise, 1 attempt</td>
<td>=2</td>
</tr>
<tr>
<td>3. Attempts to arise</td>
<td></td>
</tr>
<tr>
<td>Unable without help</td>
<td>=0</td>
</tr>
<tr>
<td>Able, requires &gt;1 attempt</td>
<td>=1</td>
</tr>
<tr>
<td>Able to arise, 1 attempt</td>
<td>=2</td>
</tr>
<tr>
<td>4. Immediate standing balance (first five seconds)</td>
<td></td>
</tr>
<tr>
<td>Unsteady (swaggars, moves feet, trunk sway)</td>
<td>=0</td>
</tr>
<tr>
<td>Steady but uses walker or other support</td>
<td>=1</td>
</tr>
<tr>
<td>Steady without support</td>
<td>=2</td>
</tr>
<tr>
<td>5. Standing balance</td>
<td></td>
</tr>
<tr>
<td>Unsteady (subject at maximum position with feet as close together as possible, examiner pushes lightly on subject's sternum with palm of hand 3 times)</td>
<td>=0</td>
</tr>
<tr>
<td>Steady but wide stance (medial heels &gt; 4 in. apart) and uses cane or other support</td>
<td>=1</td>
</tr>
<tr>
<td>Narrow stance without support</td>
<td>=2</td>
</tr>
<tr>
<td>6. Nudged (subject at maximum position with feet as close together as possible, examiner pushes lightly on subject's sternum with palm of hand 3 times)</td>
<td></td>
</tr>
<tr>
<td>Begins to fall</td>
<td>=0</td>
</tr>
<tr>
<td>Staggers, grabs, catches self</td>
<td>=1</td>
</tr>
<tr>
<td>Steady</td>
<td>=2</td>
</tr>
<tr>
<td>7. Eyes closed (at maximum position No.6)</td>
<td></td>
</tr>
<tr>
<td>Unsteady</td>
<td>=0</td>
</tr>
<tr>
<td>Steady</td>
<td>=1</td>
</tr>
<tr>
<td>8. Turning 360 degrees</td>
<td></td>
</tr>
<tr>
<td>Discontinuous steps</td>
<td>=0</td>
</tr>
<tr>
<td>Continuous</td>
<td>=1</td>
</tr>
<tr>
<td>Unsteady (grabs, staggers)</td>
<td>=0</td>
</tr>
<tr>
<td>Steady</td>
<td>=1</td>
</tr>
<tr>
<td>9. Sitting down</td>
<td></td>
</tr>
<tr>
<td>Unsafe (misjudged distance, falls into chair)</td>
<td>=0</td>
</tr>
<tr>
<td>Uses arms or not a smooth motion</td>
<td>=1</td>
</tr>
<tr>
<td>Safe, smooth motion</td>
<td>=2</td>
</tr>
</tbody>
</table>

**Balance Score:** \( \frac{13}{16} \)

**Risk of falling based on gait and balance:**
- High Risk: 0 - 18
- Greater Chance: 19 - 24
- Low Risk: 25 - 28

---

### Gait Tests

**Initial Instructions:** Subject stands with examiner, walks down hallway or across room, first at "usual" pace, then back at "rapid, but safe" pace (using usual walking aids)

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. Initiation of gait (immediately after told to &quot;go&quot;)</td>
<td></td>
</tr>
<tr>
<td>Any hesitancy or multiple attempts to start</td>
<td>=0</td>
</tr>
<tr>
<td>No hesitancy</td>
<td>=1</td>
</tr>
<tr>
<td>11. Step length and height</td>
<td></td>
</tr>
<tr>
<td>a. Right swing foot</td>
<td></td>
</tr>
<tr>
<td>does not pass left stance foot with step</td>
<td>=0</td>
</tr>
<tr>
<td>passes left stance foot</td>
<td>=1</td>
</tr>
<tr>
<td>right foot does not clear floor completely</td>
<td></td>
</tr>
<tr>
<td>with step</td>
<td>=0</td>
</tr>
<tr>
<td>right foot completely clears floor</td>
<td>=1</td>
</tr>
<tr>
<td>b. Left swing foot</td>
<td></td>
</tr>
<tr>
<td>does not pass right stance foot with step</td>
<td>=0</td>
</tr>
<tr>
<td>passes right stance foot</td>
<td>=1</td>
</tr>
<tr>
<td>left foot does not clear floor completely</td>
<td></td>
</tr>
<tr>
<td>with step</td>
<td>=0</td>
</tr>
<tr>
<td>left foot completely clears floor</td>
<td>=1</td>
</tr>
<tr>
<td>12. Step Symmetry</td>
<td></td>
</tr>
<tr>
<td>Stopping or discontinuity between steps</td>
<td>=0</td>
</tr>
<tr>
<td>Steps appear continuous</td>
<td>=1</td>
</tr>
<tr>
<td>13. Step continuity</td>
<td></td>
</tr>
<tr>
<td>Marked deviation</td>
<td></td>
</tr>
<tr>
<td>Mild/moderate deviation or uses walking aid</td>
<td>=0</td>
</tr>
<tr>
<td>Straight without walking aid</td>
<td>=1</td>
</tr>
<tr>
<td>14. Path (estimated in relation to floor tiles, 12-inch diameter; observe excursion of 1 foot over about 10 ft. of the course.)</td>
<td></td>
</tr>
<tr>
<td>Marked deviation</td>
<td>=0</td>
</tr>
<tr>
<td>Mild/moderate deviation or uses walking aid</td>
<td>=1</td>
</tr>
<tr>
<td>Straight without walking aid</td>
<td>=2</td>
</tr>
<tr>
<td>15. Trunk</td>
<td></td>
</tr>
<tr>
<td>Marked sway or uses walking aid</td>
<td>=0</td>
</tr>
<tr>
<td>No sway, no flexion of knees or back or</td>
<td></td>
</tr>
<tr>
<td>spreads arms out while walking</td>
<td>=1</td>
</tr>
<tr>
<td>No sway, no flexion, no use of arms, and no</td>
<td></td>
</tr>
<tr>
<td>use of walking aid</td>
<td>=2</td>
</tr>
<tr>
<td>16. Walking time</td>
<td></td>
</tr>
<tr>
<td>No cane</td>
<td></td>
</tr>
<tr>
<td>Cane</td>
<td></td>
</tr>
<tr>
<td>Heels apart</td>
<td>=0</td>
</tr>
<tr>
<td>Heels almost touching while walking</td>
<td>=1</td>
</tr>
</tbody>
</table>

**Gait Score:** \( \frac{10}{12} \)

**Balance + Gait Score:** \( \frac{35}{36} \)

---

**Tinetti Assessment Tool**

[Image of the Altru Health System logo]

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**Source:** The Journal of the American Geriatric Society

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**Date:** 10/19/98
ASSESSMENT PROTOCOL

The testing of subjects was conducted using the standardized assessment protocols on the Balance Master.® The description of each assessment test is stated below along with the performance measures of each test. The assessment protocols include:

**Sit-to-Stand**

The subject assumes a comfortable seated position on wooden boxes with the feet placed on designated areas of the forceplate. 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 averaged to obtain the following performance measures:

**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.

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

**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.
1) **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 forceplate 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:

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

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

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

5) **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 forceplate 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:

6) **On-Axis Velocity** - quantifies the average velocity of the rhythmic movement in degrees per second along the specified movement direction.

7) **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**

Subjects stand viewing 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:

8) **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.

9) **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.

10) **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%.

11) **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.
12) **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 forceplate. The following score was recorded:

13) **Percentage Weight Bearing** - the fraction of the total body weight placed on each foot and expressed as a percentage.
APPENDIX D
### LIMITS OF STABILITY

#### Endpoint Excursion (%)

<table>
<thead>
<tr>
<th>Movement</th>
<th>9-4-98</th>
<th>10-19-98</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td>44</td>
<td>98</td>
<td>123</td>
</tr>
<tr>
<td>Back</td>
<td>53</td>
<td>55</td>
<td>4</td>
</tr>
<tr>
<td>Right</td>
<td>106</td>
<td>101</td>
<td>-5</td>
</tr>
<tr>
<td>Left</td>
<td>71</td>
<td>107</td>
<td>51</td>
</tr>
<tr>
<td>Forward/Left</td>
<td>41</td>
<td>110</td>
<td>168</td>
</tr>
</tbody>
</table>

#### Max Excursion (%)

<table>
<thead>
<tr>
<th>Movement</th>
<th>9-4-98</th>
<th>10-19-98</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td>52</td>
<td>103</td>
<td>98</td>
</tr>
<tr>
<td>Back</td>
<td>60</td>
<td>63</td>
<td>5</td>
</tr>
<tr>
<td>Right</td>
<td>114</td>
<td>104</td>
<td>-9</td>
</tr>
<tr>
<td>Left</td>
<td>80</td>
<td>114</td>
<td>43</td>
</tr>
<tr>
<td>Forward/Left</td>
<td>59</td>
<td>124</td>
<td>110</td>
</tr>
</tbody>
</table>

#### Movement Velocity (deg/sec)

<table>
<thead>
<tr>
<th>Movement</th>
<th>9-4-98</th>
<th>10-19-98</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td>2.6</td>
<td>5.3</td>
<td>104</td>
</tr>
<tr>
<td>Back</td>
<td>1.9</td>
<td>2.6</td>
<td>37</td>
</tr>
<tr>
<td>Right</td>
<td>6.1</td>
<td>5.9</td>
<td>-3</td>
</tr>
<tr>
<td>Left</td>
<td>4.3</td>
<td>4.7</td>
<td>9</td>
</tr>
</tbody>
</table>

#### Directional Control (%)

<table>
<thead>
<tr>
<th>Movement</th>
<th>9-4-98</th>
<th>10-19-98</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td>55</td>
<td>83</td>
<td>51</td>
</tr>
<tr>
<td>Back</td>
<td>52</td>
<td>53</td>
<td>-2</td>
</tr>
<tr>
<td>Right</td>
<td>88</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td>Left</td>
<td>85</td>
<td>81</td>
<td>-5</td>
</tr>
</tbody>
</table>

#### Reaction Time

<table>
<thead>
<tr>
<th>Movement</th>
<th>9-4-98</th>
<th>10-19-98</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td>.43</td>
<td>1.04</td>
<td>142</td>
</tr>
<tr>
<td>Back</td>
<td>.59</td>
<td>.44</td>
<td>-25</td>
</tr>
<tr>
<td>Right</td>
<td>1.1</td>
<td>.75</td>
<td>-32</td>
</tr>
<tr>
<td>Left</td>
<td>.98</td>
<td>.64</td>
<td>-35</td>
</tr>
</tbody>
</table>
RESULTS (Cont.)
(Percent Change)

<table>
<thead>
<tr>
<th>Rhythmic Weight Shift</th>
<th>9-4-98 Initial</th>
<th>10-19-98 Final</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Axis Velocity (deg/sec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left/Right</td>
<td>6.9</td>
<td>7.4</td>
<td>7</td>
</tr>
<tr>
<td>Forward/Backward</td>
<td>3</td>
<td>3.6</td>
<td>20</td>
</tr>
<tr>
<td>Directional Control (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left/Right</td>
<td>82</td>
<td>89</td>
<td>9</td>
</tr>
<tr>
<td>Forward/Backward</td>
<td>77</td>
<td>84</td>
<td>9</td>
</tr>
</tbody>
</table>

Walking Test

<table>
<thead>
<tr>
<th></th>
<th>9-4-98</th>
<th>10-19-98</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step Width (cm)</td>
<td>22.8</td>
<td>21.3</td>
<td>7</td>
</tr>
<tr>
<td>Step Length (cm)</td>
<td>30.7</td>
<td>36.8</td>
<td>20</td>
</tr>
<tr>
<td>Speed (cm/sec)</td>
<td>38.5</td>
<td>49.4</td>
<td>28</td>
</tr>
<tr>
<td>EndSway (deg/sec)</td>
<td>2.3</td>
<td>2.7</td>
<td>17</td>
</tr>
</tbody>
</table>

Sit-to-Stand Test

<table>
<thead>
<tr>
<th></th>
<th>9-4-98</th>
<th>10-19-98</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight Transfer (sec)</td>
<td>.28</td>
<td>.26</td>
<td>-7</td>
</tr>
<tr>
<td>Rising Index (% body wt)</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>COG Sway Velocity (deg/sec)</td>
<td>6.4</td>
<td>6.6</td>
<td>3</td>
</tr>
<tr>
<td>Left/Right Weight Symmetry (%)</td>
<td>1</td>
<td>7</td>
<td>600</td>
</tr>
</tbody>
</table>

Step-up and Over Test

<table>
<thead>
<tr>
<th></th>
<th>9-4-98</th>
<th>10-19-98</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lift Up Index (% body wt)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Side</td>
<td>11</td>
<td>9</td>
<td>-18</td>
</tr>
<tr>
<td>Right Side</td>
<td>20</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Movement Time (sec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Side</td>
<td>3.2</td>
<td>2.44</td>
<td>24</td>
</tr>
<tr>
<td>Right Side</td>
<td>3.3</td>
<td>2.66</td>
<td>19</td>
</tr>
<tr>
<td>Impact Index (% body wt)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Side</td>
<td>35</td>
<td>28</td>
<td>-20</td>
</tr>
<tr>
<td>Right Side</td>
<td>19</td>
<td>19</td>
<td>0</td>
</tr>
</tbody>
</table>
RESULTS IN COMPARISON TO NORMATIVE DATA

WEIGHT BEARING

<table>
<thead>
<tr>
<th></th>
<th>Initial Evaluation</th>
<th>Final Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage Weight-Bearing</td>
<td>Normal</td>
<td>Normal</td>
</tr>
</tbody>
</table>

LIMITS OF STABILITY

<table>
<thead>
<tr>
<th></th>
<th>Initial Evaluation</th>
<th>Final Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time required to react to stimuli</td>
<td>Abnormal</td>
<td>Abnormal</td>
</tr>
<tr>
<td>The movement distance</td>
<td>Abnormal</td>
<td>Normal</td>
</tr>
<tr>
<td>The movement overshoot distance</td>
<td>Abnormal</td>
<td>Normal</td>
</tr>
<tr>
<td>The coordination of movement</td>
<td>Abnormal</td>
<td>Normal</td>
</tr>
</tbody>
</table>

RHYTHMIC WEIGHT SHIFT

<table>
<thead>
<tr>
<th></th>
<th>Initial Evaluation</th>
<th>Final Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The speed of the movement</td>
<td>Abnormal</td>
<td>Abnormal</td>
</tr>
<tr>
<td>The ability to coordinate movement</td>
<td>Abnormal</td>
<td>Normal</td>
</tr>
</tbody>
</table>

WALK

<table>
<thead>
<tr>
<th></th>
<th>Initial Evaluation</th>
<th>Final Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The width of the step</td>
<td>Abnormal</td>
<td>Normal</td>
</tr>
<tr>
<td>The length of the step</td>
<td>Abnormal</td>
<td>Normal</td>
</tr>
<tr>
<td>The speed of the step</td>
<td>Abnormal</td>
<td>Normal</td>
</tr>
</tbody>
</table>

SIT-TO-STAND

<table>
<thead>
<tr>
<th></th>
<th>Initial Evaluation</th>
<th>Final Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The force of the rise to stand</td>
<td>Abnormal</td>
<td>Abnormal</td>
</tr>
<tr>
<td>Amount of sway during rise to stand</td>
<td>Abnormal</td>
<td>Abnormal</td>
</tr>
</tbody>
</table>

STEP UP/OVER

<table>
<thead>
<tr>
<th></th>
<th>Initial Evaluation</th>
<th>Final Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The force of the step up</td>
<td>Abnormal</td>
<td>Abnormal</td>
</tr>
<tr>
<td>The time to executive maneuver</td>
<td>Abnormal</td>
<td>Abnormal</td>
</tr>
<tr>
<td>The left/right symmetry of maneuver</td>
<td>Abnormal</td>
<td>Abnormal</td>
</tr>
</tbody>
</table>
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>46</td>
<td>54</td>
</tr>
</tbody>
</table>

Data Range Note:
NeuroCom Data Range: 40–59
WEIGHT BEARING TEST

Data Range Note:
NeuroCom Data Range: 40–59

Post Test Comments:
### LIMITS OF STABILITY TEST

<table>
<thead>
<tr>
<th>Transition</th>
<th>Reaction Time (RT)</th>
<th>Movement Velocity (MVL)</th>
<th>Endpoint &amp; Max Excursions (EPE&amp;MXE)</th>
<th>Directional Control (DCL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT (sec)</td>
<td>MVL (deg/sec)</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>1 (F)</td>
<td>0.55</td>
<td>2.8</td>
<td>46</td>
<td>56</td>
</tr>
<tr>
<td>2 (RF)</td>
<td>0.79</td>
<td>6.6</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3 (R)</td>
<td>0.71</td>
<td>5.1</td>
<td>86</td>
<td>101</td>
</tr>
<tr>
<td>4 (RB)</td>
<td>1.36</td>
<td>4.0</td>
<td>88</td>
<td>92</td>
</tr>
<tr>
<td>5 (B)</td>
<td>0.44</td>
<td>1.7</td>
<td>69</td>
<td>84</td>
</tr>
<tr>
<td>6 (LB)</td>
<td>1.20</td>
<td>3.8</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>7 (L)</td>
<td>0.95</td>
<td>5.3</td>
<td>70</td>
<td>77</td>
</tr>
<tr>
<td>8 (LF)</td>
<td>0.35</td>
<td>1.8</td>
<td>41</td>
<td>59</td>
</tr>
</tbody>
</table>

---

**Data Range Note:** NeuroCom Data Range: 40–59

---

**Post Test Comments:**
Name: BLUE, SEVEN R
ID: ATID00136
DOB: 7/10/1947
Referral Source: Not Specified
Height: 5'2"

Diagnosis: CVA
Operator: Not Specified

File: HBM136.QBM
Test Date: 10/19/1998
Test Time: 11:24:08 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>1.35</td>
<td>4.4</td>
<td>90</td>
<td>93</td>
<td>85</td>
</tr>
<tr>
<td>2 (RF)</td>
<td>0.91</td>
<td>8.0</td>
<td>106</td>
<td>106</td>
<td>94</td>
</tr>
<tr>
<td>3 (R)</td>
<td>0.60</td>
<td>4.0</td>
<td>87</td>
<td>94</td>
<td>91</td>
</tr>
<tr>
<td>4 (RB)</td>
<td>0.63</td>
<td>5.2</td>
<td>92</td>
<td>92</td>
<td>68</td>
</tr>
<tr>
<td>5 (B)</td>
<td>0.62</td>
<td>2.3</td>
<td>59</td>
<td>78</td>
<td>80</td>
</tr>
<tr>
<td>6 (LB)</td>
<td>0.44</td>
<td>4.8</td>
<td>93</td>
<td>93</td>
<td>50</td>
</tr>
<tr>
<td>7 (L)</td>
<td>0.51</td>
<td>3.5</td>
<td>87</td>
<td>95</td>
<td>91</td>
</tr>
<tr>
<td>8 (LF)</td>
<td>0.81</td>
<td>4.3</td>
<td>110</td>
<td>124</td>
<td>77</td>
</tr>
</tbody>
</table>

Data Range Note: NeuroCom Data Range: 40–59

Post Test Comments:
final assessment
RHYTHMIC WEIGHT SHIFT TEST

Left/Right

FAST (1 sec per transition)

Front/Back

FAST (1 sec per transition)

deg/sec  On-Axis Velocity

0.0  2.0  4.0  6.0  8.0

L/R  F/B  Comp

UR  FIB  Comp

%  80  60  40  20  0

L/R  F/B  Comp

Data Range Note: NeuroCom Data Range: 40–59

Post Test Comments:
subject was assessed at level 3
c cane

RHYTHMIC WEIGHT SHIFT TEST

Left/Right

FAST (1 sec per transition)

Front/Back

FAST (1 sec per transition)

deg/sec

On-Axis Velocity

% Directional Control

Data Range Note: NeuroCom Data Range: 40–59

Post Test Comments:

subject was assessed at level 3
pt assessed forwards/backwards @ level 3

RHYTHMIC WEIGHT SHIFT TEST

Left/Right

FAST (1 sec per transition)

Front/Back

FAST (1 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>8.0</td>
<td>7.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td></td>
<td></td>
<td>5.5</td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0</td>
<td></td>
<td></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>80</td>
<td>89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td>87</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data Range Note: NeuroCom Data Range: 40–59

Post Test Comments:
- final assessment
- final assessment

**WALK TEST (Level One)**

**Trial 1**

**Trial 2**

**Trial 3**

**Data Range Note:**

NeuroCom Data Range: 40–59

**Post Test Comments:**

S cane
WALK TEST (Level One)

Data Range Note:
NeuroCom Data Range: 40–59

Post Test Comments:
final assessment s cane

---

Name: BLUE, SEVEN R  
ID: ATTD00136  
DOB: 7/10/1947  
Referral Source:  
Height: 5'2"  
Comments:  

Diagnosis: CVA  
Operator: Not Specified  
File: HBM136.QBM  
Test Date: 9/4/1998  
Test Time: 11:32:26 AM

SIT TO STAND TEST

Trial 1

Trial 2

Trial 3

% Body Wt Rising Index

Mean

Deg/sec COG Sway Velocity

Mean

% Left/Right Weight Symmetry

50

Coefficient of Variation

6% (68%)

Coefficient of Variation

39% (28%)

Coefficient of Variation

11% (64%)

Coefficient of Variation

10% (20%)

Data Range Note:  
NeuroCom Data Range: 40–59

Post Test Comments:
12" box

Name:  BLUE, SEVEN R  
ID:     ATID00136  
DOB:    7/10/1947  
Referral Source:  
Height: 5'2"  
Comments:  

Diagnosis:  CVA  
Operator:  Not Specified  

File:  HBM136.QBM  
Test Date:  10/19/1998  
Test Time:  11:37:03 AM  

SIT TO STAND TEST

Trial 1

Trial 2

Trial 3

Data Range Note:
NeuroCom Data Range: 40–59

Post Test Comments:
final assessment 12" box

STEP UP/OVER TEST (2 inch curb)

Data Range Note:
NeuroCom Data Range: 40–59

Post Test Comments:
- s cane
- s cane

STEP UP/OVER TEST (2 inch curb)

LEFT SIDE

RIGHT SIDE

Data Range Note:
NeuroCom Data Range: 40–59

Post Test Comments:
final assessment cane
cane assessment cane

REFERENCES


