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The Effects of Hypermobility on Static and Dynamic Balance in Physical Therapy and Occupational Therapy Students

Laura Elbert  
*University of North Dakota*

Teresa Tostenrud  
*University of North Dakota*

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THE EFFECTS OF HYPERMOBILITY ON STATIC AND DYNAMIC BALANCE IN PHYSICAL THERAPY AND OCCUPATIONAL THERAPY STUDENTS

by

Laura Elbert
Bachelor of Science in Physical Therapy
Bachelor of Science in Honors
University of North Dakota, 2003

Teresa Tostenrud
Bachelor of Science in Physical Therapy
University of North Dakota, 2003

A Scholarly Project
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Doctor of Physical Therapy

Grand Forks, North Dakota
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This Scholarly Project, submitted by Laura Elbert and Teresa Tostenrud in partial fulfillment of the requirements for the degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Chairperson, Physical Therapy)
PERMISSION

Title The Effects of Hypermobility on Static and Dynamic Balance in Physical Therapy and Occupational Therapy Students

Department Physical Therapy

Degree Doctor of Physical Therapy

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Signatures

Date 12-18-2004
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Laura Elbert
ABSTRACT

A significant percentage of Physical Therapy and Occupational Therapy students have been found to exhibit signs of systemic hypermobility. Hypermobility can be defined as joints displaying excessive range of movement. Balance is an integral aspect of the job tasks of Physical Therapists and Occupational Therapists and involves collaboration of muscles, joints, ligaments, and the proprioceptive input they collectively provide. The purpose of this study is to assess the effects of hypermobility on static and dynamic balance in a population of Physical Therapy and Occupational Therapy students at the University of North Dakota.

Seventy nine physical therapy and occupational therapy students (60 females and 19 males) between the ages of 20-28 years voluntarily participated in the hypermobility screening portion of this study. All subjects were screened for hypermobility using the Beighton Scale for hypermobility. Twenty subjects were found to be hypermobile and were asked to further participate in a balance test on the NeuroCom® Balance Master(NBM), of these 20, 19 were able to participate. Twelve subjects who were not found to exhibit hypermobility were randomly assigned to a control group and also performed tests on the NBM. Tests on the NBM included modified Clinical Test for Sensory Interaction on Balance (mCTSIB) and Limits of Stability (LOS) test which tested static and dynamic balance respectively.
The independent samples t-test was completed to determine the mean difference between the control group and the group of subjects with signs of hypermobility. Statistical significance was set at \( \alpha = .05 \) level.

Independent Samples t-test was used to analyze the results of the NBM tests. No significant difference was found between subjects in the control group (\( M=1.11, SD=0.36 \)) and in the group displaying hypermobility (\( M=1.20, SD=0.26 \)) for the mCTSIB foam eyes closed score, \( t(29)=-0.823, p=0.42 \). No significant difference was found between subjects in the control group (\( M=0.44, SD=0.10 \)) and in the group displaying hypermobility (\( M=0.51, SD=0.09 \)) for the mCTSIB composite score, \( t(29)=-1.95, p=0.06 \). No significant difference was found between subjects in the control group (\( M=81.25, SD=7.90 \)) and in the group displaying hypermobility (\( M=79.95, SD=6.51 \)) for the LOS end point excursion composite score, \( t(29)=0.50, p=0.62 \). No significant difference was found between subjects in the control group (\( M=91.75, SD=6.62 \)) and subjects in the group displaying hypermobility (\( M=92.0, SD=3.59 \)) for the LOS maximum excursion composite score, \( t(29)=-0.12, p=0.91 \). No significant difference was found between subjects in the control group (\( M=80.08, SD=3.60 \)) and subjects in the group displaying hypermobility (\( M=79.05, SD=5.14 \)) for the LOS directional control composite score, \( t(29)=0.61, p=0.55 \). A significant difference was found between subjects with hypermobility of the upper extremities (\( M=0.98, SD=0.19 \)) and in subjects with upper extremity, lower extremity, and trunk (\( M=1.26, SD=0.25 \)) for the mCTSIB foam eyes closed score, \( t(17)=-2.09, p=0.05 \). A Mann Whitney U-test was used to determine if a mean difference existed between subjects with hypermobility in the upper extremities only (\( n=4 \)) and subjects with hypermobility in the upper extremities, trunk,
and lower extremities (n=15). The results indicate no significant difference between groups for LOS directional control composite score, $U=29$, $p=0.92$ with the sum of ranks equal to 39.00 for the upper extremity group and 151.00 for the trunk, upper extremity, and lower extremity group. A significant difference was found between groups for mCTSIB composite score, $U=9.00$, $p=0.03$ with the sum of ranks equal to 19 for the upper extremity group and 171 for the trunk, upper extremity, and lower extremity group.

Hypermobility does not appear to have an effect on static or dynamic balance in this population of Physical Therapy and Occupational Therapy students. More research is needed to assess the functional impacts of hypermobility on balance.
CHAPTER I
INTRODUCTION

Hypermobility is a clinical sign that affects a variety of people. Previous research has found that 22% of a population of Physical Therapy students exhibited signs of systemic hypermobility.\(^1\) Hypermobility is defined as joints displaying a range of movement that is considered excessive, taking into consideration the age, gender, and ethnic background of the individual.\(^2\) The job duties of Physical and Occupational Therapists can require challenging postures that, in the absence of proper body awareness and the application of proper body mechanics, can put the therapist at risk for work-related injuries. Application of proper body mechanics requires a collaboration of the muscles, joints, and ligaments associated with posture. This collaboration is highly associated with body awareness, known as proprioception. Both conscious and unconscious proprioception are considered to be important for efficient and safe joint movement and stability.\(^2\) Research has demonstrated proprioception, ankle, hip, and stepping strategies were all essential components of balance. The presence of systemic hypermobility was associated with a change toward the ankle strategy.\(^3\) The ankle strategy is one of the many components that is utilized to maintain static and dynamic balance.
Problem Statement

There has been little research that studies the effects of hypermobility on balance in Physical Therapy and Occupational Therapy students.

Purpose of study

To determine the effects of hypermobility on balance in Physical Therapy and Occupational Therapy students at the University of North Dakota.

Significance of Study

Preliminary research has shown that there is a higher prevalence of hypermobility among physical therapy and occupational therapy students.¹ Both professions require balance as an essential component of the job specific skills. An example of a balance-intensive job duty is transferring and handling of a patient. Loss of balance is dangerous for the patient as well as the therapist. Loss of balance can be attributed to many factors, including decreased joint proprioception. Proprioception at the ankle, known as the ankle strategy, can be altered in individuals with hypermobility. According to a study by Hestekin,¹ twenty-one percent of physical therapy students exhibit systemic hypermobility. It is important for therapists to be aware of their hypermobility and its effect on strategies used to maintain balance and incorporate strategies to compensate for this deficit while performing work-related activities.

Research Questions

1) Do Physical Therapy and Occupational Therapy students who display systemic hypermobility demonstrate a significant difference in static and dynamic balance in comparison to Physical Therapy and Occupational Therapy without systemic hypermobility?
2) Is there a significant difference in static and dynamic balance between hypermobility in only the upper extremity verses hypermobility in both upper and lower extremities?

Hypotheses

The null hypothesis states: there is no significant difference in static and dynamic balance between students who are hypermobile and students who are not hypermobile.

The alternate hypothesis states: there is a significant difference in static and dynamic balance between students who are hypermobile and students who are not hypermobile.
CHAPTER II
LITERATURE REVIEW

Previous research has shown that Physical Therapy students exhibit signs of hypermobility more frequently than the normal population.\textsuperscript{1} Research has demonstrated that hypermobility may have an effect on proprioception during balance.\textsuperscript{3} The professions of Physical Therapy and Occupational Therapy require static and dynamic balance as essential components of job specific skills. These skills often require challenging postures that, in the absence of proper awareness of body mechanics, can put the therapist at risk for work related injury. Application of proper body mechanics requires a collaboration of muscles, joints, and ligaments associated with posture which is highly associated with proprioception. The body has many ways of consciously and unconsciously controlling movement at the joints during balance. These mechanisms are known as the ankle, hip, and stepping strategies. Previous research has shown that the presence of systemic hypermobility is associated with a change in the ankle strategy during balance.\textsuperscript{3} It is important for therapists to be aware of their hypermobility and to incorporate strategies to compensate for this deficit while performing work related activities.

Hypermobility

Hypermobility is commonly known to the general public as being “double jointed.” However, according to Kirk\textsuperscript{4}, hypermobility syndrome is defined as unduly lax joints where the range of motion exceeds normal limits in ‘otherwise healthy individuals’
in the absence of other rheumatic or connective tissue disorders. According to Russek\textsuperscript{5}, hypermobility syndrome is a dominant inherited connective tissue disorder described as generalized articular hypermobility with or without subluxation or dislocation. Hypermobility can also be acquired in certain joints by training the joints to move beyond normal end range in order to accomplish daily tasks, such as the work demands of ballet dancers, gymnasts, or baseball pitchers.\textsuperscript{2}

Prevalence

Russek\textsuperscript{6} reports that hypermobility syndrome is prevalent in 0.6-31.5\% of adults. It is 1.1 to 5.5 times more prevalent in females than males. Women who are hypermobile tend have a greater number of joints affected compared to men who are hypermobile.\textsuperscript{5} Hypermobility is more prevalent among Asians than Africans, and more prevalent among Africans than Caucasians.\textsuperscript{6,8,9,10} Hypermobility appears to decrease with age, however, in women joint laxity may persist into the fifth decade whereas hypermobility in men declines in the early twenties.\textsuperscript{7} Women may display signs and experience symptoms of hypermobility during the childbearing years because the presence of the hormone relaxin. Relaxin has been implicated in systemic joint hypermobility, particularly in synovial joints.\textsuperscript{11} Decoster et al\textsuperscript{12} reported that there is a 12\% prevalence rate of hypermobility in adolescents. The rate of occurrence of hypermobility among children is greater in Chinese than Caucasian.\textsuperscript{13}

Diagnostic Criteria

In order to determine if an individual has systemic mobility, there are many assessment tools to help diagnose hypermobility syndrome such as clinical goniometers, the hyperextensometer, and clinical scoring systems.\textsuperscript{14} The global index measurement is a
goniometric measurement of range of motion at most joints in the body. This method is comprehensive but very time consuming and not appropriate when assessing large populations. The hyperextensometer, a spring device, is used to measure extension of the second or fifth metacarpophalangeal joint to a pre-set torque.

A clinical scoring scale for hypermobility syndrome was proposed by Carter and Wilkinson. This scale gave criteria for hypermobility syndrome as a score of 3 out of 5 or higher on a 5-point scale of unilateral tests as described in Table 1. These criteria were modified by Beighton et al and the modified scale has remained the most commonly used diagnostic criteria for hypermobility today. In the Beighton scale, subjects are given a numerical score of zero to 9, 1 point being allocated for the ability to perform each of the tests outlined in Table 1. Other assessment tools for measuring hypermobility exist but are less commonly used, such as Rotés’ eleven point scale and Diaz’s 5 point scale, which tests only non-dominant side joints outlined in the Beighton Scale. Rotés’ scoring system integrates 6 additional joint measurement criteria in addition to Beighton’s 9 scoring criteria, rendering it less clinically efficient. In a study by Bulbena et al, hypermobility scales proposed by Carter and Wilkinson, Beighton et al, and Rotés were compared to determine which criteria most clearly distinguished individuals with hypermobility syndrome from individuals without hypermobility syndrome. The authors suggest a different cut-off point for women (a 4 or 5 out of 9) than for men (a 3 or 4 out of 9) due to the fact that women tended to have a higher frequency of positive signs of laxity and in order to avoid false positives in women.
Table 1. Hypermobility Criteria of Carter and Wilkinson's\textsuperscript{16}, Beighton et al\textsuperscript{9}, and Rotés\textsuperscript{17}.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Carter and Wilkinson</th>
<th>Beighton, et al</th>
<th>Rotés</th>
</tr>
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<tbody>
<tr>
<td>Thumb abduction</td>
<td>1</td>
<td>1*</td>
<td>1</td>
</tr>
<tr>
<td>Elbow extension &gt; $10^\circ$</td>
<td>1</td>
<td>1*</td>
<td>1</td>
</tr>
<tr>
<td>Finger extension &gt; $90^\circ$</td>
<td>1</td>
<td>1*</td>
<td>1</td>
</tr>
<tr>
<td>metacarpophalangeal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee extension &gt; $10^\circ$</td>
<td>1</td>
<td>1*</td>
<td>1</td>
</tr>
<tr>
<td>Ankle dorsiflexion and foot eversion</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palms flat on the floor</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>External shoulder rotation</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Cervical rotations</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Cervical inflexions</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Hips abduction</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Metatarsophalangeal &gt; $90^\circ$</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Lumbar lateral hypermobility</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total Score</td>
<td>5</td>
<td>9</td>
<td>11</td>
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* Tested bilaterally, one point given for each positive side.

Past research has demonstrated little agreement on scoring for the cut-off point to determine hypermobility. Normally cut-off points have been up to the researcher’s discretion.\textsuperscript{14} Currently, the Beighton method has a standard cut-off point of 4 out of 9.\textsuperscript{10} This method is not sensitive to populations that have a higher prevalence of hypermobility. Cheng\textsuperscript{13} has suggested formulating a positive score of at least 2 standard deviations above the mean of the population under study.

With use of any clinical test, it is important to consider the validity of the measure. In Bulbena et al\textsuperscript{14}, it was found that both correlation coefficients and predictive efficiencies between Carter and Wilkinson scale and Beighton scale and Rotés’ scale were uniformly high, suggesting high concurrent and predictive validity. The Beighton test is the most widely used by researchers in past literature and will be used in this study.
Clinical Presentation of Hypermobility Syndrome

The onset and presentation of problems associated with hypermobility is variable. According to Russek, the onset of symptoms may occur at any age from 3 to 70 years. In a study by Al-Rawi, Al-Aszawi, and Al-Chalabi a population of Iraqi university students who scored 7 out of 9 on the Beighton scale had significantly more frequent joint complaints, ligamentous sprains, flat feet, Raynaud’s phenomenon, easy bruising, high palate and varicose veins as compared to students who scored a 3 or less out of 9 on the Beighton scale. El-Shahaly and El-Sherif state that there is a significant occurrence of mitral valve prolapse among patients with hypermobility syndrome. Hypermobility has also been implicated in the pathogenesis of motor delay in infancy, rectal prolapse, juvenile episodic arthritis, osteoarthritis, and chondrocalcinosis. It has also been suggested that the presence of hypermobility in an individual can lead to traumatic synovitis and later to osteoarthritis in the forth or fifth decades. Chondrocalcinosis appears around the sixth decade and the final stage in the progression almost resembles a Charcot joint with gross deforming osteoarthritis, chondrocalcinosis, and a tough calcified synovium. Joint hypermobility is also associated with genital prolapse and this relationship may indicate that hypermobility may be a clinical marker for patients at risk for developing genital prolapse.

Joint hypermobility syndrome has also been associated with panic disorders. In a study by Martín-Santos, joint hypermobility was found in 67.7% of patients with anxiety disorders but in only 10.1% of psychiatric and 12.5% of medical control subjects, thus patients with anxiety disorder were over 16 times more likely than control subjects to have joint laxity.
Pathophysiology

The pathophysiology of hypermobility syndrome is not yet fully understood. It appears that the disorder is a systemic collagen abnormality in which the ratio of Type I to Type III collagen is decreased in skin.\textsuperscript{23} This abnormality of collagen ratios seen in the skin is found to be associated with joint hypermobility and laxity in other tissues. Criteria for diagnosing hypermobility syndrome typically assess joint abnormalities, however, hypermobility syndrome may affect cardiac tissue and smooth muscle in the gastrointestinal system and in the female genital system.\textsuperscript{21,24} Joint position sense (proprioception) may also be adversely affected with the presence of hypermobility.\textsuperscript{25,26,27}

Type I collagen is the most prevalent collagen in the human body and is most abundant in tissues such as tendon, ligament, joint capsule, skin, demineralized bone, and nerve receptors.\textsuperscript{28} Type III collagen is also present in the same tissues as Type I collagen, but in a smaller proportion and predominantly found in more extensible connective tissue structures such as the lungs, skin, and vascular system.\textsuperscript{18}

Structures or connective tissue within the neurological system may also be affected in an individual with hypermobility. In hypermobility syndrome, there is a higher incidence of acroparaesthesia (abnormal sensation in the hands and feet), decreased joint proprioception and joint spatial awareness at end-range of movement of the joints.\textsuperscript{21,25} The intrinsic feedback derived from sensation, proprioception, and joint spatial awareness are all essential components that help maintain balance.
Balance

Balance is a crucial element for optimal function of the body's motor system in order to perform activities of daily living. Balance is controlled by three systems: visual, vestibular, and somatosensory. Vision measures the eyes in relation to surrounding objects. Somatosensory provides information regarding the support surface. The vestibular system is an internal inertial gravitational reference that determines the orientation of the head in space. At any time, one or more of these systems are being used to maintain orientation and balance. Under most conditions, somatosensory and vision dominate the control of balance as they are more sensitive than the vestibular system to subtle movements in the center of gravity. These two systems, visual and somatosensory, are also most likely to report erroneous information to the brain but are checked by the vestibular system. A discrepancy in one or more of these systems can lead to dysfunctional balance. The three systems work together with the central nervous system to achieve the overall goals of balance: safety and function.

One of the key components of balance is postural control, which is the ability to maintain the body's center of gravity over the base of support, defined as the area between the feet, during quiet standing (static), and during movement (dynamic). Static balance, also known as steadiness, is the ability to maintain a certain posture with a minimal amount of sway on a stable surface. Dynamic balance is the ability to move to the center of gravity around the base of support without loss of balance. In order to maintain static and dynamic balance, the limbs must be properly positioned to help
support the body. Limb position is maintained by a well-known sensory phenomena known as proprioception.\textsuperscript{35}

According to Hall et al,\textsuperscript{35} proprioceptive information is thought to be used within the central nervous system to ensure that the limbs are correctly positioned and have suitable muscle tone, especially during load bearing. Furthermore, it has been shown that the receptors responsible for proprioception are located in the muscles, tendons, joint capsule, and ligaments that stabilize the joint. Deficiencies in the proprioceptive sense may lead to biomechanically unsound limb positions being adopted resulting in hyperflexion and/or hyperextension of the joint. Unsound limb positions can have an effect on one’s ability to maintain dynamic balance and stay within their limits of stability.

Limits of Stability

The limits of stability can be defined as the furthest distance a person can displace their center of gravity beyond their base of support without stepping, stumbling, or falling.\textsuperscript{32} Combined, anterior-posterior limits of stability are approximately 12 degrees. Anterior-posterior stability can be influenced by height and foot length. Lateral limits of stability are dependent on the spacing of the feet and height and are approximately 16 degrees from side-to-side when 4 inches are between both feet. When a person attempts to maintain quiet (static) standing, they will cycle back and forth and from side to side within the limits of stability. This is commonly referred to as postural sway.

Muscle contractions of the lower extremities assist in maintaining upright stance. The contractions of these muscles result in small movements around a vertical axis which contributes to postural sway. Postural sway is an indicator of the integrity of the
equilibrium system. Postural sway appears to increase with age, as well as with the presence of hypermobility.³

**Balance Strategies**

In order to reach their limits of stability, a person must displace his or her own center of gravity. As this occurs, specific automatic postural synergies are used to maintain balance.³⁻⁵ Muscle contractions of the legs and trunk work to activate postural synergies. These contractions can be categorized as strategies including the ankle, hip, and stepping strategies. When there is a small disturbance within the limits of stability, the ankle strategy is the first utilized to maintain upright balance. During this strategy, the body is shifted anterior and posterior around the ankles as a rigid unit. Activation of muscles occurs distally to proximally. The most effective use of this strategy is with small perturbations on a firm surface.

Larger disturbances of balance activate the hip strategy.³⁻⁵ During this strategy, the center of gravity is shifted by flexing and extending the hips using a proximal to distal muscle recruitment pattern. With the hip strategy, the body’s center of gravity is moved more quickly as compared to the ankle strategy, rendering it more effective on a variety of surfaces and with larger disturbances in balance.

The stepping strategy allows the body to respond to large postural perturbations by using rapid steps to maintain balance.³⁻⁵ The stepping strategy is utilized when the limits of stability are exceeded and the ankle and hip strategies are insufficient to maintain the center of gravity over the base of support. All of these strategies are normally used in combination to respond to conditions that jeopardize balance.
Balance Assessment Tools

There are several tests used clinically to assess static and dynamic balance. For static balance testing, the commonly used tests include the Rhomberg Balance Test and the One-Legged Stance Test. Dynamic balance can be assessed using Berg Balance Measure, the Tinetti Assessment Tool, Functional Reach, and Timed Up and Go.30

Another useful assessment tool is the NeuroCom® Balance Master 8.02 (NBM). The NBM is a clinical measurement tool that is used to assess balance and its associated disorders. The NBM is comprised of a computerized force plate system that provides objective feedback on balance performance. There are many tests that can be performed to assess balance on the NBM including limits of stability (LOS) and the modified Clinical Test for the Sensory Interaction on Balance (mCTSIB). The use of force plates, such as those used with the NBM have demonstrated reliability in a study by Goldie, Bach and Evans.36 The NBM was tested on a group of 28 healthy subjects using four different stance positions including two-legged, step, tandem, and one legged. This repeated measures design correlated scores using the NBM to a horizontal pressure measurement method. Approximately 40% of the correlations were non-significant (p>.05). Additionally, it was found that force measurements were more sensitive than center of pressure measurements (COP) in discriminating the changes in steadiness, which resulted in alterations to the base of support in the four stance positions. Liston and Brouwer29 used the NBM and determined that test-retest reliability is greater for complex tests of balance and that dynamic tests (i.e. LOS) rather than static tests (i.e. mCTSIB) are valid indicators of functional balance performance. Computerized balance

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measurements are preferred over standard clinical measures primarily because they allow quick, reliable, and objective balance measurement and feedback.29,37,38

NeuroCom ® Balance Master Limits of Stability Test

The Limits of Stability test measures maximum weight shifting to 8 different targets in a combination of anterior, posterior, and lateral directions. These targets are displayed on a computer screen as visual feedback to subjects. During weight shifting in each direction, the LOS test measures many different variables such as endpoint excursion, maximum excursion, and directional control. Endpoint excursion is the distance traveled by the center of gravity on the primary attempt to reach the target, expressed in percent of LOS. The end point is the point at which the initial movement toward the target ceases, and subsequent corrective movements begin. Maximum excursion is the furthest distance traveled by the center of gravity during the trial. This value may be larger than the end point excursion value if the subject makes additional corrective attempts to reach the target after the primary attempt has fallen short. If a subject can reach the target on the initial attempt, it indicates that the subject knows where in space to go and knows how to get there. Directional control is a comparison of the amount of movement in the intended direction to the amount of extraneous movement away from the target. Directional control can be calculated as follows:

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

If a subject moves directly toward the target, the amount of extraneous movement would equal zero and the perfect directional control score is 100%. Because the subject is instructed to go directly to the target, a straight-line path to the target is desirable and is
represented by a high directional control score. High directional control scores (close to 100%) are good, lower scores are worse and reflect the subject’s coordination.

The LOS test has demonstrated high test-retest reliability in 12 normal subjects in a study by Hagemen et al. Interclass coefficients revealed high test-retest reliability for measures of sway (ICCs > .90). LOS measures of movement time and path sway were moderately reliable (ICCs = 0.78 & .83), respectively. Rose et al. found reliability was good to excellent in 176 normal adults tested twice on separate days. Test-retest reliability was good to excellent (r values between 0.73 and 0.80) for all variables.

NeuroCom Balance Master modified Clinical Test for the Sensory Interaction on Balance

The analysis of the mCTSIB is completed using degrees per second to determine the mean center of gravity sway velocity on firm and foam surfaces with eyes closed and eyes open during static standing for 10 seconds. These scores are used to determine a composite score for all surfaces. Røgind, Lykkegaard, Bliddal, and Danneskiold-Samsøe’s used the Sensory Organization Test (SOT) to determine the amount of postural sway in normal subjects aged 20 to 70 years. The mCTSIB is modeled after the SOT and was developed by Nashner and Black. The mCTSIB provides quantitative measures of center of gravity sway referenced to an age-matched normative database. Cohen et al. examined the test-retest reliability of the mCTSIB in a group of 84 subjects, which included normal young adults, elderly adults, and adults diagnosed with vestibular disorders. These authors reported high retest and interrater reliability. In another study by Scheib and Chen, highly reliable measures were produced in 47 postural stability sessions conducted over 14 months. Rose et al. found that reliability was good in 176
normal adults tested twice on separate days. Subjects were between 20 and 80 years of age. The one exception was the easiest “firm surface-eyes open” condition, which demonstrated poor reliability when analyzed separately.

Consequences of Generalized Joint Hypomobility on Balance

Children with hypermobility often present with clumsiness and poor balance, especially at end range of movements.\(^{(2, p. 40)}\) These presentations can be attributed to reduced proprioception in joints. Deficiencies in proprioception arising from the ligaments and capsule in the joints of hypermobile individuals, may be counteracted by increased usage of proprioception derived from muscles and tendons.\(^{26}\) Barrack et al\(^{43}\) tested various knee positions in ballet dancers with hypermobility and a non-athletic control group in relation to the ability to correctly recognize one’s position in space, known as proprioception threshold. They found significantly better threshold acuity in the ballet dancers than in a control group of non-athletic hypermobile individuals. This occurs as a result of the large degree of athletic training undertaken by ballet dancers to improve postural stability while maintaining joint mobility.

Postural synergies, such as the hip and ankle strategy, can also be affected by hypermobility. According to Beckman and Buchanan\(^{44}\), there is a decreased latency of hip muscle activation after ankle inversion in the hypermobile population. This decreased muscle latency, when left untreated, can lead to articular degenerative changes, altered joint reaction forces, and muscle imbalances. The authors of this study suggest that clinicians should address altered hip muscle recruitment patterns or accept the recruitment pattern as an adaptation to ankle instability thereby accepting the long-term
consequences of joint damage due to inadequate muscle recruitment during tasks requiring the use of postural synergies.

In a study by Røgind, Lykkegaard, Bliddal, and Danneskiold-Samsøe\(^3\), postural sway was assessed on a random sample of 133 subjects. The presence of articular hypermobility was assessed using the Beighton scale. The Balance Master Pro was used to assess static and dynamic postural sway. The ankle stability was affected by gender, body weight, alcohol consumption, and articular hypermobility using a 95% prediction interval. Subjects determined to be hypermobile seemed to make greater use of movements in the joints near the force platform than subjects without hypermobility. Further research needs to be conducted in order to determine the effects of hypermobility on static and dynamic balance. This study has been designed to address the issue of hypermobility and its effect on balance in Physical and Occupational Therapy students.
CHAPTER III

METHODOLOGY

Seventy nine subjects were voluntarily recruited to participate in this Institutional Review Board (IRB) approved study (IRB #200404-320, Appendix A). Individuals interested in participating were asked to read and sign an informed consent form. (Appendix B) After informed consent was obtained, the subject was asked to fill out a health background questionnaire prior to inclusion in the study. This questionnaire was utilized to determine if the subject has any pathology that may have affected balance. (Appendix C)

Subjects

Male and female Physical Therapy and Occupational Therapy students between 20-30 years of age enrolled at the University of North Dakota were recruited through verbal requests and flyers. Selection criteria included the following for all participants:

1. No current or past medical diagnosis or history affecting balance
2. Currently taking no medications effecting the central nervous system or medications known to effect balance or coordination
3. No symptoms of dizziness or lightheadedness
4. No symptoms suggestive of vestibular or neurologic disorders
5. No psychological disorders including depression
6. No history of two or more unexplained falls in the past 6 months
7. Normal vision with or without glasses or corrective lenses in order to read
directions on a computer screen
8. No injuries or surgeries that may have an effect on balance
9. No self-reported pregnancy

Seventy nine students met the above criteria and were selected to participate in a
hypermobility screening using the Beighton Hypermobility Test.

**Beighton Hypermobility Test**

Measurement of joint range of motion were assessed using a universal
goniometer. The actions associated with the Beighton Scale and their subsequent
positive criteria are as follows:

1. Bilateral passive extension of the fifth digits beyond 90 degrees, measured with a
   universal goniometer.
2. Bilateral passive apposition of the thumbs to the flexor aspect of the forearm.
3. Bilateral hyperextension of the elbows beyond 10 degrees, measured with a
   universal goniometer.
4. Bilateral hyperextension of the knees beyond 10 degrees, measured with a
   universal goniometer.
5. Forward flexion of the trunk with the knees straight so that the palms of the hands
   rest easily on the floor.

Photographs of positive testing maneuvers can be found in Appendix D. Scores for each
subject were recorded on a data collection form. (Appendix E) Subjects with scores of at
least 4 out of a possible 9 were categorized as hypermobile and proceeded to the second
portion of the study, which assessed static and dynamic balance. A group of 12 randomly
selected individuals from the Physical and Occupational Therapy students who had a
Beighton score of less than 4 out of 9 were selected as a control group.

Instrumentation

The NeuroCom ® Balance Master 8.02 was used to assess balance. Dynamic
balance was assessed using the Limits of Stability test (LOS). The modified Clinical Test
for the Sensory Interaction on Balance (mCTSIB) was used to assess static balance. A
picture of the NBM can be found in Appendix F. The NBM provided objective feedback
in the form of computerized printouts depicted as numerical charts, graphs, and picture
representations of the center of gravity movement.(Appendix G) In order to maintain
consistency of results, the NBM was calibrated between subjects.

Assessment Procedure

Subjects were instructed to report to the second floor of the UND Physical
Therapy Department during their pre-arranged assessment time. Consent was obtained
from subjects who displayed hypermobility to photograph static standing with their eyes
closed during the mCTSIB test.(Appendix H) Randomization was established by
instructing each subject to draw a number (1 or 2) to determine if LOS test or mCTSIB
test would be performed first. Subjects’ randomly assigned identification number, date of
birth, and height were entered in the file on the computer database. The date of birth is
necessary to determine the appropriate age group used during data analysis. The
subject’s height is used to determine the proper foot placement on the force plate during
testing. All subjects were asked to remove their shoes and socks and were tested on the
NBM barefoot. Subject’s feet were aligned according to the instructions given on the
NBM computer screen based on the subject's height. Proper foot placement involved alignment of the medial malleolus with the wide blue line on the forceplate and the lateral calcaneous on the “M” or “T” line. (Appendix I)

Limits of Stability Test

Prior to administration of the LOS test, a warm up session and practice trial session were allowed for up to 5 minutes or until the subject felt comfortable moving the “man figure” on the screen. The warm up session consisted of weight shifting to 100% (maximum) of LOS, which was indicated by “man figure” on computer screen. The subject was instructed to lean in all eight directions. (Figure 1)

![Figure 1. Eight directions of Limits of Stability](image)

During administration of the LOS test, a complete set of verbal instructions was read to each subject prior to testing. (Appendix J) The subject was instructed that they would to lean in all eight directions as pictured in Figure 1, starting with the box labeled ‘1’ and ending with the box labeled ‘8’ at the direction of the tester. The subject was then instructed to reach each target as quickly and as accurately as possible as soon as the green “go” indicator appeared on the bottom of the screen. Each testing position had to
be held until the cursor disappeared, followed by movement back to the center of the screen. Subjects were allowed to lift their toes, bend at the knees and hips, and use their arms for balance, as long as their feet maintained contact with the force plate. Contact is defined as the balls of the feet and heels remaining in contact with the force plate at all times during testing. If contact was not maintained testing was repeated for that direction.

Modified Clinical Test for the Sensory Interaction on Balance

During the mCTSIB test, subjects were instructed to stand without moving or talking for 10 seconds in each of the following positions: firm surface with eyes open, firm surface with eyes closed, foam surface with eyes open, and foam surface with eyes closed. Verbal instructions were given to each subject and they were told to “go” at the start and to “stop” at the end, as the tester read and followed the onscreen instructions. A copy of the verbal instructions can be found in Appendix J. Subjects were assisted in proper foot placement based on their height both on the firm surface and on the foam square. Each testing condition was repeated 3 times and an average of the results was reported by the NBM computer data sheet. The subject was allowed to gain their balance on the foam square prior to administration of testing procedure. A spotter was present and the use of a gait belt was offered to each subject during the foam tests. When using the foam surface, a foam square was placed on the force plate so that the markings on the foam were immediately over the identical markings on the force plate. Trials were repeated if the subject did not maintain contact with the force plate or foam square or if the subject attempted to regain balance through contact with external support structures.
Reliability Study

A reliability study was performed with 10 different subjects age 18-55 using the universal goniometer to measure elbow extension. Subjects were measured on three separate occasions on 3 different days, 2 days apart by one of the researchers. The SPSS Version 11.5 (SPSS, Inc., Chicago, IL) was used to calculate intrarater reliability for all tests.45

A separate reliability study on the NBM was performed by a separate researcher in order to establish intrarater reliability. Seventeen subjects from the general population, aged 18-60 years, were assessed using the LOS test and mCTSIB test in the same manner as described in the assessment procedure. Subjects were tested 3 times on 3 separate days, 1 to 3 days apart. The NBM procedure manual was followed and both researchers were present during the assessment of the subjects, with assessments done by the same researcher throughout the study.

Intrarater Reliability

An intraclass correlation coefficient (ICC) was calculated from a repeated measure analysis of variance (ANOVA) in order to assess test-retest reliability for each rater using both the NBM and the universal goniometer. Intrarater reliability results for the universal goniometer are reported in Table 2, and intrarater reliability results for the mCTSIB test and LOS test are reported in Table 3 and 4 respectively.

Table 2. Goniometric Measurement of Elbow Extension Intrarater Reliability Using ICC and r values.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ICC Value</th>
<th>r-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow extension</td>
<td>.95</td>
<td>.95</td>
</tr>
</tbody>
</table>
Table 3. mCTSIB Test Intrarater Reliability Using ICC.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ICC Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foam Eyes Closed</td>
<td>.83</td>
</tr>
<tr>
<td>Composite</td>
<td>.84</td>
</tr>
</tbody>
</table>

Table 4. LOS Test Intrarater Reliability Using ICC.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ICC Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endpoint Excursion Composite</td>
<td>.80</td>
</tr>
<tr>
<td>Maximum Excursion Composite</td>
<td>.75</td>
</tr>
<tr>
<td>Directional Control Composite</td>
<td>.81</td>
</tr>
</tbody>
</table>

ICC and r-value Interpretation

When interpreting analysis of the ICC, it is important to remember that no specific standard values have been set for acceptable reliability. ICC values range between 0.00 and 1.00, with those numbers following falling closer to one determining stronger reliability scores. Generally, values above 0.75 are considered to be good indicator of reliability, while values below 0.75 indicate poor to moderate reliability.46

The correlation coefficient r is used to mathematically state the relationship between two variables. The r value ranges from +1.00 to -1.00. An r value of +1.00 indicates a perfect positive relationship, while 0.00 indicates no relationship, and -1.00 indicates a perfect negative relationship.

The results point towards good reliability for mCTSIB Foam Eyes Closed, mCTSIB Composite, LOS Endpoint Excursion Composite, and LOS Directional Control Composite. Moderate reliability was demonstrated with the LOS Maximum Excursion Composite.
Composite. Very high reliability was found with goniometric measurements of elbow extension.

Data Analysis

The data gathered for all subjects on the LOS and mCTSIB tests were entered into the SPSS Version 11.5 software system. With this program descriptive statistics were analyzed for mean, standard of deviation, and frequency. The independent samples t-test was completed to determine the mean difference between the control group and the group of subjects with signs of hypermobility. Statistical significance was set at $\alpha = .05$ level.
CHAPTER IV

RESULTS

Subject Profile

A total of 79 subjects (60 females and 19 males) between the ages of 20-28 years participated in the hypermobility screening portion of this study. The mean calculated age was 23.01 years ± 1.68. The mean height of the subjects was 67.65 inches ± 3.59. The mean weight was 158.34 pounds ± 32.97. The mean hypermobility score was 2.2 ± 2.12. Frequencies of hypermobility scores can be found in Table 5. Twenty subjects had hypermobility scores of 4 or greater, indicating 25.3% incidence of systemic hypermobility in Physical Therapy and Occupational Therapy students at the University of North Dakota.

<table>
<thead>
<tr>
<th>Hypermobility Score</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
</tr>
</tbody>
</table>

A group of 12 randomly selected subjects, 7 females and 5 males who did not display signs of hypermobility were assigned to a control group. The mean age of these
12 subjects was 23.42 years ±1.51. The mean hypermobility score of the control group was 2 ±0.95.

Of the 20 subjects who displayed signs of systemic hypermobility, 19 met the inclusion criteria. One subject was eliminated from the NeuroCom ® Balance Master portion of the study due to a medical diagnosis made after the hypermobility screening. The final group consisted of 1 male and 18 females. The mean age of these 19 subjects was 23.47 years ±2.12. The mean hypermobility score was 5.16 ±1.17. Seven subjects had a hypermobility score of 4 out of 9, 6 subjects had a score of 5 out of 9, 2 had a score of 6 out of 9, and 4 had a score of 7 out of 9. Four of the subjects displayed only upper extremity hypermobility, while 15 subjects demonstrated both upper extremity and lower extremity hypermobility. Upper extremity hypermobility includes elbow extension, extension of the 5th MCP joint, and thumb apostion. Lower extremity hypermobility includes knee hyperextension and trunk flexion.

Results for Modified Clinical Test for Sensory Interaction on Balance

The means and standard deviations for the foam eyes closed and mCTSIB composite variables are reported in Table 6. The data was normally distributed, therefore an Independent Samples t-test was used to determine if a mean difference existed between groups. No significant difference was found between the control group and the group with hypermobility, indicating that the groups performed similarly during tests for static balance on the NeuroCom ® Balance Master.
Table 6. Results for mCTSIB Test. Population, Mean, Standard Deviation, Skewness, Kurtosis, t-score, Degrees of Freedom, and Significance (2-Tailed).

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>t</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foam</td>
<td>Control</td>
<td>12</td>
<td>1.11</td>
<td>0.36</td>
<td>0.84</td>
<td>0.17</td>
<td>-0.823</td>
<td>29</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>Hypermobile</td>
<td>19</td>
<td>1.20</td>
<td>0.26</td>
<td>-0.12</td>
<td>0.05</td>
<td></td>
<td></td>
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<tr>
<td>Eyes</td>
<td>Control</td>
<td>12</td>
<td>0.44</td>
<td>0.10</td>
<td>0.27</td>
<td>-0.65</td>
<td>-1.95</td>
<td>29</td>
<td>0.06</td>
</tr>
<tr>
<td>Closed</td>
<td>Hypermobile</td>
<td>19</td>
<td>0.51</td>
<td>0.09</td>
<td>-0.68</td>
<td>-0.47</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Results for Limits of Stability Test

The means and standard deviations for the endpoint excursion, maximum excursion and directional control composite scores are reported in Table 7. The data was normally distributed, therefore an Independent Samples t-test was used to determine if a mean difference existed between groups. There was no significant difference between the control group and the group with hypermobility, indicating that the groups performed similarly during tests of dynamic balance on the NeuroCom® Balance Master.

Table 7. Results for LOS Test. Population, Mean, Standard Deviation, Skewness, Kurtosis, t-score, Degrees of Freedom, and Significance (2-Tailed).

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>t</th>
<th>df</th>
<th>p</th>
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<tbody>
<tr>
<td>End Point</td>
<td>Control</td>
<td>12</td>
<td>81.25</td>
<td>7.90</td>
<td>0.18</td>
<td>-0.32</td>
<td>0.50</td>
<td>29</td>
<td>0.62</td>
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<tr>
<td>Excursion</td>
<td>Hypermobile</td>
<td>19</td>
<td>79.95</td>
<td>6.51</td>
<td>-0.47</td>
<td>-0.49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composite</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>Control</td>
<td>12</td>
<td>91.75</td>
<td>6.62</td>
<td>0.12</td>
<td>-1.12</td>
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<td>0.91</td>
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<tr>
<td>Excursion</td>
<td>Hypermobile</td>
<td>19</td>
<td>92.0</td>
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<td>-0.02</td>
<td>-0.71</td>
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<td></td>
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<tr>
<td>Directional</td>
<td>Control</td>
<td>12</td>
<td>80.08</td>
<td>3.60</td>
<td>-1.12</td>
<td>0.75</td>
<td>0.61</td>
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<td>0.55</td>
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<tr>
<td>Control</td>
<td>Hypermobile</td>
<td>19</td>
<td>79.05</td>
<td>5.14</td>
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<td>-0.01</td>
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<tr>
<td>Composite</td>
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</tr>
</tbody>
</table>

Results for Comparison of Upper Extremity Hypermobility to Trunk, Upper Extremity and Lower Extremity Hypermobility

Since no significant difference between the control group and the group with hypermobility was found, the data collected from the group with hypermobility was
further analyzed to determine whether or not there was a significant difference between those individuals with hypermobility in just the upper extremity and those individuals with hypermobility throughout the upper extremity, trunk, and lower extremity. The data that was analyzed comparing upper extremity hypermobility to upper extremity, trunk, and lower extremity hypermobility for the LOS test can be found in Table 8 and data analyzed for the mCTSIB test can be found in Table 9.

The Independent Samples t-test was used to determine if a mean difference existed between subjects with hypermobility in the upper extremities only and subjects with hypermobility in the upper extremities, trunk, and lower extremities. A significant difference was found between the subjects with upper extremity hypermobility and subjects with upper extremity, lower extremity, and trunk hypermobility for the mCTSIB foam eyes closed score. This indicates that subjects with upper extremity, lower extremity, and trunk hypermobility had more postural sway during static standing on a foam surface without visual feedback. Data from the Directional Control Composite and Composite mCTSIB tests were found to be kurtosed and skewed respectively. The remaining data was normally distributed and no significant difference was found between groups. Data that was not normally distributed was additionally analyzed using the Mann-Whitney U-test. The original scores were rank ordered to compare the rank for the four subjects with upper extremity hypermobility and the 15 subjects with trunk, upper extremity, and lower extremity hypermobility. The results indicate no significant difference between groups for directional control composite score. A significant difference was found between groups for mCTSIB composite score, indicating that subjects with upper extremity hypermobility had less postural sway during static standing.
on both firm and foam surface, with and without visual feedback than subjects with hypermobility of the upper extremities, trunk, and lower extremities. Complete results for the Mann-Whitney U-test can be found in Table 10.


<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>t</th>
<th>df</th>
<th>p</th>
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<tr>
<td>End Point</td>
<td>UE</td>
<td>4</td>
<td>79.75</td>
<td>7.46</td>
<td>0.19</td>
<td>0.74</td>
<td>-0.07</td>
<td>17</td>
<td>0.95</td>
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<tr>
<td></td>
<td>Excision Composite</td>
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<td></td>
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<tr>
<td></td>
<td>Trunk, UE and LE</td>
<td>15</td>
<td>80.00</td>
<td>6.52</td>
<td>-0.66</td>
<td>-0.21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>UE</td>
<td>4</td>
<td>79.00</td>
<td>5.23</td>
<td>0.42</td>
<td>-0.42</td>
<td>-0.02</td>
<td>17</td>
<td>0.98</td>
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<tr>
<td></td>
<td>Excision Composite</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>UE and UE</td>
<td>15</td>
<td>79.07</td>
<td>5.30</td>
<td>-0.13</td>
<td>-0.72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Directional Control</td>
<td>UE</td>
<td>4</td>
<td>91.25</td>
<td>2.99</td>
<td>0.00</td>
<td>-5.64</td>
<td>-0.46</td>
<td>17</td>
<td>0.65</td>
</tr>
<tr>
<td>Composite</td>
<td>UE and LE</td>
<td>15</td>
<td>92.20</td>
<td>3.80</td>
<td>-0.73</td>
<td>0.45</td>
<td></td>
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</table>

Table 9. Results of mCTSIB Test Comparing Upper Extremity Hypermobility to Trunk, Upper Extremity, and Lower Extremity Hypermobility. Population, Mean, Standard Deviation, Skewness, Kurtosis, t-score, Degrees of Freedom, and Significance (2-Tailed).

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>t</th>
<th>df</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>Foam Eyes</td>
<td>UE</td>
<td>4</td>
<td>0.98</td>
<td>0.19</td>
<td>-1.66</td>
<td>2.62</td>
<td>-2.09</td>
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<td>0.05</td>
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<tr>
<td>Closed</td>
<td>Trunk, UE and LE</td>
<td>15</td>
<td>1.26</td>
<td>0.25</td>
<td>-0.33</td>
<td>0.54</td>
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<tr>
<td>mCTSIB Composite</td>
<td>UE</td>
<td>4</td>
<td>0.43</td>
<td>0.05</td>
<td>2.00</td>
<td>4.00</td>
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<td>17</td>
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<tr>
<td></td>
<td>Trunk, UE and LE</td>
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<td>0.53</td>
<td>0.09</td>
<td>-1.46</td>
<td>2.01</td>
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</table>

Table 10. Results of Mann-Whitney U test for test groups not normally distributed.

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
<th>Mann-Whitney U</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directional Control</td>
<td>UE</td>
<td>4</td>
<td>9.75</td>
<td>39.00</td>
<td>29.00</td>
<td>0.920</td>
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<td></td>
<td>Trunk, UE and LE</td>
<td>15</td>
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<td>151.00</td>
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<tr>
<td>mCTSIB Composite</td>
<td>UE</td>
<td>4</td>
<td>4.75</td>
<td>19.00</td>
<td>9.00</td>
<td>0.026</td>
</tr>
<tr>
<td></td>
<td>Trunk, UE and LE</td>
<td>15</td>
<td>11.40</td>
<td>171.00</td>
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</tbody>
</table>
CHAPTER V

DISCUSSION

Throughout this study, the following research questions were addressed: 1) Do Physical Therapy and Occupational Therapy students who display systemic hypermobility demonstrate a significant difference in static and dynamic balance in comparison to Physical Therapy and Occupational Therapy without systemic hypermobility? 2) Is there a significant difference in static and dynamic balance between hypermobility in only the upper extremity verses hypermobility in both upper and lower extremities?

The results of this study demonstrated that hypermobility has no significant effect on measurements of balance obtained using the mCTSIB test and the LOS test using the NBM with Physical Therapy and Occupational Therapy students. These results do not support the initial hypothesis that there would be a significant difference in static and dynamic balance between hypermobile and non-hypermobile Physical Therapy and Occupational Therapy students. A significant difference was found for the mCTSIB composite score and the mCTSIB foam with eyes closed score when comparing upper extremity hypermobility to trunk, upper extremity, and lower extremity hypermobility. This result indicates that hypermobility in the trunk and lower extremities has a greater influence on balance on various surfaces with and without visual feedback than hypermobility in the upper extremities alone. This may be an important factor to
consider for therapists who are systemically hypermobile and must perform job duties on uneven surfaces, such as mats. One example of this type of work environment would be a pediatric setting.

The findings of this study compliment previous research done by Riemann et al\textsuperscript{47} which found that ligamentous mechanoreceptors within the ankle joint are not important for postural control, and therefore do not have unique and irreplaceable roles in balance. It is possible that individuals are able to accommodate from the lack of mechanoreceptors through use of other sensory and motor feedback. According to a study by Brodie et al,\textsuperscript{48} ligamentous laxity is an inherited characteristic which allows for joint movement, however joint movement also comes from acquired muscular coordination. Individuals who are hypermobile and whose professions require intricate balance, such as ballet dancers, are able to train their bodies to avoid injury that may occur due to hypermobility through appropriate muscle control.\textsuperscript{49} Furthermore, Decoster et al\textsuperscript{50} reported that joint stabilization and proprioception are trainable in the hypermobile population. Thus, the training received by Physical Therapy and Occupational Therapy students lends itself to increased insight and awareness of their own body’s abilities, limitations, and subsequent adaptations which may explain why no significant difference was noted between the control group and the group with hypermobility.

The mCTSIB test has 4 subsets, measuring static balance on a firm surface and a foam surface with eyes open and eyes closed. The reliability study determined that intrarater reliability was only present in the foam eyes closed subset and the composite score. Neither test gave statistically significant results. This indicates that students with
hypermobility were able to adapt their motor coordination on various surfaces with and without visual feedback as well as students who did not exhibit hypermobility.

The LOS test provided 3 reliable subtests, out of a possible 25. No statistical significance was found in any of the 3 reliable subtests, indicating that students with hypermobility are able to reach similar limits of stability with equivalent directional control as those students who do not demonstrate hypermobility.

Limitations

This study did not support our initial hypothesis, which may be attributed to some of its inherent limitations. Factors that contributed to the limitations of this study include the use of the Beighton Hypermobility Scale, establishing reliability on the NeuroCom ® Balance Master, the control and experimental group design, the use of postural sway as a functional measure, and finally the learning curve associated with repeated testing on the NeuroCom ® Balance Master.

First, for this study a subject was considered hypermobile if they had a minimum score of 4 out of 9 on the Beighton Score for Hypermobility. The score of 4 could be obtained solely from hypermobility in the bilateral upper extremities for elbow extension beyond 10°, passive extension of the fifth metacarpalphalangeal beyond 90°, and passive thumb apposition to the flexor aspect of the forearm. The lower extremities and trunk only account for 3 of the 9 points in the Beighton Score, which is not enough to be considered hypermobile. The lower extremities and trunk, however, play a more significant role in balance strategies than do the upper extremities. The strategies produced by the ankle are of particular importance and the range of these joints is not assessed in the Beighton Score. Although the Beighton is a commonly used research
tool to measure hypermobility, it may not be the most accurate reflection of the extent of hypermobility in the lower extremities. There are many other screening tools for hypermobility that included a more detailed assessment of the lower extremities. Such tools include Carter and Wilkinson,¹⁵ which takes into account ankle dorsiflexion and foot eversion, and Rotés,¹⁶ which takes into account hip abduction and metatarsophalangeal extension greater than 90°.

A second limitation of this study concerned how difficult it is statistically to establish intrarater reliability for every test on the NeuroCom ® Balance Master. Although the researcher is giving verbal instructions and aligning the medial malleoli and heel to the force plate, the subject in largely in control of how consistently they perform between testing sessions. The NeuroCom ® Balance Master is a very precise measure of balance and can analyze even the most minute changes in balance that are not readily detectable to even a highly trained researcher. The fluctuations in balance can vary within a person from day to day and therefore the measurements made by the NBM can be very different from day to day. The researcher has no influence on the internal fluctuations in balance a subject may display, thereby making it difficult to establish intrarater reliability. Intrarater reliability was established for 5 subtests out of a possible 30. The small number of potential subtests used during statistical analysis severely limited the researchers’ ability to determine the effects of hypermobility on balance from the remaining 25 subtests from which intrarater reliability could not be established in this study.

A third limitation of this study concerned the comparison of 2 groups of Physical Therapy and Occupational Therapy students, one with hypermobility and one without
hypermobility. This homogeneous subset of individuals may have affected the ability to achieve statistical significance. The 2 groups were similar with respect to age, activity level, general health status, gender, as well as amount and type of education in anatomy and physiology, body mechanics, biomechanics of muscles and joints, and motor control. The combination of these factors in subjects with hypermobility may have contributed to accommodation strategies to allow for balance performance similar to non-hypermobile Physical Therapy and Occupational Therapy students.

Previous studies have established normative data for ages 20-39 years on the tests for the NeuroCom ® Balance Master. The pre-established norms have slightly higher means with similar standard deviations to the norms established for the control group and may have provided enough variability to establish statistical significance. Comparison of the pre-established norms to the norms of the control group can be found in Table 11.

Table 11. Mean and Standard Deviation for ages 20-39 years for LOS test and mCTSIB test for the control group.

<table>
<thead>
<tr>
<th></th>
<th>mCTSIB Foam Eyes Closed</th>
<th>mCTSIB Composite</th>
<th>LOS Endpoint Excursion Composite</th>
<th>LOS Maximum Excursion Composite</th>
<th>LOS Directional Control Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Pre-established Norms</td>
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<td>0.39</td>
<td>0.59</td>
<td>0.15</td>
<td>85.3</td>
</tr>
<tr>
<td>Control group Norms</td>
<td>1.11</td>
<td>0.36</td>
<td>0.44</td>
<td>0.10</td>
<td>81.25</td>
</tr>
</tbody>
</table>

A fourth limitation of this study is the use of postural sway as a measure of functional balance. Research has proven that postural sway does not effectively measure postural stability. Physical Therapy and Occupational Therapy are professions that
mandate the use of complex balance and stability strategies during job duties. Postural sway may be a factor in control of balance, but is not a sufficient research tool to determine the functionality of a therapist’s balance. Therefore, functional balance needs to be measured with other methods.

The fifth limitation of this study is the high learning curve for subjects using the NeuroCom ® Balance Master. This may have had a negative effect on establishing intrarater reliability for all the tests of the LOS and mCTSIB. Previous studies have discarded the first trial to account for a suspected learning curve between the first and second trials. However, there is no research to support the existence of a learning curve between the initial trial and subsequent trials, although it is highly plausible.

Recommendations

The subjects tested in this study were a homogeneous subset of young, relatively healthy individuals who maintain a physically active lifestyle. It is, therefore, reasonable to argue that this particular group of subjects may require more challenging balance tests due to their age and skill level. Additionally, the Nuerocom ® Balance Master tests skills that do not adequately re-create the functional skills used by Physical Therapy and Occupational Therapy students.

The use of Electromyography (EMG) while testing balance of individuals with hypermobility may provide more information about accommodation strategies. In a study by Rozzi et al, EMG was used to determine the relationship of muscular fatigue to knee joint proprioception in subjects displaying ligamentous laxity, which suggests that accommodations to decreased proprioception may have more to do with muscle fatigue and coordination than the presence of hypermobility.
In order to obtain a more accurate picture of the effects of hypermobility on physical and occupational therapists it may be best to study practicing therapists. These therapists will have pre-established strategies for accommodating for hypermobility during their job tasks, specifically for transferring a patient. Strategies that practicing therapists use may be quite different from novice therapists. Some strategies may be external, such as the use of a splint, rather than internal, such as the proprioceptive feedback from joints. Body mechanics may vary in novice therapists due to the fact that they are not yet an internalized skill, whereas experienced therapists are more likely to have established body mechanics which are consistent during all functional skills. This further emphasizes the role experienced Physical Therapists and Occupational Therapists may have in future studies.

Another important factor to consider with practicing therapists is complexity of their job task. It is not a normal job task for a therapist to be focusing only on their balance strategy, they must also be cognizant of their patient’s response and environmental changes with respect to the functional goal at hand. Therefore, it is difficult to get a thorough picture of the role that hypermobility may have on balance in physical and occupational therapists. A more accurate representation of balance could be established through use of dynamic upper extremity movements, volitional head movements, varying surfaces, as well as external visual and auditory stimuli while measuring static and dynamic balance.

Conclusion

Balance is an essential component of the job specific skills for Physical and Occupational Therapists. A loss of balance is dangerous for the patient as well as the
therapist. Alterations in balance can be attributed to many factors, including decreased joint proprioception. Receptors responsible for proprioception are in the muscles, tendons, joint capsules, and ligaments that stabilize the joint. Since hypermobility can be defined as unduly lax joints where the range of motion exceeds the normal limits, the abnormal integrity of the ligaments can cause deficiencies in proprioception. This in turn could have an effect on balance. The purpose of this study was to determine the effects of hypermobility on balance in Physical Therapy and Occupational Therapy students, who tend to have a higher prevalence of hypermobility than the general population and whose job tasks require higher level balance skills.

Through use of the Beighton Scale for Hypermobility and NeuroCom® Balance Master tests, it was observed that hypermobility did not appear to play a role in measurements of static and dynamic balance in physical therapy and occupational therapy students. The subject population was homogeneous with little variability, making it difficult to determine statistical significance. This homogeneity can be attributed to factors such as age, gender, physical activity level, as well as amount and type of education.

It was also determined that subjects who displayed hypermobility had significantly different balance strategies depending on the location of the hypermobility. Subjects who only displayed hypermobility in the upper extremities versus those who displayed hypermobility in the trunk, upper extremities, and lower extremities had significantly difference balance scores on various surfaces. For example, subjects with hypermobility in the knees appeared to be able to achieve greater limits of stability in the anterior direction. This was primarily accomplished by locking the knees into
hyperextension, maintaining a neutral position of the hips and pelvis, and incorporating the ankle strategy in order to maintain stability, whereas subjects who were not hypermobile in the knees had to bend at the hips in order to shift their center of gravity in the anterior direction.

In light of the limitations and recommendations of this study, further research on this topic should be conducted with respect to use of a hypermobility screening tool that more heavily emphasizes the lower extremities as well as a balance assessment that reflects functional job specific skills for physical and occupational therapists.
APPENDIX A
Kt:PUK I Ur ACTION: EXEMPT/EXPEDITED REVIEW

University of North Dakota Institutional Review Board

Date: 4/19/2004  Project Number: IRB-200404-320

Principal Investigator: Jeno, Sue; Elbert, Laura; Tostenrud, Teresa

Department: Physical Therapy

Project Title: Examination of Systemic Hypermobility and Static and Dynamic Balance in Occupational and Physical Therapy

The above referenced project was reviewed by a designated member for the University’s Institutional Review Board on 4/19/2004 and the following action was taken:

☑ Project approved. Expedited Review Category No. 4

☑ Copies of the attached consent form with the IRB approval stamp dated April 27, 2004 must be used in obtaining consent for this study.

☐ Project approved. Exempt Review Category No.

☐ This approval is valid until as long as approved procedures are followed. No periodic review scheduled unless so stated in the Remarks Section.

☐ Copies of the attached consent form with the IRB approval stamp dated must be used in obtaining consent for this study.

☐ Minor modifications required. The required corrections/additions must 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.)

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

Any changes in protocol or Consent Forms must receive IRB approval prior to being implemented. You must submit a memo with a copy of the Consent Form and a revised Human Subjects Review Form, with the appropriate signatures, to the Office of Research and Program Development for review and approval.

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

☐ Education Requirements Completed. (Project cannot be started until IRB education requirements are met.)

cc: Meridee Danks; Chair, Physical Therapy; Dean, School of Medicine

Signature of Designated IRB Member
UND’s Institutional Review Board

Date

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

(Revised 10/2002)
APPENDIX B
ID #

Consent to Participate in Research

The Association of Generalized Joint Hypermobility and Decreased Balance.

You are invited to voluntarily participate in a scholarly project conducted by students of the UND Physical Therapy Program (Laura Elbert and Teresa Tostenrud) in collaboration with faculty members Dr. Susan Jeno and Meridee Danks. This study is being conducted to determine what effect hypermobility has on balance. The study will consist of two parts, the first part will test for the presence of hypermobility and the second part will use the individuals who exhibited hypermobility to assess balance. The findings of this study will help determine if modified body mechanics need to be adopted by physical and occupational therapists who have systemic hypermobility during performance of job duties. You will be made aware if you are identified as exhibiting hypermobility. The results of this study will be made available to you to assess the need for modified body mechanics during performance of job duties.

As a participant in this study you will complete a survey indicating the demographic data such as age and gender and a short past medical history questionnaire, which will take approximately five to ten minutes to complete. All volunteers must meet the following inclusion criteria: 1) A UND physical or occupational therapy student, 2) Age 20-30 years, 3) No current or past medical diagnosis or history affecting balance, 4) Currently taking no medications affecting the CNS or medications known to affect balance or coordination, 5) No symptoms of dizziness or lightheadedness, 6) No symptoms suggestive of vestibular or neurologic disorders, 7) No psychological disorders including depression 8) No history of two or more unexplained falls in the past 6 months, 9) Normal vision with or without glasses or corrective lenses, 10) No injuries or surgeries that may have an effect on balance and 11) No subjects with the presence of self-reported pregnancy.

Part I: The Beighton test will be used to determine if you are hypermobile. You will move your joints to the end of available joint range, the amount of motion will then be assessed and scored by the researcher. This portion of the study should take approximately five to ten minutes. If the researcher determines that you exhibit hypermobility, then you will be requested to participate in the balance portion of this study; if you are not found to exhibit hypermobility and are not asked to be part of a control group for balance, your participation is complete.

Part II: The NeuroCom Balance Master (NBM) will be used to assess balance. The NBM is a clinically accepted machine commonly used to assess balance in physical therapy. You will be asked to participate in a one-time session lasting approximately 30 minutes. You will be asked to report to the research room on the second floor of the UND Physical Therapy Department at your scheduled testing time. You will be asked to wear loose comfortable clothing and will be barefoot during all balance testing. A warm up session and practice trial session will be allowed, this will last approximately 10-15 minutes. This will be followed by performance of the actual assessments. Balance master tests will include: Limits of Stability and Modified Clinical Test for Sensory Interaction on Balance (mCTISB). The limits of stability test will require you to move forwards, backwards, sideways, and diagonally without moving your feet. This test quantifies the movement characteristics associated with the subject’s ability to voluntarily sway to various locations in space, and briefly maintain stability.
at those positions. The mCTISB will require you to stand still on a firm surface with your eyes open, then closed and then stand on a foam block with your eyes open, then closed. This test will quantify postural sway velocity while the subject is standing quietly. While participating in the balance portion of the study a single photograph of your static standing on the NBM will be requested. You will be asked to sign a separate consent form for the use of photographs.

Although there is a risk of injury involved in any experimental study such as this, the tests pose minimal risk to you other than a possible temporary feeling of discomfort or loss of balance. A spotter will be present to minimize the risk of falling during balance assessment. One benefit of this study is that for the participants who discover they are hypermobile individuals insight will be gained regarding the importance of developing alternate strategies for body mechanics in the work environment. Another benefit is for the general population of physical therapists, this study may provide insight into the effects of hypermobility on balance in the work setting.

The results of this study will remain confidential and your data will be identified by a number known only to the investigators. These results will be kept in a locked confidential file in the UND Physical Therapy department for three years following the completion of this study. After this period of time the results will be destroyed. Only the researchers, the advisers, and people who audit IRB procedures will have access to the data. If you choose to participate, you are free to withdraw your 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 of the Physical Therapy Department. If it is determined that you have health issues that put you at risk for injury, or you do not meet the inclusion criteria you may be excluded from this study. However, again, you will not be penalized in any way. There is no cost to you associated with participation in this study.

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 Laura at (218)779-5041, Teresa at (406)670-7318 or Dr. Sue Jeno (701)777-2831. If you have any other questions or concerns, please call the Office of Research and Program Development at (701) 777-4279. You are encouraged to ask questions at any time. A copy of this consent form will be available to all participants in this study upon request.

In the unlikely 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 the University of North Dakota are not responsible for any such injury or treatment, however these resources will be available as they are to the general public. The payment for any such treatment must be provided by you and your third-party payer if applicable.

I have read all the above, all my questions have been answered, and I willingly agree to participate in this study explained to me by Laura Elbert and Teresa Tostenrud.

Participant’s Signature

Witness’ Signature

University of North Dakota
Institutional Review Board
Approved on APR 27, 2004
APPENDIX C
ID #:__________________

Health Background Questionnaire

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<td>Gender: M or F</td>
<td>Dominant hand: L or R</td>
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<tr>
<td>Weight (in pounds):</td>
<td></td>
</tr>
</tbody>
</table>

1. Are you currently taking any medications? (e.g. allergy medications, cold medications, etc.) Please list all over-the-counter and/or prescription medications and the frequency of use to determine if these may affect your balance. (e.g. Tylenol 3x/day.)

2. Do you have any current or past medical diagnoses or injuries occurring within the last year that could affect your balance? If so, please list them and their associated dates. (include fractures, orthopedic conditions, sprains, surgeries, etc.)

3. Do you have any symptoms (e.g. dizziness, lightheadedness) associated with a vestibular (inner ear) disorder? If yes, please explain your symptoms.

4. Have you been diagnosed with depression or any other psychological disorders? If so, please list.

5. Have you experienced any episodes of two or more unexplained falls within the past 6 months? If so, please list.

6. Do you have normal vision (either with or without glasses/contacts)?

7. Are you pregnant or could you be pregnant?

8. Do you participate in any activities beyond your normal activities of daily living? If so, please list type of exercise and frequency per week.
APPENDIX D
Figure 2. Hyperextension of the elbow beyond 10 degrees

Figure 3. Passive Extension of the fifth digit beyond 90 degrees
Figure 4. Passive apposition of the thumb to the flexor aspect of the forearm

Figure 5. Forward flexion of the trunk with the knees straight so that the palms of the hands rest easily on the floor
Figure 6. Hyperextension of the knee beyond 10 degrees
Data Collection Form

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<tr>
<td>TRUNK</td>
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<tr>
<td>TOTAL SCORE</td>
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ID #: __________

52
APPENDIX F
Figure 7. NeuroCom ® Balance Master
APPENDIX G
### Limits Of Stability

<table>
<thead>
<tr>
<th>Transition</th>
<th>RT (sec)</th>
<th>MVL (deg/sec)</th>
<th>EPE (%)</th>
<th>MXE (%)</th>
<th>DCL (%)</th>
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<tr>
<td>2 (RF)</td>
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<td>3 (R)</td>
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<td>105</td>
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<td>4 (RB)</td>
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<td>5 (B)</td>
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<td>100</td>
<td>72</td>
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<td>6 (LB)</td>
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<td>108</td>
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<td>7 (L)</td>
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<td>8 (LF)</td>
<td>0.63</td>
<td>6.5</td>
<td>70</td>
<td>88</td>
<td>79</td>
</tr>
</tbody>
</table>

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**Post Test Comment:**

---

NeuroCom System Version 8.0.2, Copyright ©1989–2004 NeuroCom® International Inc. All Rights Reserved.
Modified CTSIB

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

(0.1, 10) (0.1, 10) (0, 10) «(deg/sec)»
Trial 1 Trial 2 Trial 3

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

(0.1, 10) (0.1, 10) (0.1, 10)
Trial 1 Trial 2 Trial 3

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

(0.3, 10) (0.3, 10) (0.3, 10) «(deg/sec)»
Trial 1 Trial 2 Trial 3

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

(1, 10) (1.4, 10) (0.8, 10)
Trial 1 Trial 2 Trial 3

deg/sec

Mean COG Sway Velocity

COG Alignment

Data Range Note: User Data Range: 20–39

Post Test Comment:

COG Alignment:
Right Back, 16% LOS @ 142.5 degree
Consent for Taking and Publication of Photographs

Name: Teresa Tostenrud

Location: University of North Dakota School of Medicine and Health Sciences

Date: June 10, 2004

In connection with Laura Elbert and Teresa Tostenrud’s Scholarly Project entitled, Examination of Systemic Hypermobility on Static and Dynamic Hypermobility in Occupational and Physical Therapy Students, I consent that photographs may be taken of me and may be published under the following conditions:

1) The photographs shall be used if the researchers, Laura Elbert and Teresa Tostenrud deem that medical research, education, or science will be benefited by their use. Such photographs may be published and republished, either separately or in connection with each other, in professional journals or medical books; provided that it is specifically understood that in any such publication or use I shall not be identified by name.

2) The aforementioned photographs may be modified or retouched in any way that the researchers, Laura Elbert and Teresa Tostenrud may consider desirable.

Signature

Witness

University of North Dakota
Institutional Review Board
Approved on APR 27 2004
Expires on APR 26 2005
Consent for Taking and Publication of Photographs

Name: Melissa Mattoff

Location: University of North Dakota School of Medicine and Health Sciences

Date: 6-8-04

In connection with Laura Elbert and Teresa Tostenrud's Scholarly Project entitled, Examination of Systemic Hypermobility on Static and Dynamic Hypermobility in Occupational and Physical Therapy Students, I consent that photographs may be taken of me and may be published under the following conditions:

1) The photographs shall be used if the researchers, Laura Elbert and Teresa Tostenrud deem that medical research, education, or science will be benefited by their use. Such photographs may be published and republished, either separately or in connection with each other, in professional journals or medical books; provided that it is specifically understood that in any such publication or use I shall not be identified by name.

2) The aforementioned photographs may be modified or retouched in any way that the researchers, Laura Elbert and Teresa Tostenrud may consider desirable.

Signature: Melissa Mattoff

Witness: Teresa R. Estey

University of North Dakota
Institutional Review Board
Approved on APR 27 2004
Expires on APR 26 2005
Consent for Taking and Publication of Photographs

Name: Andrea Foley

Location: University of North Dakota School of Medicine and Health Sciences

Date: 01-04-10

In connection with Laura Elbert and Teresa Tostenrud’s Scholarly Project entitled, Examination of Systemic Hypermobility on Static and Dynamic Hypermobility in Occupational and Physical Therapy Students, I consent that photographs may be taken of me and may be published under the following conditions:

1) The photographs shall be used if the researchers, Laura Elbert and Teresa Tostenrud deem that medical research, education, or science will be benefited by their use. Such photographs may be published and republished, either separately or in connection with each other, in professional journals or medical books; provided that it is specifically understood that in any such publication or use I shall not be identified by name.

2) The aforementioned photographs may be modified or retouched in any way that the researchers, Laura Elbert and Teresa Tostenrud may consider desirable.

Signature: Andrea Foley

Witness: Teresa M. Tostenrud

University of North Dakota Institutional Review Board
Approved on APR 27, 2004
Expires on APR 26, 2005
APPENDIX I
Figure 8. Force plate

Figure 9. Force plate and foam
APPENDIX J
NeuroCom® Balance Master Verbal Instructions

Limits of Stability test:
- When we start the testing, I want you to stand with both of your feet planted on the Balance Master.
- It is okay to lift your toes, bend at the knees, move your arms, and move your hips, as long as the base of your feet stays planted and does not move.
- When we start, I want you to keep the little man figure in the center square as steady as you can until a green “GO” appears at the bottom of screen.
- You should then lean to try and move the man figure to the highlighted target with the blue circle, as quickly and accurately as possible.
- Hold it there as long as the blue circle remains, which will be for 8 seconds.
- Don’t worry if you can’t get all the way to the target, just get as close as you can.
- Once the cursor disappears, return to the center square and we’ll start the next trial.

Modified CTSIB test:
- You will have a spotter throughout this test.
- I want you to stand with both of your feet planted on the Balance Master.
- Stand as upright and steady as you can with your eyes open looking straight ahead. You will remain standing for 10 seconds. Please do not talk or move during the testing. I will tell you when to start by saying “go” and when to stop by saying “stop.”
- This will be repeated three times.
- Ready, set, Go. (Repeat 2x).
- Now I want you to stand as upright and steady as you can with your eyes closed, you will remain standing for 10 seconds, please do not talk or move during the testing. I will tell you when to start by saying “go” and when to stop by saying “stop.” This will be repeated three times.
- Ready, set, Go. (Repeat 2x).
- Now I want you to stand with both of your feet planted on the foam surface on the Balance Master. A gait belt will be placed around your waist for your protection.
- Stand as upright and steady as you can with your eyes open looking straight ahead. You will remain standing for 10 seconds. Please do not talk or move during the testing. I will tell you when to start by saying “go” and when to stop by saying “stop.” This will be repeated three times.
- Ready, set, Go. (Repeat 2x).
- Now I want you to stand as upright and steady as you can with your eyes closed, you will remain standing for 10 seconds, please do not talk or move during the testing. I will tell you when to start by saying “go” and when to stop by saying “stop.” This will be repeated three times.
- Ready, set, Go. (Repeat 2x).
REFERENCES CITED
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45. SPSS Version 11.5 (SPSS, Inc., Chicago, IL)


