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

Kelly Adams
University of North Dakota

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

by

Kelly Adams
Bachelor of Science in Physical Therapy
University of North Dakota, 1998

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

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

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

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

Department
Physical Therapy

Degree
Master of Physical Therapy

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Signature  Kelly Adams

Date  12/15/98
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ACKNOWLEDGMENTS

I would like to acknowledge the following people for their help in the preparation of this case study and support of my personal academic endeavors throughout the last seven years: Meridee Danks for her guidance through the research process and keeping me focused and on track; the faculty and staff of the Physical Therapy Department of the University of North Dakota; and most of all, my family and friends for their support and encouragement to stay the course when the end was still over yet another horizon.
ABSTRACT

This case study involved a 61-year-old male post-stroke subject who underwent six weeks of balance training using the NeuroCom® Balance Master (NCBM) system. **Purpose:** The purpose of this study was to assess the effectiveness of a six-week training program on a post-stroke individual (> 6 months). Pre- and post-test assessments were conducted utilizing the NCBM protocols and the Berg Balance Scale. **Results:** The subject showed improvement in four of five NCBM test conditions—rhythmic weight shifting, sit-to-stand test, walk test, and modified clinical test for sensory interaction on balance (mCTSIB) test. Regression was shown in the components of three test conditions—rhythmic weight shifting, sit-to-stand test, and walk test. The subject regressed in one test condition—static weight bearing. The subject remained in the abnormal range of performance for all test conditions compared to age matched controls except center of gravity end sway velocity in sit-to-stand and walking. Berg Balance Scale scores improved 48.27% from 29 to 43.

**Conclusion:** The results of the training indicate an overall improvement in static and dynamic balance control for this subject. Further research of this population is recommended to determine the feasibility of refresher training to help improve balance and coordination.
CHAPTER I

INTRODUCTION

Stroke is the number one cause of disability in the United States and the third leading cause of death, ranked behind diseases of the heart and all forms of cancer.\textsuperscript{1} According to the Atherosclerotic Risk in Communities Study of the National Heart, Lung and Blood Institute (NHLBI),\textsuperscript{2} approximately 731,000 people have a first episode or recurrent stroke each year. Government literature normally quotes a figure of 500,000 and uses the Framingham Heart Study statistics as a baseline figure, which is too low.\textsuperscript{1,2} The Framingham studies were conducted in the primarily white and affluent cities of Rochester, Minn., and Framingham, Mass., and do not accurately reflect the socio-economic or racial status of those most afflicted. Recent figures (1995) of death rates per 100,000 population for stroke were 26.5 for white males and 52.2 for black males (97.0% higher); and 23.1 for white females and 39.6 for black females (71.4% higher).\textsuperscript{1} The NHLBI figures represent a significant increase in the magnitude of stroke and are likely to increase in light of the demographic changes brought about by the more affluent and aging baby boomer population.

Etiologic categories of stroke include thrombus, embolism, and hemorrhage secondary to trauma or aneurysm.\textsuperscript{3} Atherosclerosis is a major contributing factor of occlusive artery disease and can lead to the formation of
plaque deposits in the major arteries of the heart and cerebral arteries. The end result of atherosclerotic sequella are thrombosis, the formation of blood clotting or thrombus formation in the cerebral arteries resulting in infarction and/or tissue death.\textsuperscript{3,4} Other factors include cardiac disease, diabetes, obesity, smoking, and race.

Complications of the post-stroke survivor are many. Loss of balance and coordination is one of the primary results. Disruption of the neuromuscular pathways usually leads to the development of initial flaccidity, followed generally by spasticity, hyperreflexia, and gross motor patterns of movement known as synergy patterns.\textsuperscript{3} Combined with possible sensory disruption of tactile and joint position nerve fibers, loss of somatosensory inputs to the central processing areas of the brain degrade the ability of the person to maintain control of static and dynamic postural control. This loss of function can lead to long-term debilitating effects of activities of daily living (ADLs) in stroke patients. Additionally, falls represent one of the major risks associated with post-stroke complications and increase morbidity and mortality.\textsuperscript{5,6}

In addition to somatosensory inputs, other components of balance include visual and vestibular inputs. Together, the three inputs form a somewhat redundant system of checks and balances that provide feedback to the brain about our position in relation to the surrounding environment.\textsuperscript{7} In the stroke patient, any or all of the systems can be affected, thus altering the ultimate outcome and rehabilitation of the patient.
Cognitive impairment caused by stroke can result in processing deficits that compound the recovery process. Information processing, conceptualization, execution of motor planning, inability to attend, and learning can all be affected. While most stroke survivors regain some cognitive function, retained deficits can interfere with the learning process and impede relearning of task specific skill acquisition necessary for the recovery of balance and coordination.

Balance can be broken down into three separate component parts: steadiness, symmetry, and dynamic stability. Steadiness is the ability to maintain a static posture without any sway. Symmetry is a condition of bearing weight equally on both lower extremities in an upright position and dynamic stability refers to the ability to maintain or move the center of gravity (COG) of the body within the theoretical limits of stability (LOS) without loss of balance. All three have been found to be disrupted following a stroke by numerous researchers and are implicated as barriers to a return to normal function.

The study of balance has lead to the development and refinement of force platform technology that was unavailable in the recent past. The NeuroCom® Balance Master System (NCBM), a force platform system, is capable of giving continuous visual biofeedback of the position of the COG in a variety of changing task conditions in relation to the theoretical LOS. It also provides qualitative as well as quantitative information as the subject moves through static and dynamic training protocols and provides real time visual biofeedback to the patient. Using this type of system, it is proposed learning and skill acquisition occur over a period of time and a training effect is induced (learning curve).
Performance improvement has been shown to occur in as little as two weeks, while documented permanent learning in motor control remains scarce.\textsuperscript{10} One study showed a greater percentage decline in performance of feedback trained subjects versus non-feedback trained subjects after 33 months.\textsuperscript{16} The literature in this area is scant and more research needs to be done to differentiate performance gains from actual motor learning.

Additional implications of this type of training relate to the transference and integration of skill acquisition at a functional level that prove useful to the patient beyond the clinic. Functional ambulation in a variety of changing conditions and reducing the chance of falls that are not of a biomechanical origin are probably the most important outcomes. Since falls can lead to major life threatening complications in the elderly, research in this area is required to identify the causative factors.

Problem Statement

One of the questions posed in this study concerns skill acquisition in the chronic stroke patient. Many studies deal with subjects in the acute or sub-acute stages of recovery when some return of function may be attributed to spontaneous remission of the effects of stroke. Of the literature reviewed for this study, only three articles identified an experimental group of chronic stroke patients, described as being at least six months post-stroke.\textsuperscript{8,16,17} Very little research has been done with chronic stroke patients to determine the feasibility of refresher training to help improve balance and coordination.
Purpose of the Study

The purpose of this case study is to determine if an improvement in balance can be documented in the chronic stroke patient using a custom designed training protocol with the NCBM system. The results will be of benefit to health care researchers in determining and designing research protocols used to address balance problems associated with long-term post-stroke survivors.

Research Questions

Can improvement in static and dynamic postural control be documented in chronic post-stroke patients using the NCBM system? Can NCBM training infer functional improvement as documented by an accepted functional assessment such as the Berg Balance Scale?
CHAPTER II
LITERATURE REVIEW

Relearning of task specific skill acquisition is one of the difficulties of motor relearning in the stroke patient. Learning in the motor control system is reliant on sensory information feedback.\(^3,5,7,18\) In the stroke patient, sensory disruption of tactile and joint position nerve fibers and loss of somatosensory inputs (feedback) to the central processing areas of the brain degrade the ability of the person to maintain static and dynamic postural control.

Recent studies of postural perturbations have demonstrated a multisensory interaction in motor control that is not just specific to the task of postural stability.\(^19\) It has been shown that equilibrium control is proactive, adaptive, and centrally organized based on prior experience and intention.\(^20\) This is important due to the potential effects of sensory loss on coordination and balance. Horak et al\(^7\) suggest loss of somatosensory inputs from the feet result in increased use of a hip strategy in the presence of small surface perturbations when an ankle strategy should have been effective. Wolfson et al\(^21\) corroborated earlier studies that demonstrated when tactile and proprioceptive cues are absent or distorted, older subjects experience increased decrements in balance than young controls.
Postural sway has also been shown to be increased following stroke. Wing et al.12 found impaired performance in stroke patients when forces were applied laterally at the hips over both the involved and noninvolved sides. Peak displacement and stabilization times were greater, particularly on release of the force. This suggests a greater challenge to the neuromuscular system upon release from a sustained push rather than the onset of the push. This can be interpreted to be analogous to loss of a steadying device, such as a cane or railing. Dickstein et al.22 noted a potential disadvantage to automatic lateral perturbations in balance training. While an automatic lateral push may facilitate a general response, unwanted fixations of postural muscles may have adverse effects on timing and magnitude of the desired response. Voluntary weight shifting may be a more advantageous training exercise to produce a graded response under pathologic conditions.

Lateral asymmetry of posture is very apparent after stroke. Stroke patients have increased difficulty moving their center of pressure (COP) in either anterior-posterior (A-P) or lateral (L-R) directions.24 Center of pressure is defined as an index of the distribution of body weight between the two legs. Stroke patients also show variable trajectory in repeated excursions to well defined targets with volitional movement while the feet remain stationary.25 Numerous studies have demonstrated increased stance symmetry using visual biofeedback, yet no one has conclusively shown that these increased abilities affect dynamic posture or locomotion.8,9,12,21 Also, not all the studies utilized stroke patients in the experimental groups. Weinstein and colleagues9 found an
increase in symmetrical standing posture in hemiplegic adults but with no concurrent increase in locomotor performance. Gait velocity increased, but asymmetrical gait patterns were hardly affected. It was suggested that the 'whole-part' training programs associated with complex task acquisition and motor relearning may be inadequate or inappropriately administered and, when integrated back into a complex task such as gait, something is lost. Hamman et al.\textsuperscript{26} demonstrated that normal older subjects could improve performance in static and dynamic training protocols using the NCBM. Static tests measured body sway in eyes-open and eyes-closed conditions. Dynamic testing involved moving the COG to a highlighted target without movement of the base of support (BOS). Transition time to reach the target, path error, and peripheral sway area were measured at 75% of the theoretical LOS.

There has been some discussion related to the use of biofeedback and learning versus performance. While initial performance may show increases in motor control, long-term learning of motor control and postural strategies may remain to be affected.\textsuperscript{14,16,23} At least two studies have shown a loss of acquired skills after long-term follow-up studies.\textsuperscript{14,16} Possible explanations given for the decreased performance seem to be the inability to integrate the newly acquired skills as learned behavior as opposed to motor performance. Learned behavior is defined as a permanent change in motor pattern selection strategies. This view supports the hypothesis by Salmoni\textsuperscript{15,23} that the use of knowledge of results (KR), the extrinsic information about task success, may have both beneficial and
detrimental effects. The detrimental effects occur as a result of a dependence the learner develops with respect to the feedback.

Age and gender have also been shown to be determinants of balance and coordination, albeit the differences are slight. One study noted small decremental decreases in balance existed in normal, healthy elderly versus young controls. When sensory inputs or vigorous perturbations were induced, the disparity became even greater. Possible causes suggested were impaired vestibular input, changes in the central processing areas, or biomechanical factors, notably strength or joint mechanics. Another later study conducted by Wolfson et al. examining gender differences noted a slight disparity in balance among elderly men and women in dynamic postural responses that was not noted earlier. This occurred only under the most difficult task conditions and again it was theorized vestibular inputs, central processing errors, or biomechanical factors were involved. Hamman et al. found a slight but significant gender difference in transition times when testing for dynamic variables using the NCBM system. Females were consistently slower in the age group 60 to 75 years, but overall all groups tested showed improvement and skill retention when tested for peripheral sway area and path error at 22 and 45 days post training.

These findings have serious implications for anyone who suffers a stroke. Numerous studies suggest that falls occur more often in women than men. This includes both community dwellers and those in skilled nursing facilities. It has been shown that the elderly fall more often than the young and that elderly
people with stroke were more likely to fall than others. Since falls can lead to major life threatening complications in the elderly, research in this area is needed to try to improve functional balance in this population.
CHAPTER III

METHODOLOGY

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

Subjects

Three post-stroke subjects between the ages of 40 and 80 years old were recruited to participate in a balance training program at the Altru Health Institute Physical Therapy Department utilizing the NCBM system. An initial and final assessment was performed on each subject using the NCBM protocol and the Berg Balance Scale to determine if the training was effective in improving each of the subjects' balance. All subjects were screened to ensure they could understand instructions, ambulate independently, see the characters on the computer screen, and were at least six months post from their cerebral vascular accident. 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, Clackamus, OR 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 subject’s center of gravity. The computer screen is equipped with a cursor to provide visual feedback on the location of his/her center of gravity. The system provides the subject instantaneous visual and auditory feedback on body COG position during training. The feedback allows the subject the opportunity to increase sensory appreciation and reeducate neuromuscular pathways that have been affected by the stroke. The computerized measurement and feedback system is what makes the system unique and beneficial to both the subject and researcher.

Validity of the NCBM system has been established through its ability to generate computerized printouts of objective, quantifiable data. Published literature supports the clinical use of the NCBM and acknowledges it as a reliable and valid tool for assessing global abnormalities and retraining balance deficits.

The Berg Balance Scale is a highly reliable and valid test of functional ability. It was developed for use in elderly and neurologically impaired patients and has been adopted as the ‘gold standard’ of functional, criterion referenced assessments. It consists of 14 subtests representative of activities of daily living
that are graded on a five-point ordinal scale referenced to detailed descriptors (see Appendix B). The developers of the scale have proposed a cutoff score of 45 to delineate between individuals who are safe in independent ambulation and those requiring investigation concerning their need for assistive devices or supervision. Concurrent validity of the NCBM data and the Berg Balance Scale have been established for dynamic measures of balance only.

Procedure

The study format involved an initial and final NCBM assessment, initial and final Berg Balance Scale assessment, and 30-minute training sessions three times per week. The subject also filled out a brief history questionnaire prior to any assessments being performed (see Appendix C). Each subject participated in a six-week training program using the NCBM system.

The initial and final balance assessments were individualized and dependent on each subject's ability level. The selection of assessment tests were: symmetrical weight bearing/squat test, modified clinical test for sensory interaction on balance (mCTSIB), limits of stability, rhythmic weight shifting, sit-to-stand test, walking, step-up/over, and step/quick turn. Collectively, these tests quantify 1) the patient's ability to move the COG through the LOS; 2) sway velocity defined as the distance in degrees traveled by the COG multiplied by the time of the trial; 3) LOS is defined as the maximum distance a person can lean without losing balance, reaching, or stepping; 4) weight bearing, the percentage of weight born by both legs; 5) reaction time; and 6) directional control.
The training protocol includes activities for symmetric and asymmetric weight bearing, challenges to the LOS, pre-gait activities, lunges, step-up/over, and diagonal stepping. The four main categories to choose from the NCBM menu are 1) weight shifting, 2) mobility, 3) closed chain, and 4) seated. Graduated levels of difficulty allowed for customization of programs per individual sessions. On a scale of one through six, level one is considered to be the least challenging and six the most challenging. All training for the subject was carried out at levels one and two. Refer to the NCBM manual 6.1 for specific assessment and training activities.  

The training exercises allow the subjects to learn how to control their COG while maintaining either a static or dynamic posture. The participant's movements on the force plates cause a displacement in the COG. The displacement of the COG controls the direction of the cursor on the screen. The subjects were instructed to move as quickly and accurately as possible to the designated target highlighted on the computer screen. The types and levels of training protocols were chosen by each member of the research team to target individual areas of deficits.  

After initial assessment, it was determined the subject was having much difficulty moving his COG in an A-P direction and shifting his body weight to the affected side. Both activities are essential to balance and the forward progression of ambulation and provided a starting point for training. The first two weeks training were spent focusing on symmetrical weight shifting exercises,
LOS activities in A-P and L-R directions at 50% of the LOS, and L-R paced stepping.

Week three some regression was noted in the subject's ability to initiate movement in any forward direction. The training moved from standing activities to sitting to try to improve proximal trunk control. Training activities included sitting at 51 cm height with a 15 cm foam surface added (66 cm total height) to skew somatosensory inputs. The subject was instructed to move his COG to highlighted targets situated about a circle at 45° increments and 50% to 75% of his LOS. Training also included A-P and L-R weight shifts on a 95 cm theraball in sitting. Each day's training concluded with a standing activity, usually weight shifting. Week four consisted of a gradual progression back to standing activities.

Weeks five and six training consisted of standing closed chain activities moving to highlighted targets at 45°-90°-135° right, 225°-270°-315° left, and 315°-0°-45° forward at 50% to 75% of LOS. Training also consisted of stepping alternating left and right in forward and diagonal directions and timed rhythmic weight shifting in A-P and R-L direction at three-second pacing.

Assessment Protocol

The testing of subjects was conducted using the standardized assessment protocols on the NCBM system and the administration of the Berg Balance Scale. Due to the high learning curve associated with the NCBM, the subject is allowed to perform several trial sessions before any results were collected. Final assessments replicated the initial data collection on the NCBM
system and the Berg Balance Scale. The description and summary of all
assessment tests are stated along with the performance measures of each test.
(See Appendix B - Berg Balance Scale; see Appendix D - NCBM.)

Data Analysis

The results of this study will show percent change from initial assessment
to final assessment. Percent change was determined by the following formula:
(final assessment score) - (initial assessment score) / (initial assessment score) x
100. A descriptive narrative comparison of age related normal controls will be
included as part of the discussion.

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 Care Systems. A copy of this
independent case study will be given to the preceptor involved with this research
project, and the University of North Dakota. This study was completed to fulfill
the requirements for the University of North Dakota School of Medicine and
Health Sciences Physical Therapy Program.
CHAPTER IV

DISCUSSION

The subject of this case study was a 61-year-old male with an initial onset of stroke on April 6, 1992. Past medical history includes an eleven-year history of diabetes mellitus, head injury sustained in 1964 as the result of a motor vehicle accident, and sustained use of alcohol and tobacco products prior to the stroke. At admission of the initial insult, the following neurological impression was presented as per the physician’s report of consultation: large left hemisphere cerebrovascular accident (CVA) resulting in 1) right hemiparesis, arm greater than leg; 2) right hemisensory deficit; 3) right visual deficit or at least neglect (there was not a chart entry to indicate if he had been formally tested); 4) mixed aphasia, expressive greater than comprehension; 5) insulin dependent diabetes mellitus; 6) history of hypertension; 7) recent history of cardiac dysrhythmia while in the hospital; and 8) probable peripheral vascular disease.

A formal physical therapy evaluation was not performed on the subject prior to the study, although a complete review of past physical therapy evaluations and progress notes was performed. The subject was able to carry out his normal daily routine without assistance, including loading and unloading of his motorized cart with an electric hoist system and driving his automobile. The subject used a motorized cart for most activities but could ambulate
independently moderate distances (~ 500 ft.) with a single point cane. He reported he did not use his cane in the home. Extensor synergy pattern was exhibited in the affected right lower extremity (LE) and a mild flexor synergy pattern of the affected right upper extremity (UE) in standing. Associated reactions of the right UE were evident with exertion and the subject had minimal use of the right UE. The subject exhibited minimal residual expressive aphasia and his visual field appeared normal with informal testing, including peripheral vision.

Results of the Berg Balance Scale show an improvement in nine of 14 categories, regression in one category (standing to sitting), and no change in four categories. Initial score was 29, final score was 43 indicating a 48.27% increase in total score. The regression in standing to sitting may be attributed to examiner error due to inexperience in administering the Berg Balance Scale. The patient demonstrated controlled ‘crashes’--sitting independently with the use of his left hand but with uncontrolled descent--to the sitting position throughout the test period and probably was scored too high initially. Of the unchanged scores, two remained at the maximum level of function, one scored at three (sitting to standing, 0-4 scale), and the last remained zero due to the subject’s inability to stand on one leg unsupported. While these results are no indication of sustained dynamic postural control, it is indicative of functional improvement and may more accurately reflect gains objectified by NCBM data (refer to Appendix B).
Following six weeks of biofeedback training on the NCBM, results of the training were mixed. The static weight-bearing test showed a regression of increased reliance on the uninvolved LE (left). Overall improvement was seen in four of five tests—rhythmic weight shifting, sit-to-stand test, walk test, and the mCTSIB. The rhythmic weight shift test, sit-to-stand test, and the walk test all had component parts showing regression.

NCBM Tests

Static weight bearing measures the percent body weight borne by each lower extremity (LE). The percent body weight bearing on the left LE increased 43.39%, while right side LE weight bearing decreased 48.93% (see Table 1).

Table 1.—NeuroCom® Balance Master Weight Bearing Test Results - Percent Body Weight

<table>
<thead>
<tr>
<th>STATIC WEIGHT BEARING TEST</th>
<th>Initial</th>
<th>Final</th>
<th>% Change</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right side</td>
<td>47</td>
<td>24</td>
<td>-48.93</td>
<td>Regression</td>
</tr>
<tr>
<td>Left side</td>
<td>53</td>
<td>76</td>
<td>43.39</td>
<td>Regression</td>
</tr>
</tbody>
</table>

* percent body weight

This finding is contrary to a number of authors reporting increased symmetry in weight bearing after training with the use of biofeedback. In this case, the results may not accurately reflect the true nature of the subject's performance. Due to time constraints and schedule conflicts, the final Berg Balance Scale and NCBM assessment were administered consecutively on the same day. Increased reliance of the involved LE during NCBM testing may be the result of
induced fatigue from performing the Berg Balance Scale prior to NCBM testing. It may also be attributed to learned non-use of the affected LE in situations where increased stability is needed as a result of an intrinsic or extrinsic perturbation; in this case, fatigue. The subject was clearly fatigued by the time the NCBM assessment started.

The rhythmic weight shifting test has two component parts and a composite score (see Table 2). Part one measures on-axis velocity in L/R and F/B directions: the speed of the COG movement in the intended direction, expressed in degrees per second. Part two compares the directional control which is the amount of movement in the intended direction compared to the
amount of extraneous movement. This is calculated as follows: (amt. intended mvmt) - (amt. extraneous mvmt) / (amt. intended mvmt) and expressed as a percentage. Left/right on-axis velocity showed a 35.3% increase; A/P on-axis velocity showed a 18.75% increase, and the composite on-axis velocity showed a 23.5% overall improvement in all four cardinal planes. Directional control, however, generally decreased, articularly in the A/P direction. Anterior/posterior directional control decreased 263.33%; L/R directional control increased 47.0%, and composite directional control scores decreased 96.87%. Rhythmic weight shifting attributes of the subject compared to age matched normal controls were as follows: initial assessment showed speed of movement and ability to coordinate movement in the abnormal range. Final assessment showed only the ability to coordinate movement in the abnormal range. Scores for speed of movement were all in the neutral zone and were not delineated as normal or abnormal.

This is significant because it may affect the subject’s ability to produce reciprocal movements as well as modify the timing of those movements to meet functional demands. The inability to adapt may be linked to a number of factors. Decreased peripheral sensation in the affected LE combined with any peripheral neuropathies associated with diabetes could affect sensorimotor function.7 Previous studies have shown that postural movement strategies are selected partially in advance in response to the current sensory conditions and previous experience. The loss of these inputs leaves the motor control centers of the brain without crucial information regarding proprioception and joint position.
resulting in the disruption of accurate feedback. The resulting obligatory movement pattern may prevent movement in certain directions or the use of selected postural strategies. This leads to an inability to initiate an ankle strategy to control the small oscillatory movements needed to complete the exercise successfully.

Cerebral vascular accidents can disrupt central processing areas of the brain and may limit the ability of the patient to learn new movement strategies and limit the number of patterns available for use. The subject demonstrated difficulties throughout the training period initiating movement in the A/P direction regardless of the midline. This suggests a deficit in motor planning and attempts to retrain in this instance were met with some neural resistance. Exploration into the possibility that neural plasticity and the ability of the brain to relearn preferred movement strategies is limited as the time since onset of the stroke increases would be worthwhile. Additionally, learned faulty movement patterns and compensatory actions are likely to be resistant to change once they become integrated for use regardless of neural plasticity issues.

The sit-to-stand test measures four component parts: weight transfer, rising index, COG sway velocity, and L/R symmetry (see Table 3). All trials are repeated three times for an average mean score. The proper sitting height for the subject was determined to be 51 cm. Weight transfer is the average amount of time between the onset of the cue and the end movement of the COG over the feet, expressed in seconds. Rising index is the average amount of force
Table 3.—NeuroCom® Balance Master Sit-to-Stand Test Results Showing Weight Transfer (sec), Rising Index (% body weight), COG Sway Velocity (deg/sec), and Left/Right Weight Symmetry (% L/R)

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Final</th>
<th>% Change</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight Transfer (sec.)</td>
<td>3.61</td>
<td>1.18</td>
<td>-67.3</td>
<td>Improvement</td>
</tr>
<tr>
<td>Rising Index (% body wt.)</td>
<td>40</td>
<td>9</td>
<td>-77.5</td>
<td>Regression</td>
</tr>
<tr>
<td>COG Sway Velocity (deg/sec)</td>
<td>6.8</td>
<td>2.5</td>
<td>-63.23</td>
<td>Improvement</td>
</tr>
<tr>
<td>L/R Wt. Symmetry (% body wt.)</td>
<td>29 (L)</td>
<td>16 (L)</td>
<td>-44.82</td>
<td>Improvement</td>
</tr>
</tbody>
</table>

exerted by the legs during rising, expressed as a percent of body weight. Center of gravity sway velocity is the average amount of COG sway during rising to stand and for five seconds after rising, expressed in degrees per second. Left/right weight symmetry is the relative amount of weight borne by each LE during rise to stand and for the first five seconds after standing, expressed as a percentage. Each test has a coefficient of variation calculation that consists of the standard deviation of the three trials divided by the mean of the three trials, expressed as a percentage. This value indicates consistency (low CV) or variability (high CV) of the scores between the trials.

Weight transfer showed a 67.3% decrease in time, with a CV of 23%. Rising index decreased 77.5%, indicating a regression in function; CV was 43%. The subject was using his hands for push off on trials one and two of the final assessment which would decrease the force exerted by the LEs during rising. Center of gravity sway velocity showed 63.23% improvement with a CV of 24%. Left/right weight symmetry improved 44.82% with CV of 2%. Use of the hands
may allow the subject to distribute weight more evenly during rising, although it
cannot account for symmetry after attaining an upright stance. Sit-to-stand
attributes compared to age matched normal control subjects were as follows:
initial assessment attributes in the abnormal range were 1) time required to
transfer weight forward, 2) amount of sway during rise to stand, and 3) L/R
symmetry of the rise to stand. Final assessment attributes in the abnormal range
were 1) time required to transfer weight forward, 2) the force of the rise to stand,
and 3) L/R symmetry of the rise to stand. During the final assessment of sit-to-
stand testing, the subject was clearly fatigued and required frequent, short rests
between trials.

The only attribute to improve into the normal range for age matched
controls during sit-to-stand testing was COG sway velocity. However, an overall
improvement was seen in weight transfer and L/R symmetry, although not to the
extent of age matched normal control subjects. Similar improvements were seen
in related items on the Berg Balance Scale. Scores for transfers, standing with
feet together, and standing with eyes closed all improved a minimum of one
point (see Appendix B).

The Walk Test showed improvement for all component parts except step
width in walking, which increased. The Walk Test measures four component
parts: step width, step length, speed, and end sway (see Table 4). Step width is
the average lateral distance between successive steps, measured in
centimeters. Step length is the average longitudinal distance between
successive steps, measured in centimeters. Speed is the average velocity
Table 4.—NeuroCom® Balance Master Walk Test Results Showing Step Width (cm), Step Length (cm), Speed (cm/sec), and End Sway (deg/sec)

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Final</th>
<th>% Change</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step Width (cm)</td>
<td>20.8</td>
<td>25.4</td>
<td>22.11</td>
<td>Regression</td>
</tr>
<tr>
<td>Step Length (cm)</td>
<td>9.6</td>
<td>16.36</td>
<td>69.8</td>
<td>Improvement</td>
</tr>
<tr>
<td>Speed (cm/sec)</td>
<td>16.3</td>
<td>23.4</td>
<td>43.55</td>
<td>Improvement</td>
</tr>
<tr>
<td>End Sway (deg/sec)</td>
<td>3.8</td>
<td>2.9</td>
<td>-23.68</td>
<td>Improvement</td>
</tr>
</tbody>
</table>

defined as the forward progression expressed in degrees per second. End sway is average COG sway velocity in the A-P direction during the first five seconds after forward progression stops, expressed in degrees per second. Each score has a CV value.

Step width increased 22.11%, CV was 11%; step length increased 69.8%, Cv was 6%; step speed increased 43.55%, CV was 25%; end sway velocity showed a 23.68% decrease, CV was 63%. Initial assessment attributes of the Walk Test in the abnormal range for age related normal controls were length and speed of step. Final assessment attributes in the abnormal range were width, length, and speed of step.

Based on the fact that the test was administered approximately one hour after starting, fatigue may have been a factor in the score. Fatigue would likely increase the BOS, although the subsequent increase in gait speed (43.55%) may have induced a sensation of instability as well. This was not reported by the subject. Paradoxically, increases in gait velocity in normal subjects decrease the BOS. Weinstein et al. noted the same velocity increases in controls and
feedback trained subjects and concluded balance training had no effect on locomotor activities. The subject did report increased confidence in his abilities and also reported anecdotal remarks made by family and friends that “he looked like he was walking better.” Confidence in himself and his abilities may account for his improvements.

The remaining test, the mCTSIB, measures one component - mean COG sway velocity within a circle (see Table 5). The 0° position is located at the twelve o'clock position and progresses in a clockwise fashion. The test defines four testing conditions but only two were used with this subject: eyes open firm surface (EOF) and eyes closed firm surface (ECF). The third and fourth conditions - eyes open foam surface and eyes closed foam surface - were not tested due to the subject’s inability to stand independently on the foam surface. Center of gravity sway velocity is the ratio of distance traveled by the COG (expressed in degrees) to the time of the trial (10 secs.). The mean is the average of the scores from any one trial condition. Condition one (EOF) scores improved 20.0%. Condition two (ECF) scores improved 31.42%. Note that the subject was unable to complete the third trial of the initial mCTSIB assessment.

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Final</th>
<th>% Change</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes Open Firm</td>
<td>1.5</td>
<td>1.2</td>
<td>-20.0</td>
<td>Improvement</td>
</tr>
<tr>
<td>Eyes Closed Firm</td>
<td>3.5</td>
<td>2.4</td>
<td>-31.42</td>
<td>Improvement</td>
</tr>
</tbody>
</table>

* mean COG sway velocity - deg/sec
(see Appendix D). No composite average was given. Initial and final assessment attribute of the mCTSIB in the abnormal range were unchanged - stability with eyes open or eyes closed on a firm surface.

The sit-to-stand, walk test, and mCTSIB all have the common component of COG sway velocity. The first two tests record COG sway after a dynamic movement while the mCTSIB is a static test. Numerous authors have reported decreased postural sway after biofeedback training yet none has shown any correlation to functional dynamic activities.\textsuperscript{9,10,23,26} The subject showed a decrease in sway velocity in all three tests but most dramatically, he showed a 31.42% decrease in condition two (ECF) of the mCTSIB. This finding correlates with an improvement seen on the Berg Balance Scale of standing with the eyes closed (subtest #6) for three seconds to standing with eyes closed and standby assist for ten seconds. Given the subject’s right side sensory deficit, level of fatigue, and the concurrent removal of visual inputs, this seems to be remarkable. It must be noted that identifying specific sensory deficits with forceplate technology is unreliable at this time, but the tests can be used to identify global abnormalities.\textsuperscript{13}

Upon inspection of the data, the question arises as to whether the subject was using fixation of the postural stabilizers in order to complete the mCTSIB test and possibly the sway components of the other tests. At initial assessment, the average COG position for both mCTSIB test conditions was located left 282.5° at 12% of the LOS. Average COG position at the final assessment was located left/forward 306.5° at 33% of the LOS (see Appendix D). This was also
the last test administered in the NCBM series. It has been suggested that patients challenged beyond their current abilities may react with undesirable muscle stiffness. This could account for the decreased sway velocity, given the fact the subject was in a difficult boundary area that had already been established (forward). Shumway-Cook et al\textsuperscript{10} reported increased stance asymmetry with decreased postural sway in a group of hemiparetic subjects. In studies involving dynamic movement, postural fixations have been noted as a means of controlling anticipatory perturbations and the resultant oscillatory motion.\textsuperscript{22} As stated earlier, the subject expressed his fatigue and facial grimaces observed during condition two testing of the mCTSIB confirmed an increased level of concentration and focus by the subject. Due to this, he may have been bracing, using his non-affected LE to produce stability, thereby reducing postural sway by default.

In an examination of the overall performance of the subject, it must be noted that the subject shows a regression of performance in only on test condition - static weight bearing. Regression was also noted in components of three test conditions - rhythmic weight shifting, sit-to-stand test, and the walk test. In areas the subject showed improvement, scores are still in the abnormal range compared to normal age matched controls with the exception of COG end sway velocity in sit-to-stand and walking. One of the questions that arises from the examination of the data is the controversy of performance versus learning. In this situation, the answer will remain unresolved due to the fact that this researcher is unable to retest the subject at some point in the future. Engardt\textsuperscript{16}
recorded a net decrease of 9% of body weight distribution over the paretic leg in rising and sitting down 33 months after training with auditory feedback; the control group experienced a net loss of 5%. Initial training started one week to three months after the stroke. Reasons given for the decline were asymmetrical strength, favoring of the non-paretic limb, and a possible dependence on the feedback which may have blocked the development of an internal frame of reference of experience.

In other studies involving motor learning, it has been shown that both knowledge of performance (KP) and knowledge of results (KR) are important for learning. But, KR is much more important to long-term learning since it serves as a basis for error correction and can lead to a more effective performance of subsequent practice trials. In this study, KP and KR were used concurrently and continuously. One of the goals of this study was to determine the efficacy of the use of high tech equipment for balance training in the chronic stroke patient. While it would have been efficacious to control the amount and type of feedback, that was not one of the primary concerns of the study. To do so would have required a more extensive evaluation and screening of the subjects which probably would have eliminated this subject from the study due to his level of involvement. In addition, it has already been shown that KR is important for learning, especially absolute frequency, which is the total number of KR presentations during a given practice session. What has not been determined is the importance of relative frequency, the ratio of the total number
of KR presentations to the total number of practice trials. Further research involving chronic stroke patients may explore these areas of motor learning.

Limitations of Study

The limitations of this study are many. The NCBM system is a high tech tool designed and marketed as an aid to rehabilitation. In some patient populations, it may not be an appropriate tool due to the complexity and accuracy required to replicate repetitive tests and measures. As such, all test scores could be affected. Maintenance of foot placement on the forceplate platforms is critical to generate valid and reliable data. During the assessment and training periods, the subject did exhibit difficulty maintaining foot placement in the proper alignment on the force platforms. This was due to the subject's inability to accurately control volitional movement of the right LE. Patients with faulty movement patterns, ataxia, or excess LE synergy patterns may have difficulty maintaining foot placement during testing, therefore rendering all results invalid. The limits of stability test was not performed due to the inability to generate a score for the subject at any level of assessment. The complexity of the test and the subject's inability to complete the required action in the allotted time resulted in no scores being recorded.

The NCBM also has a very high learning curve associated with all assessment and training protocols. In patients with aphasias, learning deficits, visual deficits, or general cognitive debility, this could present a barrier to conceptualization and execution of the intended action. At times, the subject displayed confusion regarding an exercise and it was impossible to determine
the source of the confusion—error in instructions given by the tester or inability of
the subject to comprehend the intended action and coordinate that action with
the cursor on the monitor. In general, the subject demonstrated good
comprehension throughout the training period.

Frequency, rate, and type of feedback was uncontrolled throughout the
study period. This has been shown to have an impact on learning.\cite{14-16,23} Without
a extinguishing period or future retest, it is impossible to know if learning has
occurred or if the subject was acclimated to the learning curve and merely
performing the intended actions.

The experience and ability of the tester in administering NCBM
assessment and training protocols prior to the start of the study was limited to
the use of normal, healthy subjects exclusively. This lack of experience working
with involved subjects imposed a learning curve on the tester that impinged on
the actual study time and, as a result, appropriate cueing and guidance may
have been withheld in the early stages of training. Additionally, the inability of
the tester to recognize the limits of the subject's endurance probably contributed
to a decreased performance during the final assessment period. Final
assessment should have been spread over a two-day period to lessen the
effects of cumulative fatigue. In retrospect, the subject's performance probably
would have improved on the final NCBM assessment had this been done.

The subject had extraneous variables impacting his mental and physical
self which may have altered his level of performance. Several friends and family
members were terminally ill and expected to pass on within six months of the
start of the study. This produced an exacting emotional and physical drain on
the subject which manifested in fatigue and diminished affect. In addition, the
subject trained with progressive resistive exercise for one hour prior to one of the
test days which may or may not have contributed to his performance.

Clinical Implications

Post-stroke survivors have been shown to have a higher incidence of falls
than normal, healthy elderly in the general population. Periodic retraining in
balance activities may reduce the incidence of falls in this population, adding to
their quality of life, ability to remain productive, and reduce the economic burden
associated with medical complications as a result of falls. This would indicate
further testing is justified to explore the parameters of protocol design, motor
learning, and efficacy of training in post-stroke subjects.

Conclusions

In conclusion, this case study involved clinical assessment and training
using the NeuroCom® Balance Master System 6.1 of a 61-year-old male post-
stroke subject to determine the efficacy of a six-week training program to
improve balance. Despite numerous limitations and lack of ability to generate a
statistical analysis of the results, the data show a generalized improvement of
the parameters tested on the NCBM system and the Berg Balance Scale.
Improvement in static and dynamic postural control was documented in four of
five test conditions using the NCBM assessment protocols and a 48.27%
increase was recorded for the Berg Balance Scale scores. The subject's
improved Berg Balance Scale scores infer an increase in functional ability and
can be attributed least least partially to training received using the NCBM. Extraneous factors beyond the parameters of this case study causing improvement cannot be ruled out and the results are not mutually exclusive.
Institutional Review Board
Research Project Action Report

Date: August 12, 1998  IRB#: PT-008
Principal Investigator: Kelly Adams, Joe Brenner, Jim Sillanpaa
Department: Physical Therapy  Phone #: 775-4103

Kelly - 780-8817, Joe - 777-9188

Address to which notice of approval should be sent: _______________________

Research Coordinator: Meridee Green  Phone #: 777-2831

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

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

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

☐ Project approved. EXPEDITED REVIEW NO. 3, 8
   Next scheduled review is on ______________________

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

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

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

☐ Amendment approved

☐ Administrative change approved

☐ Protocol revision approved

☐ Revised consent form approved

☐ Adverse event reviewed - Date of event ______________________

☐ Other ______________________

REMARKS:

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

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

Date

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.*

- **Principal Investigator:** Joe Brenner, Jim Sillanpaa  
  - Phone #: Jim 775 4103  
  - Date: 7/14/98
- **Institution:** University of North Dakota  
  - Department: Physical Therapy
- **Research Coordinator:** Meridee Green  
  - Phone #: 777-2831

**Proposed Project Dates:**

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

---

**Funding Agencies (if applicable):**

**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 ☒.

- ☒ Expedited Review requested under item 3, 8 (number) of HHS Regulations (see attached explanation)
- ☐ Exempt Review requested under item (number) of HHS Regulations (see attached explanation)

---

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.
2. PROTOCOL: (Describe procedures to which humans will be subjected.)

Background and Objectives

Balance is critical for optimal function in activities of daily living. Deficits in balance are common among post-stroke patients and can result in decreased functional capability. The Balance Master will be used to assess the balance of post-stroke individuals and help determine areas of limitation in regard to functional activities. The Balance Master system is designed to provide visual feedback to the patients regarding their center of gravity as well as training protocols to enhance equal weight distribution in upright positions, stability, and overall functional balance. The objective of this study is to determine if the training protocol performed on the NeuroC 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: 7/14/98

Project Director: ___________________________ Date: 7/15/98

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

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

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

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

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

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

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

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

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

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

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

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

Participant’s Signature

Date
Witness (not the scientist)  Date
APPENDIX B
**BALANCE SCALE**

**Name** Initial Assessment - LD  
**Date** 9/4/98  
**Location** Altur, G.F., MD  
**Rater** Kelly Adams, SPT

<table>
<thead>
<tr>
<th>ITEM DESCRIPTION</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1. Sitting to standing</td>
<td>3</td>
</tr>
<tr>
<td>2. Standing unsupported</td>
<td>4</td>
</tr>
<tr>
<td>3. Sitting unsupported</td>
<td>3</td>
</tr>
<tr>
<td>4. Standing to sitting</td>
<td>3</td>
</tr>
<tr>
<td>5. Transfers</td>
<td>3</td>
</tr>
<tr>
<td>6. Standing with eyes closed</td>
<td>2</td>
</tr>
<tr>
<td>7. Standing with feet together</td>
<td>1</td>
</tr>
<tr>
<td>8. Reaching forward with outstretched arm</td>
<td>2</td>
</tr>
<tr>
<td>9. Retrieving object from floor</td>
<td>4</td>
</tr>
<tr>
<td>10. Turning to look behind</td>
<td>0</td>
</tr>
<tr>
<td>11. Turning to 360 degrees</td>
<td>2</td>
</tr>
<tr>
<td>12. Placing alternate foot on stool</td>
<td>0</td>
</tr>
<tr>
<td>13. Standing with one foot in front</td>
<td>2</td>
</tr>
<tr>
<td>14. Standing on one foot</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>29</strong></td>
</tr>
</tbody>
</table>

**GENERAL INSTRUCTIONS**

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

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

Equipment required for testing are a stopwatch or watch with a second hand, and a ruler or other indicator of 2.5 and 10 inches. Chairs used during testing should be of reasonable height. Either a step or a stool (of average step height) may be used for item #12.
BALANCE SCALE

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>SCORE (0-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sitting to standing</td>
<td>3</td>
</tr>
<tr>
<td>2.</td>
<td>Standing unsupported</td>
<td>4</td>
</tr>
<tr>
<td>3.</td>
<td>Sitting unsupported</td>
<td>4</td>
</tr>
<tr>
<td>4.</td>
<td>Standing to sitting</td>
<td>1</td>
</tr>
<tr>
<td>5.</td>
<td>Transfers</td>
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</tr>
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</tr>
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<td>13.</td>
<td>Standing with one foot in front</td>
<td>3</td>
</tr>
<tr>
<td>14.</td>
<td>Standing on one foot</td>
<td>1</td>
</tr>
</tbody>
</table>

TOTAL 43

GENERAL INSTRUCTIONS

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

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

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

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

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

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

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

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

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

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

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

10. TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDER WHILE STANDING
INSTRUCTIONS: Turn to look directly behind you over toward left shoulder. Repeat to the right. Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.
( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
( ) 2 turns sideways only but maintains balance
( ) 1 needs supervision when turning
( ) 0 needs assist to keep from losing balance or falling

11. TURN 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

12. PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.
( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/unable to try

13. STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width.
( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead of other independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

14. STANDING ON ONE LEG
INSTRUCTIONS: Stand on one leg as long as you can without holding.
( ) 4 able to lift leg independently and hold > 10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold = or > 3 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently
( ) 0 unable to try or needs assist to prevent fall

( ) TOTAL SCORE (Maximum = 56)

II - E - 10

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APPENDIX C
1) Do you need to use assistive devices for ambulation or activities for daily living?

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

3) Are you currently on any medications?

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

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

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

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

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

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

10) Do you have any health problems that may be preclude you from doing this study?
APPENDIX D
WEIGHT BEARING TEST

% Body WT

<table>
<thead>
<tr>
<th>Percentage Weight Bearing:</th>
<th>Angle</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>53</td>
<td>47</td>
<td></td>
</tr>
</tbody>
</table>
WEIGHT BEARING TEST

% Body WT

LEFT SIDE RIGHT SIDE

Percentage Weight Bearing:
Angle Left Right
0° 76 24

Data Range Note:
NeuroCom Data Range: 60–69

Post Test Comments:
approx 1 hr into testing - possible fatigue (test start time = 1:00 PM)
A. 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:

1) **Percentage Weight Bearing** - the fraction of the total body weight placed
   on each foot and expressed as a percentage.
Name: L, D  
ID: ATTD0013  
DOB: 9/23/1937  
Referral Source:  
Height: 6'0"  
Comments: Initial Assessment 09/04/98

Diagnosis: right hemi  
Operator: ADAMS, KELLY  
Test Date: 9/4/1998  
Test Time: 10:23:48 AM  
File: HBM138.QBM

RHYTHMIC WEIGHT SHIFT TEST

Left/Right  
Front/Back

SLOW (3 sec per transition)

deg/sec  
On-Axis Velocity

%  
Directional Control

Data Range Note: NeuroCom Data Range: 60–69

Post Test Comments:

Name: L, D
ID: ATID00138
DOB: 9/23/1937
Height: 6'0"

Diagnosis: right hemi
Operator: Not Specified
Referral Source: Grand Forks, ND 58202-9037
Comments: Initial Assessment 09/04/98

File: HBM138.QBM
Test Date: 10/20/1998
Test Time: 1:47:23 PM

RHYTHMIC WEIGHT SHIFT TEST

Left/Right

Front/Back

SLOW (3 sec per transition)

deg/sec

On-Axis Velocity

% Directional Control

Data Range Note: NeuroCom Data Range: 60–69

Post Test Comments:

B. Rhythmic Weight Shift

The subject is instructed to stand in place with the 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 back and forth between two boundaries spaced in opposite directions from center at 50% of the distance to the LOS perimeter. The required rhythm of the back and forth movement is demonstrated by a pacing target. The task is repeated with rhythmic movements between antero-posterior and lateral boundaries. To accommodate different functional levels, the test includes three different pacing speeds. The following parameters were calculated from the COG cursor:

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

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

Trial 1

Trial 2

Trial 3

Data Range Note:
NeuroCom Data Range: 60–69

SIT TO STAND TEST

Trial 1

Trial 2

Trial 3

Data Range Note:
NeuroCom Data Range: 60–69

Post Test Comments:
push off within 1 tests 1,2 - use of hands for leverage tests #1, 2
at approx 1 hr into testing at this point - possible fatigue setting in

C. 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:

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

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

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

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

Data Range Note:
NeuroCom Data Range: 60–69

Post Test Comments:
overstep end plate with 2nd and 3rd test
**Name:** L., D  
**ID:** ATID00138  
**DOB:** 9/23/1937  
**Height:** 6'0"  
**Diagnosis:** right hemi  
**Operator:** Not Specified  
**Referral Source:**  
**Comments:** Initial Assessment 09/04/98  

**File:** HBM138.QBM  
**Test Date:** 10/20/1998  
**Test Time:** 1:47:23 PM

### WALK TEST (Level One)

**Trial 1**

**Trial 2**

**Trial 3**

**Data Range Note:**
NeuroCom Data Range: 60–69

Post Test Comments:

---

D. 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:

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

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

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

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

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.
MODIFIED CLINICAL TEST FOR SENSORY INTERACTION ON BALANCE (CTSIB)

1. Firm--Eyes Open (FIRM-EO)

2. Firm--Eyes Closed (FIRM-EC)

3. Foam--Eyes Open (FOAM-EO)

4. Foam--Eyes Closed (FOAM-EC)

Data Range Note: NeuroCom Data Range: 60–69

Post Test Comments:

unable to complete ec

Name: L, D  Diagnosis: right hemi  File: HBM138.QBM
ID: ATID00138  Operator: Not, Specified  Test Date: 10/20/1998
Height: 6'0"  Comments: Initial Assessment 09/04/98

MODIFIED CLINICAL TEST FOR SENSORY INTERACTION ON BALANCE (CTSIB)

1. Firm--Eyes Open (FIRM-EO)

2. Firm--Eyes Closed (FIRM-EC)

3. Foam--Eyes Open (FOAM-EO)

4. Foam--Eyes Closed (FOAM-EC)

deg/sec  Mean COG Sway Velocity

Average COG Position

Data Range Note: NeuroCom Data Range: 60–69

Post Test Comments:

E. Modified Clinical Test for Sensory Integration and Balance

The modified clinical test for sensory integration on balance (mCTSIB) consists of four test conditions:

1. Firm surface - eyes open
2. Firm Surface - eyes closed
3. Foam rubber surface - eyes open
4. Foam rubber surface - eyes closed

The subject is instructed to stand with the feet placed in the standard position and maintain static posture for the length of the test. Time for each test is ten seconds. Stability under each condition was tested and the results were averaged. In trials where the subject steeped off the forceplate, the trial was terminated and repeated. The following results were quantified:

1. **Mean COG Sway Velocity** - was calculated by determining the total length of the sway path followed by the body COG over the duration of the trial divided by the ten second trial duration.

2. **Average COG Position** - reflects the alignment in degrees from center of the average COG position, expressed in X and Y axis components.
F. 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 degree intervals around the center target to form an oval. The center target represents the COG position of the subject during static standing. The eight peripheral targets represent 100% of the distance from the center position to the theoretical limits of stability. The subjects are instructed to stand as still as possible while maintaining the COG cursor within the highlighted center target. The subjects are then instructed to move as quickly and accurately as possible to the highlighted peripheral target, hold the position until the end of the trial, and then return the cursor to the center target. To minimize anticipation, highlighting of the designated target is delayed randomly relative to the start of each trial. The sequence is repeated until each subject can move successfully to each of the eight LOS targets, beginning with the forward target and progressing in a clockwise direction. During movement to each of the eight targets, COG is recorded based on the following parameters:

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

2) Mean Velocity (MVL)- the mean COG velocity over the time interval beginning with the point at which the subject moves 5% of the distance to the target and ending with the point at which the subject moves to within 95% of endpoint excursion. Mean COG velocity is expressed in degrees per second.
3) **Endpoint Excursion (EPE)**- the distance the COG is displaced toward the target during the subject's primary movement. This movement segment ends when the COG movement first ceases progression toward the target. Endpoint excursion is expressed as a percentage of the distance to the target. Therefore, a subject whose initial movement ends precisely at the target has an endpoint excursion of 100%.

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

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


