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Association of Generalized Joint Hypermobility and Occurrence of Musculoskeletal Injury in Physical Therapy and Occupational Therapy Students

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ASSOCIATION OF GENERALIZED JOINT HYPERMOBILITY AND OCCURRENCE OF MUSCULOSKELETAL INJURY IN PHYSICAL THERAPY AND OCCUPATIONAL THERAPY STUDENTS

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A Scholarly Project

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This Scholarly Project, submitted by Katie Harris, Annika Larsen, Anthony Simons, and Bennett Westrich in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been thoroughly read by the Advisor and Chairperson of Physical Therapy under whom this work has been conducted and is hereby approved.

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PERMISSION

Title	Association of Generalized Joint Hypermobility and Occurrence of Musculoskeletal Injury in Physical Therapy and Occupational Therapy Students.
Department	Physical Therapy
Degree	Doctor of Physical Therapy

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ABSTRACT

Background: Previous studies have found a higher rate of hypermobility among physical and occupational therapy students compared to the rate of hypermobility within the general public. Hypermobility has been linked to increased injury rates. This raises the question of the influence hypermobility has on injury type and recurrence.

Purpose: The goal of this study was to examine the rate of hypermobility and injury history among physical and occupational therapy students. The injury type and frequency of those with hypermobility was compared to those without hypermobility to determine if there was a relationship. The Foot Posture Index was used to determine if there was a relationship between foot posture and hypermobility.

Methods: A total of 46 subjects (16 male and 30 female) subjects volunteered and were assessed for hypermobility using the Beighton Scale of Hypermobility. A score of four or higher out of nine indicated the presence of generalized joint hypermobility. The foot posture index was used to assess the degree to which a foot can be considered to be in a pronated, supinated, or neutral position. Participants filled out a survey regarding current activity level, previous and current athletic participation, injury regarding type and mechanism of injury.

Results: It was found that 21.74% (10/46) of the subjects were systematically hypermobile according to the Beighton Scale of Hypermobility. There was no statistically significant difference found between the number of soft tissue injuries reported by PT and OT students with systemic hypermobile compared to those who are not hypermobile. There was no relationship found between foot posture and hypermobility.

Conclusion: From the results of this study, it can be concluded that there is an increase in prevalence of hypermobility between PT and OT students in relation to the general public. Physical Therapy students, along with the three OT students, were found to have a rate of hypermobility of 21.74% in comparison to the 4-13% that the general public has.[1] In future studies, it is recommended that a larger sample size is utilized.

Keywords: hypermobility, occurrence; recurrence; prevalence; physical therapy; occupational therapy; students; injury

CHAPTER I

INTRODUCTION

Scope of Study

This study examined the prevalence of hypermobility and rates of associated injuries within a population of graduate students enrolled in the Physical Therapy (PT) and Occupational Therapy (OT) programs at the University of North Dakota. This is a continuation of 7 previous studies conducted at the University of North Dakota. The initial study conducted by Hestekin[2] found that the percentage of physical therapy students with systemic hypermobility was 21%. This number is approximately 3 times that of the general public's hypermobility prevalence. The percentage of hypermobility within the general public has been estimated to range anywhere from 4% to 13%.[1] Later studies, Selinger et al[3] and Bisek et al,[4] confirmed that PT and OT students have higher rates of hypermobility than the general public with 32.6% and 39.5%, respectively. The most recent study conducted in 2020 by Erdmann and Klein,[5] examined just physical therapy students and found the rate of systemic hypermobility to be 18%. All 7 prior studies, including this study, were conducted at the University of North Dakota, sampling from PT and OT students present at the time.

Selinger et al[3] examined the relationship between types of musculoskeletal injuries and hypermobility in PT students. Shoulder dislocation was found to be the most common injury sustained among students. In 2015, Bisek et al,[4] replicated the Selinger et al[3] study, but no additional recurrence rates were researched. The results did not indicate an increased rate of injuries among those with hypermobility. Selinger et al[3] mentioned there is minimal research regarding recurrence rates.

Healthcare workers with direct patient contact are amongst the professions with the highest rates of work-related musculoskeletal injuries.[6] Physical and occupational therapists are at a higher risk of injury due to the physical and "hands-on" aspects of the occupation. According to Bork et al,[7] physical therapists were most at risk for injuries to the low back (45% reported symptoms), the wrist and hand (roughly 30% reported symptoms), and the upper back (almost 29% reported symptoms). Milhem et al[6] found the lifetime prevalence of work-related musculoskeletal injuries among PTs to range from 55-91%. This study also found low back injuries to be the most common injury for PTs with the lifetime prevalence of injury ranging from 26-79.6%. Risk factors for work-related back pain include lifting, transferring, repetitive movements, and awkward static postures. There was a higher prevalence of injuries among younger and female therapists[6]. It has been hypothesized that hypermobility, along with the physical nature of the job, could cause therapists to experience increased rates of injury*. It is of utmost importance to identify therapists with hypermobility and implement preventative measures to allow the therapists to work safely and effectively.

Problem Statement

This study focused on determining the prevalence of hypermobility along with the correlation with the musculoskeletal injuries that occur within PT and OT students. Individuals with increased joint laxity are at a higher risk of soft tissue injuries.[8] The types of injuries are inconsistent throughout the literature and there is little research regarding the occurrence between PT and OT students with hypermobile joints. For that reason, this study sought to expand the information currently available regarding musculoskeletal injuries and the correlation to hypermobility in PT and OT students.

Purpose of Study

The purpose of this study was to assess the hypermobility of joints in PT and OT students. It also looked at the type and frequency of different injuries sustained by the students, regardless of if they were hypermobile or non-hypermobile. The Beighton Hypermobility Scale was used to assess whether the participants were hypermobile. Someone is considered hypermobile if they score a 4/9 or higher on the scale, which indicates systemic hypermobility. These results were then compared to the injury history of the participants to see if there was a relationship between hypermobility and injury types and frequency. The clinical application of this study was to become aware of hypermobility and any associated risks or injuries. Hypermobility can be assessed for, and preventative measures can be taken to decrease the likelihood of future injuries that are linked to hypermobility. These include education on the risks that come with hypermobility as well as the use of proper body mechanics.

Significance of Study

This study is assisting in obtaining more data for a long running study. There have been seven studies before this that use the Beighton Hypermobility Scale. This scale and study have shown that there is a significantly higher rate of hypermobility in PT and OT students as compared to the general population. With hypermobility, one is put at in increased risk of soft tissue injuries due to how hands on the professions are and with the amount of manual therapy performed on patients.[6] This study can bring awareness to this topic and help educate workers in the PT and OT fields to be more thoughtful and proactive in the use of correct body mechanics to protect joints and allow for a longer and more successful time in those fields.

Research Question

1. What is the prevalence of hypermobility among PT and OT students?
2. Is there a higher incidence of soft tissue injuries in the PT and OT students who are hypermobile as compared to their non-hypermobile peers?
3. Is there a significant difference in the recurrent rate of injuries among PT and OT students who are hypermobile as compared with those who are not hypermobile?
4. Is there a correlation between foot posture and systemic hypermobility?

Hypotheses and Alternative Hypotheses

<u>Null Hypothesis:</u> There is no significant difference present between PT and OT students as compared to the general population when it comes to the prevalence of hypermobility. Physical Therapy and OT students are no more hypermobile than the general public.

<u>Alternative Hypothesis:</u> A significant difference is present between PT and OT students as compared to the general population when it comes to the prevalence of hypermobility. Physical Therapy and OT students are more hypermobile than the general public.

<u>Null Hypothesis:</u> No significant relationship exists between the incidence rate of soft tissue injuries among PT and OT students who are hypermobile and those students who are not hypermobile.

Alternative Hypothesis: Physical Therapy and OT students who are more hypermobile have a significant relationship to soft tissue injuries as compared to their peers who are not hypermobile.

Null Hypothesis: There is no significant difference in the recurrent rate of injuries among PT and OT students who are hypermobile as compared with those who are not hypermobile.

Alternative Hypothesis: There is a significant difference in the recurrent rate of injuries among PT and OT students who are hypermobile as compared with those who are not hypermobile.

Null Hypothesis: There is no significant difference in the correlation between foot posture index score and systemic hypermobility.

Alternative Hypothesis: There is a significant difference in the correlation between foot posture index score and systemic hypermobility.

CHAPTER II

LITERATURE REVIEW

Hypermobility or excessive joint laxity refers to an increase in the range of motion at a joint or several joints. The general public commonly uses the term "double-jointed" to describe an increase in the range of motion at a joint. The phrase is misleading, as the increase in motion is not due to the individual truly having two joints. Instead, the increase in range of motion is caused by ligamentous laxity in the joint. The terms "laxity" and "instability" are often used synonymously. However, there is a difference between these two terms. Generalized joint laxity is defined as an increase in length and elasticity of normal joint restraints, resulting in an increase in range of motion and distractibility of the joint.[9] Instability, on the other hand, is caused by deficient static and dynamic stabilizers of the joint. Hypermobility has been linked to an increased rate of musculoskeletal injuries including ankle sprains, ACL tears, shoulder dislocations, osteoarthritis in the thumb, carpal tunnel, and chronic regional pain syndrome.[8]

There are a large variety of terms and classifications used to describe joint hypermobility and syndromes associated with hypermobility. Joint hypermobility syndrome is an "inherited disorder with an autosomal dominant pattern; is characterized by joint hyperlaxity and musculoskeletal pains."[10] Ehlers-Danlos syndrome (EDS) is a group of inherited disorders that affects the connective tissue, primarily in the joints, skin, and walls of blood vessels.[9] Individuals with Ehlers-Danlos syndrome typically present with hypermobile joints as well as stretchy and fragile skin that bruises easily. Marfan syndrome is an autosomal dominant condition caused by mutations to the fibrillin-1 gene.[11, 12] Marfan syndrome affects the cardiovascular system, the eyes, and the skeleton, resulting in scoliosis and pectus excavatum. Osteogenesis imperfecta is a heritable disorder of the extracellular matrix resulting in fragile bones and increased risk of fractures.[13]These various health conditions would sway the results, as they are a specific cause of joint laxity.

Individuals with previous hypermobility diseases were excluded from the study. This study assessed joint laxity in PT and OT students with healthy connective tissue. For the purpose of the study, the term generalized hypermobility or systemic hypermobility will be used to describe individuals with general hypermobility in their joints.

Prevalence

Joint hypermobility is relatively common and can occur in any joint of the body and be influenced by things such as age, gender, ethnicity, and training. In the general United States population of children and adolescents, Beighton scores are statistically similar in prepubertal males and females, but during puberty females scores increased while male scores decreased.[14] This shows hormones and some genetics can play a role in hypermobility. The prevalence of generalized joint laxity reported in children ages six to fifteen years of age varied between 8.8% and 64.6%. The girls with generalized joint laxity were shown to be positively associated with levels of physical activity, BMI, and mothers' education level. The rate of hypermobility in the general public ranged from 4-13%.[1] Heritable disorders of connective tissue (HDCTs) are caused by gene mutations and code for proteins that are related to the connective tissue matrix. Ehlers Danlos syndrome, Marfan Syndrome, and osteogenesis imperfecta are all examples of HDCTs, although many studies do not include these populations. Also, generalized hypermobility was reported to be higher among Asians than Africans and higher among Africans than people of European descent.[15]

Internal Factor Cause

Collagen fibers provide ligaments, tendons, and the joint capsule with the required strength to stabilize joints. Collagen fibers are very strong, flexible, and resistant to damage from tensile or compressive stresses. These fibers are typically arranged in parallel bundles, which help multiply the strength of the individual fibers. Kobayasi.[16] studied the structural properties of collagen and elastin in skin biopsies and reported abnormalities in both collagen fibrils and dermal elastin fibers in patients with inherited hypermobility disorders, such as Marfan and EDS. Twisted collagen fibrils were found to be abnormally thin compared to controls. A significantly higher percentage of disordered fibril patterns were seen in patients with higher Beighton scores.[8] The most common type of collagen in the human body is Type I, which is found in all ligaments, tendons, joint capsules, skin, demineralized bone, and nerve receptors. Mutations to the genes that code for type 1 collagen, COL 1A1 and COL 1A2, are seen in individuals with osteogenesis imperfecta.[17] Fibrillin-1 molecules are found in the extracellular matrix and provide support to bone, joints, and muscles. Mutations of the fibrillin genes, FIB 1 and FIB 2, have been linked to hypermobility. Lumican and fibromodulin are two proteoglycans that modulate the assembly of collagen into high-order fibrils in connective tissues.[18] Fibromodulin deficiencies lead to significant decreases in tendon stiffness. Genetic mutations affecting the production and function of these proteoglycans could result in joint laxity.

External Factor Cause

There are external factors that also can contribute to generalized joint hypermobility. For example, certain sports can lead to athletes developing an increase in range of motion beyond physiological norms due to the excessive stretching that is incorporated into their training. Generalized joint hypermobility is much more prevalent in dancers, specifically jazz dancers, according to one study.[19] These athletes must be able to create movements that go beyond the average range of motion and often create strain on the musculoskeletal system, leading to a higher likelihood of developing generalized joint hypermobility. Also, these professional athletes often start their sport at a young age, and the numerous years of repetitive stress on the musculoskeletal system puts excess strain on the joint capsules and can lead to the development of generalized joint hypermobility. Another study also found that several musculoskeletal disorders have been linked to hypermobility.[20] Some of these conditions include congenital hip problems, delayed motor development, lower limb arthralgias, congenital limb deficiencies, chronic pain syndromes, and foot disorders. Many of these diseases are correlated with excessive distention in joint spaces or put the bodies in position to develop recurrent sprains from unequal muscular activity. This study also found that obesity, sedentary lifestyles, and poor exercise can correlate with the development of hypermobility due to the weakness of the muscles surrounding the joint and excessive pressure on the joints. Genetic disorders can also contribute to the development of hypermobility as disorders such as Ehlers Danlos syndrome is often passed down through families and leads to a disruption of the joint.

Implications

Hypermobile joints can have several implications for those who are involved in athletics. According to one study, it has been shown that hypermobility can increase the occurrence of injuries in those involved with contact sports due to the increased range of motion and instability of the athlete and the reduced core stability that can result.[21] The unstable positions the hypermobile joint is put into combined with the excess flexibility of the joint leads to an increased risk of injury. In particular, runners and hockey players had the highest number of participants with hypermobility when compared to other sports such as rugby, tennis, swimming, and football. Another study also found that athletes with joint hypermobility are at a higher risk of developing shoulder injuries when compared to athletes without joint hypermobility.[22] This is found in those who have general joint hypermobility affecting several joints and in those participating in the military, gymnastics, and other various competitive sports which can lead them to have a threefold higher chance of developing a shoulder injury.

Measures

The Beighton Score uses a nine-point scoring system that assesses hypermobility. It was developed as an epidemiological tool in 1964 called the Carter and Wilkinson scoring system but was later adopted as a diagnostic clinical tool.[23] In this test, there are 5 maneuvers to perform. Four passive bilateral movements and one active full body motions that can be a quick screen done in around two minutes. The five maneuvers consist of 1) passive hyperextension and dorsiflexion of the 5th metacarpophalangeal joint greater than ninety degrees, 2) passive hyperextension of the elbow greater than ten degrees, 3) passive hyperextension of the knee greater than ten degrees, 4) passive opposition of the thumb to the flexor aspect of the forearm, 5) and the ability to actively forward flex with knees fully extended so to touch palms flat to the floor. The first four maneuvers are given a maximum score of 2 due to the fact they are performed bilaterally with the last maneuver being scored with a 0 or 1. The maximum score is nine indicating hyperlax ligaments whereas a score of zero is tight. It is commonly agreed that scores between 0-3 are normal whereas scores between 4-9 represent ligamentous laxity although there is no universal agreement on thresholds.[23] Boyle investigated the interrater and intrarater reliability of the Beighton Score were 81% and 89% and concluded that the reliability was good to excellent.[24] Smits-Engelsman et al evaluated the validity of this test and found that when a goniometer is used, it is a valid instrument to measure generalized joint mobility in children 6 to 12 years. In addition, it showed no significant differences in sex in the population.[25] Although there are other hypermobility scoring systems such as the 10-point hospital Del Mar Criteria, Bulbena scale, Lower Limb Assessment Scale, and the Rotés-Quérol scale, the Beighton Scale was used in this study due to its ease of use, validity, and good interrater and intrarater reliability.

The Foot Posture Index (FPI) was an additional measure utilized in this year's continuation of the study. The FPI was developed by Anthony Redmond in 1996 to quantify foot posture.[26] The six criteria examined in the FPI include: talar head palpation, infra and supra lateral malleolar curve, calcaneal frontal plane position, prominence in the region of the talonavicular joint, congruence of the medial longitudinal arch, abduction/adduction of the forefoot on the rearfoot. The criteria are scored on a -2 to +2 scale. Each component test is graded a 0 for neutral, -2 for clear signs of supination, and +2 for clear signs of pronation. Unless the criteria for each score are obviously met, a more conservative score should be awarded. The aggregate scores give an estimate of the overall posture of the foot. A high positive aggregate score indicates a pronated posture, significant negative values indicate a supinated posture. The patient should stand in double limb support with their arms at their side and look straight forward before starting the observation. Having the patient march in place may be helpful to ensure the patient is in a natural position.

The most common foot posture for men and women ranges from neutral to slightly pronated. A previous study found the average FPI score to be 2.76 for all subjects, 2.98 for men and 2.55 for women.[27] Hawke et al[28] reported that a higher FPI score was associated moderately with a higher Beighton score in children. Children with significantly pronated feet have greater lower limb and whole-body flexibility, but not greater ankle joint flexibility. Runners with significantly supinated feet (score from -12 to -5 on the FPI) are at 76.8 times greater risk of injury compared to runners with a neutral (scores from 0 to 5) Foot Posture Index score.[29] On the other hand, runners with significantly pronated (scores from 10 to 12) feet are at 20 times greater risk of injury compared to those with a neutral foot posture.

CHAPTER III

METHODS

Subjects

A total of 46 participants from the University of North Dakota PT and OT programs volunteered to partake in this study. Their ages range between 21 to 31 years, with 30 females and 16 males. This research study was approved by the IRB, IRB-201904-285 (Appendix A). All subjects in this study were fully enrolled in the physical therapy and occupational therapy professional curriculum at the time of data collection. Participants were excluded if they were: pregnant, currently under the care of a physician for a musculoskeletal injury or had a known connective tissue disorder. The final subject inclusion was n=46 due to no one being excluded. Refer to Table 1 for the demographic particulars for the participants.

Table 1: Demographics of Participants

Characteristic	Mean	Age range
Age (years)	22.8	21-31
Height (inches)	63.9	60-76
Weight (pounds)	163.7	110-265

Instrumentation

Goniometric measurements for the elbow, 5th digit, and knee were assessed with an EasyAngle® digital goniometer. The joints assessed were determined based on the Beighton Hypermobility scale[30]. The cut-off to be considered hypermobile for each joint were 10 degrees of hyperextension for the knee and elbow and 5th metacarpal phalangeal joint extension over 90 degrees based on goniometric measurements. The ability to achieve passive thumb apposition to forearm and forward trunk flexion with palms flat on the floor was assessed as well (see Figures 1-7). The Foot Posture index was used to assess the degree to which a foot can be considered to be in a pronated, supinated, or neutral position. Five of the six criteria in the FPI are assessed by observation only with the participant standing in a relaxed position. The talar head position is the only criterion that requires palpation. The FPI was documented in the format found in Appendix C.

Intra-rater reliability was established prior to data collection to confirm goniometric consistency and reliability within the researchers. Reliability for clinical measurements is defined as at least .95. Following the completion of the reliability study, it was found that researcher one had the most reliability testing the knee, researcher two had the most reliability testing thumb to forearm and hands to floor, researcher three had the most reliability testing the foot posture index, and researcher four had the most reliability testing the elbow and finger. The reliability for these measures were between .906 and .961 across the measures. The researcher collected the same goniometric measurement of all the participants for the sake of the least possible measurement of error throughout the study. The EasyAngle® digital goniometer was used for measurements of the elbow, 5th digit, and knee. It was found that digital goniometers were found to have higher inter-rater ICC values, according to Carey et al[30.] The EasyAngle® digital goniometer and standard goniometer were used by all four researchers to establish reliability, and just the digital goniometer was used for the study due to the greater reliability and consistency.

The joints measured were determined based upon the Beighton Hypermobility Scale which includes the aforementioned along with passive opposition of the thumb to the forearm and forward trunk flexion (See Figures 1-7).[31] Joints were documented in the format found in Appendix C.

Prior to the study, the researcher performing the FPI completed 30 assessments using the index as recommended for novice users to increase the reliability of the assessment. The intra-tester reliability of the FPI ranged from 0.81 to 0.91.

Procedure

To start the study process, the participants read and signed the consent form (Appendix B). The participants were given insight into the intent and process of the study. Each participant was asked to do an online Qualtric survey regarding the participants' injury history. Once the participants completed the survey, the researchers assessed range of motion by performing the Beighton Hypermobility Assessment along with assessing foot positioning using the Foot Posture Index on each participant (figure 2). The assessments were performed in a private room in a standardized fashion to ensure patient confidentiality and authenticity of the results. Each volunteer performed fifth metacarpal extension, thumb opposition, elbow extension, knee extension, forward trunk flexion, and foot posture assessment in no specific order. Ratings of hypermobility were given on a scale of zero to nine. Points were attributed to each joint measurement that was considered hypermobile according to the Beighton Hypermobility Assessment. When subjects were measured and had four or more points in the "yes" column, they were classified as hypermobile.

The results of the Beighton Hypermobility Assessment were recorded on the data collection form marked with the participant's identification number (Appendix C). In accordance with maintaining participant confidentiality, the identification number related to their survey was the only information linked back to the participant. Each joint measured was recorded with an "X" in the column marked "yes" or "no" signifying hypermobility or the lack thereof.

The results from the FPI were scored on a scale of -2 to 2 for each individual foot. The score for each of the six criteria included in the index was added to calculate the total score for each foot. One participant's right foot was scored all zeros due to significant swelling from a recent ankle sprain. This participant was still included in the study.

Data Analysis

The survey utilized for this study included questions pertaining to the subject's injury history, along with the subjects' age, gender, height, weight, dominant hand, whether they are pregnant or nursing, under the care of a physician, and if they have a diagnosed connective tissue disorder. Additional questions were asked that pertained to athletics, such as whether or not the participant completed athletics at any time during school, what their current athletic activity level is, and any history of injury. If the subject answered "yes" to any history of injury, follow-up questions were asked regarding the mechanism of this injury, when it occurred, if they sought medical attention for the injury, if they received PT or OT for this injury, if they had surgery for this injury, and if it resulted in lasting disability.

The data was compiled and analyzed using IBM statistical descriptives, which was used to define the sample. Systemic hypermobility was analyzed along with each individual joint. Even if the individual did not have systemic hypermobility, the data was analyzed to determine if the individual has hypermobility in each particular joint. Hypermobility was also compared to the participants' non-hypermobile peers, along with correlation to any soft tissue injury, any recurrence rates of injury, and any correlation between foot posture and hypermobility.

Table 2: Beighton Scale Measurements

Measurement	Position	Directions	Goniometric Alignment	Point Obtained If
Trunk Flexion Test	Standing with feet shoulder width apart and knees extended	The examiner demonstrated and verbally described, then was completed by the subject	N/A	Subject was able to touch their palms flat on the floor
Thumb Apposition	Seated	The examiner demonstrated and verbally described, the the subject passively performed	N/A	Subject was able to oppose the thumb to the forearm, one point per side (R/L)
Elbow Extension	Supine with 20° of abduction, neutral rotation, no flexion, and full wrist supination	Subject relaxed in supine with 2" rolled towel	Axis: lateral epicondyle Stationary arm: Acromion Moveable arm: radial head and styloid process	Subject had 10° or more of hyperextension, one point per side (R/L)
Knee Extension	Supine with neutral hip rotation	Subject relaxed with heel on 10" rolled towel	Axis: joint line Stationary arm: Lateral epicondyle and greater trochanter Moveable arm: Fibular head and lateral malleolus	Subject had 10° or more of hyperextension, one point per side (R/L)
Fifth Metacarpal Extension	Seated with shoulder abduction, 90° elbow	Subject asked to pull the proximal phalanx into extension to a degree	Axis: 5th MCP joint Stationary arm: 5th metacarpal Moveable arm: 5th proximal phalanx	Subject had 90° or more of extension. One point per side (R/L)

Table 3: Criteria for Scoring the Foot Posture Index

	-2	-1	0	1	2
Talar head palpation	Talar head palpable on lateral side/but not on medial side	Talar head palpable on lateral side/ slightly palpable on medial side	Talar head equally palpable on lateral and medial side	Talar head slightly palpable on lateral side/palpable on medial side	Talar head not palpable on lateral side/but palpable on medial side
Supra and infra lateral malleolar curvature	Curve below the malleolus either straight or convex	Curve below the malleolus concave, but flatter/more than the curve above the malleolus	Both infra and supra malleolar curves roughly equal	Curve below the malleolus more concave than curve above malleolus	Curve below the malleolus markedly more concave than curve above malleolus
Calcaneal frontal plane position	More than an estimated 5° inverted (varus)	Between vertical and an estimated 5° inverted (varus)	Vertical	Between vertical and an estimated 5° everted (valgus)	More than an estimated 5° everted (valgus)
Prominence in the region of the talonavicular joint (TNJ)	Area of TNJ markedly concave	Area of TNJ slightly, but definitely concave	Area of TNJ flat	Area of TNJ bulging slightly	Area of TNJ bulging markedly
Congruence of the medial longitudinal arch	Arch high and acutely angled towards the posterior end of the medial arch	Arch moderately high and slightly acute posteriorly	Arch height normal and concentrically curved	Arch lowered with some flattening in the central portion	Arch very low with severe flattening in the central portion – arch making ground contact
Abduction/adduction of the forefoot on the rarefoot	No lateral toes visible. Medial toes clearly visible	Medial toes clearly more visible than lateral	Medial and lateral toes equally visible	Lateral toes clearly more visible than medial	No medial toes visible. Lateral toes clearly visible

Figure 1: Measure of hypermobility at the knee

A researcher is taking a goniometric measurement at the knee joint.

Figure 2: Foot Posture Index Analysis From the Posterior View

A researcher is examining a participant to determine their foot posture index.

Figure 3: Foot Posture Index Analysis, Palpation of Talus

A researcher is palpating a participant's talus to determine their foot posture index.

Figure 4: Measure of Hypermobility at the Elbow

A researcher is taking a goniometric measurement at the elbow joint.

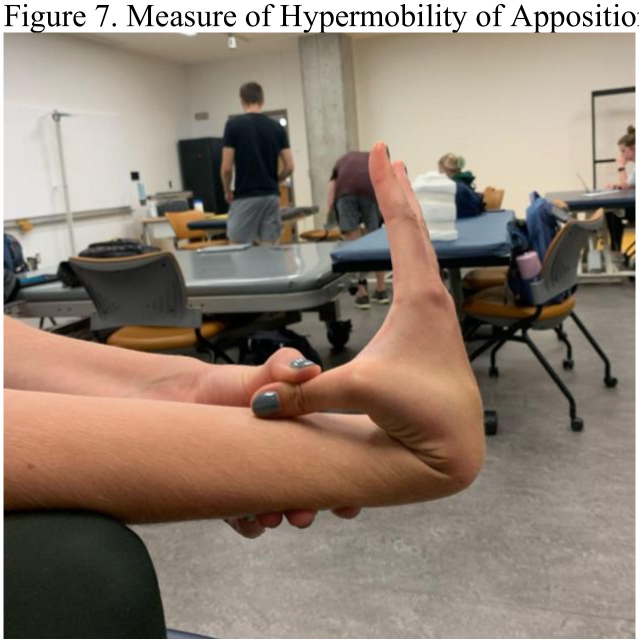
Figure 5: Measure of Hypermobility at the Fifth Digit

A researcher is taking a goniometric measurement of the fifth digit.

Figure 6: Measure of Hypermobility with Trunk Forward Flexion

A participant is demonstrating the trunk forward flexion with palms flat on the floor.

Figure 7. Measure of Hypermobility of Apposition of the Thumb to the Forearm



A participant is demonstrating apposition of the thumb to the forearm.

CHAPTER IV

RESULTS

Forty-six PT and OT students from the University of North Dakota volunteered to partake in this study. Their ages range between 21 to 31 years, with 30 females and 16 males. No students were excluded due to the criteria set forth. Findings show that 21.74% (n=10) of all subjects were considered to be systematically hypermobile.

Table 4: Total Systemic Hypermobility Among PT and OT Students.

Characteristics	n	Percentage
Systemic Hypermobility		
Yes	10	21.7
No	36	78.3

These findings were found based on the use of the Beighton Hypermobility Scale, with a score of four or greater. Data from these tests were grouped into categories by location of the injury and the percentage of sprains seen in hypermobile participants. The relationship between injuries and hypermobility at a joint was also assessed in individuals who were hypermobility but did not have systemic hypermobility.

Table 5: Relationship Between Individual Joints and Hypermobility.

Joint	# Hypermobile	% of Participants
Left 5th Finger	2	4.3%
Right 5th Finger	2	4.3%
Left Thumb	12	26.1%
Right Thumb	13	28.3%
Left Elbow	17	37%
Right Elbow	15	32.6%
Left Knee	7	15.2%
Right Knee	7	15.2%
Trunk	15	32.6%

Table 6: Characteristics of the Volunteer Participants

Characteristics	n	Percentage
Gender		
Female	30	65.2
Male	16	34.8
Hand Dominance		
Left	1	2.2
Right	45	97.8
Joint Involvement (sprains)		
Ankle	27	58.70
Knee	2	4.38
Any finger	6	13.04
Elbow	2	4.38
Physical Activity (days/week)		
0	2	4.38
1	1	2.17
2	2	4.38
3	6	13.04
4	12	26.09
5	16	34.78
6	5	10.87
7	2	4.38

There is not a statistically significant difference between the number of soft tissue injuries reported by PT and OT students with systemic hypermobile compared to those who are not hypermobile. A large majority of the reported soft tissue injuries were from participants without systemic hypermobility. The average number of soft tissue injuries reported for individuals who were not hypermobile was 1.53 injuries per participant. The average number of soft tissue injuries reported for individuals with systemic hypermobility was 1.40 injuries per participant. One systemically hypermobile participant did report four soft tissue injuries which was the highest number reported.

Table 7: Association of Soft Tissue Injuries and Participants With Systemic Hypermobility.

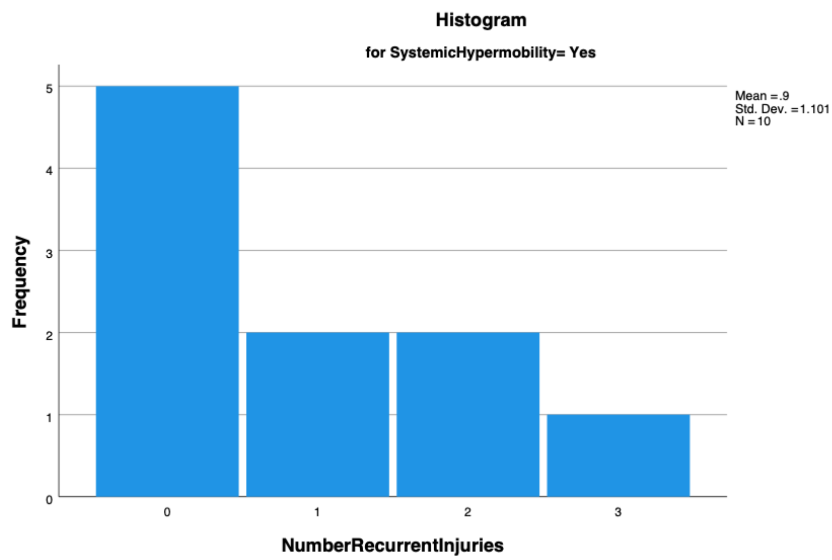
Number of soft tissue injuries	Number of participants	Percentage within Soft Tissue Injury
0 Soft Tissue Injuries	3 participants	37.5%
1 Soft Tissue Injury	3 participants	20.0%
2 Soft Tissue Injuries	2 participants	12.5%
3 Soft Tissue Injuries	1 participant	16.7%
4 Soft Tissue Injuries	1 participant	100%

Table 8: Association of Soft Tissue Injuries and Participants Without Systemic Hypermobility.

Number of soft tissue injuries	Number of participants	Percentage within Soft Tissue Injury
0 Soft Tissue Injuries	5 participants	62.5%
1 Soft Tissue Injury	12 participants	80.0%
2 Soft Tissue Injuries	14 participants	87.5%
3 Soft Tissue Injuries	5 participant	83.3%
4 Soft Tissue Injuries	0 participants	0%

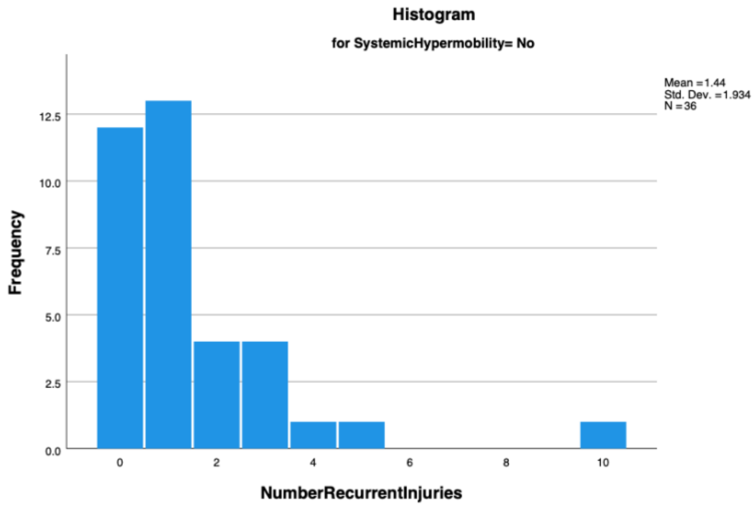
As the data shows in the bar graph below, there seem to be more recurrent injuries in those who are not hypermobile than those who are hypermobile. The number of recurrent injuries in those who are hypermobile only goes up to three recurrent injuries, with only one person. One and two recurrent injuries also only had two people each. For those who are not considered to be hypermobile, there is one who has had a recurrence of ten times, followed by the next highest recurrence of four and five times for one person each. Overall the mean for those who are not hypermobile was 1.44, whereas for those who are hypermobile the mean rate of recurrence was 0.9 showing there was no increase in the rate of recurrence for those with hypermobility than those without.

Figure 8: Association Between Recurrent Injury and Systemic Hypermobility



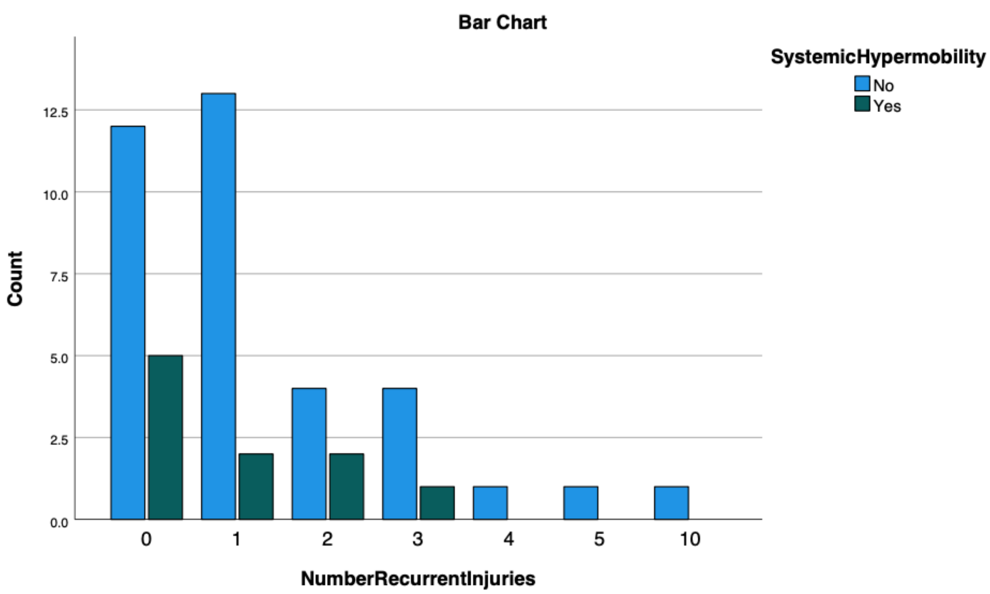
This graph compares the number of injuries among individuals who exhibit systemic hypermobility.

Figure 9: Association Between Recurrent Injury and No Systemic Hypermobility



This graph compares the number of recurrent injuries with individuals who do not exhibit systemic hypermobility.

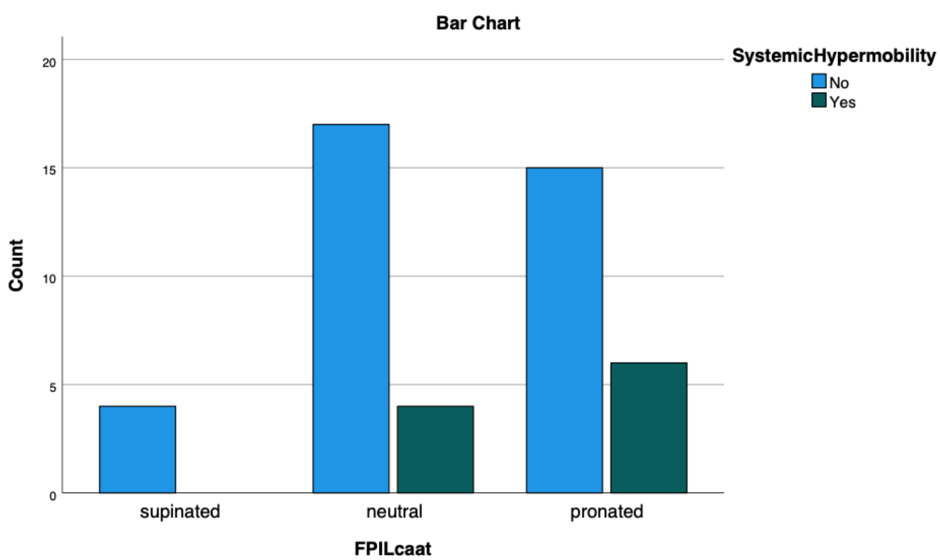
Figure 10: The Association Between the Number of Recurrent Injuries and Systemic Hypermobility



This graph compares individuals with and without systemic hypermobility along with the number of recurrent injuries they have had.

As shown in the figure below, 4 participants in this study were shown to have supinated foot posture and none of them have systemic hypermobility. There were shown to be 21 total participants with neutral foot posture, 17 of which do not have systemic hypermobility, and 4 participants were shown to have systemic hypermobility. There were 21 total participants with pronated foot posture, 15 participants without systemic hypermobility, and 6 participants with systemic hypermobility. When determining the correlation between systemic hypermobility and foot posture, there appears to be no relationship between foot posture and systemic hypermobility.

Figure 11: The Association Between Systemic Hypermobility and Foot Posture.



This graph displays the number of participants with each foot posture and whether they exhibit systemic hypermobility.

CHAPTER V

DISCUSSION AND CONCLUSION

Discussion

This study was carried out to assess hypermobility in physical therapy and occupational students as well as inquire about their previous injury history. The data was analyzed to see if there were any correlations between the hypermobility and injury information collected. Following our study, it was shown that 10/46 physical and occupational therapy students demonstrated systemic hypermobility. The prevalence of systemic hypermobility among our participants was 21.7%, which is greater than the rate systemic hypermobility of the general public at 4-13%.[1]

It has previously been found that individuals with hypermobility have increased incidence of musculoskeletal injuries. Our research did not reflect what the literature has shown in the past. Those who are systematically hypermobile reported less soft tissue injuries along with less recurrent injuries when compared to those who do not have systemic hypermobility[8]. Furthermore, it was shown that there was no specific relationship between foot posture and systemic hypermobility. Those with systemic hypermobility did show to have slightly more pronated foot posture over neutral foot posture, however this was not a statistically significant value. Those without systemic hypermobility were shown to have mostly neutral and pronated foot posture, with only 4 participants demonstrating supinated foot posture.

The individual joints found to have the highest prevalence were the L elbow (37%) and the R elbow (32.6%). Only 2 out of the 46 participants reported sprains of their elbow in the questionnaire. It is intriguing that a joint with such a high rate of hypermobility has very few sprains. Further research should examine the rate of other injuries beyond just sprains among individuals with hypermobile elbows. This would provide better understanding of the types of injuries individuals with hypermobile elbows are susceptible to and ways to avoid said injuries. The trunk was tied for the second highest rate of hypermobility (32.6%). Seven out of the forty-six participants reported a previous strain or contusion of their low back. Further breakdown of how many of these individuals experienced a strain versus how many had contusions would be beneficial. The relationship between the individuals who had a low back strain and individuals who are hypermobile in this area would be an interesting aspect to examine further. The active forward flexion test with palms flat on the floor used to determine hypermobility of the trunk in this study is impacted by other joints. The hip and ankle joints play a large role in this test along with the trunk. It is possible that limitations in range of motion of the hip and ankle could produce a negative test result in individuals who have hypermobility of their trunk. On the other hand, individuals with excessive range of motion at the hip and ankle could produce a positive test result even if their trunk is not hypermobile. To help address this issue, the FPI was included to provide more information on the ankle's role in hypermobility. Ankle sprains were the most common injury reported (58.7). The relationship between foot posture and the rate of ankle sprains was not assessed in this study. This relationship could potentially help identify individuals who are at a greater risk for ankle sprains in a timely manner, as the FPI only takes two minutes to complete. Following the study, it was also shown that the left thumb hypermobility was present in 26.1% of the participants, while the right thumb was hypermobile in 28.3% of participants. This data is relevant because of the nature of physical and occupational therapists work. They are hands-on every day at work, especially while performing manual therapy such as soft tissue massage. This could be a concern if they are hypermobile because joint problems could arise from repetitively being used over long periods of time.[6]

Preventative measures should be taken by those with hypermobile joints.[8] There are many different ways to avoid injuries second to hypermobility. Going into movements past the end range of motion should be avoided, so as not to stress structures that may be. Exercises to improve proprioception can also decrease the chance of future injury. General muscle strengthening is widely implemented as a way to prevent injuries as well.[32] Athletes can perform sport-specific strengthening exercises to further reduce risk of injury. Another intervention that can be used is taping, such as McConnell taping.[33] This can reduce the range of motion allowed at the joint which can protect the individual. Using proper body mechanics may be beneficial for anyone, especially those with hypermobility.[34] Following guidelines like these can allow PT's and OT's to stay in the profession longer and with less rates of injuries.

Limitations of the Study

One limitation to this study was the limited number of participants that were involved in the data collection for this study. It would have been beneficial to recruit more participants as this would decrease the chance of error or bias and would be more representative of the larger population. This study was also limited by the amount of occupational students who participated. There were only three occupational students who volunteered in this study, which is not very representative of the occupational therapy population. The rest of the participants were all physical therapy students. Additionally, a limitation of this study is the possibility that participants misunderstood the electronic questions, were unable to recall previous injuries, and the potential to neglect questions on the survey. Another limitation to this study was the time frame that this data was collected during. The data collection took place over the course of one week during the summer, however it would have been beneficial to increase the time frame to winter, spring, and fall in order to gain more participants.

To improve this study, a more detailed analysis could have been made by utilizing more of the data from the survey that participants completed. For example, it would be beneficial to determine the correlation between hypermobility and specific injuries, such as sprain, strains, fractures, and dislocations. It would also be beneficial to determine which sports the participants were involved in and its correlation with systemic hypermobility along with any correlation between gender and hypermobility. In future studies, it is recommended to have a larger sample size and include a more detailed data analysis between systemic hypermobility and the specific characteristics of the participants.

Conclusion

This research study investigated the prevalence of hypermobility between physical therapy and occupational therapy students, the correlation of soft tissue injuries and hypermobility, the correlation of recurrent rate of injuries and hypermobility, and the correlation between foot posture and hypermobility. Overall, there was no statistically significant data found in this research study as there was not a correlation between hypermobility with any of these factors. This data did not support the research found in literature, which is likely due to the small sample size of this study and the limitations and potential errors that occurred during data collection. Future studies are necessary and should utilize a larger sample size with repeated measures in order to determine the influence that systemic hypermobility can have on physical therapy and occupational therapy students.

APPENDIX A

UNIVERSITY OF NORTH DAKOTA

UND.edu

Office of Research Compliance & Ethics
Tech Accelerator, Suite 2050
4201 James Ray Drive Stop 7134
Grand Forks, ND 58202-7134
Phone: 701.777.4279
Fax: 701.777.2193

July 6, 2022

Principal Investigator:	Susan H.N. Jeno, PT, Ph.D., CES
Project Title:	Association of Generalized Joint Hypermobility and Occurrence of Musculoskeletal Injury Among Physical and Occupational Therapy Students
IRB Project Number:	IRB-201904-285
Project Review Level:	Expedited 4, 7
Date of IRB Approval:	7/6/2022
Expiration Date of This Approval:	6/14/2023

The Protocol Change Form and all included documentation for the above-referenced project have been reviewed and approved via the procedures of the University of North Dakota Institutional Review Board.

You have approval for this project through the above-listed expiration date. When this research is completed, please submit a termination form to the IRB. If the research will last longer than one year, an annual review and progress report must be submitted to the IRB prior to the submission deadline to ensure adequate time for IRB review.

The forms to assist you in filing your project termination, annual review and progress report, adverse event/unanticipated problem, protocol change, etc. may be accessed on the IRB website: http://und.edu/research/resources/human-subjects/

Sincerely,

Michelle L Bowles

Michelle L. Bowles, M.P.A., CIP
Director of Research Assurance & Ethics

APPENDIX B

INFORMED CONSENT

TITLE: *Association of Generalized Joint Hypermobility and Occurrence of Musculoskeletal Injury in Physical and Occupational Therapy Students*

PROJECT DIRECTOR: *Susan H N Jeno, PT, PhD*

PHONE # *777-2831*

DEPARTMENT: *Physical Therapy*

STATEMENT OF RESEARCH

A person who is to participate in the research must give his or her informed consent to such participation. This consent must be based on an understanding of the nature and risks of the research. This document provides information that is important for this understanding. Research projects include only subjects who choose to take part. Please take your time in making your decision as to whether to participate. If you have questions at any time, please ask.

You are invited to be in a research study comparing generalized joint hypermobility and injury rates because you are a student in the professional program of either Physical or Occupational Therapy at the University of North Dakota.

The purpose of this study is to determine if individuals identified with generalized joint hypermobility (excessive joint mobility) are at a higher risk of incurring musculoskeletal injury. The findings of this study will help determine if preventative steps need to be taken to prevent injury in individuals with hypermobility during the academic preparation and future professional practice. You will be made aware if you are identified as being hypermobile. Results of the study will be available to you to assess the need of a preventative program. Approximately 200 people will take part in this study at the University of North Dakota. Your participation in the study will last approximately 20 minutes. You will need to visit the Department of Physical Therapy one time.

WHAT WILL HAPPEN DURING THIS STUDY?

Each subject will be asked to complete a questionnaire pertaining to demographic data, activity, and injury history. The subject is free to skip any questions that he/she would prefer not to answer. The Beighton method of testing joint laxity and criteria will be used to as the measure of generalized joint hypermobility. Subjects will be assessed on their ability to do the following tests: Hyperextend the little finger beyond 90 degrees, hyperextend the elbows beyond 10 degrees, hyperextend the knees beyond 10 degrees, apposition of the thumb to the flexor aspect of the forearm, and forward flex the trunk so the palms easily touch the floor with the knees fully extended. A scoring system of zero to nine is utilized with one point given for each extremity bilaterally and one point for the trunk if the test is positive for the aforementioned criteria. A subject with a score of 4 or more will be considered hypermobile. It is expected that the entire procedure will take approximately 20 minutes to complete.

Approval Date: 30
Expiration Date: 9
University of North Dakota IRB

Date________
Subject Initials: ________

WHAT ARE THE RISKS OF THE STUDY?
There may be some risk from being in this study, though the risks to the subjects are anticipated to be minimal and unlikely in this study. The only risk the subject may experience is a momentary slight discomfort if excessive force is used to move their joint into position for the tests. The subjects will be asked to move their joints only within their available range. If injury should occur, medical treatment will be available, including first aid, emergency treatment, and follow-up care as it is to a member of the general public in similar situations. payment for such treatment must be provided by the subject and their third party payer, if any.

WHAT ARE THE BENEFITS OF THIS STUDY?
By assessing if individuals with generalized joint hypermobility are at a greater risk of injury during normal daily activities compared to individuals who are not hypermobile, therapeutic methods can be developed to prevent injury. With this knowledge, hypermobile individuals may be able to avoid injury. The subjects in this study will be made aware if they have generalized joint hypermobility or not. Following the study, the results will be made available to the subjects to allow them to assess whether a preventative program would be beneficial to them. The findings of this study will be directly applicable to injury prediction and the need for preventative intervention. To society as a whole, recognition of injury rates and taking preventative measures to limit the those injuries will help to control health care costs for the professionals and hopefully help them lead longer, injury free careers. You will not have any costs for being in this research study nor will you will not be paid for being in this research study.

WHO IS FUNDING THE STUDY?
The University of North Dakota and the research team are receiving no payments from other agencies, organizations, or companies to conduct this research study.

CONFIDENTIALITY
The records of this study will be kept private to the extent permitted by law. In any report about this study that might be published, you will not be identified. Your study record may be reviewed by persons that audit IRB procedures at the University of North Dakota. Any information that is obtained in this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained as each participant will be assigned a randomly selected identification number at the beginning of the study, which will be known by the researchers only. All information involving the research study will be secured in a locked cabinet inside the Department of Physical Therapy at the University of North Dakota. A hard copy of the statistically analyzed data along with the data collection sheets from the study will be secured in a locked cabinet inside the Department of Physical Therapy located at the University of North Dakota. Unless the data is required for future studies, the information will be destroyed via shredding three years after the study has been completed.

If we write a report or article about this study, we will describe the study results in a summarized manner so that you cannot be identified.

Approval Date: 30
Expiration Date: 9
University of North Dakota IRB

Date______
Subject Initials: ______

COMPENSATION FOR INJURY

In the event that this research activity results in an injury, treatment will be available including first aid, emergency treatment and follow-up care as needed. Payment for any such treatment is to be provided by you (you will be billed) or your third-party payer, if any (such as health insurance, Medicare, etc.) No funds have been set aside to compensate you in the event of injury. Also, the study staff cannot be responsible if you knowingly and willingly disregard the directions they give you.

IS THIS STUDY VOLUNTARY?

Your participation is voluntary. You may choose not to participate or you may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Your decision whether or not to participate will not affect your current or future relations with the University of North Dakota.

CONTACTS AND QUESTIONS?

The researchers conducting this study are Susan H. N. Jeno, PT, PhD and Year 2 Graduate Physical Therapy Students. You may ask any questions you have now. If you later have questions, concerns, or complaints about the research please contact Susan Jeno at 777-2831 during the day. If you have questions regarding your rights as a research subject, or if you have any concerns or complaints about the research, you may contact the University of North Dakota Institutional Review Board at (701) 777-4279. Please call this number if you cannot reach research staff, or you wish to talk with someone else.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Subjects Name: ____

________________________________ ______________
Signature of Subject Date

Approval Date: ______30______
Expiration Date: ______9______
University of North Dakota IRB

Date__________
Subject Initials: __________

APPENDIX C

ID #______________

DATA COLLECTION FORM

JOINT TESTED	YES	NO
5TH FINGER LEFT		
RIGHT		
THUMB LEFT		
RIGHT		
ELBOW LEFT		
RIGHT		
KNEE LEFT		
RIGHT		
TRUNK		
TOTAL SCORE		

Foot Posture Index Datasheet

Patient name ***ID number***

	FACTOR	PLANE	SCORE 1 Date______ Comment______		SCORE 2 Date______ Comment______		SCORE 3 Date______ Comment______	
			Left -2 to +2	**Right** -2 to +2	**Left** -2 to +2	**Right** -2 to +2	**Left** -2 to +2	**Right** -2 to +2
Rearfoot	Talar head palpation	*Transverse*						
	Curves above and below the lateral malleolus	*Frontal/ transverse*						
	Inversion/eversion of the calcaneus	*Frontal*						
Forefoot	Prominence in the region of the TNJ	*Transverse*						
	Congruence of the medial longitudinal arch	*Sagittal*						
	Abd/adduction forefoot on rearfoot	*Transverse*						
	TOTAL							

Reference values
Normal = 0 to +5
Pronated = +6 to +9, Highly pronated 10+
Supinated = -1 to –4, Highly supinated –5 to -12

APPENDIX D

ID#__________

Patient Questionnaire

Name____________________________________

Date of Birth________________ Height_______________ Weight___________

Dominant Arm _ _ _ _ _ _ _ _ _ _

Sensitivity to: Latex Y N lsopropyl Alcohol skin sensitivity Y N
If yes, please explain

Do you have any history of shoulder pain/pathology? Y N

If yes, please explain

Do you have any history of back or spinal disc/pathology? Y N

If yes, please explain

Are you pregnant? Y N

Do you have any condition for which lying on your stomach would be a problem? Y N

If yes, please explain.

All the information provided in this questionnaire has been answered accurately and to the best of my knowledge.

Signature of participant Date

Place indicate your **age** at time of injury in the appropriate box to indicate the type of injury you have sustained, if more than one injury, please indicate the **number** (ie. 2 left ankle sprains age 16 and 18).

Sprain			**Strain/contusion**			**Fracture**			**Disclocation**		
Joint	Right	Left	**Muscle**	Right	Left	**Bone**	Right	Left	**Bone**	Right	Left
Toes			Foot			Toes			Toes		
Ankle			Anterior leg			Metatarsal			Metatarsal		
Knee			Posterior leg			Tarsal			Tarsal		
Hip			Quadriceps			Tibia			Tibia		
Back/Neck			Hamstrings			Fibula			Fibula		
Shoulder			Hip Adductors			Patella			Patella		
AC/SC			Hip Flexors			Femur			Femur		
Elbow			Gluteals			Pelvis			Pelvis		
Wrist			Low back			Vertebrae			Spine		
Fingers			Mid back			Rib			Rib		
Thumb			Neck			Clavicle			Clavicle		
Other			Abdominals			Scapula			Scapula		
			Anterior Chest			Humerus			Humerus		
Ligament Rupture			Biceps			Radius			Radius		
ACL			Triceps			Ulna			Ulna		
PCL			Wrist flexors			Carpal			Carpal		
MCL			Wrist extensors			Metacarpal			Metacarpal		
LCL			Finger flexors			Finger			Finger		
ATF			Other hand muscles			Thumb			Thumb		
Other			Thumb muscles			Skull			Skull		
						Jaw			Jaw		

Other (Please specify and include age you were when you were injured):

Of your listed injuries, please indicate how many injuries were due to:							
Condition	**Sprain**	**Strain**	**Contusion**	**Fracture**	**Dislocation**	**Concussion**	**Other**
Overuse							
Trauma							
Other							
If known, please indicate what activity caused each injury listed above, choose 1 option for each injury.							
Sport Performance							
Work							
General Activity							
Other							

Please indicate which, if any, injuries for which you sought medical attention.

Please indicate which, if any, injuries for which you received Physical or Occupational Therapy.

Please indicate which, if any, injuries required surgery.

Please indicate which, if any, injuries resulted in lasting disability.

Thank you for your time with this research study.

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