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Knee stability as a predictor of knee injuries in high school football

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Knee Stability As a Predictor of Knee Injuries in High School Football

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in High School Football

APPROVED:

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Abstract

Knee Stability As a Predictor of Knee Injuries
in High School Football

by David Rodwell Walters II

The purpose of the study was to determine if flexibility or anthropometric measures could be used to predict the incidence of knee injuries in high school football players in North Carolina. The study included 101 subjects from three of the four levels of athletic classification in North Carolina. The investigation began in the summer of 1987 and data collection was completed in December, 1987. The preseason assessment involved measuring flexibility via the Nicholas Flexibility Protocol. Girth measures of the thigh and gastrocnemius musculature and body weight were obtained. Following the season, assessments of subjects shoe types, intended uses, manufacturers, material of the shoe, and whether the subjects used prophylactic knee braces were made. Incidences of injuries were reported regarding the specific structures injured and the severity of injuries. Statistical analyses revealed no predictive value of a preseason assessment on the incidence of injury. A factor analysis of preseason, postseason, and postinjury assessment data did reveal subjects with fewer

quarters of participation experienced higher rates of injury to the structures of the knee. An injury rate of 13.8% was reported in subjects with preseason flexibility scores of 2 or less and 10.3% in the group having 3 or more positive scores. Players with a lower body weight and smaller thigh and gastrocnemius girth measures experienced a higher injury rate.

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CHAPTER 1

Introduction

Injury to the athlete's knee poses concern for the athlete, coach, and a challenge for health care personnel. Injuries to adolescent's knees encompass astounding numbers. Kennedy (1979) defined the adolescent as youth whose chronological ages are 12 to 18 years. The American Academy of Pediatrics reports soft tissue pathology in 95% of sports injuries with ligaments constituting an incidence of 33% (Garrick, 1983). O'Donoghue (1955) reported 55% of clinical surgical knee cases were individuals less than 20 years of age with only one patient under 15 years of age. Mayer (1984) reported that injuries to knee ligaments were rare in children under 14 years of age. Cahill (1979) also reported conditioning effective to reduce injury and postinjury surgery associated with high school football.

The proposed research will provide information for athletic training courses as well as innovative and new knowledge for students. The study will also benefit the sports medicine team working with contact sports including: professionals dealing with conditioning; athletic trainers evaluating and treating athletic injuries; physicians treating students; and coaches and administrators responsible for the performance of the physically active. The goal is to make all involved more aware of the effects of knee stability on the incidence and severity of knee injuries.

The concepts of flexibility by active and passive structures of the body will be explored in detail. The author will attempt to determine the effect of the properties of passive and active structures on stability of the knee. Funk (1984) reported the importance of total knee stability as dependent on static and dynamic restraints.

Statement of the Problem

The study identified preseason parameters and their correlation with the incidence of knee injuries in high school football players in selected high schools in North Carolina.

Hypotheses

The hypotheses for this study were:

1. Loose-jointed (less than a total positive flexibility score of 2 on the Nicholas Flexibility Protocol) subjects will be more susceptible to sprains of the knee joints than tight-jointed subjects.

2. Tight-jointed (greater than a total positive flexibility score of 2 on the Nicholas Flexibility Protocol) subjects will have less susceptibility to soft tissue injury than loose-jointed subjects.

Significance of the Study

The incidence of knee sprains is significant in terms of time and money. The study will investigate knee stability and its relationships to the incidence and severity of knee injuries among high school football players. An evaluation will be made to determine if shoe type, style, or use have any effect on the incidence of knee injury. The ability to determine stability of knee joints and differentiate those predisposed to knee sprains would be of significant value preventing injury, decreasing the cost of health care, and improving the quality of subjects's knees. Others may need to engage in conditioning programs to enhance flexibility of joints and increase strength of related muscle groups. Results may indicate that others have conditions so severe they need to suspend activity.

Delimitations of Study

For the purpose of selection of subjects for the study, the investigator included schools from the four levels of athletic classification in North Carolina including A, AA, AAA, and AAAA levels of athletic participation. The institutions selected represent a varied level of athletic achievements over the past 10 years. Also, each embodies a geographic and demographic region representative of the state of North Carolina.

Subjects with history of anterior cruciate deficiencies will be excluded from the study. Evaluation of previous knee history will be made during the preseason assessment.

Definition of Terms

Active range of motion--the movement of the body through ranges of motion with subject initiating action.

Arthroscopy--the use of an endoscope to examine the interior of a joint via a small incision.

Dynamic stability--stability controlled by muscles (active structures) (Enneking, Brower, & Ralston, 1979).

Flexibility--the inherent motion of a joint limited by contractile structures.

Hemarthrosis--the presence of blood in a joint capsule.

Instability--a joint property due to laxity of ligamentous structures. May be a combination of two or more injured ligaments.

Laxity--the inherent looseness of passive joint structures which may be acquired or congenital.

Ligament--the passive tissue of the body connecting bone to bone.

Passive range of motion--the movement of the body through ranges of motion with action being initiated external to the subject.

Range of motion--degrees of motion within a plane of a joint.

Severity--the degree of injury to connective tissue, including muscles, tendons, and ligaments; ranging from microscopic tears to complete separation of tissue ends.

Sprain--the stretching and/or tearing of ligaments and capsular or noncontractile structures.

Static stability--stability as controlled by ligamentous (passive) structures (Enneking et al., 1979).

Strain--the stretching and/or tearing of contractile structures generally comprised of muscles and tendons.

Stability--the capacity of a joint to remain intact during motion.

Tendon--the passive tissue of the body connecting the muscles to bones.

Valgus--force applied toward the midline to determine inherent stability of tissue.

Varus--force applied away from the midline to determine inherent stability of tissue.

Review of Related Literature

A review of the literature regarding joint motion, whether defined as flexibility of the active structures or stability of the passive structures, reveals a changing and well researched area.

Nicholas (1970) reported a study of 139 professional football players tested with five gross mobility tests of the upper and lower extremities. Subjects were evaluated on the five tests and received a score of positive (ability to successfully complete task) or negative. The subjects were classified as loose- or tight-jointed (according to the number of positive scores) and were then followed to determine the incidence of knee ligament rupture of a magnitude requiring surgery. Thirty-nine players had three or more positive scores and were classified as loose-jointed. Twenty-eight of the 39 (72%) ruptured knee ligaments and required surgery. One hundred subjects (72%) had two or less positive scores and were classified as tight-jointed. Of the group, nine (9%) ruptured knee ligaments. He concluded there was an increased likelihood of knee ligament rupture with loose-jointed subjects, as determined by the gross mobility tests utilized. The author recommended strengthening of the loose-jointed subjects and increasing the flexibility of the tight-jointed subjects. Also suggested was proper screening to facilitate a possible reduction of potential disabling knee ligament rupture in loose-jointed players in contact sports and high velocity athletics.

Moretz, Walters, and Smith (1982) applied Nicholas' study of 1970 to three collegiate football teams. The authors found no correlation between laxity test scores and knee injuries. Of the 155 athletes examined, 33 were injured. The mean flexibility score of study groups were as follows: athletes sustaining meniscal injuries was 1.22; athletes sustaining knee sprains was 1.71; athletes as a group was 1.63; while the control group was 2.3. The authors found no statistically significant difference between any of the groups or subgroups.

Grana and Moretz (1978) applied the five tests used by Nicholas to study injuries in high school athletes. The authors tested athletes as follows: 166 football subjects, 32 men's basketball subjects, and 84 women's basketball subjects. The results were compared to 167 male controls and 223 female controls in high school not involved in interscholastic sports. No correlation was found between ligamentous laxity and occurrence or type of knee injuries in high school athletes.

Kalenak and Morehouse (1975) studied the knees of college football players. A biomechanical device was used to evaluate the laxity's inherent predictability on incidence of injury. No relationship was found between joint laxity tests and biomechanical knee ligament stability tests.

Markolf, Mensch, and Amstutz (1976) tested 35 cadaver knees manually to determine ligamentous stability by load-displacement and moment-rotation relationships during manual examination. The authors measured changes in stability in 35 specimens when specific ligamentous structures or combinations were severed or removed. The responses of all knees tested by similar modes of loading were nonlinear, reflecting increasing stiffness of involved structures. At full extension, stiffness was maximum and laxity was minimal. The authors found changes in stability (laxity and stiffness) were best demonstrated when ligamentous structures were sectioned. The study compared right and left knees of intact paired specimens. Torsional laxity and internal rotation stiffness were most affected by sectioning of the medial collateral ligament. External rotation stiffness was only affected by disruption of the lateral collateral ligament and the posterior capsule. Varus-valgus laxity was relatively unaffected by meniscectomy or sectioning of the cruciate ligaments. Laxity greatly increased in the medial-lateral plane when the medial or lateral collateral ligaments were cut. The medial collateral ligament was the main contributor to valgus stiffness. The lateral collateral ligament had no gaugeable effect on varus stiffness. Anterior-posterior stability was affected minimally by virtually every sectioning. Independent section of the anterior cruciate ligament produced its greatest increases in anterior-posterior laxity at full extension. Section of the posterior cruciate ligament resulted in great increases in laxity at 90° of flexion. The authors found large increases in anterior-posterior laxity with combined medial collateral ligaments and posterior capsular sectioning.

Warren, Marshall, and Girgis (1974) studied the medial anatomical structures as prime static stabilizers in the knee. The long fibers of the superficial medial collateral ligament were prime stabilizers of the medial side with valgus and rotary stress. The medial collateral ligament had a complex pattern of the anterior-most fibers tightening with knee flexion. The long fibers originate from the medial femoral condyle to maintain isometricity with motion while keeping the anterior border under tension from full extension to 90° of knee flexion. The authors formed a consensus that the medial collateral ligament forms a check against external rotation thus compromising the medial collateral ligament to loads to increase rotational instability.

Ellasser, Reynolds, and Omohundro (1974) studied 74 ligamentous knee injuries in professional football players. The knees were treated by a nonoperative criteria according to the following parameters. The knee had to be stable in extension regardless of medial or lateral injuries. The laxity with 30° of flexion could be no more than 10° greater than the uninjured side. Also, the clinical test had to provide a firm endpoint, not one mushy or unstable. The athlete could have no increased rotatory instability. Tenderness also had to be localized, not diffuse. Minimal effusion is permissible, but a significant hemarthrosis is contraindicated. The athlete should be roentgenographically examined to rule out fractures. The authors aggressively treated the subjects meeting said criteria. The authors reported a 98% success rate with the nonoperative approach as compared to 74% percent with the operative approach.

Markolf, Graff-Radford, and Armstutz (1978) studied 28 female and 21 male subjects with no previous history of knee injuries. The subjects were examined with a newly developed clinical testing apparatus to record anterior-posterior tibial force versus displacement and varus-valgus moment versus elongation during manual manipulation of the knee. Joint stiffness and laxity were measured with the muscles of the thigh relaxed and also measured with the muscles of the thigh tensed. Right to left differences were 25 to 35% for laxity and 19 to 24% for stiffness. Anterior posterior laxity averaged 3.7 mm in full extension, 5.5 mm in 20° of flexion, and 4.8 mm in 90° of flexion. The mean varus-valgus laxity was 6.7° in full extension. The authors determined tension of the thigh muscles during examination of the knee increased stiffness an average of two to four times while knee laxity was reduced to 25 to 50% of normal values.

Torzilli, Greenberg, Hood, Pavlov, & Insall (1984) used in vivo radiographic study and biomechanical stress tests with the knee in 90° of flexion to validate the test criteria with the presence of knee injuries. The nature of the study required congruent knee flexion angles and forces. Thus the authors concluded isolated biomechanical measurement will not suffice to evaluate specific knee injuries. The authors felt evaluation requires a system of tests to accurately diagnose specific lesions of injured structures.

Dagiau, Dillman, and Milner (1980) studied the relationship between exposure time and injury in football at the collegiate level, and evaluated the trends associated with injury levels at various levels of participation. The study involved collection of data for practice and game sessions for two seasons. Subjects were varsity football players and were required to be members of the team's travel squad. The authors found an inverse relationship between exposure time and injuries for games during the 2 years. A curvilinear relationship skewed slightly to the right for exposure time and injury for practice data for both seasons was found.

Steiner, Grana, Chillag, & Schelberg-Karnes (1986) used a commercial knee laxity testing device to quantify anterior-posterior laxity prior to and following exercise. Measurements were made at 20° of knee flexion with 30 lb of force. Sedentary controls had no changes in laxity after 2 hours. Squat power lifters had no significant change after series of lifts with 160% of their body weight. There was an 18 to 20% increase in the average anterior-posterior laxity tests with college basketball players after 90 min of practice and also in recreational runners after 10 k races. The role of muscle relaxation in tests was evaluated by measuring laxity in normal knees before and during anesthesia. The authors noted negligible laxity changes and suggested complete relaxation can be obtained with cooperating individuals. Thus it appears repetitive physiological stresses at high strain rates produce significant ligamentous laxity, while relatively few large stresses at low strain rates do not.

Skinner, Wyatt, Stones, Hodgdon, & Barrack (1986) studied highly motivated athletes to determine the effect of exercise on laxity. Subjects were worked to fatigue and the consequential risk for ligamentous injury to the knee when fatigued was studied. The authors found increased anterior laxity of the knee joint due to exercise. The findings imply more accurate clinical examinations of the knee may be obtained after cool-down in athletes with suspected ligamentous laxity. The authors recommended that athletes be encouraged to perform vigorous warm-up exercises when entering organized sports activities and cool-down periods of greater than 15 minutes.

Noyes, Bassett, Grood, & Butler (1980) examined 85 knees arthroscopically and under anesthesia. Sixty-one of the knees (72%) had varying degrees of instability of the anterior cruciate ligament. Of the subjects, 33% revealed history of a popping sensation at the time of injury but normal anterior cruciate ligaments on arthroscopic examination. An additional 36% of the subjects with a popping sensation had a torn anterior cruciate ligament. Collectively, 33% of the knees had no pain to slight pain at the time of injury. Anterior drawer tests without anesthesia were positive in only 24% of the knees with torn anterior cruciate ligaments. The authors concluded traumatic hemarthrosis indicates significant knee injury. Of the subjects with acute hemarthrosis, 75% had anterior cruciate pathology. Also, examination under anesthesia and arthroscopy provided a more accurate diagnosis.

Derscheid and Garrick (1981) studied knee injuries over 4 academic years and found 51 of 70 knee injuries in football were grade one-plus or two-plus sprains of the medial collateral ligament. The treatment plan involved active rehabilitation with partial to no immobilization. Athletes were returned to full unprotected participation within an average of 10.6 days for one-plus instability and 19.5 days for grade two-plus instability. Neither of the groups had increased likelihood of reinjury. The authors also reported the likelihood of sustaining any knee injury was three times greater during spring football practice than fall football practice.

Norwood, Andrews, Meisterling, & Glancy (1979) studied 36 knees with acute anterolateral rotary instability to document ligamentous and meniscal injuries and classify the value of the jerk test and anterior drawer test in anterolateral rotary instability. At surgery, 21 knees had tears of the anterior cruciate ligament and the mid-third of the lateral capsular ligament. Six of the knees had isolated lateral capsular tears. Isolated anterior cruciate ligament tears were found in four subjects. Three of the subjects had anterior cruciate ligament, lateral capsular ligament, and fibers of the Ilio-tibial band torn. Two subjects had anterior cruciate ligament and fibers of the Ilio-tibial band torn. Four subjects had lateral meniscus tears, 5 had medial meniscus tears, 6 had medial and lateral meniscus tears, and 11 had no meniscus injuries. The anterior drawer with the tibia neutral was most sensitive for anterior-lateral rotary instability. The jerk test which is subjected to patient guarding, was positive in the initial exam in only 9 of 36 subjects. The anterior drawer was positive in 14 of 36 subjects on initial examination. Each of the tests was markedly positive under anesthesia. Four knees with acute anteromedial rotary instability had anterolateral rotary instability under anesthesia, thus the authors recommended testing the subject under anesthesia prior to repairing knees with anteromedial rotary instability.

Shoemaker and Markolf (1985) measured the effects of progressive sectioning of the medial collateral ligament and anterior cruciate ligament. The authors evaluated the ligaments and the subsequent forces to which they were exposed. Regardless of the angle or position of the knee, the anterior cruciate ligament was the primary structure controlling the unloaded knee. The medial collateral ligament provided significant resistance to the anterior drawer only after failure of the anterior cruciate ligament. With resection of the medial collateral and anterior cruciate ligaments, tibial excursion with anterior force was excessive when not guided by muscle action. Joint loading with knee flexion and external tibial rotation resulted in irregular force versus displacement response curves that were indicative of joint subluxation. The authors found the medial collateral ligament better suited to control torsional laxity than is the anterior cruciate ligament. With loss of medial collateral function, the anterior cruciate ligament undergoes greater strain as it winds about the posterior cruciate ligament. When sectioned, the anterior cruciate ligament produces a greater increase in tibial rotaticn than if sectioned in the intact knee. Similarly, with the anterior cruciate ligament deficiencies, section of the more highly tensed medial collateral ligament produces a greater increase in torsional laxity than if it is sectioned in an intact knee. Joint load plays a relatively minor role in limiting the increases in torsional laxity due to sectioning of a single ligament, even with the knee in full extension when joint congruency is greatest. When joint load is applied to a knee in which both ligaments have been sectioned, uneven torque versus rotation response curves are indicative of subluxation of the joint, as the tibia is seeking a new axis for rotation. The finding most probably represents the instability experienced by patients with ligament deficits when attempting to change direction on a planted foot.

Markolf, Kochan, and Amstutz (1984) used a clinical testing apparatus to measure 35 patients with documented absence of the anterior cruciate ligament. The authors measured response curves for anterior-posterior versus displacement at full extension, 20° and 90° of knee flexion; varus-valgus moment versus elongation at full extension, 20°, and 90° of knee flexion; and tibial torque versus rotation at 20° of flexion. Uninjured asymptomatic subjects and anterior cruciate ligament deficient knees tested at 20 and 90° of flexion exhibited greater anterior-posterior laxity at 15° of external rotation of the foot. Injured knees had significantly greater total anterior-posterior laxity and decreased anterior stiffness as compared to uninjured subjects in all tested positions of the foot and knee. The average increase in paired anterior-posterior laxity for injured knees was 3.1 mm (39%) at full extension, 5.5 mm (57%) at

20° of flexion, and 2.5 mm (34%) at 20°. Only a slight reduction in posterior stiffness (16%) was measured at 20° of flexion. Patients with medial menisci deficient knees had greater total anterior-posterior laxity at all three positions than subjects with intact or torn menisci. Varus-valgus laxity at full extension increased an average of 1.7° (36%) for injured knees and varus-valgus stiffness decreased 21 and 24%. Absence of the medial meniscus in knees with no anterior cruciate ligament had increased varus-valgus laxity at zero and 20° of flexion. The clinical drawer test performed at 90° of flexion. Studies of right versus left knees revealed differences in anterior stiffness greater at 20° of flexion.

Hughston, Andrews, Cross, & Moschi (1976) classified knee injuries by severity. The work was based on quantification of displacement of bone ends at joints in surgery and correlating the findings with clinical impressions of the injuries recorded prior to surgery.

Grood, Noyes, Butler, & Suntay (1981) studied cadaver knees to determine the primary and secondary restraining structures at various positions. In 16 cadaver knees tested at 5 and 20° of flexion, the collateral ligaments provided primary restraints at both angles. At 5°, the posterior capsule and cruciate ligaments were secondary restraints. As the knee was flexed, the posterior capsule slackened. The mid-third of the medial and lateral capsule provided little restraints to valgus and varus forces. The Ilio-tibial tract and popliteal muscle provided little passive restraints. Forces to the Ilio-tibial band and biceps tendon produced additional forces thought to be significant in vivo to protect the lateral capsule. Isolated cutting of the medial collateral ligament and lateral collateral ligament produced 3 to 5 mm of increased joint opening. However, the authors felt the increases to be minimal as secondary restraints blocked the motion and provided stability. Near full extension, the secondary restraints almost completely blocked the opening.

Hughston, Andrews, Cross, & Moschi (1976) examined lateral knee ligament instabilities and determined instabilities of the lateral aspect of the knee are less frequent but more disabling than medial instabilities. However, clinical evaluation of lateral side instabilities are also often misinterpreted. Posterolateral rotatory subluxation is demonstrated by an apparently positive posterior drawer test with the tibia in neutral rotation or by the external rotation-recurvatum test with the knee in extension. Anterolateral rotatory instability is the subluxation present during the anterior drawer test with the tibia in neutral rotation. The positive test demonstrates the lateral tibial condyle becomes more prominent or both candles become equally prominent.

Anterolateral rotatory instability is confirmed by the jerk elicited at about 30° of knee flexion as the moderately internally rotated tibia is brought from a position of 90° of flexion to full extension while a mild abduction stress is applied. Combined anterolateral and posterolateral rotatory instability is characterized by a positive anterior drawer test and apparently positive posterior drawer test, an adduction stress test that is one-plus or two-plus at 30° of flexion, and positive external rotation-recurvatum and jerk tests. Straight lateral instability is confirmed by a positive adduction stress test of varus force at full extension without associated external rotation and recurvatum of the tibia, and is present when the lateral compartment ligaments are completely torn with an associated tear of the posterior cruciate ligament. The authors emphasized the importance of the soft tissues and the evaluation of structures to allow for appropriate treatment.

Furman, Marshall, and Girgis (1976) studied 40 fresh human cadaver knees to determine the function of the anterior cruciate ligament and its two parts; the posterolateral and the anteromedial portions. The sections were studied by cutting the ligaments in different sequences and combinations and manually stressing the knees. The anterior drawer sign cannot be obtained unless the anteromedial band is severed. The posterolateral part and the medial collateral ligament are, respectively, the secondary restraints limiting the anterior drawer sign. Combined motions of internal and external rotation are limited by the anterior cruciate ligament, especially with knee extension. The anterior cruciate ligament also limits hyperextension.

Fetto and Marshall (1979) studied 25 fresh cadaver knees and found the pivot shift test was highly correlated with sprains of the anterior cruciate ligament. The pivot shift test corresponded to a sudden anterior-internal rotation subluxation-dislocation of the tibia on the posterior horn of the lateral meniscus beneath the lateral femoral condyle of the femur.

Larson (1983) discussed the functional examination of the knee for rotational instabilities. The pivot shift test involved externally rotating the knee during the anterior drawer test to detect anterolateral rotary instability. Anterolateral instability was often found with the anterior cruciate deficient knee, and the functional disability is the pivot shift phenomenon. Posteromedial rotational instability was noted by posteromedial displacement of the medial tibial plateau with valgus stress. Posterolateral rotary instability was evaluated by external rotation recurvatum, posterior cruciate drawer test, and the reverse pivot shift tests.

Curran and Linquist (1986) studied prophylactic knee braces and subsequent knee injuries. The authors found a reduction in knee injuries due to wearing preventive knee braces with a confidence level of 99.998%.

CHAPTER 2

Method

This investigation began in June, 1987, with initial contact of the athletic trainers at selected schools in North Carolina (see Appendix A). The preseason assessments were completed prior to August 1, 1987. Following the final game of the regular season, each of the athletic trainers was contacted to request that final data be returned to the investigator (see Appendix B). The postseason and postinjury assessments were completed in December, 1987.

The study involved a flexibility assessment of high school football players to determine active flexibility. The assessment was performed prior to engaging in organized team practice sessions and included anthropometric measures. Records of athletic related injuries were reported by the athletic trainer for each school in communication with the consulting physician. The athletic trainers recorded injuries during the regular football season to determine incidence of injuries. An injury was defined as an episode requiring the athlete to miss a session or receive medical attention from the attending athletic trainer or a physician prior to returning to competition. The injuries were categorized from the physician's diagnosis and limited to the soft tissue structures of the knee listed in Table 1. The severity of injury and history was also obtained by the athletic trainer.

Subjects

Subjects were 101 junior and senior year athletes from varsity level football teams of member institutions of the North Carolina High School Athletic Association. A listing of schools included in the study can be found in Appendix C.

Description of Test Procedures

Preseason Assessment

The preseason assessment involved performance of the Nicholas Flexibility Protocol and anthropometric measures. Results of the tests were recorded on the individual's Preseason Assessment form (see Appendix D). The investigator evaluated all preseason assessments.

Nicholas Flexibility Protocol

The Nicholas Flexibility Protocol parameters were scored as positive or negative, with no partial scores allowed. The ability to complete the test constituted a positive score and the inability to perform the task was recorded as a negative score. Subject's scores were recorded on the Preseason Assessment Form (see Appendix D).

Palms to Floor. Subjects were required to flex the spine and touch the floor with the palms bilaterally

Table 1

Soft Tissue Structures of the Knee

1. Medial Collateral Ligament
2. Lateral Collateral Ligament
3. Anterior Cruciate Ligament
4. Posterior Cruciate Ligament
5. Medial Meniscus
6. Lateral Meniscus
7. General Joint Capsule
8. Pes Anserine Musculature
9. Medial Collateral Ligament and Medial Meniscus
10. Lateral Collateral Ligament and Medial Meniscus
11. Anterior Cruciate and Medial Collateral Ligaments
12. Anterior Cruciate and Lateral Collateral Ligaments
13. Medial Collateral Ligament, Medial Meniscus, and Anterior Cruciate Ligament
14. Anterior Cruciate Ligament and Lateral Meniscus
15. Anterior Cruciate Ligament, Medial Meniscus, and Lateral Meniscus
16. Vastus Medialis Obliqus
17. Medial Collateral and Anterior Cruciate Ligament

with the knees fully extended. Subjects were scored as positive or negative according to completion of the task.

Genu recurvatum. Subjects were placed in a prone position with the knees extended over the end of an examining table. A goniometer was used to measure hyperextension of the knee joint. The presence of 20° or more of recurvatum of the knee indicated a positive score.

Upper extremity external rotation. Subjects were requested to demonstrate upper extremity laxity by shoulder flexion to 90°, elbow hyperextension, and supination of the forearm to position the hypothenar eminence inferior to the thenar eminence of the hand, thus a positive score.

Lower extremity external rotation. Subjects knees were flexed to more than 15° and not less than 30°. The hips, knees, and ankles were externally rotated maximally to attain a straight angle of 180°, with the low leg externally rotated. Subjects were scored as positive or negative according to completion of the task.

Lotus position. Subjects were allowed to sit or lie on the floor with ankles on the floor with knees flexed and hips internally or externally rotated. The legs and thighs were parallel to the floor. Subjects were scored as positive or negative according to completion of the task.

Body weight. Body weights were assessed using medical scales. The scores were recorded in half pound (.227 kg) units.

Postseason Assessment

Following the season, data were recorded on an individual form for each subject (see Appendix E). A sheet was provided for each subject to record the following information. Athletic trainers of each school recorded information needed for the study and maintained records for each subject as follows.

Shoe Type

A record was made of the brand of shoe worn, the style (low cut, three-quarter cut, or high top), the intended use of the sole of the shoe (screw in cleat for grass surface, molded bottom for grass surface, or multiple cleats for synthetic surface), and the material used by manufacture (leather, mesh, nylon, or other).

Knee Braces

Subjects wearing derotational braces for anterior cruciate ligament deficiencies were excluded from the study. Record was also made of athletes wearing prophylactic braces. The evaluation included the type of brace, type of application (commercial neoprene straps or taped on), the age of the brace (in months), and whether the brace was worn on left and/or right legs.

Game Participation

The total number of quarters participated in per regular season game was recorded. No record was maintained for postseason competition.

Postinjury Assessment

The athletic trainer was supplied forms (see Appendix F) to record knee injuries occurring to the subjects. The incidence of injuries was recorded according to the structures injured. Injuries were categorized from the supervising physician's diagnosis and the athletic trainer's report.

A checklist was supplied to the attending physicians (see Table 2) to provide a reference regarding diagnosis of knee symptoms. The information was used in addition to the following discussion regarding degree of sprain. Reference was also made to Ellison (1984) for the evaluation of the injured knee (see Table 3).

Severity of injury was classified by the American Medical Association's criteria of mild, moderate, and severe injuries. The American Medical Association (1976) described sprains as injury to the ligament (passive structures) of the joint. Thus, injury is to primary stabilizing ligaments may have led to instability of the involved joint.

Joint Stability Tests

With joint laxity testing of injured structures, the examiner attempted to apply forces to distract joints similar to those forces causing initial injury. The

Table 2

Checklist for Knee Ligament Injury

1.	Location and extent of tenderness
2.	Amount and rapidity of swelling
3.	Location of swelling-- intra- or extra-capsular
4.	Deformity
5.	History of locking or giving out
6.	Active range of motion
7.	Passive range of motion
8.	Severity of injury (mild, moderate, or severe)
9.	Degree of instability (zero, one-plus, two-plus, or three-plus)

Note: From Treatment of injuries to athletes (p. 480) by D. H. O'Donoghue, 1984, Philadelphia: W. B. Saunders.

Table 3

Classification of Ligament Injury Laxity

First-degree	Mild (less than 5 millimeters of distraction
Second-degree	Moderate (5-10 millimeters of distraction)
Third-degree	Severe (over 10 millimeters of distraction)

Note: From Athletic Training and Sports Medicine (p. 267) by A. E. Ellison, 1984, Chicago: American Academy of Orthopaedic Surgeons.

subsequent force usually equals 10 to 20 lb (6.81 to 9.08 kg), yet not near the magnitude placed on joints during high speed physical activity (Noyes et al., 1980). Following are descriptions of specific joint stability tests and the corresponding structures for each test. The tests were discussed by planes of applied force and thus positive tests were identified from laxity in specified planes.

Clinical stability tests were evaluated bilaterally on the subject and recorded according to the specific structure involved and severity of sprain. The results were recorded on the Postinjury Evaluation Form (see Appendix F).

Straight Anterior Laxity. The anterior cruciate ligament was tested by the anterior drawer test and the Lachman test. The anterior drawer test was performed on the supine patient with knee flexed to 90° and the hip flexed to 45°. The examiner cupped the hands around the subject's knee joint and drew the tibia anteriorly from under the femur. The test was recorded as millimeters of distraction of the tibia on the femur.

Anterior laxity may be difficult to access in the acutely swollen knee. The Lachman test, or anterior drawer test, was performed at 30° of knee flexion in the supine subject. The patient's tibia was again distracted anteriorly from the femur. According to the review of literature, the Lachman test was more reliable than anterior drawer tests at 90° of flexion as secondary ligamentous restraints are less taut at 30° than 90° of flexion. Tests showed drawer tests conducted at 20 to 30° of knee flexion were more reliable in detecting injury to the anterior cruciate ligament (Noyes et al., 1980).

The anterior cruciate ligament, the primary restraint to straight anterior drawer testing at 30° and 90° of knee flexion, provided straight anterior stability and anterolateral rotary stability. Also, the amount of laxity depended on the tightness of the hamstring, the remaining secondary restraints of the knee (Noyes, Grood, Butler, & Paulos, 1980). A positive anterior drawer sign in 90° of flexion emphasizes anteromedial fiber injury of the anterior cruciate ligament. Positive anterior drawer sign at 5° of flexion suggests injury to the posterolateral fibers of the anterior cruciate ligament (Kennedy, 1979).

Straight posterior laxity. The posterior cruciate ligament was tested by the posterior drawer test on the supine patient with knees flexed to 90° and the hip flexed to 45°. The examiner cupped the hands around the subject's knee joint and forced the tibia posteriorly from under the femur. The test was recorded as millimeters of distraction of the tibia on the femur.

The posterior cruciate ligament was the primary ligamentous restraint providing 95% of the resisting force for posterior displacement of the tibia. Posterior laxity can be confused as false-positive anterior laxity. The neutral point for the knee joint for anterior-posterior laxity was established prior to testing. The posterior cruciate ligament was the primary restraint to straight posterior laxity at 30° and 90° of flexion (Noyes et al., 1980).

Straight medial laxity. Testing for straight medial instability required straight valgus force applied to produce opening in one plane. Increased external rotation and medial joint opening were produced simultaneously. The test was a more sensitive test for anteromedial rotation than the Slocum external rotation test as medial opening and increased external rotation occur simultaneously (Ellison, 1984).

The medial aspect of the knee was tested with the subject supine, preferably on an examining table. The knee was tested in full extension, with increased tension placed on the medial collateral ligament, the anterior cruciate ligament, and the posteromedial capsular structures. The examiner stabilized the subject's knee with one hand placed on the lateral side of the knee and grasped the medial side of the ankle with the other hand. The examiner applied a valgus force to the knee medially and recorded the degree of laxity as millimeters of distraction (Hoppenfeld, 1976).

Laxity with the knee in extension also indicated damage to the posteromedial capsular structures. Opening of the medial joint greater than 10 mm, constituted damage to the anterior or posterior cruciate structures (Ellison, 1985).

Medial laxity with 20° of flexion. The superficial structures of the medial collateral ligament of the knee were tested with the subject supine, preferably on an examining table. The knee was flexed to 20° to isolate the superficial structures of the medial collateral ligament. The examiner stabilized the subject's knee with one hand placed on the lateral side of the knee and the other hand grasped the medial side of the ankle. The examiner applied a valgus force to the knee and recorded the degree of laxity as millimeters of distraction.

Increased medial opening with 30° of knee flexion indicated damage to the medial collateral ligament, the primary valgus restraint. The medial collateral ligament resists about 80% of the force applied to the knee joint at 30° of flexion. Since isolated failure of the medial collateral rarely occurred, laxity indicated damage to the secondary restraints, namely the medial capsular structures. With the knee flexed to 25°, the superficial medial collateral ligament was the primary restraint to valgus testing (Ellison, 1984). The medial collateral ligament provided 78% of the restraining forces at 5 mm of opening. The secondary restraints at this position were the anterior cruciate ligament and the posterior cruciate ligament (Noyes et al., 1980). At 5° of flexion, the superficial medial collateral ligament provided 57% of the restraining force. Knee extension increased the importance of the posterior medial capsule. The posteromedial capsule accounted for 18% of the total valgus restraints (Noyes et al., 1980).

Straight lateral laxity. The lateral collateral ligament was the primary ligamentous restraint to the lateral aspect of the joint and accounted for 70% of resisting force during the testing procedure. With knee extension, the posterolateral capsular structures were tightened (Noyes, et al., 1980).

Lateral laxity with 20° of Flexion. Varus laxity with the knee in 20 to 30° of flexion indicated an injury to the fibular collateral ligament and lateral capsular structures. The lateral collateral ligament was the primary ligamentous restraint to the lateral aspect of the joint, accounting for some 70% of resisting force during the testing procedure. The lateral collateral ligament resisted 70% of the varus forces at 25° of flexion (Noyes, et al., 1980).

Anteromedial rotatory instability. There were two primary tests for anteromedial rotatory instability. The Slocum external rotation tests was done with the hip flexed to approximately 45° and the knee flexed to around 80° while the foot rests on the examining table. The examiner sat on the table, keeping the subject's externally rotated foot trapped by the examiner's upper thigh and grasped the upper portion of the lower leg. The index fingers palpated the hamstring insertions to maintain relaxation. A gentle forward symmetrical pull was applied. The degree of anterior drawer was recorded. External tibial rotation unwound the cruciate ligaments and placed increased stress on the medial capsular structures (Booher & Thibodeau, 1985).

Anterolateral rotatory instability. Anterolateral rotatory instability was characterized by an anterior internal rotational subluxation of the lateral tibial condyle on the femur. The lateral pivot shift was used to diagnose the laxity. The lateral tibial condyle subluxates anteriorly from underneath the lateral femoral condyle (Ellison, 1984).

The primary restraint for anterolateral rotatory instability was the anterior cruciate ligament. The Ilio-tibial band and the lateral capsule provided a secondary restraint (Noyes et al., 1980). However, clinically tested isolated anterolateral rotatory instability tests were seldom accurate when performed on the acutely injured knee. The procedure generally required examination under anesthesia to provide reliability and validity of the tests (Booher & Thibodeau, 1985).

The lateral pivot shift test was performed on the supine and relaxed subject. The heel of the involved leg was placed in the evaluator's distal hand. The examiner was located lateral to the subject. The proximal hand of the examiner was placed over the lateral tibia with the thumb behind the fibular head. The knee was flexed to 5° and both hands were used to internally rotate and place valgus stress on the lower leg at the femur. Simultaneously, the proximal tibia was pushed anteriorly with the proximal hand. Lifting the fibular head gently with the thumb, the lateral tibial plateau was observed for anterior subluxation at around 30° of flexion (Booher & Thibodeau, 1985).

The jerk test for anterolateral rotatory instability was performed on the supine subject with the knee flexed approximately 90° and the hip flexed to 45°. The examiner's distal hand supported the foot and applied internal rotation. The proximal hand was placed over the proximal tibia and fibula to aid internal rotation and serves as a fulcrum for valgus force. With internal rotation and valgus forces maintained, the knee was extended. The positive test produced a snap and a pop with subluxation of the lateral femoral articulation at around 30° (Booher & Thibodeau, 1985). If the knee was carried to complete extension, reduction again occurred.

Genu Recurvatum

Three types of recurvatum may be found. The first type is physiologic, related to generalized laxity of the knee joint. Hyperextension to 15° may be seen in the loose-jointed individual. An individual with this amount of hyperextension generally does poorly after sustaining ligamentous injury because the knee joint lacks additional supporting ligamentous structures.

A second type of genu recurvatum was a posterolateral rotary instability. Instead of pure hyperextension, the tibia rotated posterolateral The third type of recurvatum was due to posterior capsular laxity and associated cruciate ligament damage (Ellison, 1984).

Data Analyses

The preseason, postinjury, and postseason assessment data were entered in a PC-File software package for filing purposes. To perform statistical analyses, the data were uploaded to the Appalachian State University mainframe using the Kermit uploading program. The Statistical Package of the Social Sciences (SPSS*), a product of the Statistical Package of the Social Sciences, Incorporated were used for comparison and analyses of data. A Principal Component Factor Analysis was used to build a model for analyzation of parameters to determine if any of the factors in the preseason assessment are valid predictors of injury to the knee joint in high school football players. The data were then subsequently loaded into seven factors and the variables defined were placed into a discriminate analysis. A factor analysis was used to determine if the parameters were valid, and if so, a chi square performed to validate results.

Subsequent to preseason assessment, postseason assessment, and postinjury assessment, the preseason assessment data were cross referenced with postseason and postinjury assessment data to determine significance of active flexibility as a predictor of incidence or severity of knee injuries.

The total number of positive scores were correlated with incidence of specific knee injuries as reported by the athletic trainers and physicians on the postinjury data sheet (see Appendix F). Knee injuries were studied by incidence of single injuries and also grouped for similar injuries of medial or lateral compartments or intracapsular structures.

A multiple correlation was performed on dependent and independent factors. The independent factors were defined and controlled by injury incidence. The independent factors are found regardless of injury and appraised in the preseason and postseason assessment session. Each injury was also categorized by severity and thus constituted three possible variables for each injury. A complete listing of dependent and independent variables are found in Appendix G.

The independent and dependent variables were correlated singly to determine significance. A factor analysis was then performed to determine predictive values.

CHAPTER 3

Results

In the preceding chapter the study's procedures and methods were discussed regarding preseason, postseason, and postinjury assessment of the subjects. This chapter discloses the results of the computerized data analyses.

Following the season, a comparison was made of current rosters and those at the beginning of the season. Subjects terminating participation, other than for injury, were excluded from the study. The 126 subjects evaluated in the preseason assessment procedures described in Chapter 2 were thus reduced by 19.8% to 101.

Frequency Analysis

The schools included in this study represent varied geographic and demographic regions of North Carolina. Three levels of athletic participation in North Carolina, class AAAA, AAA, and A levels, are represented. A total of 52.2% (n = 53) of the subjects were from the class AAAA level, 28.7% (n = 29) from the AAA level, and the remaining 18.8% (n = 19) were from the class A level.

Preseason Assessment

Nicholas Flexibility Scores

The flexibility scores from the Nicholas Flexibility Protocols are reported by each of the individual tests.

The number of positive and negative scores are included in Table 4 for each of the 101 subjects.

The summation of positive scores is reported in Table 5. The total number of positive flexibility scores and the individual scores were used to determine if any significant statistical relationships were found between flexibility and the incidence of knee injuries. A total of 71.3% (*n* = 72) of the subjects had two or less positive scores on the preseason assessment as measured by the Nicholas Flexibility test. The mean flexibility score (total positives) of all subjects was 1.703.

A bar graph of subject's performance on the Nicholas Flexibility Protocol is included in Figure 1. Data is presented as number of subjects scoring positive and negative for each test. The bar graph differentiates injured and uninjured subjects.

The graph in Figure 2 illustrates that the mean flexibility score was 1.703 with a mode of 2.000. The median score was also 2.000. The graph illustrates the distribution of scores about the median, mean, and mode, approximating a normal distribution.

Figure 3 represents an analysis of the incidence of total positive scores by injured and uninjured subjects. The figure reveals total scores representing proportions from the injured and uninjured groups. The data for Figure 3 is found in Table 5.

Table 4

Nicholas Flexibility Score Results of Subjects

Test	Negative Inj.	Negative Uninj.	Positive Inj.	Positive Uninj.
Palms to Floor	10	56	3	32
Genu Recurvatum	11	70	2	18
Upper Extremity				
External Rotation	7	43	6	45
Lotus Position	11	75	2	13
Lower Extremity				
External Rotation	7	43	6	45

Table 5

Incidence of Positive Scores

	All Subjects	Injured	Uninjured
N	101	13	88
%	100.0%	12.9%	87.1%
0	26	4	22
	25.7%	30.8%	25.0%
1	16	2	14
	15.8%	15.3%	15.9%
2	30	4	26
	29.7%	30.8%	29.5%
3	21	3	18
	20.8%	23.1%	20.5%
4	7	0	7
	6.9%	0%	8.0%
5	1	0	1
	1.0%	0%	1.1%

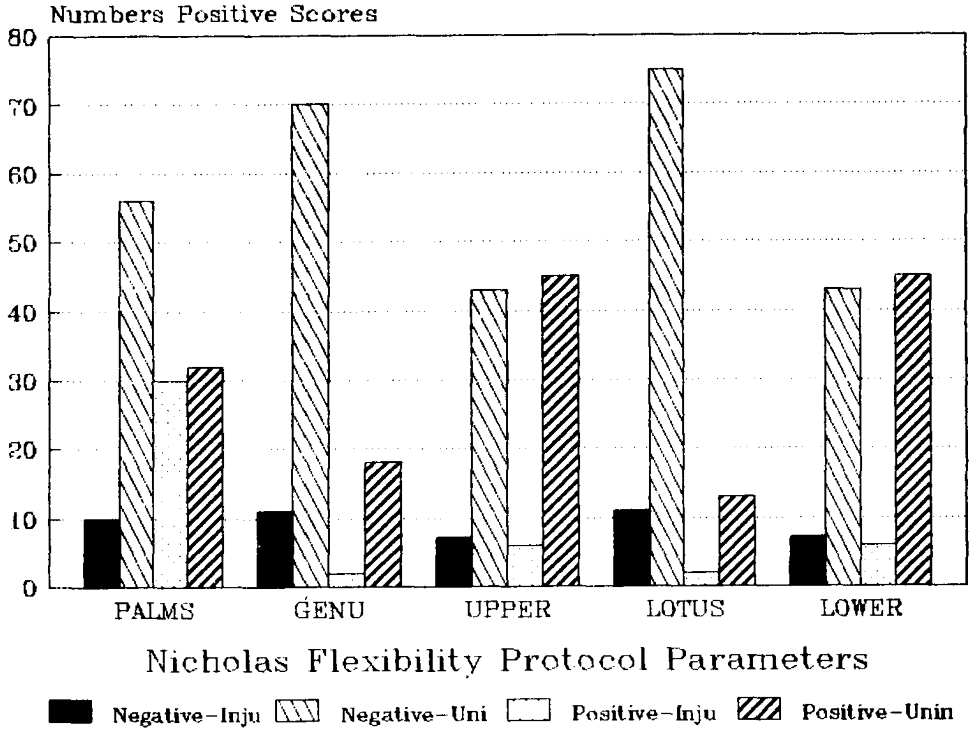


Figure 1. Results of Nicholas Flexibility Protocol reported by individual test scores of negative and positive for injured vs. uninjured subjects.

Note: Palms = Palms to Floor, Genu = Genu Recurvatum, Upper = Upper Extremity External Rotation, Lotus = Lotus Position, Lower = Lower Extremity External Rotation.

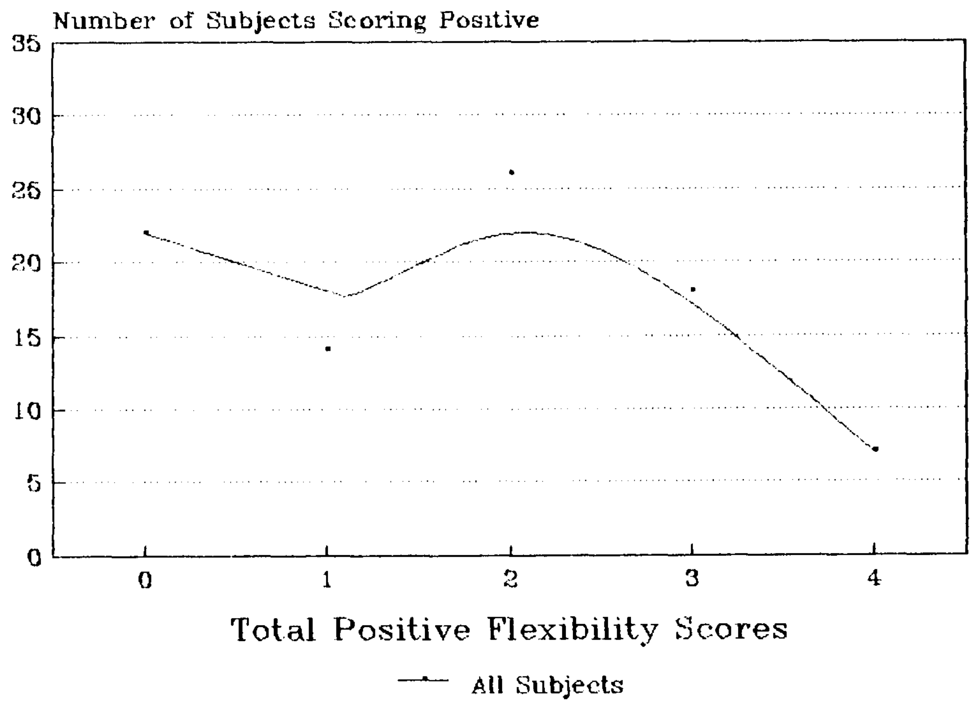


Figure 2. Graph of total flexibility scores.

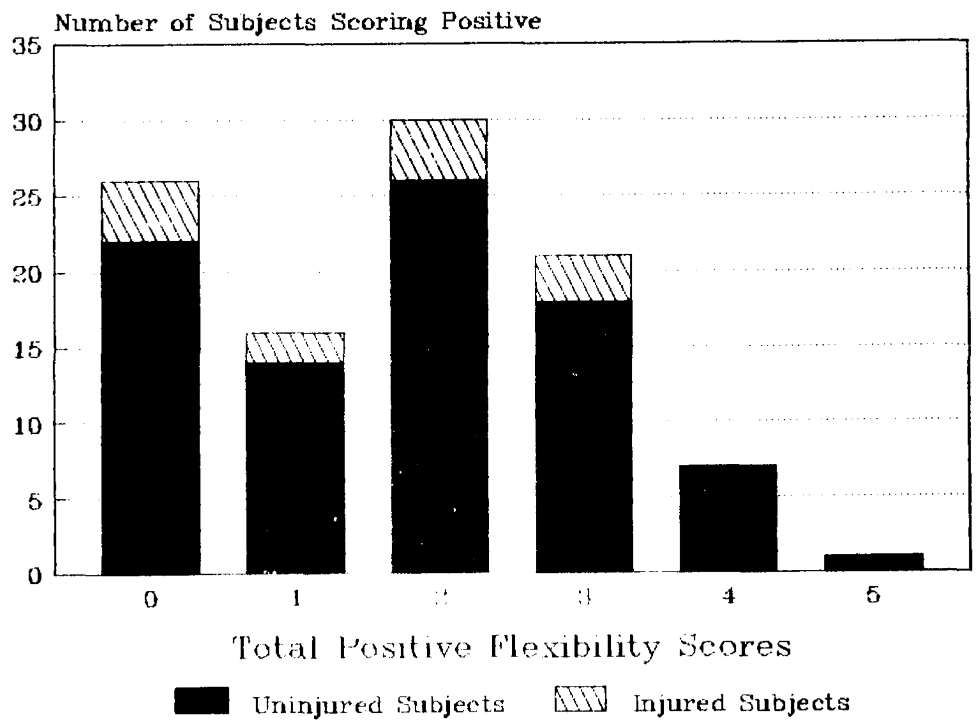


Figure 3. Incidence of total positive scores on Nicholas Flexibility Protocol of all subjects and injured vs. uninjured subjects.

Body Weight

Body weight was analyzed in a frequency distribution by subject's weight in Table 6. The preseason assessment revealed 80% of the subjects weighed less than 200 lb (90.80 kg). The mean body weight was 178.069 lb (80.84 kg) with an inclusive range of 133.000 to 275.000 lb (60.32 to 124.85 kg). The 13 subjects injured during the study had mean body weights of 144.900 lb (65.78 kg) and the 88 uninjured subjects averaged 177.500 lb (80.59 kg).

The values of body weight are displayed in Figure 4 and allow analysis of the 101 subjects. The distribution approximates a normal distribution of scores as the mode was 175.000 pounds and the median body weight was 175.000 pounds.

Gastrocnemius Girth Measures

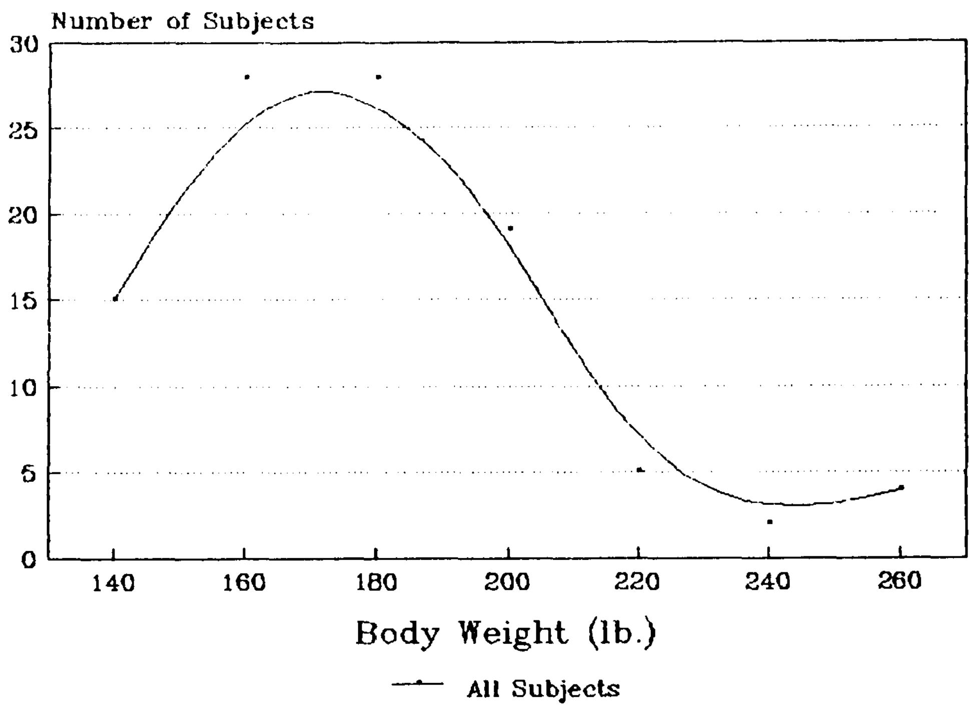
Girth measures of gastrocnemius musculature of subject's are presented in Table 7. The mean circumference measure was 14.809 in. (37.62 cm) with a mode of 14.000 in. (35.56 cm). The most frequent score was 14.760 in. (37.47 cm). The mean score for the uninjured subjects was 14.8 in. (37.60 cm) and the injured subjects had an average measure of 15.5 in. (39.37 cm).

Figure 5 features a graph with a normal distribution of gastrocnemius girth measures. The range of scores was from 11.50 to 18.50 in. (29.21 to 46.99 cm). Analysis of

Table 6

Body Weight of Subjects

Value (lb)	Frequency	Percent	Cumulative Percent
130-139	8	7.9	7.9
140-149	7	6.9	14.8
150-159	15	14.9	29.7
160-169	13	12.9	42.6
170-179	11	10.9	53.5
180-189	17	16.9	70.4
190-199	10	9.9	80.3
200-209	9	8.9	89.2
210-219	4	3.9	93.1
220-229	1	1.0	94.1
230-239	1	1.0	95.1
250-259	1	1.0	96.1
260-269	1	1.0	97.1
270-279	3	2.9	100.0



<u>Figure 4</u>. Graph of subjects' body weight.

Table 7

Gastrocnemius Girth Measures

Value (in.)	Frequency	Percent	Cumulative Percent
11.50-11.75	2	2.0	2.0
12.00-12.25	4	3.9	5.9
12.50-12.75	5	5.0	10.9
13.00-13.25	4	3.9	14.8
13.50-13.75	5	5.0	19.8
14.00-14.25	22	21.7	41.5
14.50-14.75	10	10.0	51.5
15.00-15.25	15	14.9	66.2
15.50-15.75	6	5.9	72.1
16.00-16,25	14	13.9	86.0
16.50-16.75	2	2.0	88.0
17.00-17.25	7	6.9	94.9
17.50-17.75	2	2.0	96.9
18.00-18.25	2	2.0	98.9
18.50-18.75	1	1.0	99.9

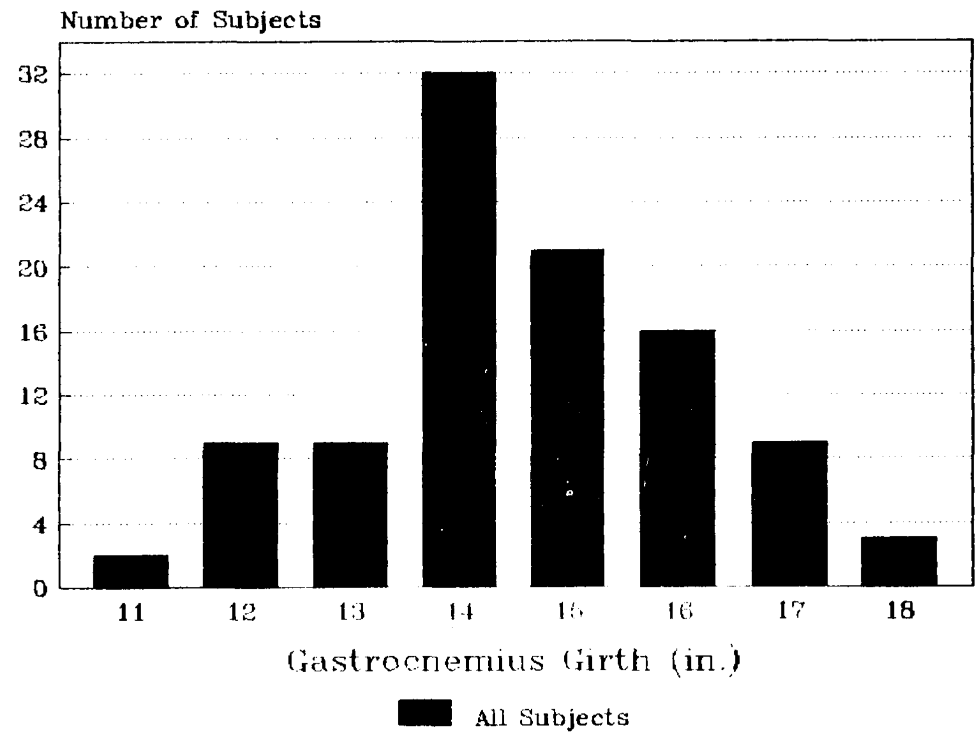


Figure 5. Graph of subjects' gastrocnemius girth.

the data shows 20% of all subjects had girth measures in excess of 15.75 in. (40.01 cm).

Thigh Girth Measures

Thigh girth measures are presented in Table 8. Figure 6 displays values assimilating a normal distribution as quantified by the mean of 19.079 in. (48.46 cm), mode of 18.000 in. (45,72 cm), and the median measure of 19.000 in. 48.26 cm). The range of thigh girth measures was 13.750 to 24.500 in. (34.93 to 62.23 cm).

Analysis of the data revealed that 40% of the subjects had girth measures of 19.500 in. (49.53 cm) or above. The mean thigh girth measure of the injured subjects was 20.100 in. (51.05 cm) whiled the uninjured subjects had average thigh girth measures of 19.100 in. (48.51 cm).

Postseason Assessment

Analysis of Shoes Worn by Subjects

Analysis of the frequency distribution revealed 73.3% ($\underline{n}$ = 74) of the subjects wore Nike brand shoes. Eight percent ($\underline{n}$ = 8) of the subjects wore Spotbilt brand shoes while the remaining 19% ($\underline{n}$ = 19) wore seven other brands (see Figure 7). An analysis of shoes by manufacturer is found in Table 9.

The majority of the subjects ($\underline{n}$ = 82) participated in shoes with leather uppers while 15 subjects used a shoe with mesh top. The low cut style shoe was the most popular with 61 subjects wearing this model. An analysis of shoe

Table 8

Thigh Girth Measures

Value (in.)	Frequency	Percent	Cumulative Percent
13.50-13.75	1	1.0	1.0
14.50-14.75	1	1.0	2.0
15.50-15.75	2	2.0	4.0
16.00-16.25	3	3.0	6.9
16.50-16.75	3	3.0	10.0
17.00-17.25	6	6.0	16.9
17.50-17.75	5	4.9	21.8
18.00-18.25	16	15.9	37.7
18.50-18.75	13	12.9	50.6
19.00-19.25	10	9.9	60.5
19.50-19.75	8	7.9	68.3
20.00-20.25	8	7.9	76.2
20.50-20.75	5	4.9	81.2
21.00-21.25	7	6.9	87.1
21.50-21.75	1	1.0	88.1
22.00-22.25	6	5.9	94.0
22.50-22.75	1	1.0	95.0
23.00-23.25	3	3.0	98.0
24.5-24.75	2	2.0	100.00

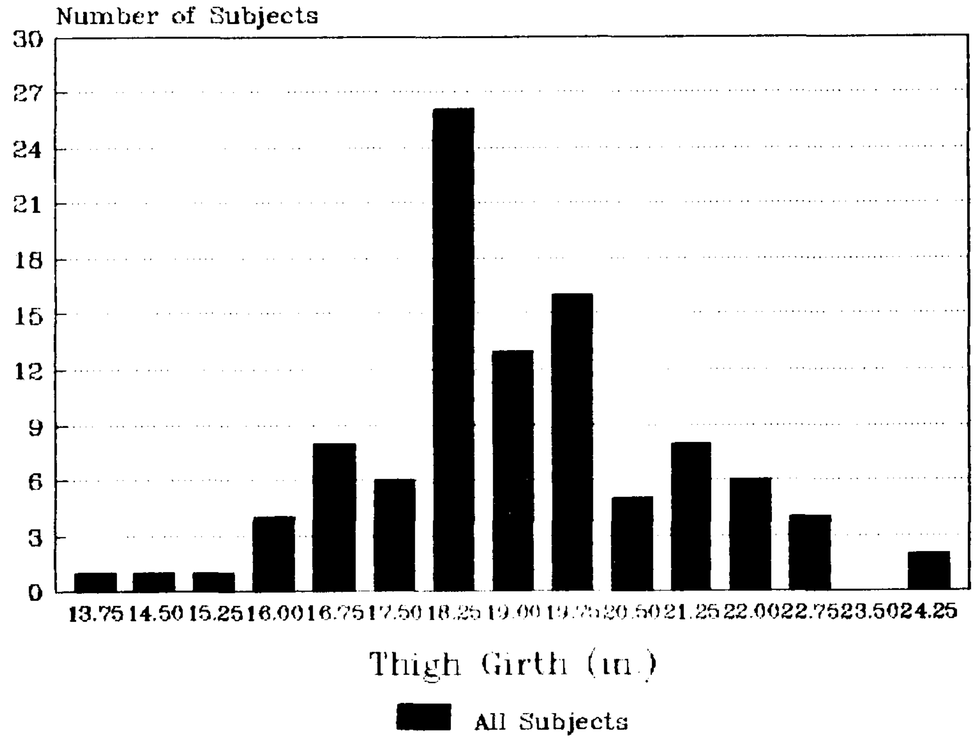
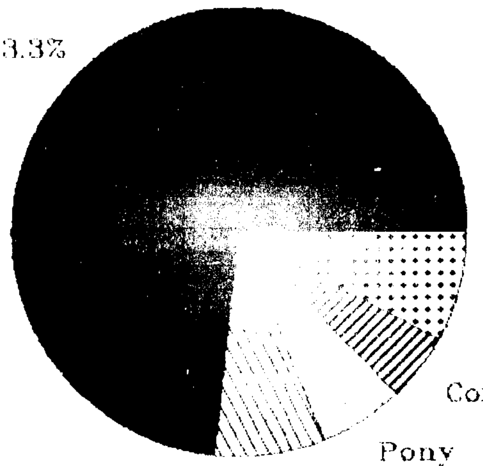


Figure 6. Graph of subjects' thigh girth.



<u>Figure 7</u>. **Analysis of shoe by manufacturer.**

Table 9

Analysis of Shoe by Manufacturer

Manufacturer	Frequency	Percent
Converse	5	5.0
Cuga	1	1.0
Medalist	1	1.0
Mizuno	2	2.0
Nike	74	73.0
Pony	6	6.0
Riddell	3	3.0
Spalding	1	1.0
Spotbilt	8	8.0
Totals	101	100.0

according to their intended use, style, and material of manufacturer is found in Table 10. An additional 35 subjects used high top style while the remaining five used a three quarter or midankle height shoe.

The design of the shoe sole is dependent upon the surface on which the shoe is to be used. The common screw-in cleat has long been used for football or other outdoor activities on natural turf. However, the molded bottom shoe is becoming popular for football. Table 10 reveals that 55 of the subjects used a screw in cleated shoe, while 42 subjects used the molded bottom shoe, and 4 subjects used a shoe designed for synthetic surfaces.

Of the 13 injured subjects, 8 wore Nike brand shoes while the remaining 5 represented an equal distribution of the brands. Regarding the sole style of the shoe, 61.5% (n = 8) used the molded bottom sole and the remaining 5 subjects wore shoes with screw-in cleats. Of the subjects, 76.9% (n = 11) wore low top height shoes and the remaining 2 wore high top height shoes.

Prophylactic Knee Braces

The use of prophylactic knee braces in selected high schools in North Carolina was also reported. The data revealed that the use of prophylactic knee braces was prevalent in only 16 subjects as 85 did not wear any preventative knee braces. Of the 16 who did wear knee braces, 75% (n = 12) wore the DonJoy knee brace.

Table 10

Analysis of Shoe Controlled By Intended Use and Material

Manufacturer	Screw-in Cleats	Molded Bottom	Multi-Cleats
Low Top Mesh Shoe ($\underline{n}$ = 5)			
Converse	0	1	0
Nike	1	1	1
Spotbilt	1	0	0
Three Quarter Level Mesh Shoe ($\underline{n}$ = 5)			
Nike	0	0	2
Spotbilt	2	1	0
High Top Mesh Shoe ($\underline{n}$ = 5)			
Nike	0	5	0

(table continues)

Manufacturer	Screw-in Cleats	Molded Bottom	Multi-Cleats
	Leather Low Top (n = 53)		
Converse	1	1	0
Medalist	0	1	0
Nike	19	16	2
Pony	0	5	0
Riddell	3	0	0
Spalding	0	1	0
Spotbilt	4	0	0
	Leather High Top (n = 29)		
Converse	1	0	0
Mizuno	0	2	0
Nike	22	4	0
	Canvas Low Top (n = 2)		
Cuga	0	1	0
Pony	1	0	0

(table continues)

Manufacturer	Screw-in Cleats	Molded Bottom	Multi-Cleats
	Canvas High Top (n = 1)		
Nike	0	1	0
	Other, Low Top (n = 1)		
Converse	0	1	0
Totals	55	42	4

Game Participation

Quarters of game participation ranged from 1 to 40 quarters. The data (see Table 11) revealed that 32 of the subjects participated in less than 20 quarters of game participation. Also, 17 subjects had 21 to 30 quarters of participation and 52 subjects had 31 to 40 game quarters of participation.

The mean quarters of participation for the 101 subjects was 37.1. However, the mean quarters of participation for the 13 injured subjects was 22.1 and for the 88 uninjured subjects was 39.3.

Postinjury Assessment

During the study, 12.9% (n = 13) of the subjects sustained injuries to the knees. The study defined an injury as an episode requiring the athlete to miss a session or receive medical attention from the attending athletic trainer or a physician prior to returning to competition. Specific data of the specific injuries and severity of the injuries is found in Table 12. The individual clinical tests used to detect ligamentous deficiency are found in Table 13.

The medial collateral ligament was involved in 53.8% (n = 7) of the injuries. Collectively, the intracapsular structures (medial meniscus, lateral meniscus, anterior cruciate ligament, and posterior cruciate ligament) were involved in 53.8% of the injuries as seven injuries

Table 11

Participation by Quarters

Value	Frequency	Percent	Cumulative Percent
0 - 5	11	10.9	10.9
6 - 10	5	4.9	15.8
11 - 15	6	5.9	21.7
16 - 20	10	9.9	31.6
21 - 25	5	4.9	36.5
26 - 30	12	11.8	48.3
31 - 35	9	8.9	57.2
36 - 40	43	42.8	100.0

Table 12

Injured Structures by Severity

Frequency	Injured Structure	Severity
2	MCL	Mild
3	MCL	Moderate
1	MCL	Severe*
1	LM	Moderate*
1	MM	Severe*
1	ACL	Moderate*
1	ACL & MCL	Moderate*
1	ACL & LM	Severe*
1	ACL, MM, & LM	Moderate*
1	ACL, MM, & LM	Severe*

Note: ACL = Anterior Cruciate Ligament; LM = Lateral Meniscus; MCL = Medial Collateral Ligament; MM = Medial Meniscus; * = Required Surgical Treatment.

Table 13

Types of Instability Determined by Stress Tests and Corresponding Injured Structures

Positive Test	Injured Structure
	Medial Instability
Abduction at 0°	Medial Collateral Ligament and Posterior Cruciate Ligaments
Abduction at 30°	Superficial Medial Collateral Ligament
	Lateral Instability
Adduction at 0°	Lateral Collateral and Posterior Cruciate Ligaments
Adduction at 30°	Lateral Collateral Ligament

(table continues)

Positive Test	Injured Structure
Lachman's Test	Anterior Cruciate Ligament
Anterior Drawer	Anterior Cruciate and Medial Collateral Ligaments
Posterior Drawer	Posterior Cruciate, Posterior Oblique and Arcuate Complex Ligaments
Anteromedial Instability	
Abduction at 30°	Medial Compartment
Anterior Drawer--15° external rotation	Anterior Cruciate and Posterior Oblique Ligaments
Anterolateral Instability	
Pivot Shift or Jerk	Lateral Capsular Ligament
Adduction at 30°	Anterior Cruciate Ligament

Note: From Orthopaedic and Sports Physical Therapy (p. 138) by J. A. Keene, 1985, St. Louis: C. V. Mosby.

included at least one of these structures. Specifically, the anterior cruciate ligament was injured in 38.5%, or 5 of the accidents. Due to the severity of injury, 61.5% (n = 8) of the subjects underwent surgery to repair the injured structures. However, with advances in orthopaedic surgery, only one of the procedures required an arthrotomy. The remaining seven cases were performed arthroscopically.

Varimax Rotated Factor Matrix

Table 14 is a Varimax Rotated Factor Matrix and identifies preseason, postseason, and postinjury factors that are related. By statistically determining communality, the cumulative frequency of 80.3% was established following the seventh factor from the factorial analysis. Thus like measures in this specific study allows researchers to make a confident judgement 80.3% of the time with the involved data.

Similar scored variables of a single factor suggest the ability to make an assessment based on either of the variables, provided scores approximate zero or one. Accordingly, Factor 1 suggests the ability to predict body weight, gastrocnemius girth, or thigh girth, with similar predictability at 80.3% for each of the parameters.

The second factor from the analysis expresses similar predictive powers for upper extremity external rotation, lotus position, and total positive scores from the Nicholas

Table 14

Varimax Rotated Factor Matrix

	Factor 1	Factor 2	Factor 3	Factor 4
Preseason Assessment Parameters				
Palms to Floor	.04423	.07804	.10369	.05576
Genu Recurvatum	-.01116	.11675	-.05039	.38439
U. E. Ext. Rot.	-.03623	.97857*	-.05109	-.09762
Lotus Position	-.24060	.04748	.01445	-.15348
L. E. Ext. Rot.	-.03623	.97857*	-.05109	-.09762
Total Positives	-.08137	.83408*	-.01306	.02138
Thigh Girth	.90227*	-.09270	-.05070	-.02878
Gastroc. Girth	.87288*	.14063	-.01968	-.13598
Body Weight	.90540*	-.11075	.11045	-.00433
Postseason Assessment Parameters				
Number Cleats	-.07583	-.08380	.10200	.94768*
Shoe Material	-.04758	-.25637	.00946	-.18842
Style of Shoe	.46828	-.14073	-.23013	-.09316
Intended Use	-.08786	-.11429	.15888	.92291*
Knee Brace	-.00384	-.05324	.97752*	.11752
Game Part.	.29578	.06954	.09077	.02483
Postinjury Assessment Parameters				
Incidnc/Injury	.07869	.03056	.16166	.06245

(table continues)

	Factor 5	Factor 6	Factor 7
<u>Preseason Assessment Parameters</u>			
Palms to Floor	.78987*	-.19257	.14858
Genu Recurvatum	.19472	-.01462	.54689*
U. E. Ext. Rot.	-.02410	-.01301	-.07644
Lotus Position	.72622*	.22415	-.16499
L. E. Ext. Rot.	-.02410	-.01301	-.07644
Total Positives	.52931	-.02313	.11845
Thigh Girth	-.03185	-.06196	-.07987
Gastroc. Girth	-.19158*	-.08608	-.11309
Body Weight	-.01201	-.06427	.08098
<u>Postseason Assessment Parameters</u>			
Number Cleats	-.02251	.06052	.02441
Material Shoe	-.04090	.13511	.68888*
Style of Shoe	.11350	.03090	-.47443
Intended Use	-.07507	-.02533	-.01528
Knee Brace	.05784	.03350	.02344
Game Part.	-.15617	-.68990*	.09622
<u>Postinjury Assessment Factors</u>			
Incidnc/Injury	-.17271	.77877*	.21153

<u>Note</u>: U. E. Ext. Rot.= Upper Extremity External Rotation; L. E. Ext. Rot. = Lower Extremity External Rotation; Game Part. = Quarters of Game Participation; Incidnc/Injury = Incidence of Injury; * = Score Significant for Analysis.

Flexibility Protocol. Thus, the subjects passing or failing either upper extremity external rotation or the lotus position, were consistent with both tests and likewise the total cumulative positive score.

Factor 3 expressed identical values for subjects wearing the left and right knee braces. This finding suggests the braces were worn in pairs, not isolated on either the left or right leg.

Upon analysis of shoe use, screw-in cleat, molded bottom cleated shoe, and multipurpose sole intended for synthetic surface were found. Collectively the items correlated high with the number of cleats on the shoe. The common screw-in cleated shoe generally has seven cleats while the molded bottom shoe have 15 to 25 cleats, and the multipurpose shoe intended for synthetic surfaces have in excess of 80 cleats. Thus, the author expected to find continuity with cleat numbers by the design of the three identified shoe sole types.

Factor 5 reveals a comparison of palms to floor flexibility and the performance of the lotus position. Findings present a relationship of similarity and thus the successful performance of either of the scores are valid predictors of the ability to perform the converse test.

An inverse relationship was found in Factor 6, the incidence of injury and game quarters of participation. The finding is significant as the incidence of injury increased as the exposure time of subjects decreased. The finding was inconclusive as no data suggested whether the increased injury rate was related to decreased exposure time due to level of skill/athletic ability or simply due to the injury.

Factor 7 dealt with genu recurvatum and the material of which the subject's shoes were manufactured. No basis was found for this significant relationship.

CHAPTER 4

Discussion

The purpose of the study was to identify preseason parameters correlating with the incidence of knee injuries of high school football players in selected high schools in North Carolina. Included in the sample population were 101 varsity high school football players, sustaining a total of 13 injuries to the knee.

This investigation began in the spring of 1987 and data collection was completed in December, 1987. The preseason testing instrument used for classification of the flexibility of subjects was the Nicholas Flexibility Protocol. The postinjury evaluation was compiled from the diagnosis of the attending physician in cooperation with the athletic trainer at the schools. A postseason assessment was made in cooperation with athletic trainers at each school.

The author hypothesized that loose-jointed (less than a total positive flexibility score of 2 on the Nicholas Flexibility Protocol) subjects would be more susceptible to sprains of the knee joints than the tight-jointed subjects (greater than a total positive flexibility score of 2 on the Nicholas Flexibility Protocol) and tight-jointed subjects would have less susceptibility to soft tissue injuries of the knee than would loose-jointed subjects.

The investigator reported 71.2% (n = 72) of the subjects had positive scores of 2 or less while 28.8% (N = 29) had scores of 3 or greater. Nicholas reported 28.1% of his subjects having 3 or more positive flexibility scores with 71.9% scoring positive on up to 2 scores. Of Nicholas' 100 subjects with 2 or less positive scores, 9 sustained knee ligament ruptures for a 9% injury rate. However, 28 of the 39 subjects classified as loose-jointed (2 or less positive scores) sustained knee ligament ruptures for an injury rate of 72%. In comparison, the investigator reports an injury rate of 13.8% in the tight-jointed (10 injuries in 72 subjects) and 10.3% in the loose-jointed (3 injuries to 29 subjects).

Thus, no increased incidence of injury was found in subjects exhibiting increased or decreased gross flexibility scores. Statistical analyses revealed no significant parameters contributing to the predictability of the incidence of knee injuries in high school football players.

Injury to the extracapsular ligamentous structures in and prior to the 1970s warranted surgery, as reported by Nicholas (1970) and others. Identical pathology today is treated aggressively with rehabilitation protocol as reported by Ellasser, Reynolds, and Omohundro (1974).

Thus, subjects are not exposed to the trauma of surgery nor is long term stability of the knee joint compromised.

Derscheid and Garrick (1981) reported the aggressive treatment of medial collateral ligament injuries of one-plus and two-plus severity. The mean return for one-plus sprains was 10.6 days and 19.5 days for two-plus sprains. The nonoperative approach to ligamentous injuries is used provided the subjects had no injury to the intracapsular structures of the knee, that is the anterior or posterior cruciate ligaments or the medial and lateral menisci.

Of the 11 subjects sustaining injury during the study, 64% ($\underline{n}$ = 7) injured intracapsular structures including but not limited to the anterior and posterior cruciate ligaments and the medial and lateral menisci. A concern to sports medicine professionals in the 1980s is the need for validity and reliability in the diagnosis of hemarthrosis, a common sign associated with the intracapsular pathology. Accurate diagnosis dictates the course of treatment and eventuality of the prognosis.

The presence of hemarthrosis warrants scrutinized evaluation due to the potential involvement of the anterior and posterior cruciate ligaments and the medial and lateral menisci. Diagnosis of hemarthrosis and/or anterior cruciate pathology may lead to anterolateral rotatory instability. The diagnosis is vital to successful recovery due to the complexity of anterolateral rotatory instability. Hughston et al. (1976) reported anterolateral rotatory instability as rare, but a more significant instability as compared to anteromedial rotatory instability.

Noyes et al. (1980) reported 72% of injured knees had pathology involving the anterior cruciate ligament. The authors also reported acute hemarthrosis resulting in anterior cruciate ligament injury in 75% of their cases. Thus, with 64% (n = 7 of 11 subjects) of the subjects injured in the study sustaining injury to the anterior cruciate ligament, the importance of diagnosis and the inherent role in knee stability was seen. The relationship of anterior cruciate ligament involvement was also reported by Norwood et. al. as the authors found 58% of subjects with anterolateral rotatory instability had associated anterior cruciate pathology. The presence of the anterior cruciate ligament in 64% (n = 7 of 11 subjects) of the cases correlates with Shoemaker and Markolf's (1985) report of the anterior cruciate's role as the primary controlling structure in the unloaded knee.

From the statistical analysis, no evidence was found regarding the predictability of injury to the intracapsular structures of the knee. The factor analysis revealed the parameters of thigh girth, gastrocnemius girth, and body weight, all having identical communality of 80.3% and thus any of the three factors could be used to obtain identical results of the other two factors.

The parameters of upper extremity external rotation, lower extremity external rotation, and the total positive scores of the flexibility tests had similar communality. Thus, either upper extremity external rotation or lower extremity external rotation could be used in the place of the other measure with similar success.

Anthropometric measures of palms to floor and lotus position flexibility and gastrocnemius girth had an inverse relationship. Thus, subjects with lower flexibility measures tended to have increased gastrocnemius girth measures.

Subjects with fewer quarters of game participation had a higher incidence of injuries. The scores produced an inverse relationship. The relationship between game participation and the incidence of injury suggests subjects not playing significant amounts of time have increased susceptibility to injury. Also, the mean quarters of participation for injured subjects was 22.1 as compared to the uninjured subjects' 37.1.

The significant finding of increased injury rate with decreased game quarters of participation should alarm the sports medicine professional. Attention needs to be directed to the sports participants not obtaining average amounts of participation time as this study shows these subjects have increased rates of injury. Possibly, injury rate is secondary to decreased level of skill. The decreased performance level may be due to the poor overall athletic ability and lack of skill development in the injured subjects. A possible explanation is that due to decreased exposure to drills in practice sessions the subjects are not afforded the opportunity to increase skill level. Perhaps the average skill level subjects are not allowed to practice with the above average skill level and thus are injured. Even if the unskilled subjects are allowed to practice, they do not receive the instruction from the coaches the superior subjects receive. They never seem to achieve much above their present level as they do not practice and thus remain average.

Conclusions

From the results of the study, several factors of the preseason assessment could have been deleted or combined as identical results were obtained from other test items. Also, no predictive values for the incidence of injury were obtained from the Nicholas Flexibility Protocol or the other anthropometric measures.

The majority of all groups of subjects studied had two or less total positive scores on the Nicholas Flexibility Protocol. The results lead the investigator to presume active flexibility measures of high school level subjects is identical to the measures reported by Nicholas and others in the 1970s. The measures of active flexibility identify the inherent stability of the joint including control by passive structures and the active structures.

Although laboratory results of subjects today are identical to the findings of the 1970s, the treatment protocols are varied. Also, the diagnostic procedures are enhanced and today specific intracapsular and extracapsular lesions may be diagnosed.

The physical symptom of a buckling or locking knee in the 1970s, and the sign of hemarthrosis were generally diagnosed as a lesion of the medial or lateral meniscus. However, with increased clinical expertise, the lesion is being seen as not only injury to the menisci but often injury to the anterior cruciate ligament.

Further research on the intracapsular ligaments has identified the role of the anterior cruciate ligament as a prime stabilizer of the knee. In addition, clinical evaluation is very important to guarantee appropriate treatment protocol specific to the injury.

Study of body composition has received increased attention regarding preparticipation preparation of athletes and the physically active. Often, subjects with increased body weight have corresponding increases in percent body fat. The lower body weight and increased thigh and gastrocnemius girth measures of subjects injured in the study compared to uninjured subjects, leads the investigator to recommend that coaches, athletic trainers, and others who supervise the physically active should monitor body composition. Often the overweight athlete is more predisposed to the incidence of injury.

Coaches should also be aware of the possibility of an increased injury rate in subjects not trained to the degree of the superior athlete. The degree of attention given to subjects is definitely seen as a factor leading to increased skill level and thus a decreased chance for injury.

Implications and Suggestions

The investigator encountered several problems in completing this study. Specifically, measures of skinfold thickness would have been informative to determine the effect of the percentage of body fat on the incidence of injury.

Regarding future replication of this study, the author offers a few suggestions. The increasing interest in flexibility warrants study concerning the effect of strength training on active flexibility measures. With the increased interest in conditioning and wellness of the physically active, the study could identify all persons and not just athletic populations.

The predictive value of preseason assessment of the passive stability of the knee joint could also be studied specifically for the physically active. Again, the identification of factors predisposing one to the incidence of injury could be significant in the saving of time to subjects, as well as represent significant saving of personal and insurance dollars.

Appendices

Appendix A

Preliminary Cover Letter to Athletic Trainers

at Selected Schools in North Carolina

Appalachian State University

Boone, North Carolina 28608

Department of Athletics

July 2, 1987

Mr. Gene Brooks, A. T., C.
Athletic Trainer
St. Stephens High School
Route 2, Box 150
Hickory, NC 28601

Dear Gene:

As a follow-up to our recent conversation, I want to thank you for agreeing to assist me by screening the junior and senior football players at St. Stephens High School thus assisting me in the completion of my doctoral studies. Enclosed are forms to record the preseason assessment measures. I will be in contact with you in the next week to set a time to collect the data.

At that time, I will also provide you with a form to record each injury incurred to the knees of the involved subjects, regardless of the amount of days of practice missed or the severity of the injury.

Following the season, a postseason assessment form will need to be filled out on each subject completing the season. Please give me a call if any of these instructions are not clear.

Again, many thanks.

Sincerely,

Rod Walters, A. T., C.
Head Athletic Trainer

/rw

Enclosures

Appendix B

Follow-up Letter to Athletic Trainers

at Schools in North Carolina

Appalachian State University

Boone, North Carolina 28608

Department of Athletics

November 11, 1987

Mr. Gene Brooks, A. T., C.
Athletic Trainer
St. Stephens High School
Route 2, Box 150
Hickory, NC 28601

Dear Gene:

I hope all is going well for you. Let me begin by again thanking you for your assistance in screening the junior and senior football players at St. Stephens High School in order to allow me to complete my doctoral studies. This has been quite a task and only with your cooperation would it have been possible.

In August I sent forms to be filled out for each knee injury requiring the athlete to be miss a practice or game or being cared for professionally prior to be able to return to competition. I have enclosed more of the forms if needed.

Also, please complete a postseason assessment form for each subject. These forms are also enclosed for your use. I would like to have the materials back by November 23, 1987 if at all possible. Give me a call if any of these instructions are not clear.

Sincerely,

Rod Walters, A. T., C.
Head Athletic Trainer

/rw

Enclosures

Appendix C

Selected High Schools

in North Carolina

Selected High Schools in North Carolina

I. AAAA Level of Classification

A. Hickory High School

1234 Third Street, Northeast

Hickory, North Carolina 28601

B. South Mecklenburg High School

8900 Park Road

Charlotte, North Carolina 28210

II. AAA Level of Classification

A. St. Stephens High School

Route 2, Box 150

Hickory, North Carolina 28601

III. A Level of Classification

A. Hendersonville High School

311 West Eighth Street

Hendersonville, North Carolina 28739

Appendix D

Preseason Assessment

PRESEASON ASSESSMENT FORM

ATHLETE'S NAME____________________________

SCHOOL _______________

Nicholas Flexibility Protocol ("+" or "-")

____ Palms to Floor

____ Genu Recurvatum

____ Upper Extremity External Rotation

____ Lotus Position

____ Lower Extremity External Rotation

Anthropometric Measures

____ Thigh Girth at four inches suprapatellar (one quarter inch units)

____ Gastrocnemius Girth at mid-belly (one quarter inch units)

____ Body Weight (half pound units)

Appendix E

Postseason Assessment Form

POSTSEASON ASSESSMENT FORM

ATHLETE'S NAME________________________________

SCHOOL________________

<u>Shoe Type</u>:

Manufacturer_____________________
Number of cleats per shoe___________________
Shoe size______________
Material:
___nylon mesh
___leather
___canvas
___other (please specify)

Style:
___low cut
___three quarter cut
___high top

Intended Use
___grass- screw in cleat
___grass- molded sole
___synthetic surface

<u>Knee Braces</u>:

Left Leg	Right Leg
Manufacturer______________	Manufacturer________________
Type of Application: ___tape on ___strap on	Type of Application: ___tape on ___strap on
Age of Brace_____________ (months)	Age of Brace______________ (months)

<u>Game Participation</u>:

Total number of quarters participated during regular season games________________

Appendix F

Postinjury Assessment Form

POSTINJURY EVALUATION FORM

ATHLETE'S NAME_____________________________

SCHOOL_______________

History (Provide brief history of the injury and how it happened.)

Findings (Include the signs observed and symptoms the athlete complained of relating to the injury.)

Injury (Check one)

____Medial Collateral Ligament

____Lateral Collateral Ligament

____Anterior Cruciate Ligament

____Posterior Cruciate Ligament

____Medial Meniscus

____Lateral Meniscus

____General Joint Capsule

____Pes Anserine Musculature

____Medial Collateral Ligament and Medial Meniscus

____Lateral Collateral Ligament and Medial Meniscus

____Anterior Cruciate Ligament and Medial Meniscus

____Anterior Cruciate Ligament and Lateral Collateral Ligament

____Medial Collateral Ligament, Medial Meniscus, and Anterior Cruciate Ligament

Severity of Sprain (Check one)

____mild ____moderate ____severe

Was knee brace worn when injured? _____yes ____no

Brand____________________________

Type of Application: ____Taped on ____Neoprene straps

Appendix G

Listing of Dependent and

Independent Factors

Listing of Dependent and Independent Factors

I. Dependent Factors

A. Medial Collateral Ligament

B Lateral Collateral Ligament

C. Anterior Cruciate Ligament

D. Medial Meniscus

E. Lateral Meniscus

F. General Joint Capsule

G. Pes Anserine Musculature

H. Medial Collateral Ligament and Medial Meniscus

I. Lateral Collateral Ligament and Medial Meniscus

J. Anterior Cruciate Ligament and Medial Meniscus

K. Anterior Cruciate Ligament and Lateral Collateral Ligament

L. Medial Collateral Ligament, Medial Meniscus, and Anterior Cruciate Ligament

M. Type of Knee Brace Worn

N. Brand of Knee Brace

O. Mode of Application of Knee Brace

P. Age of Knee Brace

II. Independent Factors

A. Palms to Floor

B. Genu Recurvatum

C. Upper Extremity External Rotation

D. Lower Extremity External Rotation

E. Lotus Position

F. Body Weight

G. Manufacturer of Shoe

H. Style of Shoe

I. Material of Shoe Manufacturer

J. Intended Use of Shoe

K. Game Quarters of Participation

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