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Correlation of Generalized Joint Hypermobility and Knee Mobility with Knee Injury Prevalence and the Role of Lower Extremity Dominance

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CORRELATION OF GENERALIZED JOINT HYPERMOBILITY AND KNEE MOBILITY WITH KNEE INJURY PREVALENCE AND THE ROLE OF LOWER EXTREMITY DOMINANCE

By

Darin John Didier
Bachelor of Science in Physical Therapy
University of North Dakota, 1996

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

Grand Forks, North Dakota May 1997
This Independent Study, submitted by Darin John Didier in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

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In Memory Of My Grandfather Kermit Harstad
ABSTRACT

The purpose of this study was to determine the relationship of generalized joint hypermobility and knee mobility with knee injury prevalence among female high school basketball players. The role of lower extremity dominance with knee injury prevalence was also examined.

Sixty female subjects evaluated for generalized joint hypermobility and knee mobility using the Beighton hypermobility criteria and KT-1000 knee ligament arthrometer, respectively, were followed-up for this study. Subjects were previously evaluated as sophomore high school basketball players. Fifty-eight of the sixty eligible subjects participated in this study as high school juniors by: 1) completing a survey indicating their level of participation in basketball and any occurrence of injury since the previous measures were taken and 2) performing tests and answering questions to determine lower extremity dominance.

No significant relationship (p > .05) was found when correlating the Beighton hypermobility scores and KT-1000 values with the number of knee injuries reported. None of the tests selected to assess lower extremity dominance proved to be significant predictors of knee injury. Data analysis for this study was limited due to the small sample size and a low number of reported knee injuries.
CHAPTER I
INTRODUCTION

Female athletes are at increased risk for certain sports-related injuries, particularly those involving the knee. In quick stopping and cutting sports such as basketball, females have an increased incidence of anterior cruciate ligament (ACL) injury by noncontact mechanisms.\textsuperscript{1,2,3,4,5,6}

An ACL rupture typically occurs as a deceleration injury in which an athlete has made an unanticipated change of direction with the foot in a fixed position. The athlete describes hearing or feeling a pop from deep within the joint and demonstrates an inability or unwillingness to continue play.\textsuperscript{7} Athletes who participate in basketball are at great risk for ACL injuries as it is well known that these type of injuries may occur as a result of external or internal rotation of the tibia with or without hyperextension. All of these mechanical phenomena occur repetitively in a running, jumping, and cutting sport such as basketball.\textsuperscript{8}

In 1985 the staff of the British Columbia Sports Medicine Clinic noticed an apparent trend toward an increasing frequency of referrals of female basketball players with acute or stress-related knee injuries. A study was undertaken to determine the frequency of ACL injuries seen in female basketball players referred to their clinic. Seventy-six basketball-related injuries in women were recorded during the stated time period of 30 months. Fifty-five (72\%) involved the knee, and 19 (35\%) of these knee injuries were ACL ruptures. The authors concluded that ACL rupture appears to be an injury
to which adolescent female basketball players are especially predisposed as the incidence in the clinic was five times that of their male counterparts. The mean age of injury was 17 years with 95% confidence limits of 14 to 20 years.\(^2\) The relation of gender to ACL injuries in intercollegiate basketball players was studied by Malone et al.\(^3\) Knee injury data collected from 29 institutions showed that females were 6.19 times as likely to sustain an ACL injury during their competitive season than their male counterparts. A report from the National Athletic Trainers' Association clinical symposium which projected high school injury rates in the United States found twenty-three percent of girls in an estimated 333,149 participants sustaining one time loss injury per year. It was estimated that of the injuries sustained, 18% were knee related.\(^9\)

Although a variety of hypotheses have been studied, at present there continues to be no conclusive evidence to support a reason for the increased rate of ACL injury in women.\(^4\)

The purpose of this study was to determine if female high school basketball players with higher generalized joint hypermobility scores and knee mobility scores are at increased risk for sustaining a knee injury, particularly involving the ACL. The reliability of using tests which assess lower extremity dominance for prediction of knee injury was also examined.
CHAPTER II
LITERATURE REVIEW

Women's participation in organized and recreational sports has increased dramatically over the past two decades as a result of added accessibility, encouragement and an increased focus on fitness.¹ With the increase in women's participation there has been a proportional increase in the incidence of sport-related injuries in women.¹⁰,¹¹ However, the increased number of sport-related injuries is not explained by the increased number of female participants alone. Instead, the literature indicates that females have a higher incidence of certain sports-related injuries, particularly those involving the knee, than males.¹,²,³,⁴,⁵,⁶,¹²

A study by Arendt et al⁴ collected data on a national sample of collegiate soccer and basketball athletes from 1989 to 1993 using the NCAA Injury Surveillance System. The study found that knee injuries were more prevalent among female athletes in both sports when expressed either as an injury rate or as a percentage of all injuries. A significantly higher rate of ACL injury was also found when comparing females to their male counterparts. Female soccer players sustained ACL injury at twice the rate of males while female basketball players had an injury rate four times that of male participants. No other knee structure examined (collateral or posterior cruciate ligament and patella or patellar tendon) exhibited such a distinctive difference in injury rates. The authors concluded that the increased risk of ACL injuries among women is
likely multifactorial, with no single structural, anatomic, or biomechanical feature solely responsible.

The anterior cruciate ligament (ACL) is the primary stabilizer of the knee. The ACL is composed of two or three principal parts, with each portion contributing to different aspects of stability and, therefore, susceptible to different stresses. From a structural and dynamic view, the two major portions of the ACL are the anteromedial and posterolateral bands.13 The fascicles of the anteromedial band (AMB) originate at the proximal aspect of the femur and insert on the anteromedial portion of the tibia. The remaining fascicles, the posterolateral band (PLB), originate at the proximal aspect of the femur and insert at the posterolateral portion of the tibia.14

The multiple fascicles which make up the ACL are primarily composed of well-aligned collagen fibers, with approximately 10% of the structure consisting of elastic fibers enmeshed in a mucopolysaccharide ground substance. Due to the nonparallel orientation of ligamentous collagen, only those fibers oriented in the direction of the principal load straighten and maintain a maximal load.

Because of its structural orientation, a portion of the ACL remains taut throughout the range of motion. Simply stated, the PLB becomes taut with knee extension, while the AMB becomes moderately lax. The opposite occurs with knee flexion due to the horizontal position of the femoral attachment, causing the AMB to become taut and the PLB to relax.

The collagen structure, alignment and anatomical placement of the ACL provides the ability for completion of its primary and secondary functions. The primary function of the ACL is to resist anterior displacement of the tibia on the femur. The secondary function of the ACL is to limit internal and external rotation of the tibia with respect to the femur.
The ACL is the strongest and least compliant ligamentous structure around the knee. Due to the unique structure of the ACL, however, it is particularly vulnerable to injury.\textsuperscript{13}

The various factors which may predispose an athlete to ACL injury has been an area of concern. In particular, many theories have been suggested concerning the increased rate of ACL injuries in women. Possible contributing factors can be divided into extrinsic factors (body movement in sport, muscular strength and coordination, shoe-surface interface, and level of skill and conditioning) and intrinsic factors (limb alignment, notch dimensions, ligament size, joint laxity).\textsuperscript{4}

Differences in sports undertaken between men and women may account for differences in knee injury rates, with most injuries considered sport and not gender specific.\textsuperscript{15} Comparable sports such as basketball, however, require adherence to rules and body movements that are very similar between genders. Despite this, females still experience a greater rate of ACL injuries than males competing in comparable sports.\textsuperscript{1,2,3,4,5,6}

Muscular weakness of the limbs has also been suggested as contributing to differences in rate of ACL injury between genders.\textsuperscript{4} Moore and Wade\textsuperscript{16} found that the hamstrings-to-quadriceps strength ratios in women were less than those in men. Grace et al\textsuperscript{17} found no significant relationship between the hamstrings-to-quadriceps strength ratio and the incidence of knee injuries in high school football players. A study by Lund-Hanssen et al\textsuperscript{18} showed a significantly higher hamstrings-to-quadriceps strength ratio in female handball players who experienced ACL injuries than in their uninjured teammates. No conclusions could be drawn from the study since the groups were not matched.
In general, males have been found to have greater absolute strength, defined as the absolute amount of force exerted or weight lifted, than females.¹⁹ In a literature review, Laubach²⁰ found studies of female's lower body strength to range from 57-86% of men's, averaging 71.9%. However, when body mass or relative strength is used as comparison, the female's lower body strength is almost identical when expressed relative to body mass.²¹ Wilmore²² measured strength relative to lean body mass and found greater upper body strength in men, but slightly greater lower body strength in women.

No conclusive evidence has been found suggesting muscular weakness of the limbs as a contributor to gender differences in ACL injury rate.⁴ Shoe-surface interface, particularly those with high coefficients of friction, has been suggested as a cause of ACL injury.⁴ However, this theory provides little explanation for differences in injury rates between males and females participating in sports which use the same playing surfaces and similar footwear.

Conditioning and experience may also contribute to gender differences in ACL injury rate.⁴ Poor conditioning has been associated with an increased incidence of knee injuries in female athletes.²³,²⁴ Most women have a baseline level of conditioning which is significantly lower than for their male counterparts.⁵,²⁵,²⁶,²⁷,²⁸ Experience is another factor as rapid increases in new programs may introduce new participants who are more susceptible to ACL injuries.¹,⁴

Intrinsic factors have also been suggested as a possible cause for the differences in knee injury rates between genders.⁴
Lower extremity alignment contributes directly to the forces and strain on the knee compartments, ligaments and musculotendinous structures. The female pelvis is generally wider than the male pelvis. The wider female pelvis produces varus at the hips (femoral angle usually <125°) and is frequently associated with increased anteversion of the femoral head. This increased femoral anteversion is accompanied by greater valgus at the knee. The quadriceps pull (Q angle) is higher with increased knee valgus. The greater varus at the hip and valgus at the knee have been blamed for a number of overuse syndromes seen around the hip, knee, and ankle in female athletes.

A retrospective study by Gray et al concluded that there was no apparent relationship between the tibial-femoral alignment, Q angle, and knee injury, particularly ACL injury, in a series of female basketball players with injured ACLs. Little data are available to support anatomic limb variations as a reason for injury differences between males and females.

The dimensions of the intercondylar notch have been implicated as a reason for ACL failure in both the newly injured and ACL-reconstructed knee. In 1987, Houseworth et al compared notch view roentgenograms measuring the areas of the anterior notch opening, posterior arch, and distal femur of ACL-injured patients with noninjured controls. A significant difference in the ratio of the posterior arch area to the total area of the distal femur between patients with an ACL injury and noninjured controls was found. The authors concluded that a stenotic or narrowed posterior notch may predispose the ACL to injury. Anderson et al compared the intercondylar notch dimensions of subjects with bilateral ACL injuries, unilateral ACL injuries, and no ACL injury using computerized tomography (CT) scan measurements. The authors concluded
that notch stenosis may predispose a person to an ACL injury as ACL-injured subjects had a significant degree of notch stenosis, specifically at the anterior outlet, in comparison to noninjured subjects.

In 1988, Souryal et al. evaluated standard radiographic measurements of intercondylar notch dimensions and developed a notch width index (NWI). The notch width index was defined as the ratio of the width of the intercondylar notch to the width of the distal femur at the level of the popliteal groove. No significant differences in NWI were found when comparing acute ACL-injured subjects with noninjured ACL subjects. However, when comparing bilateral ACL-injured subjects with acute ACL-injured subjects, a significant difference was found in NWI. In reviewing the subjects with bilateral ACL injuries, the authors found a large subgroup of subjects (59%) that tended to be young at time of initial ACL rupture (X=16 years), sustained their injuries through a noncontact cutting maneuver, and who had a relatively stenotic intercondylar notch on a tunnel view radiograph. The mechanism of injury for the subjects with bilateral ACL injury was described as a noncontact maneuver in 58 knees (79.5%); contact in 15 knees (20.5%); and in the remaining 9 knees the exact mechanism was not known. Of the 58 noncontact knees, 3 described hyperextension as the mechanism of injury, and the remainder were cutting maneuvers (foot planted, knee partially flexed, and a rotational force applied). Football, followed by basketball and soccer, was the most common activity at the time of ACL injury. The authors concluded that young individuals who sustain an ACL tear by noncontact mechanisms and have a low NWI, carry a significant risk for contralateral ACL rupture. No statistically significant difference was found in mean NWI of males versus females in the bilateral population.
A study by Schickendantz and Weiker\textsuperscript{33} in 1993 used standard radiographic measurements of intercondylar notch and femoral condyle dimensions to compare subjects with bilateral ACL injuries, unilateral ACL injuries, and no ACL injury. No significant differences in the radiographic measurements, demographic information, or clinical ligamentous laxity tests were found between the three groups. The authors concluded that intercondylar notch measurements made from standard radiographs should not be used to predict potential for ACL injury.

Two recent prospective studies in large groups of athletes have examined the relationship between the intercondylar notch index and risk for ACL injury.\textsuperscript{34,35} A study by Souryal et al\textsuperscript{34} in 1993 found notch width indices in women to be less than those in men. A 1994 study by LaPrade and Burnett\textsuperscript{35} found no sex difference in notch width index or rate of ACL injury. An increased risk of ACL injury with reduced notch size was suggested in both studies.

A study in 1994 by Harner et al\textsuperscript{36} reviewed 31 patients who sustained bilateral ACL injury through noncontact mechanisms. The authors thought that they could examine the more intrinsic causes of ACL rupture by excluding patients with contact mechanisms of injury or a unilateral ACL injury from the study. A significant difference in the opening notch angle between the experimental and control group was demonstrated from analysis of CT scan measurements. The results of the study were similar to those reported by Anderson et al.\textsuperscript{31} When comparing the ratio of notch width to condylar width no significant difference was found between the two study groups. However, the studies by Anderson et al\textsuperscript{31} and Souryal et al\textsuperscript{32} reported significant differences between their population of bilateral ACL-injured patients and the noninjured
controls. The authors concluded that certain anatomic factors may predispose people to anterior cruciate ligament injury as the experimental group in their study had a significantly wider lateral femoral condyle compared to the control group.

In general, females have a decreased femoral notch to width ratio with the female knee and ACL tending to be smaller than those of males. Less available notch space and a smaller ACL combine to increase injury risk.\textsuperscript{5,37} The actual shape of the notch may also vary with gender and contribute to the incidence of ACL injury.\textsuperscript{15} The notch width index (NWI) does not take into account intercondylar notch configuration.\textsuperscript{32} A small, A-shaped notch may not actually be pinching a normal sized ACL, but rather is a sign of a congenitally smaller ACL. Radiographic findings of a decreased notch to width ratio and an A-shaped notch may place female athletes at an increased risk for a noncontact mechanism ACL injury.\textsuperscript{15} The relationship of the size of the ACL to notch dimensions in either height, width, or volume has not been studied. No conclusive study looking at intercondylar notch indices and sex variations has been reported.\textsuperscript{4}

Ligamentous laxity is another factor which may explain the differences in knee injury rates between males and females. Female athletes tend to have increased ligamentous laxity and flexibility compared with their male counterparts. This laxity may contribute to the increased incidence of patellar subluxations and ligament strains seen in female athletes.\textsuperscript{11,38} In 1970 Nicholas\textsuperscript{39} used a series of five tests (appendix) to determine laxity in the upper and lower extremities of 139 professional football players. A player was defined as loose-jointed (hypermobile) when any one of the tests was positive.
Nicholas concluded that players classified as hypermobile were at increased risk of knee ligament injury as they experienced third-degree knee ligament injuries at a rate seven times that of the tight-jointed (hypomobile) players. Kalenak and Morehouse\textsuperscript{40} used 72 collegiate football players to perform a study similar to the one described by Nicholas. A smaller percentage of the subjects were classified as hypomobile in this study than was found in the study by Nicholas. The study found no significant difference in knee ligament injury rate between the hypermobile and hypomobile subjects. The authors concluded that it was not possible to predict knee injuries by subjective evaluations of joint laxity or by objective biomechanical knee ligament evaluations. In 1975 Godshall\textsuperscript{41} reported an eight-year study on high school football players. Using the tests described by Nicholas among other criterions, the study found no significant correlation between the frequency of ankle and knee ligament injuries and whether a player was hyper- or hypomobile.

A study by Grana and Moretz\textsuperscript{42} involving high school basketball players found female players as having significantly greater joint hypermobility than males. However, joint laxity of these female players was significantly less than females not participating in sports. Based on their findings, the authors concluded that ligamentous laxity testing should not be used as a basis for restricting participation in high school athletics. A study by Weesner et al\textsuperscript{43} involving noninjured male and female high school basketball players (36 male, 54 female) found no statistically significant difference in ACL laxity between genders.

The relationship between generalized joint hypermobility and knee joint mobility in female high school basketball players was the focus of a study by
Hawbaker\textsuperscript{44} in 1995. Subjects were evaluated for generalized joint hypermobility and knee joint mobility using the Beighton hypermobility criteria and KT-1000 knee ligament arthrometer (Medmetric Corp., San Diego, CA), respectively. The Beighton hypermobility criteria consists of a series of joint maneuvers set up on a nine point scale with one point awarded for the ability to perform each maneuver (appendix). A higher score indicates a larger degree of generalized joint hypermobility. Subjects scoring four or greater on the scale are classified as hypermobile.\textsuperscript{45} The KT-1000 knee ligament arthrometer is a non-invasive, portable instrument which has proven to be a reliable and valid means of measuring the anterior-posterior translation of the tibia in relation to the femur.\textsuperscript{46,47,48,49} Statistical analysis of the data collected by Hawbaker using these measures revealed a general trend toward higher KT-1000 values in female basketball players identified with generalized joint hypermobility. A significant positive correlation between the KT-1000 values and hypermobility scores for the right knee and not for the left raised question of lower extremity dominance as a factor in mobility.

Research indicating whether or not athletes with generalized joint hypermobility are at a significantly greater risk for knee injury has been done on a limited basis with conflicting results. Generalized joint hypermobility, which is not uncommon in the general population, is a term describing persons with excessive range of joint motion.\textsuperscript{50} As many as four to seven percent of people in the general population present with hypermobility in three or more of their joints.\textsuperscript{45,51,52,53} Most of these people are asymptomatic, however, while others may suffer adverse effects due to trauma and overuse.\textsuperscript{54}
Generalized joint hypermobility has been associated with orthopedic and rheumatologic conditions not linked to any underlying connective tissue disorder.\(^5\) Kirk et al\(^5\) gave this pathology the name “hypermobility syndrome,” defined as joint hypermobility with musculoskeletal complaints in an otherwise healthy subject.

Sheon and colleagues\(^5\) have found that hypermobility syndrome has a familial tendency, with the parent or sibling usually being asymptomatic. Several studies have confirmed that hypermobility may be inherited as a sex-influenced trait or as a simple dominant or recessive trait.\(^5\)

Recurrent dislocations, subluxations, ligament and tendon injuries, and degenerative joint disease are some of the typical orthopedic problems that may be associated with hypermobility syndrome.\(^5\) Musculoskeletal complaints are presented most often by females, especially 10-15 year-old girls who participate in activities that require great agility. Recurrence of joint pain and effusion in the knees, fingers or hands, elbows, shoulders, hips, and ankles without a known cause are the most common complaints with symptoms lasting only a few hours.\(^4\) There are data stating that the knee is the most commonly symptomatic joint (46%) with teenage female athletes being most affected.\(^4\)

The question of whether generalized joint hypermobility is a significant factor in the occurrence of ACL injury has not been adequately addressed. The question raised by Hawbaker in regards to the role of lower extremity dominance in knee injury prevalence also needs to be researched.

In athletic performance, lower extremity dominance is the imagined or real superiority of one limb when compared with the contralateral limb.
Personal observations of athletic performances demonstrate athlete dependence on a single limb. This is most noticeable in track and field events, such as jumping, hurdling, and throwing. For study purposes, however, investigators often select a test to arbitrarily determine lower extremity dominance. Didia and Nyenwe used a kicking preference test to identify a significant correlation between handedness and lower extremity dominance. Greenberger and Paterno assessed leg dominance by having subjects kick a soccer ball. Determining lower extremity dominance by having subjects kick a ball from a standing position was also used in a study by Harrison et al. Kicking preference has also been used in other studies to determine lower extremity dominance. Limited data are available on athlete lower extremity dominance or symmetry. There is also conflicting data available in the literature regarding handedness and footedness or lower extremity dominance.

The purpose of this study was to determine the relationship of generalized joint hypermobility and knee mobility with knee injury prevalence among female high school basketball players. The role of lower extremity dominance with knee injury prevalence was also examined.
CHAPTER III

METHODS

Subjects

Sixty female subjects evaluated by Hawbaker for generalized joint hypermobility and knee mobility using the Beighton hypermobility criteria and KT-1000 knee ligament arthrometer, respectively, were followed-up for this study. Subjects were previously evaluated as sophomore high school basketball players. Participation in this follow-up study was on a voluntary basis contingent on parental consent and approval from area high schools to conduct research at their facility.

Instrumentation

Participant Questionnaire

A participant questionnaire (appendix) was developed to determine the subject's level of participation in basketball and any occurrence of injury during the year following the study by Hawbaker.

Dominance Testing Questionnaire

A dominance testing questionnaire (appendix) was developed for use by the examiner to record both subject response to questions related to lower extremity dominance and the results of the lower extremity dominance testing.

Procedure

Each subject completed the participant questionnaire and then performed the lower extremity dominance testing. Lower extremity dominance
tests included a single leg hopping test and a displacement test. For the single leg hopping test each subject faced the examiner and was asked to voluntarily hop on their leg of choice. The dominant leg was defined as the leg on which the subject hopped. For the displacement test each subject faced away from the examiner and stood with their feet shoulder width apart. The examiner pushed the subject forward by applying a light push between the shoulder blades. The leg that went forward first for the displacement test was defined as the dominant leg. Two trials were performed for each test. The two trials of the displacement test were performed between each trial of the single leg hopping test. An assistant recorded the results of the tests for the examiner. After completing the dominance tests the subjects were asked whether they were right or left handed and which leg they would use to kick a ball. Subject response was recorded on the dominance testing questionnaire.

Data Analysis

Data analysis was completed using SPSSXTM* computer software. Significance was set at the .05 level prior to the study. The Pearson product moment correlation was utilized to identify correlations between a subject’s mean KT-1000 scores for each leg (15 and 20 pound anterior, 20 pound posterior, 20 pound total anterior-posterior) and the number of knee injuries reported by that subject for the corresponding leg. The correlation between the subject’s generalized joint hypermobility score and the number of knee injuries reported by the subject was also identified using the Pearson product moment correlation. Multiple regression was used to determine the contribution of the lower extremity dominance tests of hopping, displacement test, kick preference, and handedness to the prediction of knee injury.

*SPSSXTM Inc., 444 North Michigan Ave., Chicago, IL 60611

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CHAPTER IV

RESULTS

Fifty-eight of the sixty eligible subjects participated in this study as high school juniors with thirty-eight subjects (66%) active in basketball during the previous season. Six of the thirty-eight athletes who were active in basketball during the previous season (16%) sustained a knee injury. However, only 3 of the 6 reported knee injuries were sustained as a direct result of participation in basketball. Of the six reported knee injuries only one was sustained through a noncontact mechanism. None of the reported knee injuries involved the ACL.

Due to the low number of knee injuries reported, the relationship between generalized joint hypermobility (Beighton hypermobility scores) and knee injury (number of knee injuries reported) could not be determined using the Pearson product moment correlation. However, of the thirty-eight participants in this study who played basketball twenty-five (65.8%) were classified as being hypermobile. Although the correlation between the number of knee injuries and generalized joint hypermobility scores did not achieve significance, it is worth noting that five of the six knee injuries (83%) sustained within this sample were reported from hypermobile subjects.

The Pearson product moment correlation coefficient (r) found no significant relationship between knee mobility (KT-1000 scores) and the number of knee injuries reported. Due to the small sample size and low number of knee injuries, significance was unable to be determined. The ability
to determine significance was further limited when factoring in involvement of the right versus left leg.

The ability of single-leg hopping, the displacement test, kick preference, and handedness to predict knee injury was not significant as determined by stepwise multiple regression (p > .05). The small sample size and the low number of knee injuries reported did not provide an opportunity to determine significance. The ability to determine significance was further limited as the knee injuries reported had to be classified as right versus left. Four of the six knee injuries reported involved the right leg while the other two involved the left.
CHAPTER V
DISCUSSION

The self-reported nature of the participant questionnaire used to gather information from the subjects was a limitation of this study. For completion of the participant questionnaire the subjects were to report and describe any type of injury they sustained as a direct result of participation in basketball (i.e. ligament injury, fractures, dislocations, sprains) along with the mechanism of the injury (contact versus noncontact). Subjects were also to report knee injuries sustained outside of involvement with basketball. Due to its self-reported nature the participant questionnaire was a limitation of the study. For example, one subject reported that the knee injury she sustained was caused by contact with another player. However, when describing the mechanism of injury she reported twisting her knee and running on it too soon. The athlete described her injury as tendinitis. This type of subjective reporting does not necessarily provide a clear and accurate assessment of the injury sustained. Also, those athletes who reported an injury may not have understood or known the full extent of their injury. Athletes may have used their own knowledge of injury or that of coaches to determine the type of injury sustained. Therefore, the description of injury reported by athletes on the participant questionnaire may not accurately represent the actual type of injury sustained. Also, the athletes may have had different perceptions as to what constituted an injury. The participant questionnaire did not ask questions to determine the severity of the injury sustained and whether or not the athletes were withheld from competition.
as a result of injury. This information would have helped provide a more accurate report from the athletes as to the type and degree of injury sustained. However, the primary objective of the participant questionnaire was to determine the subjects who sustained a knee injury during the previous year. The knee injuries reported by the subjects who participated in basketball were used to establish the correlation of the KT-1000 values and Beighton hypermobility scores with the number of knee injuries reported. The knee injuries sustained by the basketball players were used in the data analysis whether or not they occurred as a direct result of their participation in basketball.

The primary limitation of this study was that the sample size was too small to make any of the findings in regard to the number of knee injuries reported statistically significant. Only the 36 subjects who participated in basketball during the previous season could be used to determine the correlation of generalized joint hypermobility and knee mobility with knee injury prevalence. Of these 36 subjects there were six who reported sustaining a knee injury. When other variables, such as type of injury (i.e. ligament injury, fractures, dislocations, sprains), mechanism of the injury (contact versus noncontact), and the leg sustaining injury were factored in, the ability to determine significance only became more difficult.

The role of lower extremity dominance with knee injury prevalence was also examined as part of this study. The primary examiner completed all of the dominance testing with the exception of two subjects. The simplicity of the dominance tests made any intertester or intratester error very negligible. However, none of the tests selected to assess lower extremity dominance proved to be predictors of knee injury. Again, the sample used to determine
whether or not these tests are predictors of knee injury was not large enough to determine significance.

Future studies should use larger sample sizes to provide an opportunity for a more accurate determination of whether there is a significant correlation between generalized joint hypermobility and knee mobility with knee injury prevalence. The role of lower extremity dominance with knee injury prevalence is also in need of further analysis in studies using larger sample sizes. A suggestion would be to initiate a long-term study of female high school basketball players, gathering data similar to that analyzed in this study. A more accurate report from the subjects regarding the type and severity of injury sustained could be achieved using a more objective participant questionnaire. The examiner could also complete the questionnaire by interviewing the subjects so that any apparent discrepancies could be clarified. Data collected from the study could be analyzed over a period of several years, ensuring a larger sample size. Additional schools could also be involved in the study to increase the number of subjects. The larger sample size would allow the researcher to analyze the various variables related to knee injury while still having an opportunity to achieve statistical significance.
CHAPTER VI
CONCLUSION

None of the subjects in this study sustained an ACL injury during the previous season as either a direct or indirect result of participation in basketball. However, from the thirty-six subjects who participated in basketball during the previous season there were six reported knee injuries. Due to the small sample size and low number of knee injuries reported, the correlation of generalized joint hypermobility and knee mobility with knee injury prevalence could not be determined. The role of lower extremity dominance with knee injury prevalence could also not be determined due to the small sample size and low number of reported injuries in the study.

In reviewing the results of this study, it is the suggestion of the author that future studies be performed on a long-term basis. Future studies using a larger sample size would allow the researcher to analyze the various variables related to knee injury while still having an opportunity to achieve statistical significance.
Shively et al report basketball as having the highest injury rate among females participating in high school athletics, with the knee being identified as the joint most commonly affected. The anterior cruciate ligament (ACL) of the knee is the primary structure affected. An area of great concern with ACL rupture involves predisposition to injury. The purpose of this study is to determine the correlation of generalized hypermobility and knee mobility with knee injury prevalence. The role of lower extremity dominance with injury prevalence will also be determined during the study.

The study will involve sixty female high school basketball players who have previously been tested for generalized hypermobility and knee joint mobility using the Beighton hypermobility criteria and KT-1000 respectively. The subjects will complete a follow-up survey indicating their level of participation in basketball and any occurrence of injury during the previous year since the above measures were taken. Tests to determine lower extremity dominance of the subjects will also be performed as there was a suggestion of significance with the previous year's results in right versus left.
PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate, attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

   Continued participation of the sixty subjects in this study is on a voluntary basis. Testing will take place at the schools which participated in the initial phase of the study pending approval from each respective administration. Parental and subject consent will also be obtained prior to continuation of the study.

   On the day of testing each subject will be asked to complete a follow-up survey indicating their level of participation in basketball and any occurrence of injury during the previous year. The following tests to determine lower extremity dominance of the subjects will also be performed:

   1. Single leg hopping - the subject will face the examiner and be asked to hop on one leg. The subject will voluntarily hop on their leg of choice for approximately 10 seconds.

   2. Displacement test - the subject will face away from the examiner with their legs shoulder width apart. The tester will displace the subject forward by applying a light push from behind. The force of the push will be such that the subject will be able to brace themself with their dominant leg.
3. BENEFITS: (Describe the benefits to the individual or society.)

This study will be of benefit to high school athletes who are potentially at risk to injury due to 1) generalized hypermobility as indicated by Beighton hypermobility criteria and 2) excessive knee joint mobility as measured by the KT-1000. Finding a significant correlation between the above objective measures and knee injury could ultimately identify those athletes requiring additional training, orthoses utilization or direction to a sport with less potential for injury. Clinicians who utilize the KT-1000 for diagnostic purposes will benefit from this study if data will statistically support the use of the KT-1000 as a prognostic device.

4. RISKS: (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psychological, emotional or behavioral risk. If data collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

Participation in this study provides virtually no risk to the individuals involved other than a very remote chance of falling during the lower extremity dominance testing. Subjects will be free to discontinue participation in the study at any time without prejudice to future or present association with the University of North Dakota. The identity of the subjects and all results will be carefully protected by using coded ID numbers. The information from the study will be viewed solely by the examiner and members of the physical therapy staff at the University of North Dakota. Overall results will be shared with the schools involved in the study.
5. CONSENT FORM: A copy of the CONSENT FORM to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no CONSENT FORM is to be used, document the procedures to be used to ensure that infringement upon the subject’s rights will not occur.

Describe where signed consent forms will be kept and for what period of time.

The consent form will be kept on file in the Department of Physical Therapy at the University of North Dakota for five years following completion of this project.

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

Office of Research & Program Development
University of North Dakota
Box 8138, University Station
Grand Forks, North Dakota 58202

On campus, mail to: Office of Research & Program Development, Box 134, or drop it off at Room 101 Twamley Hall.

For EXEMPT or EXPEDITED REVIEW forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

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

SIGNATURES:

__________________________ DATE: ____________
Principal Investigator

__________________________ DATE: ____________
Project Director or Student Adviser

__________________________ DATE: ____________
Training or Center Grant Director

(Revised 8/199)
Consent to Participate in Research

Correlation of knee joint mobility and generalized hypermobility with knee injury prevalence and the role of lower extremity dominance.

You are invited to participate in year two of a three year longitudinal study conducted to determine if female high school basketball players identified with generalized joint hypermobility (excessive joint mobility) are at a higher risk of knee injury. This study is also being done to determine if the KT-1000, a device used to measure movement available at the knee joint, can identify those athletes at risk for injury. The role of lower extremity dominance with injury prevalence will also be determined during the study.

The tests to determine general hypermobility, as well as the measures of knee joint movement using the KT-1000, were done last year during the initial phase of the study. The second year of the study will involve follow-up of others like yourself who participated in the study the previous year as sophomores. You will be required to have parental consent to participate in the study.

The second year of the study will involve your completion of a survey indicating your level of participation in basketball over the previous year as well as any injuries that occurred during that time. A copy of the survey is enclosed. As a participant in the study you will also perform tests to determine lower extremity dominance. The dominance tests will be: 1) single leg hopping - you will be asked to voluntarily hop on your leg of choice for approximately 10 seconds and 2) displacement test - you will face away from the person performing the testing with your legs shoulder width apart. The person performing the testing will move you forward by applying a light push. The force of the push will be such that you will be able to brace yourself with your dominant leg. The tests pose virtually no risk to you other than a very remote chance of falling. The time required to complete the survey and dominance tests will be approximately 10 minutes.

Participation in this study is entirely voluntary. You are free to discontinue participation in the study at any time without prejudice to future or present association with the University of North Dakota. The final general results of this study will become a public document and access to this document will be provided to you following final evaluation in your senior year of high school. These results will not contain any references to yourself or others who participated in the study. Your identity and all personal data will be carefully protected by using coded ID numbers. This information will be viewed solely by the examiner and members of the physical therapy staff at the University of North Dakota.

If you have any questions or concerns about this project please contact Darin Didier or Mark Romanick at 777-2831. You are encouraged to ask questions at any time. A copy of this consent is available upon request.

I have read and understand all of the above and willingly agree to participate in this study as explained in the above consent form.

Participant’s signature  Date

I have read all of the above and willingly agree to allow my daughter to participate in this study as explained in the consent form which she has signed.

Parent or guardian signature  Date

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High School Statement of Participation

The UND Physical Therapy Department and Darin Didier, student physical therapist, would like to invite your high school to participate in the research project titled: **Correlation of knee joint mobility and generalized hypermobility with knee injury prevalence and the role of lower extremity dominance.**

The study is a continuation of a study which was initiated one year ago. The study will involve subjects completing a follow-up survey indicating their level of participation in basketball and occurrence of injury since that time. Tests to determine lower extremity dominance will also be performed by the subjects as there was a suggestion of significance with the previous year’s results in right versus left. The dominance tests will be: 1) single leg hopping - the subject will be asked to voluntarily hop on their leg of choice for approximately 10 seconds and 2) displacement test - the subject will face away from the examiner with their legs shoulder width apart. The examiner will move the subject forward by applying a light push. The force of the push will be such that the subject will be able to brace themselves with their dominant leg. The tests pose virtually no risk to the subjects other than a very remote chance of falling. Subject participation in the study is completely voluntary.

I understand that by giving permission for ________________ High School to participate in the project stated above, I am allowing testing to take place at the participating high school. This statement of participation supercedes any previous high school statements of participation.

Signatures:

________________________________________
High School Principal                   Date

________________________________________
Principal Investigator                   Date

________________________________________
Student Advisor                          Date
APPENDIX A

Joint Hypermobility Tests Described by Nicholas

1) the ability to flex the spine so that the palms could touch the floor with the knees fully extended

2) presence of 20° or more knee recurvatum with the patient prone (legs hanging over a table) measured by a goniometer

3) the demonstration, with the knees flexed 15-30° and with the hips, knees, and ankles turned out to maximum external rotation, that the feet turned a straight angle of 180° heel to heel, and the toes out

4) the ability to lie or sit on the floor with the knees or ankles parallel to the floor in external rotation/ internal rotation of sufficient degree to permit the legs and thighs parallel to the floor

5) the presence of upper extremity laxity was demonstrated by the ability of shoulder flexion, elbow hyperextension, and hypersupination of the forearm to position the hypothenar eminence to incline cephalad in a vertical plane with the elbows extended and the forearms supinated

(Taken with permission from article by: Nicholas JA. Injuries to knee ligaments: relationship to looseness and tightness in football players. JAMA. 1970:212(13):2236-2239.)

Beighton Hypermobility Criteria

1) passive dorsiflexion of the metacarpophalangeal joints 2-5 to or beyond 90 degrees (one point for the right and one point for the left)*

2) passive opposition of the thumbs to the flexor aspect of the forearm (one point for the right and one point for the left)

3) hyperextension of the elbows ≥ 10 degrees (one point for the right and one point for the left)*

4) hyperextension of the knees ≥ 10 degrees (one point for the right and one point for the left)*

5) forward flexion of the trunk with the knees fully extended so that the palms of the hand rest flat on the floor (one point)

*Metacarpophalangeal joint, elbow, and knee ROM was measured by standard goniometry as described by Norkin and White.64 The above testing criteria were used in the study by Hawbaker.44
APPENDIX B

Participant Questionnaire

Subject #__________ High School__________ Year in School__________
Age____ Height______ Weight__________

1. Did you participate in the 1995-1996 girl’s basketball season? Yes / No (circle one)
   If no, why not?______________________________

2. At what level of play did you participate?
   Varsity / Junior Varsity (circle all that apply)

3. On average how much playing time did you get?
   Quarters 1 2 3 4 (circle one)

4. Please list (describe) any type of injuries you incurred as a direct result of your participation in the 1995-1996 basketball season (ligament injury, fractures, dislocations, sprains for example) and the approximate date of injury.

   Date    Injury
   ________________________________
   ________________________________

5. Was your injury due to contact by another player
   Yes / No (circle one)

6. Please describe the mechanism of injury (how did your injury occur?)
   ________________________________
   ________________________________

7. If you had a knee injury that was sustained outside of your involvement with basketball, please describe the injury and how it occurred.
   ________________________________
   ________________________________

8. Describe the treatment for the above injury(s) if applicable
   ________________________________
   ________________________________

9. Have you recently sustained an injury involving your lower extremity (thigh, leg, ankle or foot)? Yes / No (circle one)
   If yes, which lower extremity was involved - Right / Left / Both (circle one)
   ________________________________
APPENDIX C

Dominance Testing

1. Hand dominance    right  left  both

2. Lower extremity dominance
   Trial 1    Trial 2
   Single Leg Hopping  R/L  R/L
   Displacement Test  R/L  R/L

3. Subject response when asked which leg they would use when kicking a ball
   Right / Left
REFERENCES


