The Effect of Balance Training in Healthy Subjects as Assessed by the Neurocom Balance Master

Joshua Woods
University of North Dakota

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THE EFFECT OF BALANCE TRAINING IN HEALTHY SUBJECTS
AS ASSESSED BY THE NEUROCOM® BALANCE MASTER

by

Joshua Woods
Bachelor of Science in Physical Therapy
University of North Dakota, 1999

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
2000
This Independent Study, submitted by Joshua Woods 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.

(Moder D'Ark)
(Faculty Preceptor)

(Graduate-School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title The Effect of Balance Training in Healthy Subjects as Assessed by the Neurocom® Balance Master

Department Physical Therapy

Degree Master of Physical Therapy

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Signature [signature]

Date 12/16/99
TABLE OF CONTENTS

LIST OF TABLES ........................................................................................................ vi
LIST OF FIGURES ...................................................................................................... vii
ACKNOWLEDGEMENTS ......................................................................................... viii
ABSTRACT ............................................................................................................... ix

CHAPTER

I  INTRODUCTION/LITERATURE REVIEW ............................................. 1
   Sensory Elements ......................................................................................... 1
   Musculoskeletal Elements ...................................................................... 4
   Measures of Balance .................................................................................. 6
   Problem Statement .................................................................................... 9
   Purpose ....................................................................................................... 9
   Research Questions .................................................................................... 9

II  METHODOLOGY ....................................................................................... 10
   Subjects ........................................................................................................ 10
   Instrumentation ......................................................................................... 11
   Pilot Study .................................................................................................. 13
   Assessment Procedure ............................................................................. 16
   Training Equipment .................................................................................. 17
   Training Procedure ................................................................................... 19
   Data Analysis ............................................................................................. 23
   Reporting of Results ................................................................................ 24

III  RESULTS ................................................................................................. 25
   Subject Profile ............................................................................................ 25
   Descriptive Statistics ............................................................................... 26
   Analytical Statistics ................................................................................... 26
LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Unilateral stance intrarater reliability using ICC</td>
</tr>
<tr>
<td>2.</td>
<td>Unilateral stance interrater reliability using ICC</td>
</tr>
<tr>
<td>3.</td>
<td>Limits of stability interrater reliability using ICC</td>
</tr>
<tr>
<td>4.</td>
<td>ICC interpretation</td>
</tr>
<tr>
<td>5.</td>
<td>Unilateral stance descriptives</td>
</tr>
<tr>
<td>6.</td>
<td>Limits of stability descriptives</td>
</tr>
<tr>
<td>7.</td>
<td>Repeated measures t-test results with descriptives</td>
</tr>
<tr>
<td>8.</td>
<td>Wilcoxon results with descriptives</td>
</tr>
<tr>
<td>9.</td>
<td>Descriptives for one-way ANOVA (mean gain)</td>
</tr>
<tr>
<td>10.</td>
<td>Results for one-way ANOVA and Scheffe Post Hoc</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

FIGURE

1. Neurocom® Balance Master version 6.1 .......................................................... 12
2. Hymanson, Inc.® Bodyblade ........................................................................ 17
3. Varilite® Air Cushion .................................................................................. 18
4. Sissel® SitFit ................................................................................................ 19
5. Unilateral stance with Bodyblade® shown on left without Varilite® Air Cushion and on right with Varilite® Air Cushion ....................................................... 20
6. Eight directions of limits of stability .............................................................. 21
7. Limits of stability performed forward and back with the Bodyblade® ......... 22
8. Limits of stability to the side on a stable surface shown on left, unstable surface in diagonal direction shown on right, both with the Bodyblade® ........................................................ 22
9. Tandem walk performed with the Bodyblade® ........................................... 24
ACKNOWLEDGMENTS

I would like to express my gratitude to the faculty of the University of North Dakota Department of Physical Therapy, especially Meridee Danks and Renee Mabey for donating countless hours of their time and aiding in the completion of this study. I would also like to thank my mother, two sisters, and grandparents for the added encouragement and support that they provided during the frustrating times. Lastly, I would like to thank my companion in life, Trisha Whitcomb, who made me believe that I can accomplish anything.
ABSTRACT

Balance is a critical component in maintaining optimal function in daily activities, and it is a skill that is frequently affected in individuals who have experienced some type of neurological, vestibular, orthopedic, or musculoskeletal deficit. A successful balance training program that can be used to improve such a person’s balance can be of great use and importance to a patient and a therapist. Studies have shown that balance can be improved in subjects with deficits, however little is known about the effects of training on individuals that lack balance impairments. The purpose of this study was to determine if healthy individuals could show a significant improvement in components of unilateral stance (test of static steadiness) and limits of stability (test of dynamic stability) as assessed by the Neurocom® Balance Master (NBM®). Additionally, the study will also determine if different balance treatment approaches had different outcomes in the subjects’ results.

Thirty-six subjects (8 males, 28 females) were assessed on the NBM® and divided into the following three groups: a control group (Group 0), a balance training group (Group 1), and a balance training group that used the Bodyblade® (Group 2). The two training groups participated in balance training programs for a five-week period, and the control group did not. After the five-week period all subjects were retested on the NBM® to determine if there was a statistically significant change or improvement in their data from the initial assessment. Data was also analyzed to determine if any of the groups had
significantly more improvement than any of the others. After the completion of the second assessment, the data was analyzed statistically at an alpha level of .05 using a repeated measures t-test, Wilcoxon, and one-way analysis of variance.

The two groups of healthy subjects that participated in balance training did show improvements in one component of unilateral stance and two components of limits of stability. However, statistically, these two groups did not improve significantly more than the control group, which received no training. This may have been due to multiple limitations identified by the researcher. With attention paid to these limitations, this study can be used as a preliminary model that can serve as a vantage point upon which to build future research.
CHAPTER I
INTRODUCTION/LITERATURE REVIEW

Balance is somewhat of an ambiguous term that is commonly used in the health care profession. This is a static and dynamic process that is often described as the ability to align joint segments in order to maintain the center of gravity (COG) over the base of support (BOS) with minimal sway. If this process is challenged or perturbed, the COG must quickly return within the limits of stability (LOS), or balance will be lost. A loss of balance can often have severe consequences, however the maintenance of balance is often taken for granted. Balance is a critical component in maintaining function in daily activities, and is a skill that is frequently affected in individuals who have experienced some type of neurological, vestibular, orthopedic, or musculoskeletal deficit. This is why it is important for clinicians to realize that maintaining balance through postural control is a complex process that requires integration of visual, somatosensory, and vestibular sensory inputs with motor control system outputs.

Sensory Elements

In order to determine and maintain the body’s position in space, the central nervous system (CNS) must organize information from numerous sensory inputs. Under normal circumstances the body uses information from visual, somatosensory (proprioceptive, cutaneous, and joint receptors), and vestibular systems. Each sense
provides a frame of reference in order to detect the body’s position and movement in space relative to the environment.  

**Visual Input**

Visual inputs are used to detect the orientation of the body and its parts as they relate to the external environment. Motor functions that are associated with vision include righting reactions of the head, trunk, and limbs.\(^2,3,9\) A decrease in visual acuity and/or a presence of visual field defects can affect balance. The information received from the visual system is important, but it is not essential to maintain equilibrium. Most individuals have the capability to maintain balance with their eyes closed. On stable surfaces, normal individuals should experience only a slight increase in postural sway with their eyes closed as compared to having their eyes open. However, the presence of dysfunctions that affect balance may cause a person to become unstable due to a significantly increased postural sway. Therefore the person may become more reliant on their vision.\(^3\)

**Somatosensory Input**

Somatosensory inputs are used to determine the orientation of body parts to one another and to the supporting surface. In order for this to occur, information must be relayed from cutaneous receptors that are in contact with the supporting surface and muscle/joint proprioceptors (muscle spindles and golgi tendon organs).\(^2,3,9\) At this point in time it has not been determined whether the cutaneous receptors, the muscle spindles, or the golgi tendon organs are more responsible for controlling balance. In the absence of
vision or the presence of visual defects, the somatosensory system’s importance to the maintenance of equilibrium is magnified.\(^9\)

**Vestibular Input**

Information from vestibular inputs is also an important source of information when determining the body’s orientation to itself. The vestibular system receives information from the semicircular canals and the otoliths. The semicircular canals are sensitive to angular acceleration of the head, especially fast movements that occur during gait or imbalance. The otoliths are more sensitive to linear position and acceleration, especially slower movements. This information is used to determine the relation and position of the head with respect to gravity.\(^2,9\) Unlike visual and somatosensory inputs, the information received from vestibular inputs cannot be used to determine the body’s relation to the external environment. Therefore, when visual and somatosensory systems are working properly, the information received from the vestibular system plays a minor role in maintaining balance.\(^3\)

**Sensory Interaction**

The organization of sensory information from the visual, somatosensory, and vestibular systems by the CNS is flexible. The CNS weights and uses the appropriate information depending on the situation. If the support surface and environment is stable, upright posture is maintained with the use of somatosensory inputs. If the support surface becomes unstable, visual inputs become most useful. If vision and the support surface are disrupted, the vestibular system is used to maintain equilibrium. Balance can
be maintained in the absence of information from one of the systems, but if more than one system is deficient, lack of balance control will be apparent.²

Musculoskeletal Elements

Once information from sensory inputs is obtained, the body utilizes varied musculoskeletal responses. These can include simple stretch reflexes, functional stretch reflexes, postural synergies, and complex equilibrium reactions. When balance is challenged these responses are utilized in the form of specific strategies in order to restore the COG within the LOS.²

Limits of Stability

The term limits of stability (LOS), is used when referring to the maximum angle from a vertical position that the body can sway without a loss of balance or without changing the BOS. If the COG extends beyond the BOS, the person has exceeded the LOS resulting in a loss of balance. In order for individuals to prevent themself from falling they must adjust by utilizing the step response.²,⁸⁻¹⁰ In normal adults the anteroposterior LOS, or the backward-most to forward-most position, measures to be approximately 12 degrees (eight degrees anteriorly and four degrees posteriorly). This may vary depending on the person’s height and the length of their feet. With four inches between the feet, the lateral LOS for a person considered normal is approximately 16 degrees (eight degrees to each side). This is dependent on the spacing of the feet and the person’s height.²,⁸,¹¹ Both anteroposterior and lateral LOS can be affected by the location of the COG. Normally, a person’s standing COG alignment directly coincides with the center of the LOS. If a person’s COG falls forward, backward, or to one side of the
center of the LOS, then there will most likely be a smaller sway envelope. A decrease in the sway envelope is also evident in those individuals that exhibit a musculoskeletal abnormality. An example of this is weakness or decreased range of motion (ROM) of the ankle. This decreased sway envelope may put these individuals at greater risk for a fall.8

Balance Strategies

Normally, the COG is located in the area of the lower abdomen and is dependant on the configuration of the body joints.8 When a person’s balance is challenged by an external perturbation the body utilizes strategies to return the COG to its proper position within the LOS. This is done by incorporating movements of the lower extremities and assuming a variety of postures with different joint angles. Three strategies have been identified, these include ankle, hip, and stepping.2,3,8 The effectiveness of these strategies in repositioning the COG depends on the configuration of the BOS, the COG alignment in relation to the LOS, and the speed of the postural movement.3

Ankle Strategy

The ankle strategy is used to regain balance by shifting the COG forward and back, over stationary feet, by rotating the body as a relatively rigid mass over the ankle joint.2,3,8,9 In order for this to occur a rotational torque must be generated by the ankle musculature, namely the gastrocnemius and the tibialis anterior. Activation of the gastrocnemius is used to produce a plantarflexion torque that counteracts the body’s anterior motion. Conversely, the tibialis anterior contracts to counteract posterior motion of the body.3,9 The activation of these muscles occur in a distal to proximal sequence.2 The ankle strategy has been found to be most effective when there are small disturbances.
and only large, slow COG movements (0.3 Hz) are required.\textsuperscript{2,3} The COG must also be well within the confines of the LOS with a firm BOS. Under normal sensory conditions this strategy is used to simply maintain equilibrium.\textsuperscript{3}

**Hip Strategy**

If the ankle strategy is not adequate to return the COG to a state of equilibrium, the body utilizes the hip strategy. This involves shifting the COG by flexing or extending the hips through muscular contraction.\textsuperscript{2,3,8} Unlike the ankle strategy the hip strategy is most effective when small, rapid movements (1.0 Hz or higher) are required. If an intermediate movement (between 0.3 and 1.0 Hz) is required the body will use a combination of the two strategies.\textsuperscript{8} Individuals that have a dysfunction that affects the somatosensory system rely more on the hip strategy to retain their COG within the LOS.\textsuperscript{3}

**Stepping Strategy**

If the COG is displaced beyond the LOS, and the ankle and/or hip strategies are not adequate, the stepping strategy must be used to prevent a fall. Elicitation of this strategy occurs when the LOS are reached in response to fast, large perturbations. This strategy regains equilibrium by the individual taking a step or stumbling in the direction of the displacing force and therefore establishes a whole new LOS.\textsuperscript{2,3,8}

**Measures of Balance**

Due to its complexity, the concept of balance must be analyzed in its entirety by examining all of its components. Balance can be broken down into three aspects: static steadiness, symmetry, and dynamic stability. All of these components can be analyzed objectively with use of force platforms such as the Neurocom\textsuperscript{®} Balance Master
(Neurocom® International, Inc., Clackamas, OR). The Neurocom® Balance Master (NBM®) utilizes the unilateral stance test to determine static steadiness and the LOS test was to describe dynamic stability. Data gathered from these assessments can be used to determine a person’s level of balance and whether or not a disturbance or deficit is present.6

Static Steadiness

Static steadiness refers to the body’s ability to keep itself as motionless as possible, and is measured by assessing postural sway.2,6,12 A larger sway magnitude presents with an increase in age and has been found to relate to greater postural unsteadiness.4,12 Steadiness is assessed commonly with the use of force platforms such as the NBM® that examine directional displacement of an individual’s COG and the total sway area in a static position.2,6,13,14 Literature states that many studies have used these systems to characterize sway in both normal subjects and those with impairments. With the use of objective systems that utilize force platforms it is possible to identify those with balance deficits. Baselines can also be observed to determine if training programs are having the desired effect.6,14

Symmetry

Symmetry is the ability to distribute the weight evenly or symmetrically between the feet in upright standing. As with static steadiness, symmetry can be measured with the use of force platforms.3,6 Symmetry measures show the amount of weight on each foot or the distance of the COG away from the midline. Force platforms may also be utilized to train for appropriate symmetry by providing the subject/patient with visual
feedback that displays the percentage of body weight on each limb. Studies have shown that increased stance symmetry occurs following balance training in those with balance deficits. Literature reports that symmetry training with the use of force platforms is more effective than traditional balance training due to the added continuous visual feedback. Dynamic stance training, or shifting weight to successive targets, has also been found to have a positive effect on stance symmetry.6

Dynamic Stability

Dynamic stability is the ability to vertically transfer the COG over a stationary BOS while remaining within the LOS.3,6 Often, this is used to determine one's safe LOS. In doing so, force platforms require individuals to lean or reach as far as possible without losing balance or reverting to the stepping strategy. This requires the subject to shift their weight towards one of eight targets that are located on the computer screen. This can be done at settings of 50-100% of their LOS. Subject performance is determined by analyzing the following data: transition time, sway path, sway error, and peripheral sway area. Dynamic stability training has been found to decrease the magnitude of each of these variables. This indicates that there is an increased accuracy of the weight shift and an extension of the LOS in subjects with or without balance deficits. Furthermore, this type of training may also have a positive effect on static steadiness.6 McRae et al15 found that a decrease in postural sway, in subjects with hemiparesis, after six training sessions involving dynamic stability activities. Nichols6 reports that studies in which multiple dynamic stability activities are used, have shown the best functional carry-over (ADL's, gait, transfers, etc). Even though symmetry and dynamic stability
have been found to correlate with many functional measures, the effect training of with force platform biofeedback on function has yet to be determined in the existing literature.\textsuperscript{6}

Problem Statement

Many studies have shown that balance can be improved in subjects with balance deficits, however few studies have addressed the effects of balance training programs on healthy subjects. There are also few studies that involve the Hymanson Inc.\textsuperscript{®} Bodyblade, and it has yet to be determined whether it has any affect on balance.

Purpose

The purpose of this study was to determine if healthy individuals could show a significant improvement in balance with training, more specifically components of unilateral stance (static steadiness) and limits of stability (dynamic stability), as assessed by the NBM\textsuperscript{®}. Additionally, the study will also determine if different balance treatment approaches had different outcomes in the subjects’ results.

Research Questions

The research questions that are addressed are: 1) Is there a statistically significant difference between results obtained before and after a five-week training program in balance measures of healthy individuals? 2) Is there a statistically significant difference in the amount of change in balance measures after a five-week period between the control group (Group 0), the balance training group (Group 1), and the balance training group that used the Bodyblade\textsuperscript{®} (Group 2)?
Final approval for this study was obtained from the University of North Dakota (UND) and Altru Health Systems Institutional Review Board for the use of human subjects. A copy of the Human Subjects Review Form and the approval letters from both UND and Altru Health Systems are located in Appendix A. During recruitment, all individuals were informed that their participation was strictly voluntary. The components of the study were explained to those interested in participating, with each subject giving their informed written consent. A copy of this consent form is located in Appendix B.

To identify possible safety or health concerns, a health background questionnaire was given to each individual before inclusion. This questionnaire was utilized to obtain the following information: medications, current/past medical diagnoses, symptoms associated with balance disorders, visual acuity, and exercise level. A copy of this questionnaire is located in Appendix C for further reference.

Subjects

In order to test the hypotheses associated with this study, 36 subjects (8 males, 28 females) within the age range of 20-34 years were recruited from a physical therapy class within the UND student population. It was determined that no subjects would be excluded from partaking in this study unless the health questionnaire identified a safety or health concern that would possibly put them at risk for injury. The researchers
determined that all 36 applicants were considered “safe”, based on the predetermined criteria, and would be subject to all appropriate testing/training procedures. Additional criteria that each applicant met for inclusion into this study were as follows:

1. An understanding that inclusion was strictly voluntary
2. Age was within the range of 20-39 years
3. Able to attend all training/assessment sessions

Once all components of criteria were met, 36 individuals were randomly placed in one of three groups. Group 0 (N=12) served as a control and was asked not to start any new strengthening or balance activities during the five weeks between assessments. Group 1 (N=12) and Group 2 (N=12) served as experimental groups and participated in separate five-week balance training programs. These two training programs utilized the same activities, however Group 2 incorporated the Bodyblade® in the activities while Group 1 did not. Initially, each group was comprised of twelve individuals, however it was necessary to release one individual (female) in experimental Group 1 during week four of training due to an injury requiring surgical intervention. It is noted that this injury was not related to any procedures involved with this study.

Instrumentation

The NBM® was used to assess unilateral stance and LOS. A detailed description of both tests and their components are located in Appendix D. This is a clinically acceptable machine commonly used in physical therapy to assess balance in all types of individuals. It consists of two nine inch by sixty inch force platforms resting on four load cells on which the subject stands to measure the force under each foot.
platform communicates with a computerized system integrated with a software program that interprets various data obtained during a balance assessment (Figure 1). This data is quantitative and allows the researcher or therapist to measure balance in an objective manner. Furthermore, this instrument is unique due to its ability to provide continuous visual feedback to the subject and researcher, via a computer screen, regarding the location of the subject's center of gravity.¹⁶

Figure 1. Neurocom® Balance Master version 6.1

Hamman et al¹⁸ determined that a high "learning curve" exists when using the NBM®. They concluded this after observing statistically significant improvements in normal, healthy subjects' test results after repeated training sessions. They also found that this was primarily present during the first few training sessions but eventually reached a plateau. This demonstrates the need to provide each subject with a training session before the actual assessment data is gathered.
Published literature supports the clinical use of the NBM® and acknowledges it as a reliable and valid tool for assessing balance. The LOS test has been shown to be moderately to highly reliable and significantly correlates with walking and activity of daily living (ADL) performance. The unilateral stance test, has shown high reliability and significantly correlates with knee extensor strength, walking speed, and stair climbing capacity, along with a modest correlation to ADL's in healthy elderly subjects.

Pilot Study

After instruction in and practice on the NBM®, a pilot study was performed in order to establish intrarater (test-retest) and interrater (between testers) reliability for the three raters. Ten subjects ranging in age from 18 to 24 years were assessed using the unilateral stance and limits of stability tests in the same manner as described in assessment procedures, including the amount of practice and rest each individual was given. The NBM® procedure manual was followed, and all three researchers were present during the assessment of the subjects. In order to establish interrater reliability, each subject completed both tests for each of the three testers. To establish intrarater reliability, the same procedure was followed a second time, approximately one to two weeks later. The order that the testers assessed each subject remained the same as the first assessment. One subject was released from the pilot study due to lack of effort during the second assessment, giving a remaining total of nine subjects. The SPSS Version 6.01 (SPSS, Inc., Chicago, IL) was used to calculate interrater and intrarater reliability.
Intrarater Reliability

An intraclass correlation coefficient (ICC) was calculated from a repeated measures analysis of variance (ANOVA) in order to assess test-retest reliability for each rater, testing the subject on different days. The ICC formula \((3,k)\) was used, as suggested for intrarater reliability. Since there is a lack of variance between our subjects' scores, ICC's could not be calculated on many of the tests. This could have been avoided by finding a more heterogeneous subject population (for example, select subjects from a greater age range rather than the 18-24 range in this pilot study) or selecting tests with a greater scoring range. However, the pilot study had already been completed when this information was obtained. Intrarater reliability results are reported in Table 1.

Table 1. Unilateral stance intrarater reliability using ICC.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rater 1</th>
<th>Rater 2</th>
<th>Rater 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes Open COG Sway Velocity composite</td>
<td>*</td>
<td>.73</td>
<td>*</td>
</tr>
<tr>
<td>Eyes Closed COG Sway Velocity composite</td>
<td>.82</td>
<td>.82</td>
<td>.87</td>
</tr>
<tr>
<td>Eyes Open and Closed COG Sway Velocity composite</td>
<td>.84</td>
<td>.75</td>
<td>.83</td>
</tr>
</tbody>
</table>

Key: *Unable to calculate ICC due to lack of variance

Intrarater reliability was determined statistically for LOS utilizing the ICC. movement velocity composite yielded an ICC value of .75 for Rater 1 and .90 for Rater 2. An ICC value for Rater 3 could not be determined, due to unmet assumptions because of a lack of variance between subjects. A lack of variance was also present in reaction time composite, endpoint excursion composite, maximum excursion composite, and directional control composite, thus an ICC was not calculated for these components.
Interrater Reliability

An intraclass correlation coefficient (ICC) was calculated from a repeated measures ANOVA to determine intertester reliability. The ICC formula (2,k) was used, as suggested for interrater reliability. A significant difference in variance between subjects was found, and all ICC’s were reported. Interrater reliability results from test time one and two are reported in Tables 2 and 3.

Table 2. Unilateral stance interrater reliability using ICC.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Test time 1</th>
<th>Test time 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes Open COG Sway Velocity composite</td>
<td>.90</td>
<td>.85</td>
</tr>
<tr>
<td>Eyes Closed COG Sway Velocity composite</td>
<td>.95</td>
<td>.88</td>
</tr>
<tr>
<td>Eyes Open and Closed COG Sway Velocity composite</td>
<td>.95</td>
<td>.93</td>
</tr>
</tbody>
</table>

Table 3. Limits of stability interrater reliability using ICC.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Test time 1</th>
<th>Test time 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction Time composite</td>
<td>* .87</td>
<td>* .88</td>
</tr>
<tr>
<td>Movement Velocity composite</td>
<td>.91</td>
<td>.91</td>
</tr>
<tr>
<td>Endpoint Excursion composite</td>
<td>.85</td>
<td>.92</td>
</tr>
<tr>
<td>Maximum Excursion composite</td>
<td>** .75</td>
<td>.88</td>
</tr>
<tr>
<td>Directional Control composite</td>
<td>.72</td>
<td>.76</td>
</tr>
</tbody>
</table>

Key: * Skewed and kurtosed distribution
     ** Kurtosed distribution

ICC Interpretation

There are no standard values set for acceptable reliability when calculating the ICC. Values range between 0.00 and 1.00, with numbers falling closer to 1.00 representing stronger reliability scores. Using the ICC interpretation listed in Table 4,
values obtained for intrarater and interrater reliability show high to very high reliability.

Table 4. ICC interpretation.\textsuperscript{20}

<table>
<thead>
<tr>
<th>ICC Value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>.90-1.00</td>
<td>Very High</td>
</tr>
<tr>
<td>.70-.89</td>
<td>High</td>
</tr>
<tr>
<td>.50-.69</td>
<td>Moderate</td>
</tr>
<tr>
<td>.26-.49</td>
<td>Low</td>
</tr>
<tr>
<td>0.00-.25</td>
<td>Little, If Any</td>
</tr>
</tbody>
</table>

Assessment Procedure

Subjects reported to Altru Health Institute Outpatient Physical Therapy Department for assessment on the NBM\textsuperscript{®}. Before assessment each individual was randomly assigned to a tester, and an identification number, date of birth, and height were entered in the subject’s file. All individuals were subject to testing procedures measuring various components of balance, as measured with the unilateral stance and LOS tests. Both tests required the subject to be either barefoot or wearing socks, based on their preference. This was recorded so that identical conditions could be duplicated for the second assessment. All tests were administered at the subject’s pace in order to provide adequate rest between trials. Listed in Appendix E is a summary of the procedures used for each test, as described in the NBM\textsuperscript{®} Operator’s Manual\textsuperscript{17}, along with the script used by each researcher during testing.

Six weeks following the initial assessment, the subjects were again tested on the NBM\textsuperscript{®}. The same testing conditions were used, including tester and whether the subject was barefoot or wearing socks. The subject was again required to fill out a health background questionnaire in order to identify any changes that may have occurred over the course of the study.
Training Equipment

During the five week training programs, various equipment was utilized by one or both of the experimental groups. Throughout the duration of the training, Group 2 used the Hymanson Inc.® Bodyblade during all of the balance activities. Initially, both groups trained on stable surfaces, but as the subjects progressed, there was a need to increase the difficulty of the balance activities. This was accomplished by introducing the Varilite® Air Cushion (Cascade Designs, Inc. Seattle, WA) and Sissel® SitFit (JELA, Bad Durkheim, Germany) in order to provide a more unstable surface on which to train.

The Hymanson Inc.® Bodyblade

The Hymanson Inc.® Bodyblade (Figure 2) is a piece of equipment that is frequently used in physical therapy to increase body awareness, joint mobility, flexibility, and strength. It is a four-foot long by 1.75 inch wide rod composed of graphite weighing 1.5 pounds. The Bodyblade® is held in the middle and an oscillatory force is applied by the person using it. The oscillations of the Bodyblade® require a stabilizing force by the subject, which can be utilized during both static and dynamic activities.

Figure 2. Hymanson, Inc.® Bodyblade.
The Varilite® Air Cushion

As training progressed, the Varilite® Air Cushion was used to create an unstable surface on which to perform unilateral stance activities. This creates a more dynamic environment, which makes it more difficult to maintain static steadiness. The Varilite® Air Cushion is illustrated in Figure 3.

Figure 3. Varilite® Air Cushion.

The Sissel® SitFit

The Sissel® SitFit is a disc that is composed of material similar to that of a swiss ball (Figure 4). Although the primary purpose of this piece of equipment is to challenge sitting balance, this study utilized the Sissel® SitFit to progress the training program by providing an unstable surface to challenge standing balance. In order to do so, the subjects stood on the disc while moving in the eight directions associated with the limits of stability assessment on the NBM®.
Training Procedure

The training groups participated in a five-week training program that met for 30 minute sessions two times per week. Group 2 participated in all of the activities while using the Bodyblade®, and Group 1 performed the same activities but without the Bodyblade®. During the first two weeks of the training programs the subjects performed the following activities on a stable surface:

1. Unilateral stance (20 seconds x 3 repetitions)
2. LOS (3 repetitions in each of the eight directions with 5 second holds)
3. Tiptoes and heels (3 sets of 3 repetitions with 5 second holds)
4. Tandem walk (3 repetitions of a 30 foot distance)

The balance training program was progressed in the third week in order to increase the difficulty of the activities. Subjects performed unilateral stance activities while standing on the Varilite® air cushion, and LOS activities were performed while subjects stood in a
tandem position. Tiptoes and heels were continued, but tandem walking was eliminated from the program. During weeks four and five, the training programs were progressed further by having the subjects perform the LOS activities while standing on the Sissel® SitFit with feet together.

Unilateral Stance Training Procedure

The subject stood on one leg at a time with either eyes open or eyes closed and hands on hips. Group 2 performed the same activity, however the Bodyblade® was incorporated. It was held vertically in the upper extremity that was contralateral to the lower extremity on which the subject was standing. The hand not holding the Bodyblade® was placed on the hip. An oscillatory force was applied to the Bodyblade® in the frontal plane (Figure 5).

Figure 5. Unilateral stance with Bodyblade®, shown on left without Varilite® Air Cushion and on right with Varilite® Air Cushion.
LOS Training Procedure

The subject stood with feet approximately shoulder width apart. Similar to the testing procedure, the subject shifted their weight in one of eight directions (Figure 6): forward, forward-right, right, back-right, back, back-left, and forward-left. During these weight shifts, the subject was asked to lean as far as possible without losing their balance or removing one foot entirely from the weightbearing surface. Group 2 performed this activity while holding the Bodyblade® with bilateral upper extremities in a horizontal position, applying an oscillatory force parallel to the direction they were leaning (Figures 7 and 8).

Figure 6. Eight directions of limits of stability.
Figure 7. Limits of stability performed forward and back with the Bodyblade®.

Figure 8. Limits of stability to the side on a stable surface shown on left, unstable surface in diagonal direction shown on right, both with the Bodyblade®.
Tiptoes and Heels Training Procedure

From a neutral standing position with feet approximately shoulder width apart, the subject plantarflexed up to a tiptoe position and held for five seconds. During the heels activity, the subject dorsiflexed and shifted all weight to their heels, once again holding this position for five seconds. Group 2 performed these activities in a similar fashion with the addition of the Bodyblade® being held in bilateral upper extremities, with an oscillatory force applied in the sagittal plane. This force was applied throughout the entire motion including the five seconds in the tiptoe or heel position.

Tandem Walk Training Procedure

The subject walked in a heel to toe fashion for a distance determined by the researchers. Group 1 performed this activity with hands on hips. Group 2 performed the activity while holding the Bodyblade® in a vertical position with bilateral upper extremities and applying an oscillatory force in the frontal plane (Figure 9).

Data Analysis

The data gathered for all subjects during the first and second NBM® assessment was entered into the SPSS Version 6.01 software system. With this program, descriptive statistics including mean, median, and standard deviation were calculated. Calculations were also done to determine values for repeated measures t-test or Wilcoxon depending on normality of distribution (skewness, kurtosis). A gain score was determined between the initial and final assessment on all components and was analyzed with a one-way analysis of variance.
Figure 9. Tandem walk performed with the Bodyblade®.

Reporting of Results

Upon completion of this study, a summary of the results were completed and given to the University of North Dakota Department of Physical Therapy. This study was completed to fulfill the requirements for the University of North Dakota School of Medicine and Health Sciences Physical Therapy Program.
CHAPTER III

RESULTS

At this point the study was divided into three separate studies for the purpose of differing data analysis. In order to see additional results from this study, please refer to Burchill\textsuperscript{22} for \textit{The Effect of a Five Week Balance Training Program on Individuals with Previous Ankle Sprains} or Dingmann\textsuperscript{23} for \textit{The Effects of Balance Training in Normal Young Adults as Assessed by the Neurocom\textsuperscript{®} Balance Master}. This section includes the subject profile and results from the initial and final NBM\textsuperscript{®} assessments. The data obtained from these assessments will be analyzed statistically to determine if any of the groups displayed a significant change in balance skills after the five-week training program, and also if there is a significant difference in this change based on the type of training program used. Descriptive statistics will be included to demonstrate data obtained on the NBM\textsuperscript{®} in subjects that are healthy. Analytical statistics will be used to determine if the training programs had an effect on the subjects' balance skills.

Subject Profile

Thirty-six subjects participated in this study. However, for the purpose of this data analysis five subjects were released due to injuries obtained during the five weeks between assessments, or they had a drastic change in their exercise program as determined by the health questionnaire. Analysis of data was done for the other thirty-one subjects that remained. Ten subjects in Group 0 (control group) were assessed
initially on the NBM® and then after five weeks were assessed again. These subjects were not involved in a training program between assessments. The balance training groups, Group 1 (N=11) and Group 2 (N=10), were assessed previous and prior to a five-week balance training program.

**Descriptive Statistics**

Descriptive statistics including mean, standard deviation, median, range, skewness, and kurtosis were calculated from the data gathered during the first assessment. For a listing of values, see Tables 5 (unilateral stance) and 6 (LOS). All components of unilateral stance and LOS are included for thoroughness. These values were not compared to the normative data listed in the NBM® Manual due to some question regarding the subjects meeting of normative criteria. Specifically, it states that the subjects could have no current or past medical diagnosis or injury affecting balance. There was uncertainty if this included ankle sprains that occurred more than six months prior to testing. Subjects that presented in this manner were not released from the study. Even though the meeting of the criteria is in question, this information may provide the clinician with added knowledge to use during evaluation of a variety of patients.

**Analytical Statistics**

Analytical statistics were used to determine if the training programs had an effect on the subjects' balance skills and also if there is a significant difference in this change based on the type of training program used. Instead of analyzing all the data components obtained from unilateral stance and LOS, the researcher chose to analyze the composite values for each of the components. These composite values were calculated by taking
Table 5. Unilateral stance descriptives.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes Open: Left</td>
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<td>1.25</td>
<td>1.71</td>
<td>1.30</td>
<td>.90-1.60</td>
</tr>
<tr>
<td>Eyes Open: Right</td>
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<td>1.22</td>
<td>1.61</td>
<td>1.20</td>
<td>1.00-1.60</td>
</tr>
<tr>
<td>Eyes Open: Composite</td>
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<td>1.23</td>
<td>1.14</td>
<td>1.25</td>
<td>.95-1.55</td>
</tr>
<tr>
<td>Eyes Closed: Left</td>
<td>29</td>
<td>2.22</td>
<td>.35</td>
<td>2.20</td>
<td>1.70-2.90</td>
</tr>
<tr>
<td>Eyes Closed: Right</td>
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<td>2.11</td>
<td>.32</td>
<td>2.10</td>
<td>1.70-2.90</td>
</tr>
<tr>
<td>Eyes Closed: Composite</td>
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<td>2.15</td>
<td>.28</td>
<td>2.15</td>
<td>1.70-2.85</td>
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<tr>
<td>Overall: Composite</td>
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<td>1.69</td>
<td>.19</td>
<td>1.73</td>
<td>1.33-2.15</td>
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Table 6. Limits of stability descriptives.

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<th>Mean</th>
<th>SD</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
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<td>.47</td>
<td>.27-.90</td>
</tr>
<tr>
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<td>.15</td>
<td>.40</td>
<td>.14-.75</td>
</tr>
<tr>
<td>Reaction Time: Right**</td>
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<td>.53</td>
<td>.14</td>
<td>.50</td>
<td>.29-.93</td>
</tr>
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<td>Reaction Time: Left*</td>
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<td>.57</td>
<td>.17</td>
<td>.51</td>
<td>.39-1.00</td>
</tr>
<tr>
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<td>.13</td>
<td>.46</td>
<td>.30-.85</td>
</tr>
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<td>8.80</td>
<td>4.50-12.10</td>
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<td>Movement Velocity: Back</td>
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<td>4.05</td>
<td>1.27</td>
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<td>1.40-6.50</td>
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<td>Movement Velocity: Right</td>
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<td>8.11</td>
<td>2.77</td>
<td>7.70</td>
<td>4.00-13.90</td>
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<tr>
<td>Movement Velocity: Left</td>
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<td>10.19</td>
<td>2.84</td>
<td>10.00</td>
<td>4.90-15.40</td>
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<td>8.30</td>
<td>3.90-10.90</td>
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<td>12.47</td>
<td>103.00</td>
<td>72.00-119.00</td>
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<td>57.00</td>
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<td>92.00</td>
<td>67.00-110.00</td>
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<td>9.19</td>
<td>105.00</td>
<td>83.00-125.00</td>
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<td>88.00</td>
<td>73.00-99.00</td>
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<td>111.00</td>
<td>80.00-127.00</td>
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<tr>
<td>Maximum Excursion: Back</td>
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<td>14.94</td>
<td>66.00</td>
<td>31.00-96.00</td>
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<td>Maximum Excursion: Right</td>
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<td>113.00</td>
<td>99.00-135.00</td>
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<td>98.00</td>
<td>85.00-105.00</td>
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<td>72.84</td>
<td>6.91</td>
<td>74.00</td>
<td>59.00-84.00</td>
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</table>

Key: * Skewed distribution
** Skewed and kurtosed distribution
a straight average of all the data obtained from each component. This produced eight composite variables, three for unilateral stance and five for LOS. Variables that will be analyzed for the unilateral stance test are: eyes open composite, eyes closed composite, and overall composite. Variables analyzed for LOS are: reaction time composite, movement velocity composite, end point excursion composite, maximum excursion composite, and directional control composite.

To determine if a significant change in balance skills occurred between assessments, a repeated measures t-test was utilized with an alpha level of .05 to examine data from the three groups. Results obtained from this t-test are listed in Table 7. As Table 7 demonstrates, Group 0 (control group) displayed a significant change in the LOS directional control composite; Group 1 (balance training group without the Bodyblade®) showed a significant change in LOS seen with both maximum excursion and directional control composites; Group 2 (balance training group with the Bodyblade®) displayed a significant change after the five-week period in the unilateral stance eyes closed composite. All of the changes revealed with the t-test demonstrate improvement by the subjects between assessments. A Wilcoxon was also used due to a presentation of skewed/kurtosed data for subjects in the LOS maximum excursion composite. A significant improvement was found in Group 1 subjects. Results from the Wilcoxon are listed in Table 8.

In order to determine if there was a significant difference between groups based on training or lack of, a one-way ANOVA (analysis of variance) was done using an alpha level of .05. This was done by analyzing the gain scores between assessments.
Table 7. Repeated measures t-test results with descriptives.

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<tr>
<th>Variable</th>
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<th>N</th>
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<th>SD</th>
<th>Test time 2 Mean</th>
<th>SD</th>
<th>t</th>
<th>p</th>
<th>Sig.</th>
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</table>

Key: * t-test is not appropriate due to skewness/kurtosis

Descriptives for the ANOVA are listed in Table 9. The results, listed in Table 10, show that there is a significant difference between groups for LOS endpoint excursion composite. To determine which groups the difference was between, Scheffe's
Table 8. Wilcoxon results with descriptives.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
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<td>4.35</td>
<td>101.09</td>
<td>2.81</td>
<td>2.229</td>
<td>.026</td>
<td>Yes</td>
</tr>
<tr>
<td>Excursion: Composite</td>
<td>2</td>
<td>10</td>
<td>98.00</td>
<td>4.06</td>
<td>98.30</td>
<td>5.81</td>
<td>.563</td>
<td>.574</td>
<td>No</td>
</tr>
</tbody>
</table>

Key: * Wilcoxon is not appropriate

Table 9. Descriptives for one-way ANOVA (mean gain).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>N</th>
<th>Mean Gain</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilat. Stance, Eyes Open: Composite</td>
<td>0</td>
<td>10</td>
<td>.015</td>
<td>.088</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>11</td>
<td>.009</td>
<td>.106</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>10</td>
<td>-.025</td>
<td>.089</td>
</tr>
<tr>
<td>Unilat. Stance, Eyes Closed: Composite</td>
<td>0</td>
<td>9</td>
<td>.033</td>
<td>.225</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>9</td>
<td>-.066</td>
<td>.147</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>9</td>
<td>-.155</td>
<td>.177</td>
</tr>
<tr>
<td>Unilat. Stance, Overall: Composite</td>
<td>0</td>
<td>9</td>
<td>.025</td>
<td>.125</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>9</td>
<td>-.019</td>
<td>.090</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>9</td>
<td>-.086</td>
<td>.118</td>
</tr>
<tr>
<td>LOS, Reaction Time: Composite</td>
<td>0</td>
<td>10</td>
<td>.013</td>
<td>.089</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>11</td>
<td>.007</td>
<td>.087</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>10</td>
<td>.004</td>
<td>.045</td>
</tr>
<tr>
<td>LOS, Movement Velocity: Composite</td>
<td>0</td>
<td>10</td>
<td>.750</td>
<td>1.462</td>
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<td></td>
<td>1</td>
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<td>10</td>
<td>.580</td>
<td>1.398</td>
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<tr>
<td>LOS, End Point Excursion: Composite</td>
<td>0</td>
<td>10</td>
<td>3.100</td>
<td>7.264</td>
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<td>11</td>
<td>9.454</td>
<td>8.466</td>
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<td></td>
<td>2</td>
<td>10</td>
<td>-1.300</td>
<td>5.121</td>
</tr>
<tr>
<td>LOS, Maximum Excursion: Composite</td>
<td>0</td>
<td>10</td>
<td>2.300</td>
<td>3.888</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>11</td>
<td>4.272</td>
<td>5.159</td>
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<td></td>
<td>2</td>
<td>10</td>
<td>.300</td>
<td>4.347</td>
</tr>
<tr>
<td>LOS, Directional Control: Composite</td>
<td>0</td>
<td>10</td>
<td>5.800</td>
<td>3.852</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>11</td>
<td>6.727</td>
<td>7.444</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>10</td>
<td>2.500</td>
<td>5.892</td>
</tr>
</tbody>
</table>

Post Hoc was run using an alpha level of .05. This revealed that the difference was between the training groups. Through further analysis it is evident that this is due to an increase in scores in Group 1 and a decrease in scores in Group 2.
Table 10. Results for one-way ANOVA and Scheffe Post Hoc.

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>p</th>
<th>Scheffe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unilateral Stance, Eyes Open: Composite</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>.009</td>
<td>2</td>
<td>.004</td>
<td>.515</td>
<td>.603</td>
<td></td>
</tr>
<tr>
<td>Within Groups</td>
<td>.256</td>
<td>28</td>
<td>.009</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>.265</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Unilateral Stance, Eyes Closed: Composite** |                |    |             |      |     |         |
| Between Groups           | .161           | 2  | .080        | 2.31 | .120|         |
| Within Groups            | .832           | 24 | .034        |      |     |         |
| Total                    | .993           | 26 |             |      |     |         |

| **Unilateral Stance, Overall: Composite** |                |    |             |      |     |         |
| Between Groups           | .056           | 2  | .028        | 2.22 | .130|         |
| Within Groups            | .304           | 24 | .012        |      |     |         |
| Total                    | .360           | 26 |             |      |     |         |

| **LOS, Reaction Time: Composite** |                |    |             |      |     |         |
| Between Groups           | .000           | 2  | .000        | .035 | .966|         |
| Within Groups            | .168           | 28 | .006        |      |     |         |
| Total                    | .168           | 30 |             |      |     |         |

| **LOS, Movement Velocity: Composite** |                |    |             |      |     |         |
| Between Groups           | 3.819          | 2  | 1.909       | .907 | .415|         |
| Within Groups            | 58.968         | 28 | 2.106       |      |     |         |
| Total                    | 62.787         | 30 |             |      |     |         |

| **LOS, Endpoint Excursion: Composite** |                |    |             |      |     |         |
| Between Groups           | 616.144        | 2  | 308.072     | 6.04 | .007| between groups 1 & 2 |
| Within Groups            | 1427.727       | 28 | 50.990      |      |     |         |
| Total                    | 2043.871       | 30 |             |      |     |         |

| **LOS, Maximum Excursion: Composite** |                |    |             |      |     |         |
| Between Groups           | 82.715         | 2  | 41.357      | 2.02 | .151|         |
| Within Groups            | 572.382        | 28 | 20.442      |      |     |         |
| Total                    | 655.097        | 30 |             |      |     |         |

| **LOS, Directional Control: Composite** |                |    |             |      |     |         |
| Between Groups           | 101.589        | 2  | 50.795      | 1.42 | .258|         |
| Within Groups            | 1000.282       | 28 | 35.724      |      |     |         |
| Total                    | 1101.871       | 30 |             |      |     |         |

Key: *Significant with alpha level=.05 for one-way ANOVA and Scheffe Post Hoc.
CHAPTER IV
DISCUSSION

Many studies have found that balance training programs can help subjects that have balance deficits to improve their balance, however few studies have addressed the effects of balance training programs on healthy subjects. In order to do so it is essential to test healthy subjects before and after a balance training program with the use of an objective balance measure such as the NBM®. It is also essential to realize that any improvement in test results may be a direct result of this system's well documented high learning curve. In order to compensate for this, each subject was given a practice session to allow for familiarization with NBM® testing procedures.

When taking all the results of this study into consideration it is possible to determine if the researcher's hypothesis that balance training has a positive effect on healthy subjects' balance is an accurate one. In order to do so, the following research questions must be addressed: 1) Is there a statistically significant difference between results obtained before and after a five week training program in balance measures of healthy individuals? 2) Is there a statistically significant difference in the amount of change in balance measures after the five-week period between the control group (Group 0), the balance training group (Group 1), and the balance training group that used the Bodyblade® (Group 2)? The answer to the first research question is: yes, the two groups of healthy subjects that participated in balance training did show improvements in
one component of unilateral stance and two components of LOS. However, the second research question must be answered to determine if the two balance training groups improved significantly more than the control group, which received no training. When the amount of improvement in each of the groups was compared and analyzed statistically, it was evident that there was no significant difference in the amount of change or improvement in balance measures between the control group and the two balance training groups. One possible reason for the control group's improvement is the presence of the before mentioned high learning curve. A practice session was given, but Hamman et al. determined that multiple practice sessions are required in order to decrease the effects of this learning curve. Some of the subjects within the control group also noted that they had been mentally practicing for their second assessment during the five weeks. Doheny found that mental practice does have a positive affect on learning and performance of motor skills. It is likely that either the learning curve or the mental practice is the reason for the control group's improvement.

Limitations

There were many limitations that can be identified when observing this particular study. The following are the main limitations that were recognized by the researcher:
1) The testing environment was subject to auditory distraction. 2) The duration of the balance training program was only five weeks, equaling a total of 10 training sessions. 3) Progression in the training program was not done individually. 4) The second assessment that was after the five-week interval occurred during a time of high stress for the subjects as they were in the middle of final's week. 5) Only two tests, unilateral
stance (static steadiness) and LOS (dynamic stability), were used in assessing each subjects level of balance. 6) The high learning curve associated with the NBM® may have played a part in the improved scores in all of the groups. 7) Some subjects in the control group practiced mentally during the five-week period, possibly enhancing results.

Auditory distractions were a direct result of the location of the assessment. The NBM® was used in a hospital's physical therapy inpatient/outpatient clinic. All the assessments were performed during the middle of the day, which is the clinic's busiest time. A curtain was pulled to aid in isolating the environment, however auditory stimulus could not be prevented. The subjects noted on many occasions that it was difficult to concentrate on the balance tests, especially unilateral stance that requires static steadiness. It is a possibility that the presence of the auditory distractions may have affected the results of the first and second assessments.

The duration of the balance training program was five weeks due to the limited availability of the subjects after that time period. Hoffman25 found that healthy subjects increased their postural control after a 10-week proprioceptive training program that utilized similar activities to those used in this study. It is possible that the five-week balance training program that met two times per week, may not have given the subjects sufficient time to improve their balance.

The subjects attended and participated in balance training sessions in their respective groups and were not trained individually. This meant that the difficulty of the activities could only be adjusted when the entire group was ready. There were some subjects that were prepared to progress earlier to the more advanced balance training
techniques listed in methodology. If these individuals were allowed to progress at their own pace, there may have been a different result in their level of balance improvement.

During the week that the second, and final, balance assessment on the NBM® was done the subjects were all in the middle of finals week. This may have caused additional stress in the subjects' lives that was not present during the first assessment. Pensgaard \(^{26}\) found that stress does have a detrimental effect on performance. It is difficult to say what the level of stress for each individual was, but overall this possibly could have affected test results obtained during the second assessment.

Only two NBM® tests were utilized to assess the subjects' balance, unilateral stance and LOS. Unilateral stance was used to analyze each subject’s static steadiness, and LOS for dynamic stability. The NBM® has multiple tests that measure static steadiness and dynamic stability, so it is feasible that more information could have been gained by utilizing a plethora of tests rather than just two.

Recommendations

In order for the best results, it is suggested that future studies utilize the following: an isolated and quiet testing environment that is conducive to subject success, a balance training program of 10 weeks or more or an increased number of training sessions to allow for sufficient training time, a balance training program that is set up to allow for each individual subject to progress at his/her own pace, a schedule that allows subjects to be assessed during relatively stress free times, usage of multiple NBM® tests to allow for a more comprehensive balance evaluation, provision of multiple practice sessions on the NBM® to decrease the effects of the learning curve, and instruction to
participants in the control group to refrain from any mental practice associated with the balance tests utilized. Addressing all of these areas will eliminate any question regarding the accuracy of the assessment results and the effectiveness of the training programs.

The sample of subjects used for this study were all healthy individuals, but it may be beneficial to examine the results of these training programs in subjects that have balance impairments. More specifically, further studies may determine if the Bodyblade® has any benefit in regards to balance in a sample of subjects that do not already have "normal" balance.

Conclusion

Balance is an important part of daily life that is important for all functional activities (walking, standing, activities of daily living, etc.). Due to its importance in daily living, there is a need to analyze the effects of balance training programs. Many studies have previously found that balance can be improved in various patient populations that have deficits, but few studies have analyzed the effects of exercise or balance training programs in subjects that are healthy. This study has addressed this by analyzing the effect of a five-week balance training program involving healthy subjects. A significant improvement was found in the exercise groups in measures of static steadiness and dynamic stability, but there was also improvement in the control group. This means that factors other than the balance training may have played a part in furthering balance in these subjects. With attention paid to the limitations, this study can be used as a preliminary model that can serve as a vantage point upon which to build future research.
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

DATE: May 13, 1999 PROJECT NUMBER: IRB-9905-242
Ann Burchill, Steve Dingman, Anna
NAME: Josh Woods DEPARTMENT/COLLEGE: Physical Therapy
PROJECT TITLE: The Effects of a Balance Training Program Utilizing the Hymanson Inc.

Bodyblade as Compared to a Traditional Training Program

The above referenced project was reviewed by a designated member for the University’s Institutional Review Board on May 19, 1999 and the following action was taken:

☐ Project approved. EXPEDITED REVIEW NO.

☐ Next scheduled review is on May 2000

☐ Project approved. EXEMPT CATEGORY NO. ___________, No periodic review scheduled unless so stated in the Remarks Section.

☐ 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.

cc: M. 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.

(1/98)
X _EXPEDITED REVIEW REQUESTED UNDER ITEM 3.7 (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

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

PROPOSED SCHOOL/COLLEGE: University of North Dakota _DEPARTMENT: Physical Therapy _PROJECT DATES: 05/17/99 to 7/20/99
PROJECT TITLE: The Effects of a Balance Training Program Utilizing the Hymanson Inc.® Bodyblade as Compared to a Traditional Training Program

FUNDING AGENCIES (IF APPLICABLE):
TYPE OF PROJECT (Check ALL that apply):

_ NEW PROJECT _ CONTINUATION _ RENEWAL _ DISSENTATION OR
_ THESIS RESEARCH _ STUDENT RESEARCH PROJECT
_ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Meridee Danks

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

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

_ MINORS (<18 YEARS) _ PREGNANT WOMEN _ MENTALLY DISABLED _ FETUSES _ MENTALLY RETARDED
_ PRISONERS _ ABORTUSES _ UND STUDENTS (>18 YEARS)

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

IF YOUR PROJECT HAS BEEN/WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME 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 to maintain optimal function in daily activities and is a skill that is frequently affected in individuals who have experienced some type of neurological, vestibular, orthopedic or musculoskeletal injuries/surgeries/alterations. A successful balance training program that can be used to improve such a person’s balance can be of great use and importance to a patient and therapist. Through the performance of this study, two different types of balance training programs will be used, with subjects’ balance being tested before and after the training. This will give information regarding any changes that may occur in their dynamic and/or static balance skills because of their participation in the balance training. The purpose of this study is to determine if a 6 week balance training program consisting of static and dynamic exercises utilizing the Hymanson Inc.® Bodyblade increases static and/or dynamic balance, as assessed by the NeuroCom® Balance Master. There are a variety of balance training tools on the market, but this study proposes that the Hymanson Inc.® Bodyblade will provide a unique training program that can be used to
improve balance, enabling people to perform higher level balance activities required in certain sports & activities. 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.)

**Subjects:** Subjects will consist of approximately 30-45 volunteers from the UND student population which will be recruited by word of mouth. They will be randomly assigned to one of three groups, each consisting of approximately ten to fifteen subjects. Each subject will be within the age range of 20-39 years of age. No volunteers in this age group will be excluded from this study unless there is a safety or health concern. A questionnaire administered before and after participation will be used to determine health information that may influence the subject's balance or ability to participate in the training program. Informed consent for this study will be obtained via a signed consent form (attached) before any testing or training procedures are performed.

**Assessment Procedure:** The NeuroCom® Balance Master is a clinically acceptable machine commonly used in physical therapy to assess balance. It consists of a force platform on which the subject stands. This platform communicates with a software program that interprets various data obtained during a balance assessment. Standardized testing procedures will be followed by the researchers for the following tests:

1) **Unilateral Stance with eyes open and closed** (an indicator of static balance skills)

   This testing procedure requires the subject to stand on one foot at a time, tested first with their eyes open and then again with their eyes closed.

2) **Limits of Stability** (an indicator of dynamic balance skills)

   This test requires the subject to shift their weight and lean in all directions including: forward, backward, sideways, and diagonally. During this the subject will be required to maintain their balance while leaving their feet planted on the force platform. Testing will be done at Altru Health Institute before and after a 6 week balance training program. A brief objective physical assessment of the subjects will also be performed by the researchers prior to the start of the training program.

**Training Procedure:** Subjects will be divided randomly into 3 groups (1 control and 2 experimental). All groups will be assessed on the NeuroCom® Balance Master before and after the training program. The control group will not participate in the 6 week balance training. Experimental group #1 will perform various traditional dynamic and static balance activities. Experimental group #2 will consist of individuals trained by an identical program as group #1 with the addition of the Hymanson Inc.® Bodyblade during all balance activities. Subjects in the experimental groups will attend training sessions conducted by the researchers two times per week for 6 weeks. These training sessions will consist of activities similar to those used during the assessment. These include but are not limited to: 1) standing on a firm surface using one leg at a time, either with eyes open or eyes closed 2) shifting weight and leaning in all directions while maintaining standing balance. Again as stated previously, these activities will be done with or without the addition of the Hymanson Inc.® Bodyblade.

The Hymanson Inc.® Bodyblade is a piece of equipment that is used in physical therapy to increase body awareness, joint mobility, flexibility, and strength. It is a four-foot long by 1.75 inch wide rod composed of graphite weighing 1.5 pounds. It oscillates as it is held in the middle and an oscillatory force is applied by the person using it. The oscillations
of the Hymanson Inc.® Bodyblade require a stabilizing force by the subject, which can be utilized during both static and dynamic activities. This may allow for a unique training program for balance.

Data Analysis and Reporting: Statistical analysis consisting of descriptive and analytical statistics will be used to compile the data. We will be using an alpha level of .05 in determining significance of the results. The individual subjects' results will remain confidential, and the data will be identified by a number known only by the investigators. Data will be reported in a manner that maintains subject confidentiality. To ensure maximum confidentiality, data will be kept in a locked confidential file in the Physical Therapy office. Data will also be kept for three years following the completion of the study, at the end of which the documents will be shredded.

3. BENEFITS: (Describe the benefits to the individual or society.)

The primary aim of this study is to determine if these methods of balance training are effective/efficient. If this is the case, physical therapists may be able to provide a more cost-efficient balance training alternative to their patients. Additionally, the study will determine if balance skills can be improved in normal individuals. If it is found that their balance skills can be improved through training, this will be beneficial to individuals wishing to attain a higher level of performance in sports or activities requiring balance skills.

The individuals participating in the study will benefit from exposure to the research process and the knowledge that they are involved in improving the field of physical therapy and the patients they serve. The subjects will also benefit from exercise and the potential for improved 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.)

Although the NeuroCom® Balance Master is a clinically acceptable machine commonly used in physical therapy to assess balance, there is still a slight risk of falls. Prevention of falls will be prevented by the use of a second person (a spotter) in addition to the researcher performing the assessment. Also, verbal instructions will be given to the subject prior to the balance assessment.

As with any exercise program, there is a risk of some muscle soreness and a potential for injury. In order to combat this risk, each training session will include a brief warm-up and cool-down period, including adequate stretching. Close supervision and proper instruction will also be provided by the researchers during all exercises sessions to ensure safety.

Respect for the individual will be controlled by informing the subjects that all information will be kept confidential, and results will be disclosed using a number known only to the investigators. No names will be used. Subjects' balance will be assessed individually to promote privacy. Subjects will be informed on the consent form prior to beginning participation that they can withdraw from the study at any time.
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 where signed consent forms will be kept and for what period of time.

Informed consent will be obtained through the attached consent form. Each subject will be required to sign the form if they agree with the terms that are presented. Upon agreement they will be included into the study and given a copy of their consent form for future reference.

All consent forms, questionnaires, and data reports will be kept in a locked confidential file located in the Physical Therapy Office (Room 1518) of the UND School of Medicine and Health Sciences. Data and information obtained from the study will be kept for three years following the completion of this study. At the end of this three year period the documents containing this information will be disposed of with the use of a shredder. Please see attached consent form.

**References**


6. For **FULL IRB REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

   Office of Research & Program Development  
   University of North Dakota  
   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 and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

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

Project Director or Student Adviser

Training or Center Grant Director

Date

Date

Date

(Revised 3/1996)
APPENDIX B
Title: The Effect of Balance Training in Healthy Subjects as Assessed by the Neurocom® Balance Master

You are invited to participate in an independent study conducted by students of the UND physical therapy program (Anna Burchill, Steve Dingmann, & Josh Woods) in collaboration with faculty member Meridee Danks. Your participation in this study would be greatly appreciated and it should be noted that it is strictly voluntary.

The purpose of this study is to determine the effectiveness of two training programs in improving balance as measured by the Neurocom® Balance Master. The Neurocom® Balance Master is a clinically acceptable machine commonly used in physical therapy to assess balance. Subjects for this study must be healthy individuals between the ages of 20-39. No volunteers in this age group will be excluded from this study unless there is a safety or health concern. You will be asked to fill out a brief health questionnaire prior to the start of the study in order to protect you from injury & help us interpret our results. We do ask that you wear loose, comfortable clothing & socks if you prefer not to be barefoot as shoes will not be allowed when participating in the study.

Prior to the study, you will be randomly assigned to one of the six-week training program groups or the control group. Groups will consist of approximately 10-15 subjects (30-45 total). At the beginning of the study, you will be asked to report to the Physical Therapy Department at Altru Health Institute Rehabilitation Hospital where a training session & assessment on the Neurocom® Balance Master lasting 20-30 minutes will be performed. Tests will include: 1) standing on one foot at a time, tested both with your eyes open and with your eyes closed. 2) leaning forward, backward, sideways, and diagonally without moving your feet. If you are selected to the control group, you will be assessed on the Neurocom® Balance Master at the beginning of the study & also 6 weeks later without participating in any type of balance program. Those in the balance training groups will meet for 30-45 minutes 2x/week for 6 weeks at the University of North Dakota Physical Therapy Department in order to perform the balance training protocol. You will be asked to perform similar tasks to those used during the testing, these will include but are not limited to: 1) standing on one leg at a time, again with eyes open and eyes closed 2) leaning in all directions while standing on both feet. One group will perform these tasks with the Hymanson Inc® Bodyblade while the other group performs the same tasks without. At the end of the 6 weeks, you will also be re-tested on the Neurocom® Balance Master to determine the effects of the balance program.

Although the process of balance testing & training involves some risk of falling & injury, the researchers of this study feel the risk of injury is minimal. In order to combat this risk of falling, an assistant will be provided to safeguard you from possible loss of balance during the assessment. In addition, all training programs will be supervised by the researchers. As with any new training program, there is also a risk of muscle soreness.
In order to minimize this effect, each training session will include a brief warm-up & cool-down period including adequate stretching. If you should choose to participate in this study you will benefit from exposure to the research process and the knowledge that you are involved in helping to improve the field of physical therapy. You may also benefit from the exercise involved and the potential for improving your balance.

The results of this study will remain confidential & your data will be identified by a number known only by the investigators. These results will be kept in a locked confidential file in the physical therapy department for three years following the completion of the study. After this period of time the results will be destroyed. If you decide to participate, you are free to discontinue participation at any time for any reason. You may stop the experiment at any time if you are experiencing pain, discomfort, fatigue, or any other symptoms that may be detrimental to your health. Your decision not to participate in this study will not affect your future relationship with the University of North Dakota or the Physical Therapy Department. If it is determined that you have health issues that put you at risk for injury, you may be excluded from the study. Again you will not be penalized in any way.

The investigators are available to answer any questions you might have concerning this study now or in the future. Questions may be answered by contacting Steve or Josh at (701) 772-3519 or Anna at (701) 795-4987. A copy of this consent form will be provided to you for future reference. If you would like to contact Meridee she can be reached at (701) 777-3861.

In the event that this research project results in physical injury or medical treatment including first-aid, emergency treatment, or any follow-up care, the investigators along with Altru Hospital & the University of North Dakota are not responsible for any such injury or treatment. The payment for any such treatment must be provided by you & your third party payer, if any.

I have read all the above, all my questions have been answered, & I willingly agree to participate in this study explained to me by Anna Burchill, Steve Dingmann, & Josh Woods.

Participant’s Signature ___________________________ Date ____________

Witness(not Investigator) ___________________________ Date ____________
Health Background Questionnaire

1. Are you currently taking any medications? (ex: allergy medications, cold medications, etc.) Please list all over-the-counter and prescription medications in order for us to determine if these may affect your balance.

2. Do you have any current or past medical diagnoses or injury that could affect balance or your participation in a moderate training program? If so, please list. (include fractures, orthopedic conditions, sprains, etc.)

3. Do you have symptoms of dizziness or lightheadedness?

4. Have you experienced any episodes of two or more unexplained falls within the past 6 months?

5. Do you have normal vision (either with or without glasses)?

6. What is your current exercise level? Please list type of exercise and frequency (# of times per week).
Description of Neurocom® Balance Master Tests and Components

One test, Unilateral Stance, analyzes center of gravity (COG) sway velocity. This is the ratio of the distance traveled by the COG (level of S1-S2) to the time of the trial (10 seconds), expressed in degrees per second. A mean of the COG sway velocity is calculated from data obtained during 3 trials for each of the four conditions: eyes open left, eyes open right, eyes closed left, and eyes closed right.

The other test, limits of stability (LOS), assesses reaction time, movement velocity, endpoint excursion, maximum excursion, and directional control. This test requires the subject to lean in eight directions, one trial each, as far as possible without losing their balance or stepping. The directions include: forward, forward-right, right, right-back, back, back-left, left, and left-forward. Scores from back, back-right, and back-left are combined in a weighted fashion to obtain an overall value for back. For example:

\[
\frac{(.7)(\text{left-back}) + (.7)(\text{right-back}) + (1)(\text{back})}{2.4}
\]

Calculations similar to this are also performed for forward, left, and right for each of the following five components:

1. Reaction Time—the time in seconds between the cue to move and the initiation of movement.
2. Movement Velocity—the average speed of COG movement, expressed in degrees per second, between five percent and 95 percent of the distance to the primary endpoint.
3. Endpoint Excursion—the distance traveled by the COG on a primary attempt to reach the target, expressed in %LOS. The endpoint is considered to be the point at which the initial movement toward the target ceases, and subsequent corrective movements begin.

4. Maximal Excursion—the furthest distance traveled by the COG during the trial.

5. Directional Control—a comparison of the amount of movement in the intended direction (toward the target) to the amount of extraneous movement (away from the target). This is calculated as follows:

\[
\frac{(\text{Amount of intended movement}) - (\text{Amount of extraneous movement})}{\text{Amount of intended movement}}
\]

This value is expressed as a percentage. For example, if a subject’s movement is directly toward the target (a straight line), then the amount of extraneous movement would equal zero, and the perfect directional control score is 100%.
Description of Neurocom® Balance Master Testing Procedures

Unilateral Stance (Static Steadiness)

1. The subject’s feet were positioned on the NBM® forceplates using the recommended foot placement. They were allowed to in toe or out toe their feet to a comfortable position.

2. The subject was instructed in proper procedures for completion of this test. To ensure that consistency was achieved between testers, a script was composed to address all commands given throughout the assessment.

3. Each subject was given a training session in order to practice each of the four conditions tested: eyes open left, eyes closed left, eyes open right, and eyes closed right. This was done secondary to the high learning curve.

4. Once the practice sessions for both unilateral stance and limits of stability were completed, the individuals were notified that further performance of the test would be recorded for analysis by the researchers.

5. At this point, the test was performed in the same fashion as the practice session, except that three trials were completed for each condition.

6. A spotter was provided for subject safety and tallied unsuccessful attempts at completing the trial. If a subject was unable to complete one trial six consecutive times, the researchers determined that this would be recorded as “unable to perform” and proceeded to the next condition.
Limits of Stability (Dynamic Stability)

1. The subject's feet were positioned on the NBM® forceplates using the recommended foot placement. They were allowed to in toe or out toe their feet to a comfortable position, determined by their height.

2. The subject was instructed in proper procedures for completion of this test, including acceptable balance strategies. Again, to ensure that consistency was achieved between testers, a script was composed to address all commands given throughout the assessment. The subject performed the test two times during the practice session in order to increase their familiarity with the testing procedure.

3. As with unilateral stance, the subject was notified that further testing would be used in data analysis by the researchers.

4. The test was performed in a manner consistent with the two practice sessions. During movement for each of the eight directions, a spotter was present to prevent falls, ensuring subject safety. The subject was allowed to repeat that particular trial/direction if they lost their balance and took a step.
Neurocom® Balance Master Testing Script

- Make sure to position screen directly in front of the subject during practice and testing
- Take off shoes

Unilateral Stance

1. Line up subject’s medial malleolus with wide blue line, and the lateral calcaneous with the T-line.
2. Instructions (At least one practice for each test, then actual testing when subject has demonstrated comfort with procedures)
   - put your hands on your hips
   - stand on your ___ leg
   - don’t allow legs to touch, and the nonstance foot should not touch the ground
   - “Look straight ahead and stand as steady as possible until the testing is completed, which will be 10 seconds.”
   - “Make sure to avoid any movements of your arms or nonstance leg that are not necessary to maintain balance”
   - EO: Say “go” when you feel that you are as steady as possible
   - EC: “When you feel that you are as steady as possible close your eyes and say “go” when you are ready to begin testing”
3. During eyes closed: notify subject when they have reached halfway point
4. Have spotter tally failed attempts if applicable, and note in comments section

Limits of Stability

1. Line up subjects medial malleolus with the wide blue line, and the lateral calcaneous with the appropriate line (determined by computer: T, M, S)
2. Pre-test instructions (Give subject brief training in movement of cursor through weight shift demonstrating acceptable strategies; then run through at least two practice sessions)
   - Begin by centering entire cursor in middle target (box) and hold it there
   - Point out that the yellow box will be the target for that particular test
   - Explain that a blue circle will appear in this targeted box
   - “Once this circle appears you should move the cursor to the box with the circle as quickly and accurately as possible, moving the cursor in a straight path (point out on screen). Try to get as close to the circle as possible without taking a step or losing your balance. A portion of both feet should stay in contact with the ground at all times during the testing, however make sure to maintain positioning of the ankle and heel. Once you get to the circle try to stay as still as possible until the circle disappears.”
   - “You will follow these instructions for all the boxes”
   - When subject is ready begin practice/test
3. Test instructions
   - “Move to the center and hold it”
   - “Remember to move as straight and as quickly as possible” (repeat for every test)
   - Point out at first click of mouse: “get ready for the circle”; Run through the tests (8 total)
REFERENCES


23. Dingmann SM. The Effects of Balance Training in Normal Young Adults as Assessed by the Neurocomm® Balance Master [master's independent study]. Grand Forks, ND: University of North Dakota; 1999.

