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Examination of Tester Reliability Utilizing the Limits of Stability Test on the Neurocom Balance Master for Assessing Balance in Healthy Individuals

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EXAMINATION OF TESTER RELIABILITY UTILIZING THE LIMITS OF
STABILITY TEST ON THE NEUROCOM BALANCE MASTER FOR
ASSESSING BALANCE IN HEALTHY INDIVIDUALS

by

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Katie Miller
Rachael Seals
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Bachelor of Science in Physical Therapy
University of North Dakota, 2001

A Scholarly Project
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
2002
This Scholarly Project, submitted by Casey Bartolo, Katie Miller, Rachael Seals and Christal Stotesbery 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 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 Examination of Tester Reliability Utilizing the Limits of Stability Test on the NeuroCom Balance Master for Assessing Balance in Healthy Individuals

Department Physical Therapy

Degree Master of Physical Therapy

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Signature(s)

Date 12-11-01
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ABSTRACT

Balance is critical for optimal function in completion of everyday tasks. Physical therapists frequently work with people that have balance disturbances in order to help return them to optimal function. One tool used in the assessment and treatment of balance disorders is the NeuroCom® Balance Master 7.06 (NBM), a computerized forceplate system that provides objective measurements of balance performance. In order to obtain accurate measurements on the NBM, it is necessary that the tester have adequate training. The purpose of this study was to determine the amount of training necessary for a therapist to obtain reliable results using the NBM. The study consisted of 11 healthy adult subjects who participated in six testing sessions each. Data was collected and compared between test sessions to determine if results were reliable over time. Results showed that clinical reliability (ICC > 0.90) was not reached or maintained for all components of the Limits of Stability Test following familiarization and a moderate level of tester training. However, data obtained for each component either met or exceeded the level of intra-rater reliability found by the manufacturer. Because clinical reliability was not reached by the conclusion of the study, researchers were not able to determine the amount of training necessary to become clinically reliable with the NBM.
CHAPTER I
INTRODUCTION

Balance is critical for optimal function and completion of everyday tasks.\textsuperscript{1} It is necessary to have appropriate balance in order to get out of bed, ambulate and complete other activities of daily living. Balance assessment and training are important components of rehabilitation for patients with a wide variety of disorders including orthopedic, neurologic, vestibular and geriatric diagnoses.\textsuperscript{2,3}

In order to accurately assess balance and measure progress of patients, a therapist must be able to obtain reliable and valid measurements. Reliability is defined as the extent to which a measuring tool produces the same results without significant error across repeated testing sessions (intra-rater reliability) and between multiple raters (inter-rater reliability).\textsuperscript{4,5} Validity is defined by O'Sullivan and Schmitz\textsuperscript{6(p95)} as "the degree to which an instrument or tool measures what it is designed to measure; the degree to which an assessment instrument or tool is able to predict future behavior."

The NeuroCom\textsuperscript{®} Balance Master 7.06 (NBM) is one clinical measurement tool commonly used in the assessment and treatment of balance disorders. The NBM is a computerized forceplate system that provides objective measurements of balance performance. Reliability of the Limits of Stability (LOS) Test, one of eleven assessments available on the NBM, has been assessed by a small number of studies.\textsuperscript{1,4,7,8} These studies found moderate to high intra-rater reliability with some movement variables.
representing the person’s ability to voluntarily sway to different locations in space quickly and accurately. However, none of the studies addressed the amount of training necessary to reach intra-rater reliability.

Problem Statement

Although the NBM is commonly used in the assessment and treatment of balance impairments in physical therapy settings, little research has been done to show the amount of training necessary to obtain intra-rater reliability. Intra-rater reliability is important in the clinical setting in order to determine the accuracy of assessments and efficacy of therapeutic interventions performed on the NBM. A therapist must be reliable in obtaining measurements so results can be compared across test sessions and changes in performance can be documented. Thus, it is imperative to determine the amount of experience needed in order to obtain reliable results.

Purpose/Research Question

The purpose of this study is to determine the amount of training needed for a therapist to become reliable with the NBM for use in both clinical and research settings. This study will attempt to answer the following question: Will a clinical level of intra-rater reliability (ICC > 0.90) be reached in the NBM LOS Test with a moderate level of tester training (35-42 test trials), including prior familiarization with the operation of the NBM?

Hypothesis

It is hypothesized that intra-rater reliability will be reached in the NBM LOS Test upon completion of moderate tester training, including prior familiarization in the
operation of the NBM. The null hypothesis is: Intra-rater reliability cannot be achieved within 35-42 testing sessions.

Significance

Balance is a necessary component that enables individuals to participate in and safely complete a variety of everyday activities. Physical therapists assess and treat people with balance disturbances using the NBM in order to help return them to optimal function. As a result, it is necessary to determine the amount of training needed to obtain intra-rater reliability on the NBM. This will allow for objective, measurable and reliable documentation in the clinic and in future research, enabling physical therapists to provide more accurate balance assessment and training for their patients. The client will also be able to obtain reliable, understandable feedback concerning his or her progress.
Balance, or postural control, is an important component necessary for everyday function. Nichols\(^9\) defines balance as "the ability to maintain or move within a weight-bearing posture without falling." Balance is composed of components from three systems: visual, vestibular and somatosensory.\(^6,10-12\) In order to process, integrate and respond to information from all three systems an intact central nervous system is necessary.\(^10,11\) The three systems work together with the central nervous system to achieve the overall goals of balance: safety and function.\(^6\)

If a problem with balance arises that jeopardizes a person’s safety or function, a balance assessment may be performed to determine the source of the problem. There are three aspects of balance that are frequently measured during balance assessment: steadiness or static balance, symmetry and dynamic stability.\(^7,9\) Steadiness or static balance is the ability to maintain a certain posture with a minimal amount of sway on a stable surface.\(^9,13\) There are many assessments used to test static balance, some examples include the Romberg Balance Test and One-legged Stance Test.\(^14\) Symmetry is described as the ability to distribute weight evenly between the two sides of the body in an upright stance.\(^7,9\) Symmetry can be assessed using two standard scales or the Weight Bearing Test on the NBM. Dynamic stability is defined as the ability to move the center of gravity (COG) around the base of support (BOS) without a loss of balance. There are
several assessment tools used to analyze dynamic stability including the Berg Balance Measure, the Tinetti Assessment Tool, and the NBM LOS Test.$^{1,3,4}$

**Limits of Stability**

Limits of stability are defined in the NBM Operator’s Manual as “the maximum distance a person can lean in a given direction (measured as angular distance from vertical) without losing balance, stepping, or reaching.”$^{2,5}$ In the average, healthy adult LOS in standing encompasses 12 degrees from anterior to posterior and 16 degrees from side to side.$^{3,6,15,16}$ Limits of stability are variable and can be affected by the task being performed, the individual’s biomechanics and various components of the environment.$^{10}$

**Balance/Postural Strategies**

As a person displaces his or her COG to reach the LOS, specific automatic postural synergies are used to maintain balance.$^{6,10,11,15}$ Postural synergies are patterns of leg and trunk muscle contractions used to preserve standing balance. These strategies include ankle, hip and stepping strategies. The ankle strategy is the first strategy utilized to maintain balance when there is a small disturbance within the LOS. The body is shifted forward and backward around the ankles as a rigid unit. Muscular activation occurs in a distal to proximal pattern of response. This strategy is the most effective strategy with small perturbations on a firm surface.

The hip strategy is utilized with larger disturbances of balance or to maintain balance on varied surfaces.$^{6,10,11,15}$ It involves shifting the COG by flexing and extending the hips with a proximal to distal muscle activation pattern. This strategy moves the
COG more quickly as compared to the ankle strategy so it is more effective with large disturbances to balance and on a wider variety of surfaces.

The stepping strategy involves the use of rapid steps to maintain balance in response to fast, large postural perturbations.\textsuperscript{6,10,11,15} This strategy is utilized when the LOS are exceeded and the ankle and hip strategies are no longer sufficient to maintain the COG over the BOS. Although described as separate strategies, the ankle, hip and stepping strategies are used in combination in response to perturbations that may jeopardize balance. It has been found that the processes involved in balance control vary with different task requirements and are task specific.\textsuperscript{1}

**Balance Assessment Tools**

A number of tools can be utilized in the development of a balance training program including functional assessment scales (such as the Berg Balance Measure and Tinetti Assessment Tool), and the NMB.\textsuperscript{1,3,4} The Berg Balance Measure is a functionally based balance assessment developed for use in the elderly and neurologically impaired individuals. It is considered the “gold standard” of balance assessments and consists of 14 items graded from 0 to 4 including transfers, standing in various conditions and reaching with a maximum score of 56 points. The Berg Balance Measure has been shown to be reliable and correlates well with other balance tests.\textsuperscript{1} The Tinetti Assessment Tool is a balance and mobility test, which consists of 18 items graded for a maximum of 28 points. This tool is composed of two subscales assessing both gait and balance. The Tinetti Assessment tool has also shown reliability and validity in testing balance and predicting falls in the elderly.\textsuperscript{10,17}
Computerized balance measures have been utilized in the research setting for several decades but have become more prevalent in the clinical setting in recent years.\textsuperscript{1,3,4} One of the main benefits of computerized technology is that it allows therapists to quickly and reliably obtain objective, quantifiable balance measurements. It also enables the therapist to objectively evaluate a patient's initial status and subsequent progress.\textsuperscript{1,3,4} This allows for increased sensitivity in measurement of balance compared to traditional measurement tools, resulting in more accurate and quantifiable results.

**NeuroCom Balance Master/Limits of Stability Test**

The NBM is one example of a commonly used computerized form of balance assessment and training.\textsuperscript{2,3} This system is an instrument designed to provide objective, quantitative measurements of static and dynamic balance performance. Forceplate technology is utilized to determine COG excursion adjusted for the height of the subject being tested.\textsuperscript{2,3} Static and dynamic balance testing can be used to analyze the subjects' COG movements.

The NBM has the capability to objectively measure dynamic standing balance through the use of the LOS Test.\textsuperscript{2} The LOS Test is used to assess the subjects' control of direction, accuracy and speed of COG movements while weight shifting toward predetermined targets representing 100\% of the theoretical LOS. To perform a variety of standing functional activities, the speed, direction, and distance of COG movement must be controlled. The LOS Test measures all three of these, making it an accurate measure of functional balance.\textsuperscript{1} The following five components are calculated with this test: reaction time (RT), movement velocity (MVL), endpoint excursion (EPE), maximum excursion (MXE), and directional control (DCL). These will be defined in Chapter III.
The NBM has been shown to be reliable and valid for testing balance. Liston et al\(^1\) compared six assessments on the NBM to the Berg Balance Scale and the Gait Velocity Test, two reliable and valid balance tests used in the physical therapy setting. The results of these comparisons show a strong correlation between the NBM assessments and the Berg Balance Scale and Gait Velocity Test with dynamic balance testing, including the LOS assessment.

Reliability is defined as the extent to which a measuring tool produces the same results without significant error across repeated testing sessions and/or between multiple raters.\(^4,5\) Reliability can be divided into two types: intra-rater and inter-rater. Intra-rater reliability is defined as reliability across repeated testing sessions for a single rater and inter-rater reliability is defined as reliability between multiple raters. It is necessary to establish intra-rater reliability with any procedure prior to finding inter-rater reliability.

In establishing intra-rater reliability, some degree of variability should be expected; however this variability should not be statistically significant.\(^4\) Previous studies on the NBM have used composite scores in the determination of intra-rater reliability.\(^1,4,8\) Composite scores are computed by taking the average of all eight direction scores. In a study by Rose\(^8\), 176 healthy subjects ages 20-79 were assessed using the NBM version 6.1 of the LOS Test. The study found that intra-rater reliability ranged from \(R = 0.68\) to \(R = 0.80\) for the five components. A study done by Clark et al\(^4\) used 38 community dwelling older adults to establish the reliability of the LOS Test using the Pro Balance Master version 5.0b. Intra-rater reliability for MVL, MXE, EPE and DCL ranged from Generalizability (G) = 0.57 to 0.91. Liston et al\(^1\) conducted a study on 20 ambulatory hemiparetic subjects to determine intra-rater reliability of the Balance Master.
This study found ICC = 0.84 for DCL and ICC = 0.88 for RT and MVL, but did not report values for MXE or EPE.

Although the above research has shown moderate to high intra-rater reliability with some components of the LOS test, no research has shown intra-rater reliability with all of the components. Furthermore, this research has not addressed the amount of training necessary to obtain intra-rater reliability using the NBM to assess balance.
CHAPTER III

METHODOLOGY

Prior to beginning this study, approval for the use of human subjects was obtained from the University of North Dakota’s Institutional Review Board. A copy of the Human Subjects Review Form and the approval letter are located in Appendix A. During the process of subject recruitment, all individuals were informed that participation in this study was voluntary. The study was explained in detail to interested subjects and each individual signed a consent form prior to participation. A copy of this consent form can be found in Appendix B. In order to address any safety or health concerns associated with testing on the NBM, subjects were asked to complete a health background questionnaire prior to inclusion in the study. Questions were related to past medical history, medications, current symptoms, presence of a diagnosed psychological condition, number of falls, vision and previous testing on the NBM. Prior to each testing session, subjects were required to complete a current health status questionnaire to determine if any events had occurred that may have affected balance. Copies of these questionnaires are located in Appendix C.

Subjects

Participants in this study were recruited by word of mouth from the Grand Forks community and the University of North Dakota population. Inclusion criteria determined by the health background questionnaire were as follows:
1. Ages 20-59
2. No previous history of balance deficits
3. No unexplained falls within the last six months
4. No current medications that affect balance
5. No injuries or surgeries that may have affected balance
6. No prior testing or experience with the NBM.

Eleven subjects met the above criteria and were selected to participate in testing on the NBM. Subjects were tested six times with 3-7 days between testing sessions.

Instrumentation

The NBM version 7.06 (NeuroCom International Inc., 9570 SE Lawnfield Road, Clackamas, OR 97015-9611) is a clinically acceptable and safe machine commonly used in physical therapy in the evaluation and treatment of balance issues in a wide variety of patients. The NBM has been shown to be a reliable and valid instrument as discussed in Chapter II. It consists of two 9” x 60” forceplates on which the subject stands to measure forces from the subject’s feet. These forceplates rest on four load cells that relay information to a computer software system that interprets the data obtained during a balance assessment. The computer then displays the data as visual feedback on the screen, which provides the subject with information about the location of his or her COG. See Figure 1 for a picture of the NBM.

A variety of balance assessment and training options are available on the NBM. One assessment option is the LOS Test which measures the subject’s ability to weight shift forward, backward, left, right and diagonally and briefly maintain stability at eight.
predetermined positions as shown in Figure 2. These positions represent 100% of the theoretical LOS.

Figure 1. The NeuroCom Balance Master.

Figure 2. Eight targets for the Limits of Stability Test.

The LOS Test on the NBM consists of five components including reaction time, movement velocity, endpoint excursion, maximum excursion, and directional control. The definitions, as found in the NBM Operator's Manual, are as follows:
1. Reaction time – the time in seconds between the signal to move and the initiation of movement

2. Movement velocity – the average speed of COG movement expressed in degrees per second between 5% and 95% of the distance to the primary endpoint

3. Endpoint excursion – the distance traveled by the COG on the primary attempt to reach the target expressed in percent of LOS

4. Maximum excursion – the furthest distance traveled by the COG during the trial

5. Directional control – comparison of the amount of movement in the intended direction (toward the target) to the amount of extraneous movement (away from the target).

During the LOS test, the subject’s COG is represented on the computer screen by a cursor. This provides the subject with immediate feedback on his or her performance. Following each test, the computer generates a printout consisting of scores for the above five components of balance. An example of a printout can be found in Appendix D. Composite scores for each of the balance components were used to assess intra-rater reliability.

Researcher Training

Prior to beginning this study, the researchers became familiar with the NBM by reading the operator manual and administering each of the eleven NBM tests to one subject. This allowed the researchers to gain general knowledge about the machine and
how it operates. The researchers did not operate the NBM for three months following familiarization.

Assessment Procedure

Subject testing took place at the University of North Dakota Physical Therapy Research Lab. The same two researchers were present for all testing sessions. One of the testers was responsible for instructing the subjects, while the other was responsible for spotting the subjects to ensure safety and to prevent falls and/or injury during testing. One researcher was assigned six subjects to assess LOS while the other was assigned five subjects. These assignments were consistent throughout all testing trials.

The NBM is self-calibrating; however, calibration was verified during each system initialization to ensure the accuracy of forceplate readings. Subjects then completed the consent form and health background questionnaire. Following completion of these forms, subjects' height, date of birth and an identification letter were entered into his or her computer file. Subjects were tested barefoot to minimize variability due to traction and shoe height. Their feet were aligned on the forceplate according to instructions given on the computer screen. Figure 3 below shows the guide for proper foot placement, which includes alignment of the medial malleolus with the wide blue line on the forceplate and placement of the lateral calcaneous on the "M" or "T" line according to subject height. This same foot placement was utilized during all subsequent testing sessions.

To reduce practice effects and maximize subject familiarity with the test, subjects were allowed to practice weight shifting and moving the cursor to the different targets for up to five minutes or until they became familiar with the requirements of the test.
Subjects were allowed to move their arms and shift their hips but could not lift their heels from the forceplate. Once the subject was comfortable with the machine, a researcher read a prewritten set of instructions to the subject. This ensured all subjects were given the same set of instructions independent of the tester. A copy of these instructions can be found in Appendix E.

![Figure 3. Forceplate landmarks for proper foot alignment.](image)

At the initial assessment, subjects were required to complete two LOS assessments. Data from the first assessment was not used in statistical analysis due to the high learning curve shown between the first and second trials. Clark et al. found significant differences in scores on the LOS test from the first assessment to the second assessment, but no significant differences between trials two, three, and four. Immediately following instruction, subjects completed the first LOS assessment. They were given a rest period of up to five minutes. Subjects were then allowed to complete a second LOS assessment test following the above procedure.

At each of the five subsequent testing sessions scheduled 3-7 days apart, the subjects were required to complete a current health status questionnaire. Subjects were
aligned on the platform, given up to five minutes of practice time, read the instructions and then allowed to complete one LOS assessment.

Data Analysis

The data gathered from the subjects’ LOS trials two through seven was entered into the SPSS Version 10.0 software system. The data from trial one was discarded to account for the high learning curve found between trials one and two, as previously discussed. The descriptive statistics performed by this program included the mean and standard deviation. Comparisons were made between the different trials using the Pearson correlation coefficient (r) and ICC.

Intraclass correlation coefficient has no absolute standard for acceptable reliability. The ICC values range between 0.00 and 1.00, with stronger reliability indicated when the numbers fall close to 1.00. The researcher determines the ICC values needed to obtain reliability for each study. As a general guideline, values above 0.75 represent good reliability whereas those below 0.75 are indicative of poor to moderate reliability. In order to meet clinical reliability the ICC values should exceed 0.90. Table 1 outlines the ICC value interpretation for intra-rater reliability.

Table 1. Intraclass Correlation Coefficient Value Interpretation

<table>
<thead>
<tr>
<th>ICC Value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.90-1.00</td>
<td>High</td>
</tr>
<tr>
<td>0.75-0.90</td>
<td>Good</td>
</tr>
<tr>
<td>&lt;0.75</td>
<td>Poor to Moderate</td>
</tr>
</tbody>
</table>

The Pearson correlation coefficient (r) measures the degree and direction of a relationship between two variables. The r value may range from −1.00 to 1.00. A perfect positive relationship is represented by an r value of 1.00, no relationship is represented by
an r value of 0.00, and a perfect negative relationship is represented by an r value of -1.00. The direction (positive or negative) does not affect the strength of the relationship; therefore, Table 2 represents positive and negative r values. A common interpretation of r values are listed in Table 2. These parameters were then used for further analysis in determining the intra-rater reliability for the LOS assessment with the NBM.

**Table 2. Pearson Correlation Coefficient Value Interpretation**

<table>
<thead>
<tr>
<th>r value</th>
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</tr>
</thead>
<tbody>
<tr>
<td>0.90-1.00</td>
<td>Very High</td>
</tr>
<tr>
<td>0.70-0.89</td>
<td>High</td>
</tr>
<tr>
<td>0.50-0.69</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.26-0.49</td>
<td>Low</td>
</tr>
<tr>
<td>0.00-0.25</td>
<td>Little to Zero</td>
</tr>
</tbody>
</table>

**Reporting Results**

Upon completion of this study, a copy of the results of this scholarly project was given to both the preceptor of this project and the University of North Dakota Health Sciences Library. This study was completed to fulfill the requirements of the University of North Dakota School of Medicine and Health Sciences Physical Therapy Program.
CHAPTER IV

RESULTS

Results from this study consisted of measures from the NBM LOS Test. The data obtained from six separate trials were analyzed using descriptive statistics and then later compared utilizing Pearson correlation coefficient and ICC. Trials were compared in pairs (i.e., trial 1 and trial 2, trial 2 and trial 3, etc.) to determine at what point the testers reached intra-rater reliability on the NBM LOS Test.

Subject Profile

A total of eleven subjects participated in this study consisting of four females and seven males with ages ranging from 20 to 45 years old. The mean calculated age was 29.4 with a standard deviation of 9.6. Subjects were randomly assigned to one of the two testers. Subjects assigned to Tester 1 and Tester 2 had a mean age of 33.4 and 26.3 respectively. The subjects were required to return for six testing sessions over a three-week period. All subjects completed a health status questionnaire and no significant past medical histories were reported that would require exclusion from the study.

Research Questions

The purpose of this study was to determine if a clinical level of intra-rater reliability would be reached in the NBM LOS Test with a moderate level of tester training (35-42 test trials), including prior familiarization with the operation of the NBM. Clinical reliability was obtained if the ICC values were equal to or greater than 0.90.
This study investigated the reliability of each of the components of the NBM LOS Test. The results from each component are discussed separately. The Pearson correlation coefficient determined the relationship between trials, established the degree of correlation, and enabled researchers to make predictions. An ICC value determined the level of tester reliability on the LOS Test. The values used to determine the degree of correlations and reliability are presented in Tables 1 and 2 of Chapter III. Statistics reported for all components of the LOS Test include the mean, standard deviation, Pearson correlation coefficient and ICC.

Reaction Time (RT)

Reaction time results for Tester 1 and Tester 2 are reported in Table 3. According to the ICC value interpretation, Tester 1 did not reach clinical reliability (ICC > 0.90) by the sixth trial. However, the tester’s reliability improved when comparing trials 1-6, and Pearson correlation coefficient values indicated a very high correlation between trials 4 and 5 and trials 5 and 6. A negative ICC was calculated when comparing trials 1 and 2. Normally, values from ICC data range from 0.00-1.00 therefore it cannot be interpreted. The degree of variability for each subject between trials is shown in Figure 4. The lines of the graph represent the actual RT scores for each subject tested by Tester 1. The subjects did not demonstrate enough consistency between trials to reach reliability for Tester 1 on the RT component. A high degree of reliability would have been indicated by horizontal lines, instead there is a great deal of variability noted by the crossing of the lines and the change in slope. The largest amount of variability was noted between trials 1 and 2 but the amount of variability decreased and the lines straightened for most of the subjects by trial 4. This coincides with the higher ICC values found for trials 4 and 5 and
Table 3. Results for Reaction Time in Seconds for Tester 1 and Tester 2

<table>
<thead>
<tr>
<th>Trial</th>
<th>n</th>
<th>x</th>
<th>SD</th>
<th>r</th>
<th>ICC</th>
<th>Trial</th>
<th>n</th>
<th>x</th>
<th>SD</th>
<th>r</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
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<td>1</td>
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<td>.9220</td>
<td>.1486</td>
<td>-.3903</td>
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<td>5</td>
<td>.6817</td>
<td>.0933</td>
<td>.7089</td>
<td>.5882</td>
</tr>
<tr>
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<td>4</td>
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<td>.2650</td>
<td>.6848</td>
<td>.5373</td>
<td>2</td>
<td>5</td>
<td>.7000</td>
<td>.1752</td>
<td>.8933</td>
<td>.8925</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>.8760</td>
<td>.1284</td>
<td>.5792</td>
<td>.5036</td>
<td>3</td>
<td>5</td>
<td>.6500</td>
<td>.1825</td>
<td>.8751</td>
<td>.8468</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>.8400</td>
<td>.2260</td>
<td>.9202</td>
<td>.8884</td>
<td>4</td>
<td>5</td>
<td>.7083</td>
<td>.2363</td>
<td>.9803</td>
<td>.9001</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>.8540</td>
<td>.2880</td>
<td>.9549</td>
<td>.8728</td>
<td>5</td>
<td>5</td>
<td>.6217</td>
<td>.1554</td>
<td>.9257</td>
<td>.9061</td>
</tr>
</tbody>
</table>
trials 5 and 6. Graphs for all the LOS Test components for both Tester 1 and Tester 2 can be found in Appendix F.

![Graph](image)

**Figure 4.** Actual reaction time values in seconds for subjects tested by Tester 1.

Tester 2 demonstrated clinical reliability between trials 4 and 5 and trials 5 and 6, according to the ICC interpretation with values greater than 0.90. In addition, good reliability was found between trials 2 and 3 and trials 3 and 4. The Pearson correlation coefficient displayed moderate correlation between trials 1 and 2, high correlations between trials 2 and 3, and trials 3 and 4, and very high between trials 4 and 5 and trials 5 and 6.

**Movement Velocity (MVL)**

Results for MVL for both Tester 1 and Tester 2 are reported in Table 4. Tester 1 reached clinical reliability on the MVL component between trials 4 and 5 and trials 5 and 6, when examining ICC values. On the previous trials, Tester 1 produced varying results from good (ICC = 0.75-0.90) to poor/moderate (ICC < 0.75) reliability according to the ICC interpretation. When comparing these results to the Pearson correlation
Table 4. Results for Movement Velocity in Degrees Per Second for Tester 1 and Tester 2

<table>
<thead>
<tr>
<th>Trial</th>
<th>n</th>
<th>x</th>
<th>SD</th>
<th>r</th>
<th>ICC</th>
<th>Trial</th>
<th>n</th>
<th>x</th>
<th>SD</th>
<th>r</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>4.920</td>
<td>1.1520</td>
<td>.7563</td>
<td>.7520</td>
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<td>5</td>
<td>5.5333</td>
<td>1.7705</td>
<td>.8823</td>
<td>.8660</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>5.220</td>
<td>1.2677</td>
<td>.5567</td>
<td>.5053</td>
<td>2</td>
<td>5</td>
<td>5.9000</td>
<td>2.1485</td>
<td>.9787</td>
<td>.9678</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5.620</td>
<td>.8106</td>
<td>.4785</td>
<td>.3846</td>
<td>3</td>
<td>5</td>
<td>5.9167</td>
<td>2.4959</td>
<td>.9424</td>
<td>.9161</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>5.400</td>
<td>1.6087</td>
<td>.9557</td>
<td>.9557</td>
<td>4</td>
<td>5</td>
<td>6.5500</td>
<td>1.9655</td>
<td>.9363</td>
<td>.9167</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>5.700</td>
<td>1.6000</td>
<td>.9391</td>
<td>.9011</td>
<td>5</td>
<td>5</td>
<td>5.8833</td>
<td>1.5993</td>
<td>.8883</td>
<td>.8799</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>5.700</td>
<td>1.1979</td>
<td>.6883</td>
<td>.6883</td>
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<td>5</td>
<td>5.8833</td>
<td>1.8357</td>
<td>.8883</td>
<td>.8799</td>
</tr>
</tbody>
</table>
interpretation tables, the correlation was considered to be high for trials 1 and 2, moderate for trials 2 and 3, low for trails 3 and 4, the remaining trails were found to be very high. These results show a great deal of variability during the first three comparisons but the individual scores become more consistent during trials 4-6 enabling the Tester 1 to reach clinical reliability.

Tester 2 was found to be clinically reliable between trials 2 and 3, trials 3 and 4, and trials 4 and 5, with all ICC values above 0.90. Clinical reliability was not obtained on trials 1 and 2 and trials 5 and 6; however, reliability was good according to ICC interpretation. A very high Pearson correlation coefficient was determined for the trials corresponding with those found to be clinically reliable and high correlation was found for the good ICC values.

Endpoint Excursion (EPE)

Results for endpoint excursion for Tester 1 and Tester 2 are illustrated in Table 5. Tester 1 found clinical reliability between trials 1 and 2; however, EPE was not reliable for the remaining trials. Trials 2 and 3 and trials 5 and 6 were found to have poor/moderate reliability; the other trials demonstrated good reliability. The Pearson correlation coefficients also varied between trials (moderate to high) with only trials 1 and 2 displaying a very high correlation.

Tester 2 did not reach clinical reliability by the sixth trial. Good reliability was obtained for all of the trials according to ICC interpretation (0.75-0.90). High correlation values for the Pearson correlation coefficient was also found for trials 1-6.
Table 5. Results for Endpoint Excursion in Percentage of Normative Data for Tester 1 and Tester 2

<table>
<thead>
<tr>
<th>Trial</th>
<th>n</th>
<th>x</th>
<th>SD</th>
<th>r</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>8.4558</td>
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<td>.9230</td>
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<tr>
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<td>7.0214</td>
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<td></td>
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<tr>
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<td>4</td>
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<td>7.4027</td>
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<td>.6427</td>
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<tr>
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<td>.6850</td>
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<td></td>
<td></td>
<td>88.3333</td>
<td>8.2138</td>
<td>.8469</td>
<td>.8266</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80.8333</td>
<td>10.2453</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>82.5000</td>
<td>10.8028</td>
<td>.7852</td>
<td>.7842</td>
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<tr>
<td></td>
<td></td>
<td>85.0000</td>
<td>10.3344</td>
<td>.8778</td>
<td>.8770</td>
</tr>
<tr>
<td></td>
<td></td>
<td>85.0000</td>
<td>10.3344</td>
<td>.8656</td>
<td>.8614</td>
</tr>
<tr>
<td></td>
<td></td>
<td>82.1667</td>
<td>9.3684</td>
<td>.8208</td>
<td>.8155</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trial</th>
<th>n</th>
<th>x</th>
<th>SD</th>
<th>r</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
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<td>78.3333</td>
<td>8.2138</td>
<td>.8469</td>
<td>.8266</td>
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<tr>
<td>2</td>
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<td>80.8333</td>
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<td></td>
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<tr>
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<td>5</td>
<td>82.5000</td>
<td>10.8028</td>
<td>.7852</td>
<td>.7842</td>
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<td>5</td>
<td>85.0000</td>
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<td>5</td>
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<td>.8155</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>83.0000</td>
<td>10.5071</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Maximum Excursion (MXE)

Results for Tester 1 and Tester 2 are reported in Table 6. Tester 1 did not reach clinical reliability with the MXE component on any of the six trials. The lowest reliability was found between trials 5 and 6; the highest was shown between trials 1 and 2. Values ranged from poor/moderate reliability to high reliability according to the ICC value interpretation table. Pearson correlation coefficients were also demonstrated a great amount of variation with the lowest values found between trials 5 and 6 indicating a moderate correlation and the highest value found between trials 4 and 5 indicating a high correlation.

Tester 2 also did not meet clinical reliability on the MXE component during testing. Tester 2 showed good ICC values between trials 2 and 3, trials 4 and 5, and trials 5 and 6. The other trials were categorized with poor/moderate reliability. Pearson correlation coefficients were all considered to be high correlations.

Directional Control (DCL)

Results for the DCL component for Tester 1 and Tester 2 are reported in Table 7. A negative ICC value was found when comparing trials 1 and 2 for Tester 1. This value was unable to be interpreted. Clinical reliability was reached by Tester 1 between trials 4 and 5, but was not found between the remaining trials. The remaining trials, except for trials 1 and 2 were found to have a good reliability according to the ICC interpretation table. Pearson correlation coefficient values indicate a negative relationship between trials 1 and 2, but high to very high positive correlations were found between the remaining trials with values ranging between 0.72-0.95.
Table 6. Results for Maximum Excursion in Percentage of Normative Data for Tester 1 and Tester 2

<table>
<thead>
<tr>
<th>Trial</th>
<th>n</th>
<th>x</th>
<th>SD</th>
<th>r</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
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<td>1</td>
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<td>.8818</td>
</tr>
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<td>4</td>
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<td>6.7397</td>
<td>.6489</td>
<td>.6411</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>97.400</td>
<td>5.4589</td>
<td>.7899</td>
<td>.7746</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>97.600</td>
<td>6.6558</td>
<td>.8825</td>
<td>.8744</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
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<td>.5347</td>
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</tr>
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<td>4</td>
<td>98.200</td>
<td>4.4944</td>
<td>.8142</td>
<td>.7735</td>
</tr>
</tbody>
</table>

Table 7. Results for Directional Control in Percentage of Normative Data for Tester 1 and Tester 2

<table>
<thead>
<tr>
<th>Trial</th>
<th>n</th>
<th>x</th>
<th>SD</th>
<th>r</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
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<td>invalid</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>83.800</td>
<td>2.6833</td>
<td>.8003</td>
<td>.8000</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>83.400</td>
<td>2.6077</td>
<td>.8021</td>
<td>.7220</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
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<td>4.1593</td>
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<td>.9494</td>
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<td>.7819</td>
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<td>4</td>
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<td>2.8284</td>
<td>.9823</td>
<td>.9691</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trial</th>
<th>n</th>
<th>x</th>
<th>SD</th>
<th>r</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
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<td>1</td>
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<tr>
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<td>7.4409</td>
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</tr>
<tr>
<td>4</td>
<td>5</td>
<td>93.000</td>
<td>6.0032</td>
<td>.8746</td>
<td>.8648</td>
</tr>
<tr>
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<td>5</td>
<td>91.1667</td>
<td>5.1929</td>
<td>.8106</td>
<td>.8454</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>92.3333</td>
<td>7.1746</td>
<td>.7735</td>
<td>.7735</td>
</tr>
</tbody>
</table>
Tester 2 found good reliability for trials 1 and 2 but there was a slight decrease in values in trials 2 and 3 (0.85-0.80). Reliability showed improvement beginning with trials 2 and 3, and reached clinical reliability between trials 5 and 6. Between trials 1-4, the Pearson correlation coefficient displayed high values, and between the remaining trials, the correlation became very high indicating a greater relationship between trial values, which is a significant predictor of reliability.

Summary of Reliability for Each Component

The amount of reliability for each component of the LOS Test is shown in Table 8. The table displays ICC values for both Tester 1 and Tester 2. The lowest and highest ICC values are reported for each component. The asterisks located in the RT and DCL components for Tester 1 indicate negative values were obtained and the invalid numbers were not included in the table.

Table 8. High and Low ICC Values for Each Component of the LOS Test for Both Tester 1 and Tester 2

<table>
<thead>
<tr>
<th>Component</th>
<th>Tester 1</th>
<th>Tester 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction Time</td>
<td>.5036 -.8884 *</td>
<td>.5882 -.9061</td>
</tr>
<tr>
<td>Movement Velocity</td>
<td>.3846 -.9557</td>
<td>.8660 -.9678</td>
</tr>
<tr>
<td>Endpoint Excursion</td>
<td>.6427 -.9230</td>
<td>.7841 -.8770</td>
</tr>
<tr>
<td>Maximum Excursion</td>
<td>.5176 -.8744</td>
<td>.5362 -.8648</td>
</tr>
<tr>
<td>Directional Control</td>
<td>.7220 -.9494 *</td>
<td>.8309 -.9691</td>
</tr>
</tbody>
</table>

* Indicates invalid value obtained

Time for Trial Testing

Each trial was timed throughout testing on the NBM. As a result, it was discovered that the testers and subjects became more efficient in the testing procedure. This data is presented in Table 9 and Table 10.
### Table 9. Time in min:sec for Subjects Tested by Tester 1

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Trial 5</th>
<th>Trial 6</th>
</tr>
</thead>
<tbody>
<tr>
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<td>3:30</td>
<td>3:31</td>
<td>2:59</td>
<td>3:00</td>
<td>3:00</td>
</tr>
<tr>
<td>E</td>
<td>3:56</td>
<td>3:19</td>
<td>2:57</td>
<td>3:08</td>
<td>2:57</td>
<td>3:07</td>
</tr>
<tr>
<td>G</td>
<td>3:05</td>
<td>3:05</td>
<td>3:01</td>
<td>3:04</td>
<td>3:00</td>
<td>2:57</td>
</tr>
</tbody>
</table>

### Table 10. Time in min:sec for Subjects Tested by Tester 2

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Trial 5</th>
<th>Trial 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>3:16</td>
<td>3:46</td>
<td>3:11</td>
<td>3:10</td>
<td>3:03</td>
<td>3:03</td>
</tr>
<tr>
<td>K</td>
<td>4:45</td>
<td>4:05</td>
<td>4:00</td>
<td>4:10</td>
<td>3:50</td>
<td>3:10</td>
</tr>
</tbody>
</table>
CHAPTER V

DISCUSSION

Balance is a critical component for proper functioning in everyday activities. In order for a clinician to properly assess balance, results must be valid and reliable. The use of computerized assessment can identify balance disorders, but ultimately the results and measurements will depend on the reliability.4 Few studies have been performed to establish the reliability of the NBM with little or no research in the amount of training necessary to achieve clinical intra-rater reliability.1,4,7 The results of this study show that a clinical level of intra-rater reliability was not reached or maintained on all components of the LOS Test on the NBM following prior familiarization and a moderate level of tester training.

Throughout the discussion, results are interpreted and conclusions are drawn based on the data collected. Values for ICC are reported for Tester 1 and Tester 2 and are examined for clinical reliability. Also, Pearson correlation coefficients are reported and compared to a study by Rose8 that developed a database to look at intra-rater reliability for the NBM LOS Test.

Within the NBM operator’s manual the study performed by Rose8 is utilized to prove that the LOS Test produces reliable values. However, they use different correlation coefficient interpretation scales for predicting the amount of reliability. According to Rose, a correlation coefficient greater than 0.80 is considered high, 0.80-
0.60 is moderate, and less than 0.60 is poor. In a study performed by Rose, correlation coefficient values for all components of the LOS Test, except movement velocity (MVL), only achieved the moderate category for reliability. The only value that reached the high category for reliability was MVL with a borderline value of 0.80. Even though her scores have not reached clinical reliability, the NBM utilizes her study as proof of their LOS Test reliability. However, Rose recognizes the limitations in her study of LOS Test reliability.

Reaction Time (RT)

The LOS RT component measures the time between the signal to move and the initiation of movement. Tester 1 was unable to obtain values greater than 0.90, and when comparing trial 1 and 2, a negative number was calculated which makes the value invalid. This resulted because the analysis typically used for intra-rater reliability cannot be performed on a closely clustered group of values. If the differences between the subjects is small, then poor reliability is indicated by the ICC scores, despite minimal differences in the tester’s measurements. Overall, Tester 1 was inconsistent in reliability values and at this point cannot be considered reliable with testing the RT component on the NBM.

Tester 2 was found clinically reliable when comparing trial 4 to 5 and 5 to 6 with ICC values of 0.90 and 0.91, respectively. Tester 2 had one more subject in her group than Tester 1, which may have enabled her to reach reliable values at earlier trials. Tester 2 completed seven more training trials when compared to Tester 1, 42 trials versus 35 trials. One source of error resulting in increased variability between repeated trials can be attributed to the misunderstanding of directions by the subjects. The instructions
were structured prior to testing, and it was decided that they remain the same throughout the study. However, subjects reported difficulty waiting for the blue circle to appear prior to initiating movement. This aspect measures reaction time, and misunderstood instructions may have altered the collected data.

When reviewing the RT component in the study done by Rose\textsuperscript{8}, a correlation coefficient of 0.74 was reported, indicating moderate reliability. In her study, only two trials were used to calculate the correlation coefficients, whereas six trials were performed in the present study to ensure proper reliability results. When comparing the present study to Rose’s, higher correlation coefficient values were produced for the RT component (0.98 vs. 0.74).

**Movement Velocity (MVL)**

Movement velocity is the average speed of COG movement expressed in degrees per second between 5\% and 95\% of the distance to the primary endpoint.\textsuperscript{2} Tester 1 was found to have clinical reliability on the MVL component between trials 4 and 5 and trials 5 and 6. It is difficult to determine if reliability can be maintained since previous trials produced inconsistent values. Tester 1 demonstrated a gradual worsening prior to obtaining a reliable measure, beginning with an ICC of 0.75 between trial 1 and 2 and regressing to an ICC of 0.38 between trial 3 and 4. Although some degree of inconsistency in reliability testing should be expected, the extent of differences between values should not be statistically significant.\textsuperscript{4} An expected gradual increase in reliability values was anticipated, however the trials of Tester 1 demonstrated differences as great as 0.57 when comparing subsequent trials, indicating further testing may be necessary to confirm results.
Tester 2 was found to be clinically reliable between trials 2 and 3, trials 3 and 4, and trials 4 and 5. Overall, the ICC values obtained by Tester 2 were above 0.87 falling in the good to high categories according to the ICC interpretation table. The decrease in the ICC value below 0.90 between trial 5 and 6 may be explained by a reduction in motivation of the subjects. After seven trials, subjects reported testing protocols to be monotonous and felt they did not put forth the effort that was experienced in previous trials.

According to the study by Rose, the only component to reach high reliability with a correlation coefficient value of 0.80 on the NBM LOS Test was MVL. Correlation coefficients were high for Tester 1 and Tester 2 with values as high as 0.98, greater than those discovered and reported by Rose.

**Endpoint Excursion (EPE)**

The EPE component, measuring the distance traveled by the COG on the primary attempt to reach the target, for Tester 1 was found to be unreliable. Clinical reliability was obtained between trials 1 and 2, however ICC values dropped below 0.90 for the remaining trials and were unpredictable. Brouwer et al states that LOS beyond 75% causes subjects to elicit undesirable responses that reduces the ability to control their COG. The LOS Test is programmed at 100% of the subject’s LOS, a predefined setting calculated from normative data. This may have required the subjects to utilize undesirable responses in an attempt to reach the target resulting in inconsistency of the EPE values.

Tester 2, also facing these similar problems, never reached clinical reliability on the EPE component. Values did range in the good category according to the ICC
interpretation table with values ranging from 0.78 to 0.88. Rose\textsuperscript{8} found EPE to be the second least reliable component, only achieving moderate reliability at 0.73, whereas in the present study correlation coefficients were found to be as high as 0.94.

Maximal Excursion (MXE)

Tester 1 and Tester 2 did not obtain clinical reliability on the MXE component, which is the furthest distance traveled by the COG.\textsuperscript{2} For both testers, reliability values fluctuated and there was no predictable pattern between trials. Rose\textsuperscript{8} reported a correlation coefficient of 0.76 indicating moderate reliability, which is similar to the average correlation coefficient in this study (0.77). However, correlation coefficients reached as high as 0.88, which would be classified under the high category used by Rose.

The use of 100\% versus 75\% LOS setting may have also influenced the results for MXE along with EPE. Through examining results and subject comments, it was concluded that difficulty was increased when trying to reach the targets forward, forward-right, and forward left. However, previous studies discovered greater error in COG targets back, back-left, and back-right.\textsuperscript{3} Due to these repeated findings, NBM revised the system to allow for attainable backward components, but they may also need to correct problems that currently exist with forward motion.

Directional Control (DCL)

The factors that influenced EPE and MXE reliability will also impact the DCL component, since they all examine the path that the subjects’ COG travels. Directional control compares the amount of movement in the intended direction (towards the target) to the amount of extraneous movement (away from the target).\textsuperscript{2} Several studies have found these components to be very closely related and combine EPE, MXE, and DCL
into a single term, movement path. A study performed by Liston et al found that the movement path was reliable with an ICC of 0.84. However, according to the ICC interpretation table a value of 0.84 would not have been clinically reliable.

Tester 1 produced clinically reliable values for DCL between trials 4 and 5 but was unable to maintain clinical reliability for the last trial. This may also be explained by the lack of motivation of the subjects as previously discussed. Tester 1 obtained a negative ICC value between trials 1 and 2, as seen with the RT component. Since negative scores were only obtained between trials 1 and 2, it may be assumed that the subjects were not provided enough practice time to adjust for the learning curve. This allowed for improvement between trials that can be associated with increased understanding by the subjects and not influenced by the instruction provided by the testers. Rose suggests reliability is very high if the first trial is discarded and the second and third trials are compared, as was utilized in the current study. However, subjects may have needed further practice indicating the second trial should also be discarded and comparisons should not start until the third and fourth trials. Tester 2 reached clinical reliability between trials 5 and 6 and demonstrated consistent improvement beginning with trials 2 and 3. Further testing is needed to examine if this level of reliability can be maintained.

Rose found the DCL component to be the least reliable of all the components on the LOS Test with a correlation coefficient of 0.68. In the present study it was found that Tester 1 and Tester 2 had correlation coefficients greater than 0.80 for all trials except trials 1 and 2 for Tester 1. This indicates high reliability according to the interpretation table used by Rose.
Testing Trials

Past researchers have recommended that research needs to be conducted addressing the amount of training necessary to become reliable on the NBM LOS Test.\(^4\) It was found that clinical reliability for all the components of the LOS test on the NBM could not be obtained with 35-42 training trials. However, when individual components are examined, both testers were reliable on the MVL component. Tester 1 took 25-30 training trials before reaching reliability while Tester 2 reached reliability between training trials 15-20. All other individual components were not considered reliable since both testers did not maintain ICC values greater than 0.90 by the seventh training trial. However, if this study’s data were analyzed using the interpretation table presented in the study by Rose\(^8\), reliability would have been obtained on all components.

Testing Time

An unexpected finding was discovered when the length of each testing session was timed. Subjects became more proficient in testing procedures and required less processing of instructions. The number of repeated tests decreased due to the subjects increased awareness of desired outcomes, decreasing the amount of time needed to perform the testing. A drawback to decreased testing time can be attributed to the lack of motivation experienced during the final trials. The subjects were tired of returning for testing and may have lost their interest in the assessment test; therefore they may not have provided maximal effort. This further supports the decrease in reliability between trials 5 and 6.
Limitations and Recommendations

Although this study adds to the research on reliability of the NBM LOS Test, it is evident that limitations exist, and the researchers have recognized them. These limitations include small, select sample size; limited number of testers; quantity of trials; high learning curve; calibration and software of the NBM; and structured instruction.

The use of a small sample size has brought many problems in this area of study. In order to make references to the population, a sample size of at least 30 subjects should be utilized. Due to the extended time needed for this study, a sample of convenience was chosen to insure compliance. Subjects in this study were composed of normal, asymptomatic individuals, which has been shown in previous studies to cause poor intra-rater reliability. It has been shown that when a wider range of subjects with a variety of performance capabilities is used, a larger variability between subjects is found. An ICC value requires a variation between subjects to be a meaningful index of reliability. Therefore, it is recommended that a large sample size be utilized and a patient population consisting of asymptomatic and impaired individuals be used for future studies.

Secondly, there were only two testers chosen for this study. This is a small number to represent an entire population of people who may be administering the LOS Test on the NBM. It would be recommended in future studies that more than two individuals test a group of subjects so solid references about other NBM administrators could be made.

Thirdly, the study design allowed for only seven trials, in which six were used to perform statistics. With this limited number of trials, there was difficulty identifying trends or patterns in the data. If further testing were conducted, it would either solidify
the results and insure that reliability could be maintained or reveal that reliability was reached by a random occurrence between specific trials. However, one has to keep in mind that by the seventh trial in this study, the subjects were becoming unmotivated and varying in their individual scores. This may become more evident when further trials are administered. For a stronger outcome, it is recommended that more testing trials are performed and that subject motivational levels remain high. This may be achieved by selecting a larger number of subjects that are tested only once a week for up to 3 trials, resulting in more testing trials with maintained motivation. A motivational questionnaire following each testing trial may assist in discovering the time within the study that motivation of the subjects changed enough to alter data collection, which would enable the testers to modify the testing procedure. A follow-up study is also recommended approximately 2-3 weeks after initial testing has ended to discover if reliability remains unchanged.

A fourth limitation is the high learning curve for the subjects on the NBM. Previous studies have suggested that reliability is high when the first trial is discarded and the subsequent trials are compared for analysis. This technique was utilized in this study; however, it is believed but not proven that the learning curve is carried over into the second trial and discarding it will provide more accurate results. However, this would further extend the study, which could be a potential drawback. In this study, there were only 5 minutes between trials 1 and 2, which may not have provided enough practice time to eliminate the learning curve. A lengthened period of practice time may enable the subjects to become familiar with the movements of the cursor, which would facilitate greater reliability.
Another limitation of this study was possible error in the calibration of the NBM even though it automatically calibrates each time it is turned on. During the LOS Test, it appeared that a majority of the subjects had difficulty reaching forward components. Research has found that subjects are able to shift their COG forward to a greater extent than they can backward. Thus, it is assumed that subjects would be able to reach the forward components easier than the backward components. The NBM has recently updated their software to version 7.06 so that backward positions are easier to reach; therefore, it may have made it more difficult to move towards the forward destinations. When the subjects aligned with the computer in their neutral position, it was reported that they felt their weight was shifted forward. This may make it difficult as well to compare results to past studies in which different software programs were utilized. An example of this would be the use of NBM 6.1 as used in the study by Rose versus NBM 7.06 used in the present study.

Prior to the start of this study, the testers were provided with training on the use of the NBM and were allotted time for practice so familiarity with the machine and test was obtained. The study design required the testers to state a structured, pre-written set of instructions to each subject that clearly explained the LOS Test and its expectations. The design did not provide an opportunity for further explanation, deviation, or modification to meet the individual subject needs. This technique was important for a structured study so that all subjects received an equal amount of instruction. However, this did not allow the testers to provide encouragement or further explanation when needed, which enabled the subjects to make recurring mistakes. In the clinic, this technique would not be utilized because treatments need to address individual patient needs. Experienced
clinicians have already developed good communication skills and patient handling techniques versus students, such as the testers in this study, who are still developing these skills. Students may have an increased difficulty in detecting the individual patient needs and accommodating for them.

Conclusion

Vital to optimal functioning and required for safety, balance is an essential component for daily activities. There are a variety of disorders and impairments that are associated with balance deficits that can be addressed with rehabilitation. To insure correct evaluation and efficacy of treatment programs, it is imperative that the assessment measure be reliable and valid. One of the many measures for testing balance is with a computerized assessment tool such as the NBM LOS Test. The purpose of this study was to determine the amount of training needed for a therapist to become reliable with the NBM LOS Test for the use in both clinical and research settings.

Through this research, it was determined that a clinical level of intra-reliability for all components of the NBM LOS Test could not be obtained with a moderate level of tester training of 35-42 trials and prior familiarization. Out of the five components, only MVL reached clinical reliability for both testers. The other components may have reached good reliability but according to the guidelines of this study, were unable to maintain clinically required values to be utilized in daily clinical practices as an assessment tool. Nevertheless, the NBM can be used as a training device and can record measurement of patient progression. This study did not discover the minimal amount of training necessary to obtain clinically reliable measurements on the NBM LOS Test for
all components. Interestingly, the data for each component in this study either met or exceeded the intra-rater reliability requirements made by the manufacturer.

Despite the inability to prove the NBM LOS Test clinically reliable, it can still have many benefits within the clinical realm. The results received from the NBM LOS Test in the clinic should be interpreted with awareness and consideration of the limitations of the device. The LOS Test may be used as an assessment in conjunction with other functional assessment tools such as the Berg Balance Measure or the Tinetti Assessment Tool. Considering the limitations and recommendations, further research on this topic should be conducted to determine the actual amount of training required to obtain clinically reliable results on the LOS Test.
EXPEDITED REVIEW REQUESTED UNDER ITEM ___ (NUMBER[S]) OF HHS REGULATIONS

EXEMPT REVIEW REQUESTED UNDER ITEM ___ (NUMBER[S]) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED
PROJECTS INVOLVING HUMAN SUBJECTS

Please include ALL information and check ALL blanks that apply.

PRINCIPAL INVESTIGATOR: Casey Bartolo, Katie Miller, Rachael Seals, Christal Stotesbery

TELEPHONE: Casey 795-9028 Christal 777-8101

DATE: 3/29/1

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: UND Physical Therapy Department P.O. Box 9037 Grand Forks, ND 58202-9037

SCHOOL/COLLEGE: University of North Dakota

DEPARTMENT: Physical Therapy

PROJECT DATES: 4/1/01-12/20

PROJECT TITLE: Examination of Tester Reliability Utilizing the Limits of Stability Test on the NeuroCom® Balance Master for Assessing Balance in Healthy Individuals

FUNDING AGENCIES (IF APPLICABLE): N/A

TYPE OF PROJECT (Check ALL that apply):

NEW

PROJECT

CONTINUATION

RENEWAL

DISSERTATION OR

THESIS RESEARCH

STUDENT RESEARCH PROJ

CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Meridee Danks, MPT (777-3861)

PROPOSED PROJECT: INVOLVES NEW DRUGS (IND) INVOLVES NON-APPROVED USE OF DRUG INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATION, PLEASE INDICATE THE CLASSIFICATION(S):

□ MINORS (<18 YEARS) □ PREGNANT WOMEN □ MENTALLY DISABLED □ FETUSES □ PERSONS WITH MENTAL RETARDATION

□ PRISONERS □ ABORTUSES □ UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE ______

IF YOUR PROJECT HAS BEEN WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NA OF BOARD(S):

Status: Submitted; Date ______ Approved; Date ______ Pending ______
1. **ABSTRACT:** (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.)

Balance is critical for optimal function in completion of everyday tasks. It is necessary to have good balance in order to get out of bed, walk, and complete occupational duties. Physical therapists frequently work with people that have balance disturbances in order to help return them to optimal function. One tool used in the assessment and treatment of balance disturbances is the NeuroCom® Balance Master System 7.06. The system consists of a forceplate connected to a computer. Force sensors measure forces exerted by the patient's feet and send these measurements to the computer to be analyzed. It is essential that the therapist is reliable in obtaining measurements from the NeuroCom® Balance Master. The purpose of this study is to determine the amount of training needed for a therapist to become reliable with the NeuroCom® Balance Master in both clinical and research settings. In order to establish reliability, it is necessary to use human subjects to determine the number of subjects a therapist must test before he/she develops high intra-rater reliability. Research has shown the NeuroCom® Balance Master to be reliable but none has shown the amount of training the therapist should have to obtain this reliability.

**PLEASE NOTE:** Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).
2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary. Attach any surveys, tests, questionnaires, interview questions, examples of interview questions (if qualitative research), etc., the subjects will be asked to complete.)

Subjects: Subjects will include up to 50 healthy individuals ranging from the ages of 20 to 59 years old. Researchers will recruit subjects by word of mouth from the Grand Forks community and the UND population. Involvement in the study will be voluntary and informed consent will be obtained through a signed consent form before any testing or training procedures will be performed. Subjects will be excluded from this study if they have a current or past medical condition or are taking medications that affect balance. The subject will be required to complete a Health Background Questionnaire to determine eligibility.

Testing Procedure: Balance will be measured and utilized to determine the intra-rater reliability using the NeuroCom® Balance Master limits of stability assessment test. The NeuroCom® Balance Master is a clinically acceptable and safe machine commonly used in physical therapy to assess balance. A computer software program will collect and interpret data from the forceplates on which subjects stand. The computer screen is equipped with a cursor to provide visual feedback on the location of the subjects’ center of gravity. The subjects’ dynamic balance will be assessed with the limits of stability test using standardized testing procedures. The subjects control the cursor by leaning quickly and accurately so the cursor moves towards targets that are displayed on the computer screen. This test requires subjects to maintain their balance while weight shifting in all directions with feet planted on the forceplate. Subjects will be required to remove socks and shoes during testing procedures. Testing will be performed by one of the researchers at the University of North Dakota Physical Therapy Department. The preceptor will supervise the study.

At the initial assessment subjects will be given instructions on testing procedures and be allowed to practice. Subjects will then perform the limits of stability balance assessment. This trial will be recorded but not analyzed due to the high learning curve as suggested by previous research. Immediately following the first trial, a second trial will be recorded and the data from this trial will be analyzed for research. Subsequent trials will be performed every 3-7 days for up to five additional trials, until reliability is achieved. At each subsequent trial (2,3,4,5 or 6), subjects will complete a Current Health Status Questionnaire upon arrival for testing. A “warm up” session will be allowed followed by one limits of stability balance assessment trial. This trial will be recorded and analyzed to determine reliability. Data will be collected for up to a total of six sessions. The Pearson r correlation coefficient or the interclass correlation coefficient (ICC) will be used to compare trial one to trial two, trial two to trial three, etc until a high level of correlation is determined. A high level of reliability for this study is defined as $r = 0.80$ or ICC $= 0.90$. If reliability is not reached in six sessions, it will be determined that reliability cannot be reached.

Data Analysis and Recording: Traditional descriptive and analytical statistics will be used to analyze the data. The individuals’ results will remain confidential and the data will be identified by a number known only to the researchers. To ensure maximum confidentiality data will be kept in a locked office in the University of North Dakota Physical Therapy Department for three years following completion of this study. After three years the data will be destroyed.
3. **BENEFITS:** (Describe the benefits to the individual or society.)
The primary goal of this study is to determine the amount of training needed to obtain intra-rater reliability when using the NeuroCom® Balance Master to test balance in a clinical or research setting. This will allow physical therapists to provide more accurate balance assessment and training. Subjects may benefit from exposure to the research process and the knowledge that they are helping to improve the field of physical therapy. In addition, the subjects may gain knowledge of their own balance abilities from participating in this study.

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 protect the confidentiality of data obtained, debriefing procedures, storage of data, how long date will be stored (must be a minimum of three years), final disposition of data, etc.)

The risks associated with this study are minimal, but those that do exist will be controlled. Possible risks include loss of balance and/or falls. These risks will be minimized through proper instructions and supervision with a spotter throughout testing procedures. Verbal instructions will be provided prior to assessment on the NeuroCom® Balance Master to ensure safety.

In the event that this research activity results in a physical injury, medical treatment will be as available as it is to a member of the general public in similar circumstances. The University of North Dakota and the researchers are not responsible for any such injury or treatment. Payment for any such treatment must be provided by you and your third party payer, if any.

Respect for the individual will be ensured by informing the subjects that all information will be kept confidential. Confidentiality will be maintained through using assigned numbers and not attaching the subjects' names to the reported data. Subjects will be scheduled to maintain privacy and safety. Subjects will be informed of their right to withdraw from the study at any time via the consent form signed prior to participation in this study.

5. **CONSENT FORM:** Attach 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 where signed consent forms will be kept and for how long (must be a minimum of 3 years), including plans for final disposition or destruction.

Informed consent will be obtained through the attached consent form. Each subject will be required to sign the form signifying his or her agreement with the terms presented. Only the researchers will be allowed access to the consent forms and data collected which will be kept in separate locked cabinets in a locked office at the University of North Dakota Department of Physical Therapy. Information will be kept for a period of three years following the completion of this study and after that time will be destroyed using a paper shredder.

6. For **FULL IRB REVIEW** forward a signed original and fifteen (15) copies of this completed form, including fifteen (15) copies of the proposed consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to the address below. An original and 19 copies are required for clinical medical projects. In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency (agreement/contract if there is no proposal) must be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 7 copies if the proposal is clinical medical. If the proposed work is being conducted for a pharmaceutical company, 7 copies of the company's protocol must be provided.

Office of Research & Program Development
University of North Dakota

45
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For EXEMPT or EXPEDITED REVIEW forward a signed original, including a copy of the consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to one of the addresses above. In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency (agreement/contract if there is no proposal) must be attached to the completed Human Subjects Review Form.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

______________________________  ________________________
Principal Investigator Date

______________________________  ________________________
Project Director or Student Adviser Date

______________________________  ________________________
Training or Center Grant Director Date

(Revised 2/2000)
STUDENT RESEARCHERS: As of June 4, 1997 (based on the recommendation of UND Legal Counsel) the University of North Dakota IRB is unable to approve your project unless the following "Student Consent to Release of Educational Record" is signed and included with your "Human Subjects Review Form."

STUDENT CONSENT TO RELEASE OF EDUCATIONAL RECORD

Pursuant to the Family Educational Rights and Privacy Act of 1974, I hereby consent to the Institutional Review Board’s access to those portions of my educational record which involve research that I wish to conduct under the Board’s auspices. I understand that the Board may need to review my study data based on a question from a participant or under a random audit. The study to which this release pertains is Examination of Tester Reliability Utilizing the Limits of Stability Test on the NeuroCom® Balance Master for Assessing Balance in Healthy Individuals.

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

Date ________________________________  Signature of Student Researcher ________________________________

1Consent required by 20 U.S.C. 1232g.
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

Date: May 4, 2001  Project Number: IRB-200105-236
Name: Casey Bartolo, Katie Miller, Rachael Seals, Christal Stotesbery  Department/College: Physical Therapy

Project Title: Examination of Tester Reliability Utilizing the Limits of Stability Test on the NeuroCom® Balance Master for Assessing Balance in Healthy Individuals

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on May 7, 2001 and the following action was taken:

☐ Project approved. EXPEDITED REVIEW Category No. ____________________________
Next scheduled review is on: ____________________________
☐ The attached consent form dated ____________________________ is the only consent form which may be used for this study.

☐ Project approved. EXEMPT REVIEW Category No. ______
☐ This approval is valid until ____________________________ as long as approved procedures are followed. No periodic review scheduled unless so stated in the Remarks Section.
☐ The attached consent form dated May 7, 2001 is the only consent form which may be used for this study.

☐ Project approved PENDING receipt of corrections/additions. These corrections/additions should be submitted to ORPD for review and approval. This study may NOT be started UNTIL final IRB approval has been received. (See Remarks Section for further information.)

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

☐ Project denied. (See Remarks Section for further information.)

REMARKS: Any changes in protocol or adverse occurrences in the course of the research project must be reported immediately to the IRB Chairperson or ORPD.

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

cc: Meridee Danks, Adviser

Signature of Designated IRB Member
UND's Institutional Review Board

Date

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

(Revised 2/2001)
APPENDIX B
Title: Examination of Tester Reliability Utilizing the Limits of Stability Test on the NeuroCom® Balance Master for Assessing Balance in Healthy Individuals

You are invited to participate in a study conducted by students of the University of North Dakota Physical Therapy Program, Casey Bartolo, Katie Miller, Rachael Seals and Christal Stotesbery, in collaboration with faculty member, Meridee Danks. The purpose of this study is to determine the amount of tester training necessary to accurately assess balance using the NeuroCom® Balance Master. The NeuroCom® Balance Master is a machine commonly used to test balance in a physical therapy setting. Subjects for the study must be healthy individuals between the ages of 20-59. All volunteers in this age group will be eligible for the study unless there is a safety or health concern excluding you from the study. You will be asked to complete a brief health questionnaire prior to participation in the study to ensure your safety. You will be asked to wear loose, comfortable clothing and will be barefoot during all balance testing.

Your participation in the study will involve assessment on the NeuroCom® Balance Master. Testing will last approximately 15-30 minutes each session for up to 6 testing sessions. Total duration of the study will be approximately 4-6 weeks with sessions being held 3-7 days apart. The testing will include leaning forward, backward, sideways and diagonally without moving your feet. The first session will include a “warm up” session and a practice trial assessment lasting for approximately 10-15 minutes followed by performance of the actual assessment test. Each follow-up test will begin with a “warm up” session to become reoriented to the machine.

Although the process of balance assessment involves some risk of falling or injury, researchers feel the risk is minimal. Risk will be minimized through proper instructions and supervision with a spotter throughout testing procedures. If you choose to participate in this study you will benefit from involvement in a research setting and the knowledge that you will be helping to improve the field of physical therapy. You may also benefit from gaining knowledge of your own balance abilities.

The results of this study will remain confidential and your data will be identified by a number known only to the researchers. This consent form and your results will be kept in separate locked cabinets in a locked office in the Physical Therapy Department at the University of North Dakota for three years following completion of the study. After this period of time, your results will be destroyed. Your decision whether or not to participate will not change your future relations with the University of North Dakota or the Physical Therapy Department. If you decide to participate, you are free to discontinue participation at any time without it being held against you. If it is determined that you have a health condition that may put you at risk for injury you may be excluded from the study. Again you will not be penalized in any way.

The researchers will be available to answer any current or prospective questions you may have concerning this study. Questions may be answered by calling Katie or Rachael at
(701) 777-5722, Christal at (701) 777-8101 or Casey at (701) 795-9028. At your request, a copy of this consent form will be provided to you for future reference. If you would like to contact the advisor, Meridee, she can be reached at (701) 777-3861.

In the event that this research activity results in a physical injury, medical treatment will be as available as it is to a member of the general public in similar circumstances. The University of North Dakota and the researchers are not responsible for any such injury or treatment. Payment for any such treatment must be provided by you and your third party payer, 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. I HAVE READ ALL OF THE ABOVE AND MY SIGNATURE BELOW INDICATES MY WILLINGNESS TO PARTICIPATE IN THIS STUDY EXPLAINED TO ME BY CASEY BARTOLO, KATIE MILLER, RACHAEL SEALS AND CHRISTAL STOTESBERRY.

Participant’s Signature  Date

Witness  Date

APPROVED BY
MAY 07 2001
University of North Dakota
Institutional Review Board
Health Background Questionnaire

1. Do you have any current or past medical diagnosis or injury that affects your balance? (i.e. recent fractures or surgery, inner ear infections) If so, please describe.

2. Are you currently taking any medications? Please list all over the counter and prescription medications so we can determine if these may affect your balance.

3. Do you currently have any symptoms of dizziness or lightheadedness?

4. Have you been diagnosed with any psychological conditions (i.e. depression)?

5. Have you had two or more unexplained falls within the last 6 months?

6. Do you have normal vision with or without glasses/contact lenses?

7. Have you previously been tested on the Balance Master?
Current Health Status Questionnaire

Has anything happened since the last assessment that may have affected your balance? (i.e. falls, change in medications, ear infections, illness, injury). Briefly describe below.

Do you have any comments or concerns before continuing the Balance Master assessment?
**Name:** Smith, Joe  
**ID:** ATID00074  
**Date of Birth:** 3/7/1978  
**Height:** 5'4"  

**Diagnosis:** Not Specified  
**Operator:** Not Specified  
**Referral Source:** Not Specified  
**Date:** 10/1/2001  
**Time:** 10:55:17

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### Limits Of Stability

<table>
<thead>
<tr>
<th>Transition</th>
<th>RT (sec)</th>
<th>MVL (deg/sec)</th>
<th>EPE (%)</th>
<th>MXE (%)</th>
<th>DCL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (F)</td>
<td>0.70</td>
<td>7.7</td>
<td>53</td>
<td>68</td>
<td>88</td>
</tr>
<tr>
<td>2 (RF)</td>
<td>0.64</td>
<td>7.5</td>
<td>89</td>
<td>89</td>
<td>61</td>
</tr>
<tr>
<td>3 (R)</td>
<td>0.42</td>
<td>9.7</td>
<td>91</td>
<td>91</td>
<td>83</td>
</tr>
<tr>
<td>4 (RB)</td>
<td>0.43</td>
<td>10.6</td>
<td>96</td>
<td>96</td>
<td>41</td>
</tr>
<tr>
<td>5 (B)</td>
<td>0.57</td>
<td>6.5</td>
<td>75</td>
<td>80</td>
<td>76</td>
</tr>
<tr>
<td>6 (LB)</td>
<td>0.43</td>
<td>12.2</td>
<td>100</td>
<td>100</td>
<td>69</td>
</tr>
<tr>
<td>7 (L)</td>
<td>0.42</td>
<td>8.6</td>
<td>79</td>
<td>84</td>
<td>81</td>
</tr>
<tr>
<td>8 (LF)</td>
<td>0.50</td>
<td>4.1</td>
<td>79</td>
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</tbody>
</table>

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**Data Range Note:** NeuroCom Data Range: 20–39

**Post Test Comment:**
APPENDIX E
Verbal Instructions for Subjects:
Limits of Stability

Pretest Instructions:
Stand with both feet on the Balance Master. Eight targets will appear on the screen surrounding a center target. Begin by centering the entire cursor (the image of a person) in the middle target and hold it there. As you shift your weight the cursor on the screen will move in the same direction. You are allowed to use your arms and shift your hips as much as you would like, but you must not move your feet. Both feet must maintain contact with the forceplate throughout testing. Do not lift your heels from the forceplate. A blue circle will appear in one of the targets indicating you should move in that direction. As soon as the blue circle appears in the yellow outer target, move your cursor as quickly, accurately, and as far as you can towards the yellow target containing the blue circle. Hold the cursor there as long as the blue circle remains. When each trial is finished, hold the cursor motionless in the center target until the next trial begins. This procedure will be repeated for all eight targets.

Test Instructions:
Hold the cursor in the center target until the blue circle appears in the target that you will move to, then move the cursor as straight and as quick as possible and hold it in box #___. Are you ready?
Actual reaction time values in seconds for subjects tested by Tester 1

Actual reaction time values in seconds for subjects tested by Tester 2
Actual movement velocity values in degrees per second for subjects tested by Tester 1

Actual movement velocity values in degrees per second for subjects tested by Tester 2
Actual endpoint excursion values in percentage of normative data for subjects tested by Tester 1

Actual endpoint excursion values in percentage of normative data for subjects tested by Tester 2
Actual maximum excursion values in percentage of normative data for subjects tested by Tester 1

Actual maximum excursion values in percentage of normative data for subjects tested by Tester 2
Actual directional control values in percentage of normative data for subjects tested by Tester 1

Actual directional control values in percentage of normative data for subjects tested by Tester 2
REFERENCES


