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A Correlation Between Generalized Joint Hypermobility and KT-1000 Values: A Prediction of Knee Pathology

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A CORRELATION BETWEEN GENERALIZED JOINT HYPERMOBILITY AND KT-1000 VALUES: A PREDICTION OF KNEE PATHOLOGY

By

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This Independent Study, submitted by Leatha Noreen Hawbaker 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.

(Faculty Preceptor)

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Signature Leatha Haubaker

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In Memory Of Gladys June Hawbaker

ABSTRACT

The purpose of this study was to determine whether a correlation exists between students identified with generalized joint hypermobility and their values of knee joint mobility as measured by the KT-1000 knee ligament arthrometer.

Sixty healthy female high school sophomores, active in basketball, participated in this study. They were evaluated using: 1) the Beighton hypermobility criteria and 2) the KT-1000 knee ligament arthrometer. The KT-1000 variables identified were the anterior 20 lb. displacement, compliance index, and the total anterior-posterior displacement.

With an alpha level set at .05, one-tailed, the T-test for independent samples identified no significant difference in the KT-1000 displacement values when the subjects were separated into normal mobility (< four) and hypermobility (≥ four) groups. The related samples T-test identified a significant difference between the right and left KT-1000 displacement measures with significantly positive correlations between the two groups. The Pearson coefficient identified a positive correlation between the total hypermobility score and the KT-1000 values for the right knees. This statistical analysis shows a

general trend toward higher KT-1000 values in those individuals identified with generalized joint hypermobility.

CHAPTER I

INTRODUCTION

The female basketball player performs on the court with considerable risk to ligament injury. Athletes participating in sports requiring repetitive running, jumping, cutting, pivoting, and quick deceleration activities are frequently injured during play. The knee is the joint most commonly injured with the anterior cruciate ligament (ACL) as the primary structure affected.[1] The ACL is put under significant stress with the above mentioned activities, providing the opportunity for injury to occur. Shively et al[2] 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. A study relating gender and ACL injuries in intercollegiate athletes states that females were 6.19 times as likely to sustain an ACL injury during competitive play as compared to their male counterparts.[1] Gray and colleagues[3] collected data on all basketball players referred to his clinic and found that 25% of all female players treated sustained ACL ruptures. It was noted that only four of one hundred and fifty-one male basketball players at this clinic were treated for ACL ruptures.[3]

A vast amount of research has been conducted concerning many aspects of the ACL. An area of great concern with ACL ruptures involves predisposition to injury. The reasons for ACL rupture occurring more often in female basketball players has little statistical support. Studies show family history, intercondylar notch stenosis, hamstring weakness with decreased flexibility, as well as generalized joint hypermobility may predispose females to ACL rupture. There is limited and conflicting research which questions whether generalized joint hypermobility predisposes athletes to knee pathology. Generalized joint hypermobility has been associated with orthopedic and rheumatologic conditions not linked to any underlying connective tissue disorder.[4] In 1947, Sutro[5] was the first to link joint hypermobility and rheumatologic conditions. This led to the development of criteria used to identify this condition by Carter and Wilkins[4] in 1964 which was later modified by Beighton and Horan[6] in 1969. It was Kirk and colleagues[7,8] who gave this pathology a name and coined the term "hypermobility syndrome," defined as joint hypermobility with musculoskeletal complaints in an otherwise healthy subject.

There are data stating that symptoms most commonly occur in the knee (46%) with teenage female athletes being the population most often affected.[8-12] Patients developing symptoms as adults usually have a secondary diagnosis of osteoarthritis.[8] Nicholas[13] studied 139 professional football players and found that 72% of those with three or more hypermobile joints sustained ruptures to their knee ligaments during play. Another study conducted by Sturup et al[14] found that idiopathic hypermobility appeared to be associated with injury to the medial meniscus. Grana and Moretz[15] evaluated usefulness of ligamentous laxity testing in secondary school athletes to predict predisposition to injury. These research findings were not significant and do not support using ligament laxity testing as a prognostic screening tool for athletes. It was felt that it would not be of benefit for the athlete to be held out of play based on the data found in the study.

The purpose of this study is to determine whether a correlation exists between female basketball players identified with generalized joint hypermobility and significant values of knee joint mobility measured by the KT-1000 Knee Ligament Arthrometer. This information will provide baseline data for future research to determine whether a person with generalized joint hypermobility has an increased risk of anterior cruciate ligament injury. This risk identification could ultimately identify those athletes requiring additional training, orthosis utilization, or direction to a sport with less potential for injury.

CHAPTER II

LITERATURE REVIEW

Generalized joint hypermobility is a term coined to describe persons with excessive range of joint motion.[4] It is not uncommon to find this generalized hypermobility in the general population. Four to seven percent present with hypermobility in three or more of their joints.[7,8,9,12] The majority of these persons are asymptomatic, although there is a segment within this population that suffer adverse effects due to trauma and overuse.[10] Joint hypermobility is important to physical therapy due to the occurrence of orthopedic and rheumatologic symptoms secondary to this condition. Only in the last 50 years have these symptoms been identified as being due to generalized joint hypermobility. This term is not new to the medical community as it was originally noted to be a feature of inherited connective tissue disorders such as Ehlers-Danlos Syndrome, Marfan's Syndrome, and Osteogenesis Imperfecta.[10]

Hypermobility syndrome, as previously stated, is found to be the cause of musculoskeletal complaints in an otherwise healthy patient. Electron microscope studies of skin biopsies from 14 patients with this syndrome have shown an abnormally small amount of type I collagen fibrils and an increase in type III collagen, intrafibrillar matrix, elastin, and fibrocytes.[10]

Collagen is the primary component that gives tendons, ligaments, and the joint capsule their structure and flexibility to stabilize the joints of the skeletal system. Type I and Type III collagen are the most abundant types found in these connective tissue structures. Type I is a more mature collagen with greater tensile strength and comprises about 90% of the collagen in both tendons and ligaments. Type III collagen comprises the final 10%.[16,17] This collagen strength normally increases with age, but due to the congenital makeup of these connective tissue structures, a hypothesized cause of structural change, the hypermobile patients continue to have significant alterations in joint mobility.[9]

Sheon and colleagues[8] state that this syndrome is often familial in nature with the parent or sibling usually being asymptomatic. Several studies have confirmed that hypermobility may be inherited as a sex-influenced dominant trait or as a simple dominant or recessive trait.[10] Research has indicated that hypermobility is also associated with patients suffering from familial congenital hip disease, as well as recurrent patellar and shoulder dislocations.[8]

Patients with musculoskeletal complaints most often are females, especially young girls between 10-15 years of age who participate in activities that require great agility.[8,9,12] Recurrent joint pain and effusion without known cause are the most common complaints of this patient population. These symptoms only last for a few hours instead of days and most frequently occur in the knees (46%) or fingers and hands (40%).[12] Less commonly affected joints include the shoulders, elbows, hips, and ankles.[8,9,12] Typical orthopedic problems may include recurrent dislocations, subluxations, ligament and tendon injuries, and degenerative joint disease.[6,8,10,12,18] Other associated features of hypermobility may include scoliosis, pes planus, genu valgum, excessive dorsal/volar wrist motion, chondromalacia, tendinitis, hernia, varicose veins, and recurrent pneumothorax.[8,19]

The question of whether generalized joint hypermobility is a significant factor in the occurrence of ACL injury has not been adequately addressed. Several studies have indicated that ACL injury occurs more frequently in the female athlete, primarily the high school basketball player. Gray et al[3] and Harner and Paulos[20] found the mean age to be approximately 17 years of age. Gray and colleagues[3] also indicate a 95% confidence limit of 14-20 years. Angel and Hall[21] found the average age of ACL injuries to occur at 14.3 years with a range in age from 8-18 years.

In order to address whether generalized joint hypermobility is a factor predisposing female athletes to an ACL injury, it is first important to understand the role of the ACL as the principal stabilizer of the knee joint. Anatomically, the ACL attaches superiorly to the medial surface of the lateral femoral condyle. From this attachment the ACL runs anteriorly, medially, and distally across the joint, turning in a slightly outward spiral as it inserts in front of and lateral to the anterior tibial spine.[22]

The ACL is divided into two fascicular bands which provide stability to the knee through full range of joint motion. The anteromedial band (AMB) originates at the proximal aspect of the femoral attachment and inserts on the anterior medial aspect of the tibia. The remaining fascicles are referred to as the posterolateral band (PLB) and, as the name implies, it inserts into the posterior and lateral bulk of the tibial attachment. This 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.[23]

Due to the non-parallel orientation of ligamentous collagen, it is only those fibers oriented in the direction of the principal load that straighten and maintain a maximal load. This structural orientation causes a portion of the ACL to remain taut throughout the range of motion.[22,23] Cabaud[23] states the ACL is the strongest and least compliant ligamentous structure around the knee. Structurally, approximately 90% of the collagen fibers are well oriented and 10% are elastic fibers enmeshed with ground substance.[23]

The anatomical placement as well as collagen structure and alignment provide the necessary foundation for the ACL to complete its primary and secondary functions. These functions include acting to resist anterior displacement of the tibia on the femur. The ACL also plays a role in limiting internal and external rotation of the tibia with respect to the femur. The ACL's ability to resist these forces placed on it depend upon many predisposing factors such as age, systemic disease, hypermobility, hypomobility, muscle strength, and congenital bone structure.[23]

A study investigating ACL insufficiency in children classified the nontraumatic occurrence of this condition into two groups: Generalized joint hypermobility and/or a congenital absence of the ACL. These may be a precipitating factor in the occurrence of symptoms in this young population. The authors felt it was important to consider these factors when examining a child with suspected knee ligament injury.[24]

Many of the recent studies concerned with predisposing factors of ACL rupture have focused on intercondylar notch dimensions. A method to measure the notch width index (NWI) was devised by Souryal and colleagues[25] using radiographic techniques. The NWI is the ratio between the width of the intercondylar notch and the width of the distal femur at the level of the popliteal groove. A correlation of the NWI with nonsimultaneous bilateral ACL injured patients was found to be significant while this did not occur when correlated with noninjured and unilaterally injured patients. There was no significant difference when comparing the noninjured athlete to the unilateral ACL deficient athlete.[25] Studies comparing the NWI differ in their methods of measurements; therefore, authors have found it difficult to make conclusions regarding the cause of ACL rupture.[20,25]

Harner et al[20] retrospectively analyzed 31 patients with bilateral noncontact ACL injuries for intercondylar notch stenosis, generalized joint hypermobility, hamstring flexibility, and family history. This study utilized CT scans to identify the NWI and also modified the Beighton hypermobility criteria (figure 1), eliminating the knee measurements due to the presence of knee injury in the experimental group. As in the study conducted by Souryal and colleagues,[25] Harner et al[20] found a significant decrease in the NWI of patients having bilateral ACL ruptures. Thirty five percent of the patients in the study identified an immediate family member as having a previous ACL injury but the investigators did not find generalized joint hypermobility or hamstring flexibility to be statistically significant.

These studies, as well as others, have identified the mechanism of injury most often involved with an ACL rupture. This mechanism involves a noncontact, deceleration maneuver, in which a change of direction is anticipated or has occurred with the foot in a fixed position.[1,3,20,25,26] This change in direction causes an internal or external rotation of the tibia which stretches the ACL over the lateral femoral condyle or the posterior cruciate ligament.[1] This type of injury lends to the hypothesis that intrinsic factors such as hypermobility, NWI, muscle strength, and/or limb alignment may predispose the female athlete to ACL injury.

The purpose of this study is to determine whether a correlation exists between female basketball players identified with generalized joint hypermobility and significant values of knee joint mobility measured by the KT-1000 Knee Ligament Arthrometer.

CHAPTER III

METHODS

Subjects

Healthy female sophomores in high school who actively participate in basketball were recruited from eight eastern North Dakota and western Minnesota high schools. Sophomores were chosen to provide the opportunity for follow-up studies throughout their high school basketball career. Participation was on a voluntary basis contingent on parental consent and approval from the area high schools to conduct research at their facility. Guidelines were established by the Institutional Review Board at the University of North Dakota. Sixty students without prior history of knee surgery or any knee pathology within the last two years participated in this study. The ages ranged from 14-16 years, with a mean of 15.2 years (SD = .5). The subjects' mean height was 69.5 inches (SD = 1.99) and mean weight was 129.5 lbs (SD = 13.9). As stated previously, each subject actively participated in basketball, with secondary athletic participation in volleyball (56.7%) and track (41.7%).

Instrumentation

Preliminary Health Screening

A preliminary screening (appendix), developed via literature review, was performed to identify any history of knee pathology such as surgery, osteoarthritis, or rheumatoid arthritis. Immediate family history of arthritis or joint injury was also obtained to address the familial nature of joint hypermobility.

Activity Rating Scale

The Tegner and Lysholm activity rating scale (appendix) was utilized in this study to provide baseline information of each student's current activity level.[27] The primary categories associated with the study sample were the competitive sport (#7) and the recreational sport (#8) categories.

Beighton Hypermobility Criteria

The criteria to identify joint hypermobility in children was developed by Carter and Wilkins in 1964 and modified for adults by Beighton and Horan in 1969.[6] Each student in this study was assessed and graded according to the Beighton criteria which consisted of a series of joint maneuvers set up on a nine point scale (figure 1). One point was awarded for the ability to perform each maneuver with a higher score indicating a larger degree of generalized joint hypermobility.[9,10] To have a positive test score for hypermobility, the student had to obtain a score of four or greater, which is consistent with the current literature.[9]

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 hands rest flat on the floor (one point)

Figure 1

*Range of motion of the metacarpophalangeal joints, elbows, and knees were measured by standard goniometry as described by Norkin and White.[28]

Two testers carried out the Beighton hypermobility criteria utilizing standard goniometric procedures described by Norkin and White.[28] These goniometric procedures were used to measure the metacarpophalangeal joint dorsiflexion, elbow hyperextension, and knee hyperextension.

Although minimal research has been conducted concerning the reliability and criterion validity (concurrent and predictive)* of the Beighton criteria, a study conducted by Bulbena and colleagues[29] addressed both of these issues. This study addressed concurrent validity and predictive validity for three

*Concurrent Validity is the extent to which a measure correlates with another measure of the same criterion type at the same point in time.[29]

*Predictive Validity is the ability for a measure to predict the criterion, ie. the ability for one set of criteria to identify another set of criteria.[29]

different methods of testing joint hypermobility. The results for all three measures, Beighton et al, Carter and Wilkinson, and Rotes, were significant. The Beighton criteria and the Carter and Wilkinson criteria overlap except that the former identifies trunk flexion and the latter measures foot eversion and ankle dorsiflexion. The Rotes criteria, along with the former two types of criteria, includes shoulder, hip, cervical, and lateral lumbar motions. These authors concluded that these methods have high criterion validity. This study also addressed the intertester reliability for the hypermobility criterion of all three methods of measurement following the goniometric guidelines for the appropriate joint maneuvers, indicating excellent agreement beyond chance.[29]

KT-1000 Knee Ligament Arthrometer

Daniel and Stone[30] describe the KT-1000 as a non-invasive, portable instrument developed in the late 1970s to measure the anterior-posterior translation of the tibia in relation to the femur. It was developed in an effort to improve the non-invasive diagnostic accuracy and to quantify anterior-posterior joint laxity for acute knee injuries and chronic knee instability.

Numerous studies have been conducted to determine the range of displacement measures for normal subjects, average right knee/left knee displacement differences for normal and pathologic conditions, as well as reliability and validity for the instrument.[31,32,33] Results of these studies support the reliability and validity of the KT-1000 but recommend the use of total anterior-posterior displacement values versus isolating anterior or posterior displacement values. Researchers have also found it to be more clinically relevant to identify right knee/left knee differences when identifying ligament insufficiency. For purposes of this study, the KT-1000 was utilized to determine a possible correlation between those individuals identified as having generalized joint hypermobility and those having larger KT-1000 values.

Procedure

Each student was asked to refrain from athletic activity for three hours prior to testing to prevent skewing of results, therefore limiting effects that activity may have on the tissue surrounding the knee. On the day of testing each student completed a preliminary health screening and an activity rating scale. The student then performed the Beighton hypermobility criteria while anterior tibial instability of both knees was measured utilizing the KT-1000 Knee Ligament Arthrometer (Medmetric Corporation, San Diego, CA).

The subjects were tested according to standard protocol as described by Daniel and colleagues.[31] Three trials of installation-to-installation (within the day) measurements for both knees were recorded at 15 lbs (67 N) and 20 lbs (89 N) of anterior displacement as well as 20 lbs (89 N) of posterior displacement. In short, the patient was positioned in supine with both knees positioned over a bolster in 25 degrees ± 5 degrees of flexion. Heel position and knee flexion angles were recorded with each trial to ensure consistent lower extremity placement. The primary investigator performed all KT-1000 measurements in order to avoid intertester error.

Table 1 depicts the ANOVA results for all of the installation-to-installation measurements recorded from the KT-1000 knee ligament arthrometer. The results for the three displacement measurements (15 lb anterior displacement, 20 lb anterior displacement, and the 20 lb posterior displacement) were all non-significant, indicating that the primary investigator was reliable with KT-1000 measures from installation-to-installation.

Data Analysis

Data analysis was carried out utilizing the SPSSX™* computer software statistical package. An alpha level of .05 was establishsed prior to the study. One-tailed tests were chosen due to the positive correlations expected in the results. A groups t-test was performed on the KT-1000 mean variables comparign the normal mobility group, n_1, and the hypermobile group, n_2. The right and left knee KT-1000 mean displacement measurements were compared using a pairs t-test. Finally, the Pearson Product Moment Correlation was utilized to identify correlations between the total hypermobility scores and the KT-1000 mean variables.

*SPSSX™ Inc., 444 North Michigan Ave., Chicago, IL 60611

Table 1.--ANOVA Reliability Analysis for Installation-to-installation KT-1000 Displacement Measures ($p \leq .05$; one-tailed)

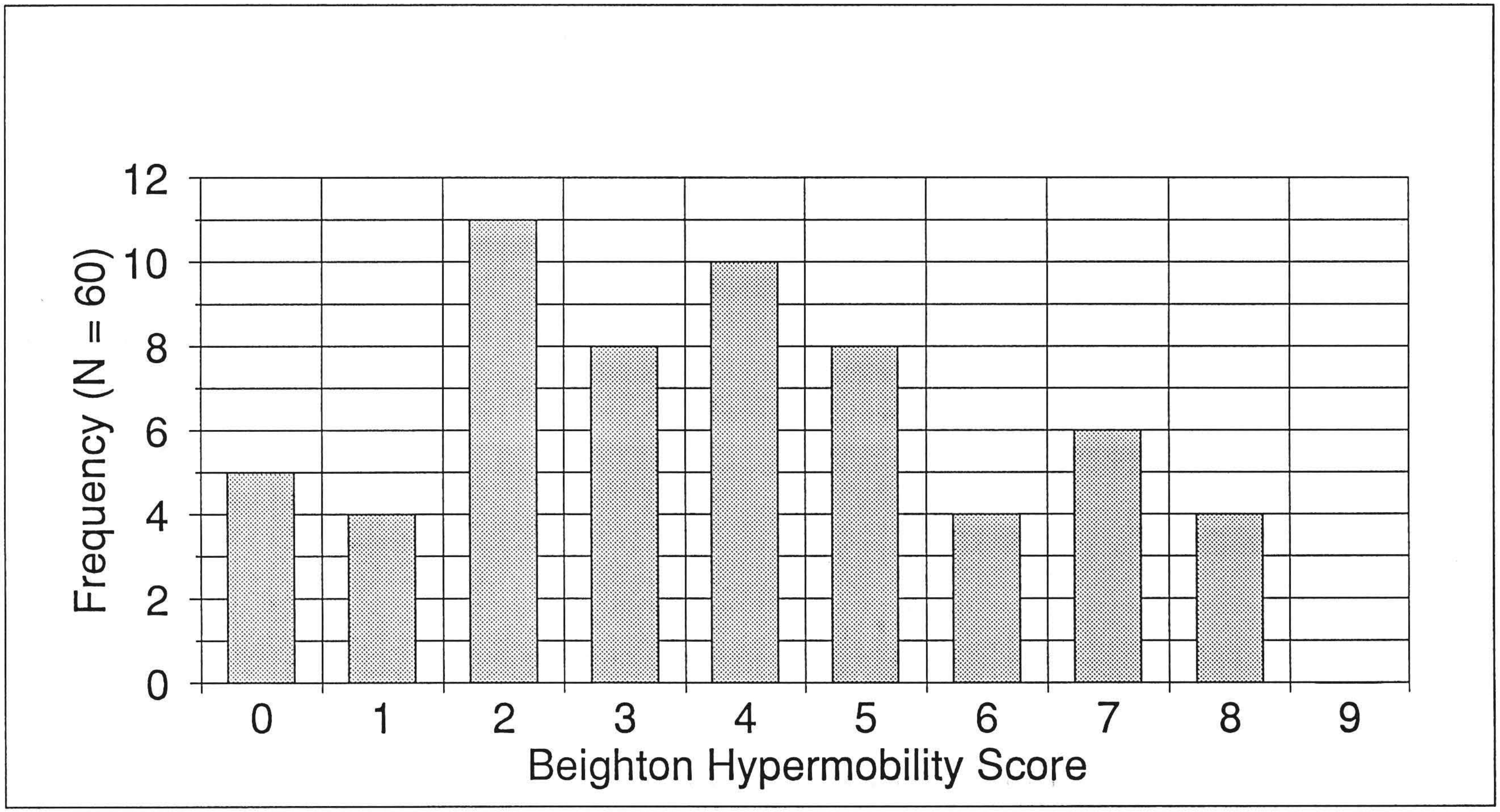
Displacement Force	F-Value	Significance Level
Anterior		
Left 15 lb force	.835	p = .436
Right 15 lb force	.064	p = .938
Left 20 lb force	.616	p = .542
Right 20 lb force	.436	p = .648
Posterior		
Left 20 lb force	.910	p = .405
Right 20 lb force	.346	p = .708

CHAPTER IV

RESULTS

The mean mobility score of the subjects tested was 3.8 with a standard deviation of 2.28. Thirty-two out of the 60 subjects (53.3%) had a hypermobility score of four or higher. Figure 2 represents the frequency of the hypermobility scores collected. Thumb opposition, knee hyperextension, and trunk flexion were found to be positive in 50% or more of the sample (table 2).

The mean, standard deviation, and range were identified for three separate KT-1000 mean variables: 1) the anterior 20 lb displacement: the anterior excursion from the measurement reference position with a 20 lb pull; 2) compliance index: the difference between the anterior excursion with a 15 lb displacement force and that with a 20 lb displacement force; 3) total anterior-posterior displacement: the anterior 20 lb displacement added to the posterior 20 lb displacement. The compliance index is an indication of the compliance of the connective tissue structures resisting displacement.[31] The total anterior-posterior displacement measure eliminates need to consistently identify a neutral knee position, therefore decreasing measurement error.[33] Three trials of each KT-1000 measurement (15 and 20 lb anterior displacement, 20 lb posterior displacement) identified during testing were averaged together to



Normal = 0-3 Hypermobile = 4-9

Fig. 2.--Frequency Distribution.

Table 2.--Hypermobility Criteria; Frequency and Percent ≥ 4
(N = 60, R = right, L = left)

Hypermobility Criteria	Side	n ≥ 4	% Positive
Dorsiflexion of MCP 2-5	R	10	16.7
	L	21	35.0
Thumb Opposition	R	35	58.3
	L	35	63.3
Elbow Hyperextension ≥ = 10 degrees	R	16	26.7
	L	15	25.0
Knee Hyperextension ≥ = 10 degrees	R	33	55.0
	L	30	50.0
Trunk Flexion	-	30	50.0

become an accurate representation of each KT-1000 measurement. These KT-1000 means were used to identify the anterior 20 lb displacement, compliance index, and total anterior-posterior displacement (table 3).

The Beighton hypermobility scores were broken into two groups: n_1 = normal mobility, or those subjects with a mobility score less than four; n_2 = hypermobility, or those subjects with mobility scores greater than or equal to four. These two groups were compared to the KT-1000 mean variables via the independent samples T-test. All comparisons were nonsignificant (table 4).

The right and left knee KT-1000 displacement measurements were compared using a related samples T-test. The anterior 15 and 20 lb displacement means for each side were found to be significantly different but the correlations were also significant and in a positive direction (table 5).

Finally, the Pearson product moment correlation coefficient was found to compare each subject's total hypermobility score with the anterior 20 lb displacement means, the compliance index means, and the total anterior-posterior displacement means. The right side values for each variable were significant. The r values were weak correlations, but they were in a positive direction (table 6).

Table 3.--Mean and Range Values for the KT-1000 Variables

KT-1000 Variables	Mean (mm)	SD	Range
R anterior 20 lb translation	5.71	1.80	1.75 - 11.17
L anterior 20 lb translation	6.65	1.55	2.17 - 10.00
R compliance index	1.26	.68	.25 - 4.00
L compliance index	1.31	.56	.58 - 3.80
R total AP translation	7.85	2.04	2.98 - 14.18
L total AP translation	9.29	1.89	3.67 - 12.75

Table 4.--T-test Comparison of Mobility Status with a 20 lb Anterior Displacement, Compliance Index, and Total AP Translation

(**Normal mobility $n_1 = 28$, Hypermobility $n_2 = 32$, DF = 58)

Variable	Mean	SD	t - Value	Significance
anterior 20 lb displacement				
R n_1	5.39	1.66	-1.28	p = .206
n_2	5.98	1.90		
L n_1	6.49	1.43	-0.77	p = .446
n_2	6.80	1.65		
compliance index				
R n_1	1.13	0.61	-1.36	p = .180
n_2	1.37	0.72		
L n_1	1.26	0.60	-0.53	p = .596
n_2	1.34	0.52		
total AP translation				
R n_1	7.52	1.86	-1.17	p = .247
n_2	8.13	2.17		
L n_1	9.19	1.73	-0.40	p = .693
n_2	9.38	2.03		

Table 5.--Pairs T-Test for Anterior 15 and 20 lb Displacement Means for the right and left knee (N=60, DF=59, p </= .05; two-tailed)

Variable	Mean	SD	Corr.	Signif.	T-Value	Signif.
R ant. 15 lb	4.46	1.46	.678	.000	-6.12	.000
L ant. 15 lb	5.35	1.37				
R ant. 20 lb	5.71	1.80	.667	.000	-5.30	.000
L ant. 20 lb	6.65	1.55				

Table 6.--Pearson Correlation Coefficients of Total Beighton Hypermobility Score with all KT-1000 Variables ($p \leq .05$; one-tailed)

Total Hypermobility Score With:	r Value	Significance Level
R anterior 20 lb displacement mean	.2444	p = .03
L anterior 20 lb displacement mean	.0763	p = .28
R compliance index mean	.2338	p = .04
L compliance index mean	.0788	p = .28
R total AP translation	.2136	p = .05
L total AP translation	.0269	p = .42

CHAPTER V

DISCUSSION

The research conducted was subject to error secondary to variability between the two testers collecting the hypermobility data, the KT-1000 tester experience, and the subject's ability to relax. Although both testers were equally trained with the Beighton hypermobility criteria, utilization of one tester would have eliminated any intertester error. The examiner completing the KT-1000 measurements was trained by an experienced physical therapist, using 12 subjects for multiple trials. This examiner controls the magnitude, direction, and point of application of the KT-1000. Finally, the subject's muscle relaxation can affect the displacement measurements; therefore, proper steps were taken to decrease muscle tension during the examination.[33]

Generalized joint hypermobility is most commonly seen in the teen female population. This study supports this statement with 53.3% of these subjects having a mobility score of four or greater. These subjects were found to have increased mobility more frequently in the thumbs and knees. Symptoms identified in the hypermobility syndrome are seen most frequently in the same joints.

The KT-1000 mean values were all within normal range for the sample tested. The compliance index mean values were higher than average (normal $\leq$ 1 mm) but not greater than 1.5 mm which is indicative of ACL deficiency.[34] This may be due to the high percentage of individuals tested that have increased mobility in their knees. This compliance index measures the end range of movement in the knee, which results from the connective tissue structures within the knee. Therefore, this compliance index may indicate laxity in the ACL.

When KT-1000 measurements are utilized, the literature supports the use of right knee/left knee differences. A side-to-side difference of greater than or equal to three millimeters is relatively accurate in identifying an ACL deficient knee.[34] When comparing the right and left knee KT-1000 mean values, there was a significant difference between the two although a significant, positive correlation was also present. These data indicate that each knee is independent of the other; although if one knee has greater mobility, then the opposite would be likely to have increased mobility (table 5).

One individual who was scheduled to be tested had to be eliminated from the sample secondary to injury the evening prior to testing. This subject was playing in a varsity basketball game and sustained a noncontact, quick deceleration injury to her right knee. She ruptured her ACL and partially tore her medial meniscus. Although this individual could not be a sample member, she was tested according to the procedure previously identified with exception to the right knee. Her total Beighton hypermobility score was a six with eleven degrees of hyperextension in the left knee. The anterior 20 lb displacement was six point five millimeters, the compliance index was one millimeter, and the total anterior-posterior displacement was eight point five millimeters.

This individual's KT-1000 values are on the higher end of normal and the Beighton score indicates generalized joint hypermobility. Although the testing is not valid secondary to the right knee injury, it does provide insight as to what type of individual may be affected. The question posed with this situation was whether the individual has an increased risk for injury which can be identified by the Beighton and the KT-1000 scores.

When the Beighton hypermobility scores were broken into the two mobility groups, n_1 and n_2, then compared to the KT-1000 mean values, there was no significance between the two groups. Placing the hypermobility scores into the two groups did not accommodate for the individuals with the higher mobility scores. Individual hypermobility totals were then correlated with the KT-1000 mean values using the Pearson correlation coefficient. These results indicated a significant correlation in a positive direction on the right knee for all three KT-1000 mean variables. This raises the question of lower extremity dominance.

Lower extremity dominance is not well documented. A study conducted by Harrison et al[35] looked at the effects of leg dominance on standing balance in subjects without knee injury and individuals eight to ten months following reconstructive ACL surgery. No significant results were found between nondominant and dominant or involved and noninvolved limbs. A second study by Herring[36] found no association between limb dominance and running injuries. More research is needed in order to identify the role that lower extremity dominance plays in knee joint mobility.

The statistical analysis shows a general trend toward higher KT-1000 values in those individuals identified with generalized joint hypermobility. With the right lower extremity values being significantly correlated, there is evidence to support the purpose of this study. Continued research is necessary to explore the issues of lower extremity dominance and to continue this pilot study. The subjects tested will be followed through their high school basketball career to identify any injuries incurred and to correlate that to their hypermobility status.

CHAPTER VI

CONCLUSIONS

This research study indicated that the thumbs and knees were the joints most often identified as hypermobile according to the Beighton criteria. This is in agreement with past research.

The KT-1000 20 lb anterior displacement mean values were well within normal limits when compared to previous studies, whereas the compliance index means for this sample appeared to be slightly higher. This may be due to the high percent of hypermobile individuals in the sample.

Separating these individuals into normal and hypermobile groups may not be an accurate way to identify potential risk for injury. Results indicated that separation into these groups was not significant for corresponding KT-1000 values. This outcome indicated that it may not be appropriate to infer that an individual within the hypermobile group will have a large KT-1000 value.

The individual Beighton hypermobility scores indicate a trend toward a direct relationship between these scores and the KT-1000 values. Individuals with high hypermobility scores tend to have higher KT-1000 values. Significant KT-1000 values for the right knee and not for the left knee raises question about lower extremity dominance.

Continued research is necessary to identify the types of injuries most frequently seen in this sample throughout their basketball career. The purpose of the continued research would be to identify whether those individuals with higher Beighton hypermobility scores and or KT-1000 values have an increased rate of injury. This research would also specifically look at the occurrence of ACL injury within this sample.

APPENDIX

_____ EXPEDITED REVIEW REQUESTED UNDER ITEM _____ (NUMBER[S]) OF HHS REGULATIONS
_____ EXEMPT REVIEW REQUESTED UNDER ITEM _______ (NUMBER[S]) OF HHS REGULATIONS

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

PRINCIPAL INVESTIGATOR: Leatha Hawbaker **TELEPHONE:** 772-1918 **DATE:** 8-22-94

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: 209 State St #309, Grand Forks ND 58202

SCHOOL/COLLEGE: UND School of Med. **DEPARTMENT:** Physical Therapy **PROPOSED PROJECT DATES:** Sep. 1994-May 1997

PROJECT TITLE: A Correlation Between Generalized Joint Hypermobility and KT-1000 Values: A prediction of knee pathology.

FUNDING AGENCIES (IF APPLICABLE): ____________

TYPE OF PROJECT:
X NEW PROJECT ____ CONTINUATION ____ RENEWAL ____ DISSERTATION OR THESIS RESEARCH ____ STUDENT RESEARCH PROJECT

____ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Beverly Johnson, MPT / Mark Romanick, MPT

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

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

X MINORS (<18 YEARS) ___ PREGNANT WOMEN ___ MENTALLY DISABLED ___ FETUSES ___ MENTALLY RETARDED

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

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

---

1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.

See attached abstract

1. ABSTRACT

Generalized joint hypermobility is an excess of joint mobility found in four to seven percent of the general population. Usually four or more of their joints are affected with the knees, fingers and hands being most common. This hypermobility has been linked to orthopaedic and rheumatologic conditions. The purpose of this study is to determine whether a correlation exists between students identified with generalized joint hypermobility and significant values of knee joint mobility as measured by the KT-1000 Knee Ligament Arthrometer. This information will provide baseline data for future research to determine if a person with generalized joint hypermobility has increased risk of anterior cruciate ligament injury.

Healthy female sophomores in high school who are active in basketball will participate in the research project. The Beighton hypermobility criteria will provide a measure of generalized joint hypermobility with a score of four or greater indicating a positive test score. Anterior knee stability will be measured with the KT-1000 Knee Ligament Arthrometer. Statistical analysis will focus on establishing correlations of the dependent variable (KT-1000 values) with subject differentiation (hypermobile vs non-hypermobile).

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.)

Participation in this study is on a voluntary basis with students recruited from area high schools such as Red River High School, GF Central High School, EGF High School, Crookston High School, Sacred Heart High School (EGF), Thompson High School, Mayville High School, and Hatton High School, etc. Approximately 70-100 students will be included in this study. Testing will take place at each individual school pending approval from each respective administration.

Parental consent will be obtained prior to testing. On the day of testing consent forms will be turned in and then each participant will be asked to complete a health history (appendix A) and an activity rating scale (appendix B). To ensure accuracy of testing, each individual must have refrained from athletic activity three hours prior to testing.

The following testing procedures will be set in accordance to standard protocol and published research:

<u>Generalized Joint Hypermobility Screening</u>

Each participant will be asked to perform the following joint maneuvers:

1. Passively extend each wrist and hand with their fingers parallel to the dorsum their forearm.
2. Passively appose each thumb to the flexor surface of their forearm.
3. Hyperextension of the elbows will be measured using standard goniometric guidelines with the participant standing with the shoulder abducted to 90° and the elbows extended.
4. Hyperextension of the knees will be measured using standard goniometric guidelines with the participant in standing position.
5. Flexion of the trunk with the knees extended so the palms of the participant's hands rest on the floor.

A point is accumulated for each hypermobile joint tested with a maximum possible score of nine.

<u>KT-1000 Knee Ligament Arthrometer Measurements</u>

Anterior Displacement: Three trials of this procedure will take place. The participant will be asked to lie prone in a relaxed position. Each heel will be bisected with pen marking in order to reproduce the leg's neutral position. Then he/she will be asked to lie supine. The thigh support will be placed under the thigh above the the superior border of the patella. The foot support will be positioned underneath the heel with the leg in neutral rotation. Heel position will be recorded. Next, the position angle of the knee will be measured using standard goniometric guidelines. The knees must be positioned between 20° and 30° of flexion. This position will be recorded.

The KT-1000 will be properly positioned, calibrated, and then measurements at 15 lbs and 20 lbs of force will be recorded for the anterior displacement. The same procedure will be done with the opposite knee and then the participant will get up, walk around for a moment and return for the next trial.

(Use of the KT-1000 Knee Ligament Arthrometer will be donated by Great Plains Physical Therapy.)

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 generalized joint hypermobility. If a positive correlation is found between hypermobility and significant KT-1000 values, this will provide the baseline data necessary to do injury follow-up.

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. Testing the knee joint prior to injury may provide objective data identifying those athletes who are at risk for knee injury.

This risk identification could ultimately identify those athletes requiring additional training, orthoses utilization or direction to a sport with less potential for injury.

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

Participation in this study does not provide any risk to the individuals involved. All of the testing procedures are completely noninvasive and are listed on the study evaluation form in appendix C.

5. **CONSENT FORM:** A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

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

The consent form will be kept on file in the Department of Physical Therapy at UND 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:

Heather Hawbaker, SPT — DATE: 8-22-94
Principal Investigator

Mark Romanick, MPT — DATE: 8-22-94
Project Director or Student Adviser

____________________ DATE: ____________
Training or Center Grant Director

(Revised 8/1992)

Consent to Participate in Research

A correlation between generalized joint hypermobility and KT-1000 values: A prediction of knee ligament injury.

You are invited to participate in a three year longitudinal study conducted to determine if female high school athletes identified with generalized joint hypermobility (excessive joint mobility) are at a higher risk of knee injury. This study is also being conducted to determine if the KT-1000, a device used to measure movement available at the knee joint, can identify those athletes at risk for knee injury.

Healthy female sophomores in high school who are active in basketball are invited to participate as a subject in this research study.

This research study will be conducted over a three year period with reevaluation of the same students on an annual basis. Each participant requires parental consent and then will be asked to complete a health history and an activity rating scale. Each participant will then be tested for generalized joint hypermobility and will have stability measurements taken of both knees with the KT-1000.

Generalized joint hypermobility is tested having the participant perform a series of joint movements.

The KT-1000 Knee Ligament Arthrometer is a non-invasive portable instrument attached to the exterior of the knee used to measure the amount of forward and backward play in the knee. The participant will be lying in a relaxed position with their thighs resting on a bolster. The KT-1000 will be properly positioned on one knee and the measurement will be taken. The opposite knee will then be measured. Three separate trials of each measurement will be performed. The KT-1000 will be removed between trials. This device, in its current configuration, has been used by doctors and physical therapists to aid in identifying ligament injury since 1982 and does not pose risk for injury.

Participation in this study is entirely voluntary and testing will take approximately 30 minutes. You are free to discontinue participation in the study at any time without prejudice to present or to future association with the University of North Dakota. The final results of this study will become a public document and access to this document will be provided to the participants following final evaluation in their senior year of high school. These results will remain confidential, specifically not to be released to school officials. Your identity and all results will be carefully protected by using coded ID numbers. This information will be viewed solely by the examiner and members of the physical therapy department at the University of North Dakota. If you have any questions or concerns about this project please contact Leatha Hawbaker, Beverly Johnson, or Mark Romanick at 777-2831. You are encouraged to ask questions at any time. A copy of this consent is available apon request.

I have read all of the above and willingly agree to allow my son/daughter to participate in this study as explained above.

____

Parent or guardian signature   Date

I have read all of the above and willingly agree to participate in this study explained to me by______________________________.

____

Participant's signature   Date

I have explained fully to the subject the above objectives of this study and what is to be expected.

____

Tester's signature

HIGH SCHOOL STATEMENT OF PARTICIPATION

The UND Physical Therapy Department and Leatha Hawbaker, student physical therapist would like to invite your high school to participate in the research project titled: **A Correlation Between Generalized Joint Hypermobility and KT-1000 Values: A prediction of knee pathology.** This project is described in the attached parental consent form.

If you would like to participate in this project, please read the paragraph below and sign in the designated area.

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 also releases the participating high school from liability secondary to any injury that may occur.

SIGNATURES:

____
High School Principal   Date

____
Principal Investigator   Date

____
Student Advisor   Date

APPENDIX A

PRELIMINARY SCREENING

SUBJECT NUMBER_______________________________

To ensure accurate use of the information received from this testing, please complete the following questions.

1. Have you had any knee problems in the last 6 months which restricted your activity? Yes_____
   No______

2. Have you ever been diagnosed as having?
   Yes No Rheumatoid Arthritis
   Yes No Other arthritic conditions

3. Please describe any injuries for which you have been treated (including fractures, dislocations, sprains) and approximate date of injury:

DATE **INJURY** **TREATMENT**

____

____

____

4. Has anyone in your immediate family (parents, brothers, sisters) ever been treated for any of the following?
   Yes No Arthritis
   Yes No Joint injury (ligament sprain or tear, dislocation, fracture).

FORM REVIEWED WITH THE SUBJECT? Yes_____ No_____

____

Tester's signature Date

APPENDIX B

TEGNER AND LYSHOLM ACTIVITY SCALE

Please circle the category that best describes your present activity level.

10. Competitive sports
    Soccer, nat'l and internat'l
9. Competitive sports
    Soccer, lower divisions
    Ice hockey
    Wrestling
    Gymnastics
8. Competitive sports
    Bandy
    Squash or badminton
    Athletics (jumping, etc.)
    Downhill skiing
7. Competitive sports
    Tennis
    Athletics (running)
    Motorcross, speedway
    Handball
    Basketball
   Recreational sports
    Soccer
    Bandy and ice hockey
    Squash
    Athletics (jumping)
    Cross-country track findings
      recreational and competitive
6. Recreational sports
    Tennis and badminton
    Handball
    Basketball
    Downhill skiing
    Jogging, at least 5X/wk
5. Work
    Heavy labor(e.g., building)
   Competitive sports
    Cycling
    Cross-country skiing
   Recreational sports
    Jogging on uneven ground at least
      twice weekly
4. Work
    Moderately heavy labor
      (e.g., truck driving, heavy
      domestic work)
   Recreational sports
    Cycling
    Cross-country skiing
    Jogging on even ground at least
      twice weekly
3. Work
    Light labor(e.g., nursing)
   Competitive and recreational sports
    Swimming
   Walking on hilly ground
2. Work
    light labor
   Walking on uneven ground but impossible to walk on hills
1. Work
    Sedentary work
   Walking on even ground possible
0. Sick leave or diability pension
    because of knee problems

APPENDIX C

SUBJECT EVALUATION FORM

Subject #____________________High School______________________
Primary Athletic Activities____________________________________
Year In School_____________Age_______Height______Weight________
Athletic Activity in previous three hours: yes_______no________

Beighton Hypermobility Scoring Criteria for Generalized Joint Laxity

(Check the blank if yes)	Right	Left
1. Passive extension of wrist & hand with fingers parallel to dorsum of forearm.	_____	____
2. Passive apposition of thumbs to the flexor aspect of the forearm.	_____	____
3. Hyperextension of elbows >/= 10°.	_____	____
4. Hyperextension of knees >/= 10°.	_____	____
5. Flexion of the trunk with the knees extended so palms rest on the floor.	______	
Total (>/= four is a positive test)	______	

KT-1000 Knee Ligament Arthrometer Measurements

Passive Drawer Test	Trial #1		Trial #2		Trial #3	
	R	L	R	L	R	L
Anterior Displacement						
1. Knee flexion angle	____	____	____	____	____	____
2. Heel position (bisected)	____	____	____	____	____	____
3. 15 lb force (anterior)	____	____	____	____	____	____
4. 20 lb force						
a. anterior	____	____	____	____	____	____
b. posterior	____	____	____	____	____	____

Grand Forks Clinic, Ltd.
Our Specialty is You

August 19, 1994

Bev Johnson
Department of Physical Therapy
PO Box 9037
Grand Forks, ND 58202-9037

To Whom It May Concern:

I am writing to request your support of a research project to be performed by Leatha Hawbaker, a physical therapy student. This is an interesting, well-organized study attempting to determine whether or not there is a correlation between hypermobility ~~and~~ in female basketball players and the incidence of knee ligament injuries. We hope the findings of this study will provide us with very valuable information.

I hope this has been of some assistance.

Sincerely,

Lori Klabunde
Lori Klabunde, RN, FNP for
Brian T. Briggs, MD
BT Briggs
dkv 08/22/94 T

1000 S. Columbia Rd. P.O. Box 6003 Grand Forks, ND 58206-6003 (701) 780-6000 Admin. FAX (701) 780-6641

GREAT PLAINS
PHYSICAL THERAPY CLINIC, P.C.

Clifford Lafreniere, P.T. and Associates
P.O. Box 14857 2617 South Columbia Road Columbia Woods
Grand Forks, ND 58208-4857 (701) 746-8374

August 23, 1994

Mark Romanick
UND Physical Therapy Department
Grand Forks ND 58202

RE: UND Student Research for Leatha Hawbaker

This letter is to offer the support of the staff at Great Plains Physical Therapy Clinic in completing this student's research project involving the utilization of a KT-1000 to measure joint laxity in making a correlation between joint laxity, hypermobility signs and risk of injury in a high school student athlete population. The clinic is willing to offer the services of this clinical device at this time and in the future.

At this time, we have made contacts and are working with the high schools in Thompson, Fisher/Climax, Northwood, Sacred Heart East Grand Forks and Grand Forks Central and Red River high schools to secure a sufficient number of students to provide a reasonable data base for statistical significance.

Thank you for the opportunity to answer these questions and offer support for this student research project. If we can be of any further assistance, please let us know.

Sincerely,

Clifford Lafreniere P.T.

Clifford Lafreniere, PT

CL/lb

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