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THE RELATIONSHIP OF HAMSTRING AND HIP FLEXOR FLEXIBILITY TO INJURY RATES IN COLLEGIATE FOOTBALL PLAYERS

By

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ABSTRACT

The Relationship of Hamstring and Hip Flexor Flexibility to Injury Rates in Collegiate Football Players

By

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Fifty collegiate football players volunteered to participate in the study to examine the relationship between flexibility and injury rate of muscle strain, specifically the Hamstring and Hip Flexor muscle groups. Participants were evaluated for range of motion and monitored for non-contact hamstring strains occurring throughout the competitive season. Participants with any muscle strain within the past year were excluded from this study. Measurement of the hamstrings was done with a passive knee extension test; hip flexors were measured with prone hip extension test. Sixteen hamstring strains occurred within the fifty participants. Correlation statistics were done to show relationship between the two factors. The analysis failed to show significant relationships between flexibility and injury rates. This indicated that decreased injury occurrence was not related to increased flexibility. Injured participants also completed a subjective questionnaire to determine possible contributing factors to muscle strain. No single factor was identified in connection with injury.

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CHAPTER 1

INTRODUCTION

Muscle strains are common injuries occurring in many athletes in a variety of sports. The majority of collegiate athletes have experienced a "pulled" muscle sometime in their career. Although there are many, the most commonly accepted mechanism to this injury is an overload to the muscle fibers resulting in a stretch or tear. Researchers have investigated the causes of these muscle strains on many different occasions (e.g., Orchard, Marsden, Lord, & Garlick, 1997; Wilson, Wood, & Elliott, 1991; Corbin & Nobel, 1980). The exact cause of muscle strain has not been determined to the satisfaction of most researchers (e.g., Garrett, 1996; Best & Garrett, 1996; Page, 1995; Worrell, Smith, Winegardner, 1994). What is likely, is that muscle strain injuries are not caused by a single factor, but rather by a variety of factors. Variables that have been researched in muscle strain injury include strength variables such as imbalances or deficits, fatigue, inadequate warm up, and flexibility (e.g., Watson, 1995; Worrel, 1994; Worrell & Perrin, 1992; Knapik, Bauman, Jones, Harris, Vaughan, 1991; Corbin & Noble, 1980). Of these factors, the flexibility relationship is suspect. Lack of flexibility has long been associated with muscle injury. If a muscle is stretched beyond its available range of motion, the muscle will experience fiber tearing. Likewise, if a muscle has a greater available range of motion, it can withstand more force and be less susceptible to injury. Many, if not most, athletic trainers, doctors, physical

therapists, and coaches constantly stress improving muscle flexibility to prevent muscle strain. Exactly why this is done is unknown because a relationship between flexibility and injury has not been clearly documented in the literature. In rehabilitation of injured muscles, it is important to rehabilitate flexibility to pre-injury amounts. This fact has been generalized beyond rehabilitation of the injured muscle to healthy muscle tissue. Many believe the need to improve flexibility in order to prevent strain-type injuries from occurring during periods of work or exercise.

One must continue to ask the question, does increased flexibility in a muscle correspond with a decreased incidence of injury? This relationship appears to have potential implications, but it must be documented through research to be valid. There are few published studies reporting this relationship between flexibility and muscle strain in athletes participating in physical activity, specifically football, or other team sports. Football is a sport that requires maximal force production from muscles in quick bursts, changing directions, and exercise periods that can last for somewhat extended amounts of time. With the current interest in flexibility, research needs to be done to show the degree of relationship, between flexibility and injury rate.

Purpose of the Study

The present study, was to examine the relationship between flexibility (amount of range of motion) and incidence of muscle strain injury, in healthy college football players. Specifically, the purpose of this study was to determine the degree of relationship between hip flexor and/or hamstring flexibility and injury rates of hamstring muscle strain, in collegiate football players over the course of a competitive season. A competitive season

was defined as the time from the beginning of pre-season two-a-day practices to the last game of the year, a period of approximately fifteen weeks. It was not the purpose of this study to compare the various methods of increasing flexibility or to determine the best way to stretch.

Need for the Study

As stated earlier, few studies exist which test the relationship of flexibility to muscle injury. The lack of research for an idea so common as this indicates the importance of the present study. Studies have been completed that have included flexibility and injury rates, but post hoc analyses have been used to show the relationship (Orchard et al., 1997; Hennesey & Watson, 1993). The method for testing flexibility, the sit and reach test, in these studies has been shown in other research to have only moderate to minimal correlation with actual analysis of flexibility in the hamstrings (Patterson, Wiksten, Ray, Falanders, & Sanphy, 1996; Minkler & Patterson, 1994). Another common measurement evaluation procedure, the straight leg raise test, has also been found to have too many confounding factors to be an accurate test (Worrell & Perrin, 1992). Most researchers investigating flexibility and injury have used one of these methods to evaluate the flexibility of the hamstrings.

Prevention of muscle strain injuries is a primary goal of health care professionals. If increased flexibility is an effective method of prevention, this needs to be documented and published in scholarly journals. If increased flexibility is effective, the best method needs to be established to prevent these strains from occurring. If increased flexibility is not related to decreased injury rates, the time and effort being spent on increasing the athletes' range of

motion needs to be evaluated. Perhaps more attention should be spent on improving strength of the muscles, strength deficits with antagonist muscles and/or conditioning to reduce the fatigue factor in strain injuries.

The present study researched this relationship with collegiate football players. Fifty University of Nevada Las Vegas (UNLV) football players participated in the study. Because research has shown that previously injured muscles are both less flexible and more prone to injury (Worell, Perrin, Gansneder, & Gieck, 1991); players that have had an injury to the hamstring muscles within the past twelve months were excluded from the study. An initial flexibility measurement was taken from the players at the hamstring and hip flexor muscle groups. Injuries were then tracked throughout the season to monitor for non-contact hamstring strains. Re-evaluation of the participants' flexibility was taken an additional time approximately halfway through the season to note any changes and to insure accuracy. Correlation statistics were then performed to show the degree of the relationship.

Hypothesis

The question that was asked in the present study is, "does an increased amount of muscle flexibility relate to a decreased incidence of non-contact, muscle strain injuries"? The null hypothesis was, "there is no significant relationship between muscle flexibility and non-contact muscle injury rates in collegiate football players". The alternate hypothesis was "there is a significant relationship between muscle flexibility and non-contact injury rates in collegiate football players".

Assumptions/Limitations

There were a number of assumptions and limitations with the present study. Firstly, it was assumed that participants were honest about their conditions, were free from prior injury, and reported any injury that may have occurred to them. It is assumed that the tester was knowledgeable in the measurement and reporting procedures and was accurate throughout the length of the study. Limitations of the study included the possibility of other occurrences from affecting the results such as field conditions, weather, or other chance factors. The results may not be able to be translated to other sports or activities.

CHAPTER 2

LITERATURE REVIEW

Most current articles on physical fitness today at least mention flexibility, or more specifically, the importance of flexibility as part of a whole fitness program. Injury prevention and rehabilitation have long been associated with good flexibility (Corbin & Noble, 1980). Indeed, studies have proved the value of flexibility, or range of motion, exercises on injured muscle (Page, 1995). After an injury, muscles lose range of motion (ROM) that can effectively be regained through proper flexibility activities. Along with effective rehabilitation, it is the popular belief that the amount of injuries can be reduced if a person has increased flexibility (Knapik et al., 1991; c.f. Klafs & Arnheim, 1969). Most doctors, athletic trainers, and physical therapists agree that an athlete has a better chance of not experiencing injury if he/she has better flexibility. Studies to show this relationship are lacking, however.

Measurement Techniques

Two popular measurement techniques for hamstring flexibility are the sit and reach test and the straight leg raise test. The sit and reach test has long been a measure of flexibility. The original sit and reach test (Wells & Dillon, 1952) involved the patient sitting on a flat surface and reaching forward with the arms in front to a spot on the floor,

creating the score for measurement. The backsaver sit and reach test (Cailliet, 1988) was developed to protect the back discs by only testing one hamstring at a time. A third variation, the modified sit and reach test (Hoeger, Hopkins, Button, & Palmer, 1990) was developed to take into account upper limb length differences between people. In this test, the participant sits flat against a wall and reaches forward. The point at which the hand reaches is the zero point. The participant then performs the test as Wells and Dillion (1952) describe for the original sit and reach test, as stated earlier in this paper. Regardless of the variation of sit and reach test used, Minkler and Patterson (1994) state the sit and reach correlation to actual hamstring flexibility is only moderate at best. Another measure of flexibility is the straight leg raise (SLR) test. In this test, the participant is supine and passively stretched into hip flexion while maintaining full knee extension. Pelvic rotation has been shown to occur in the SLR movement (Bohannon, 1982). Another confounding factor in the SLR test is foot position (Gajdosik & Lustin, 1983). Therefore, it has been recommended that use of the SLR method for testing flexibility in the hamstring be reconsidered (Sullivan, Dejulia, & Worrell, 1992). It is the current belief that the active knee extension test (AKET) and/or passive knee extension test (PKET) is most accurate and should be used for measurement of hamstring flexibility (Worrell & Perrin, 1992). This evaluation test was used for the present study and is explained later in the methods chapter.

Related Studies

Research has been done that has dealt with flexibility in many different ways. Orchard et al. (1997) performed a study in which aerobic and anaerobic fitness, running

speed, body composition, strength, and flexibility were measured in rugby football players who were then followed throughout the 1995 season. Of these variables, only strength deficits were shown to have a significant association with the occurrence of injury. The method of measurement for hamstring flexibility that was used (the sit and reach test) has been shown to have only moderate correlation (r = .75) with actual flexibility amounts in the hamstrings. The causative factors shown in the study were strength deficits of the injured hamstring to quadriceps ratio and injured hamstring to opposite hamstring ratio.

Strength and flexibility imbalances associated with injury have also been researched (Knapik et al., 1991). In the study of 138 female collegiate athletes, preseason strength and flexibility tests were performed and athletes were then followed for injuries over a three-year period. Flexibility was measured through active range of motion. Lower extremity injuries accounted for 80% of total injuries, while muscle strains accounted for 29% of all injuries. The study determined that athletes experienced more injuries if a flexibility deficit existed between right and left legs of 15% or greater. General flexibility amounts did not relate to injuries. These data suggest that injury is more associated with flexibility imbalances in muscle, rather than flexibility alone.

Preparticipation physical exams can identify possible musculoskeletal problems that may lead to injury. In research of 2107 athletes from junior high through college, it was consistently observed that females were more flexible than males in all measurements, including lower extremities. Males were also more likely to have flexibility deficits below normal for the overall population (Kibler, Chandler, Uhl, & Maddux. 1989). The straight leg raise was the method used to evaluate the hamstring. It

was hypothesized from those facts that in order to prevent muscle injury, males should spend more time improving flexibility in their muscles.

Research has also been published comparing injured and non-injured hamstrings in strength and flexibility measures (Worell, Perrin, Gansneder, & Gieck, 1991). Results of the study show that the injured hamstring was significantly less flexible than the non-injured hamstring within the injured group, and the hamstring injured group was less flexible than the non-injured group. There also appears to be a high incidence of re-injury in hamstring strains (Dorman 1971). These facts can be put together, showing that as a muscle gets injured and loses flexibility, it is more likely to become re-injured. This may lead to the belief that reduced hamstring flexibility will predispose that muscle to injury.

The effect of stretching on flexibility (Sullivan et al., 1992), effect of repeated stretching on flexibility (Magnusson, Simonsen, Aagaard, & Kjaer, 1996), effect of stretching on hamstring muscle performance (Worrell et al., 1994), have recently been studied. Sullivan et al (1992) investigated the effects of different stretching techniques and pelvis positions on hamstring flexibility. All techniques of stretching resulted in flexibility increases, although some were more effective. It was shown through the study that pelvic positioning, either anterior or posterior, is significantly more important than the stretching technique for improving hamstring flexibility. Magnusson et al. (1996) reported the response of the hamstring muscle to repeated stretches. He had reported the lack of understanding of the mechanisms, and lack of research on the topic, and indicated a need for additional study for better understanding on the subject. Passively warmed or preconditioned muscles can withstand greater length changes and force, according to

Magnusson et al. (1996). Tests to show if repeated stretches would lead to increased muscle length, or flexibility amounts, were positive. It is believed that stretching or more specifically, repeated stretching causes a reduction in the reflex activity, which inhibits the muscle to be stretched. A lowered reflex response results in an increased range of motion. Repeated stretching did cause an increase in flexibility. However, it is important to note that the effects of the five repeated stretches disappeared within one hour. The long-term effects of this method remain unknown (Magnusson et al., 1996).

Worrell et al. (1994) have reported the effect of stretching on muscle performance. They state that factors that determine the amount of energy absorbed by muscles are the speed of muscle contraction and the length of the muscle. Thus, if the length of the muscle can be increased (through stretching), more force will be absorbed during the eccentric phase and more force will be generated during the concentric contraction. If a muscle has an increased amount of length to contract, theoretically it can generate more force, which leads to better performance. The participants were strength tested at 60 degrees/second and 120 degrees/second on both eccentric and concentric contractions on a BIODEX isokinetic dynamometer between 0 and 90 degrees of motion. After the stretching protocol was complete, the participants were re-tested. Although there were increases in flexibility, they were not significant. Peak torque increases occurred eccentrically at 60 degrees and 120 degrees and concentrically at 120 degrees. The increases in eccentric force at 60 and 120 were attributed to increased hamstring flexibility. The increase in concentric peak torque production was attributed to an increased storage of potential energy from the increase in range of motion. It is important to note that these increases in strength that were thought to be occurring from

the increased hamstring range of motion were observed in the open chain movement, which rarely occur in athletics. Assumptions can be made theoretically, that a muscle which has increased flexibility can absorb more force and stretch further to avoid an injury.

The incidence of injury in relation to posture and body mechanic deficits has also been examined (Watson, 1995). Participants were evaluated in 15 different areas of body mechanics and placed into one of three categories per body part; good body mechanics, moderate deviation, or marked deviation. Body mechanics were also assessed through photographs in the anterior, posterior, and lateral views. The prints were then taken and a metric grid was superimposed upon the image of the participant. This method has been determined to be very effective in detecting asymmetry. Injuries were then followed over a 24-month period. Incidence of injury, specifically muscle injury, was significantly related to defects in posture and body mechanics. Even more specifically, muscle strains of the hamstring muscles were related to sway back lordosis.

The role of flexibility in reducing the incidence of delayed onset muscle syndrome (DOMS) has been studied (Page, 1995). This possibly has contributed to the perception that flexibility is effective in reducing the chance of injury. DOMS is described as a dull, aching pain usually beginning 12 to 48 hours after exercise. In addition to pain, other symptoms included decreased force production and decreased motion (Armstrong, 1984). There is evidence that flexibility may reduce the effects of DOMS, if done before and after exercise sessions (Page, 1995).

Muscle stiffness as it relates to flexibility has also been researched (Wilson et al., 1991). Muscle stiffness has been defined as the muscle response, or how much a muscle

"gives", to an external force that is imposed on the musculature. A compliant system will extend to a greater amount, allowing the applied force to be absorbed over a larger distance and greater amount of time, as compared to a stiff system. In other words, the cushioning effects of a compliant system can reduce the injury on the muscle fibers as compared to a stiff system. Wilson et al. (1991) states that flexibility is significantly correlated (r = -0.54) with maximal stiffness. It has been outlined that the stiffness of muscle, or how compliant a muscle is, has the potential to effect the incidence of muscle injury. The author goes on to say that further study and research is needed to substantiate these claims. While Wilson et al.'s (1991) work showed a correlation between flexibility and stiffness, Klinge, K., Magnusson, S.P., Simonsen, E.B., Aagaard, P., Klausen, K., & Kjaer, M. (1997) performed a study researching the effects of a strength and flexibility program on muscle stiffness that showed some different results. Although the stretching program showed an increase of joint range of motion that was significant, the characteristics of the involved muscle did not significantly change.

As stated before, uncertainty exists as to the factors that cause hamstring injuries. The influences in amount of flexibility, strength, fatigue, and moderate warm-up have all been discussed as causes of injury. More so, contradiction about the relationship to injury has been shown through research of different authors. Lielmoln (1978) and Worrell et al. (1991) have supported the statement that lack of flexibility is related to injury, while Burkett (1970) and Ekstrand & Gillquist (1982) have conducted research that failed to show any relationship. There is a possibility that a number of factors contribute to injury. A multiple factor injury model (See APPENDIX I) has been developed by Worrell and Perrin (1992) that offers some explanation for this. The four

factors of strength, warm-up, fatigue, and flexibility are listed on a grid. The more of each factor the athlete has, the better chance he/she has of becoming injured. In other words if an athlete has inadequate strength and flexibility, and is tired, he has a better chance of becoming injured than one that is just tired. In this article, it states that it seems logical that the stronger or more flexible a hamstring is, the better the muscle can withstand higher amounts of force. Worrell and Perrin also state that more research is necessary in this area. Worrell (1994) states how the lack of understanding of contributing factors, as well as mechanisms of injury, have made research into hamstring injury difficult.

There have been a number of studies done on different populations with the occurrence of hamstring injury. Jones, Cowan, Tomlinson, Robinson, Polly, & Frykman (1993) conducted research on injuries occurring to army trainees. Three hundred three trainees were followed over a 12-week period. In identifying risk factors, the amount of flexibility was included. Interestingly, trainees with high amounts of flexibility were just as likely to suffer injury compared to those with low flexibility. The sit and reach test was used, which has been identified as an inaccurate measure of flexibility (Minkler and Patterson, 1994).

Factors contributing to injury in soccer have also been researched (Keller, Noyes, & Buncher, 1987). In this study, a variety of factors were examined, ranging from strength and flexibility to equipment and field conditions. The research revealed a relationship of flexibility to injury in senior players only, and the total percentage of injuries related to flexibility at 11%.

In summary, there is inconsistent literature on the subject of flexibility and how it specifically relates to the incidence of muscle strain injury. Research is needed to determine any relationship between flexibility and the occurrence of injury. Currently, there appears to be inconsistencies with regard to measurement and testing procedures in published literature. Most helpful would be the establishment of a flexibility measurement procedure that is considered valid and reliable.

CHAPTER 3

METHODS

Participants

The participants in this study were UNLV varsity football players. The participant population consisted of 50 players from all class standings, from both skill and line positions, and starters and back-ups. The participants were randomly selected from the UNLV football team to be involved in the study. The Institutional Review Board Biomedical Sciences Committee (See APPENDIX II) approved the protocol. The participants were naive to the purpose of the study. The participants had read and signed a consent form (See APPENDIX III) before participation in the study. All participants were experienced in football and were receiving a scholarship from the university to play football. A UNLV team physician had cleared all participants in a preseason physical examination for full participation in practice and competition.

Experimental Design

The experiment was a one way within subjects design. The independent variable was the flexibility measurements across time. The dependent variable was whether the participant experienced an injury or not.

Apparatus

The athletes were placed on a flat treatment table for flexibility measurements. A universal goniometer was used to assess the flexibility measurements. A universal goniometer is the most widely used measuring device used by health care professionals such as athletic trainers and physical therapists. A three-inch strap was used to stabilize the participant's pelvis during the measurement of the hip flexors. In past research, authors have used the straight leg raise test for measurement of the hamstrings (Li, McClure, & Pratt, 1996; Kibler et al., 1989; Ekstrand & Cinllquist, 1982; Lielmoln, 1978). Bohannon (1985) reported that pelvic rotation occurs during the SLR method. Gajdosik and Lusin (1985) reported that foot position also influences the SLR method. The Wells sit-and-reach test for hamstring flexibility may be altered by the flexibility of the upper extremity and lumbar and thoracic spines (Minkler and Patterson, 1994). Therefore, it appears a more accurate method of measurement is warranted. A passive knee extension test (PKET) was used to measure the hamstrings (Worrell et al., 1991).

Procedure

An initial measurement was taken as the participants began mandatory practice for the year. The first measurement gave a baseline for each participant that is unaltered by any amount fatigue or injury. Two testers were used for measuring the hamstring flexibility; the first tester performed the stretch on the participant and the second tester took the measurement with the goniometer. The first and second tester performed the same tasks throughout the study to eliminate any potential problems with inter-tester reliability in measurement or recording procedures. During the PKET, the participant

was placed supine with the hip positioned at 90 degrees of flexion. The hip was then stabilized in this position by the participant placing both hands around his own distal thigh just proximal to the knee joint with the fingers interlocked while maintaining the foot in relaxed plantar flexion. The opposite leg was maintained in zero degrees of hip flexion. To determine flexibility of the hamstring, the tester passively extended the knee, while the participant held the hip in ninety degrees of flexion. The axis of the goniometer was located at the knee joint mid-line. The stationary arm of the goniometer was placed parallel to the midline of the femur, in line with the greater trochanter. The moveable arm of the goniometer was placed parallel to the midline of the fibula, in line with the lateral malleolus. The primary limiting factor was the athlete's perception to a full stretch. A full stretch was defined as a slight feeling of discomfort in the muscle, without any sharp painful sensations. Secondary limiting factors included any changes in position of accessory muscles or joints. This stretch was considered full range of motion (ROM) for the participant being tested. Once the participant reached full ROM, the measurement was taken (See APPENDIX IV) with a universal goniometer. As the first tester held the athlete in position, the second tester read and recorded the degrees of flexibility. After the number was recorded, a second measurement was taken to ensure the measurement was accurate. The measurements were then repeated on the opposite leg. Once this procedure was completed, the athlete was allowed to ambulate briefly if desired. The hip flexor muscles were then measured for their amount of flexibility. The procedure began with the participant lying prone on the same flat surface. The participant was then secured to the table with a belt strap to stabilize the pelvis. The placement location of the strap was superior to the Iliac Crest. Once the participant was

secured to the table, the measurement was taken. The tester took the involved leg into passive knee flexion of 90 degrees. As the tester's one hand was holding the knee in 90 degrees flexion, the other hand was placed superior to the patella and under the leg. The tester then moved the hip into extension to stretch the hip flexor. Once the hip flexor muscles were fully stretched (full ROM) the measurement was taken. Full ROM was defined in this study primarily as participant tolerance, meaning the slight discomfort with no pain as discussed earlier. Secondary limiting factors were any low back pain resulting from the measurement procedure, or movement of the hip; either up off the table or any twisting noticed of the hip. As full ROM was attained, the second tester recorded the flexibility measurement. Landmarks for the goniometer include the stationary arm placed parallel to the midline of the torso to the axilla, and the moveable arm placed parallel to the femur midline of the involved leg. Axis placement of the goniometer was over the greater trochanter of the femur. After the measurement was taken, a second measurement was taken to ensure accuracy. The measurements were taken bilaterally.

These flexibility measurements were listed together with the athletes' name and flexibility figures for the hamstring and hip flexor muscles, for both the right and the left legs. This same procedure was repeated approximately halfway through the season. This repetition was done for two reasons. First, to note any change in the individual or trends of change in the group. Second, to have a flexibility measurement that was accurate at the time that the injury occurred throughout the study period.

The study also consisted of injury surveillance. Specifically, muscle strains occurring to the hamstring muscle complex. Any strain that occurred was recorded,

along with the degree of severity, according to the American Medical Association in *Standard Nomenclature of Athletic Injuries* (Rachun, 1976). A first-degree strain is described as the mildest form with little associated damage to muscle and tendon structures. Pain is most noticeable during use; there may be mild swelling and muscle spasm present. Second-degree strains imply more-extensive damage to the soft tissue structures involved. Pain, swelling, and muscle spasm will be more pronounced, and functional loss will be moderate. These types of injuries are associated with excessive, forced stretching or a failure in the synergistic action within a muscle group. Third-degree strains are the most severe form and imply a complete rupture of the soft tissue structures involved. Damage may occur at a variety of locations, including the bony attachment of the tendon (avulsion fracture), the tissues between the muscle and tendon, or those within the muscle itself. A defect may be apparent through the skin and will be associated with significant swelling. Obviously, this type of injury will involve significant loss of function (Rachun, 1976). Participants in the study were given a number classification according to whether an injury was experienced or not over the season. If no injury occurred, the participant was assigned a zero (0). Participants that experienced injury were given a one (1). The injuries were evaluated by a certified athletic trainer (the tester) immediately following the injury occurrence, as well as follow up evaluations every one to two days. In addition, the injuries were recorded by the tester in both a daily written record, and imput into a computer program for injury tracking. The program, T-Wiz, is a widely used record keeping system in the field of athletic training.

CHAPTER 4

RESULTS

Correlation Results

During the three-month period of data collection, sixteen injuries occurred to the 50 athlete participants. Eight of the hamstring strains occurred to the right leg and eight occurred to the left leg. The analysis method used in this study was a multiple logistical regression analysis. The significance level was set at 0.05. The computer software program used was the Statistical Analysis System (SAS), release 6.12, for Windows. The analysis failed to indicate a significant relationship (See APPENDIX V) between injury and flexibility of either the hamstring or hip flexor muscle groups. For injuries occurring to the right side hamstring, Wald Chi-Square = 2.59, p = 0.1074, while the hip flexor Chi-Square = 0.00 , p = 0.9975. At the left leg, Chi-Square = 0.0306, p = 0.8612 for the hamstring, and for the hip flexors, Chi-Square = 0.1235, p = 0.7252. Therefore, these findings indicate increasing an individual's muscle flexibility does not relate to a decrease in the chance of injury.

An additional correlational analysis was performed to show any significant relationship between right and left leg injuries. The analysis revealed a strong relationship between right and left hip flexor muscle groups (0.8251). That is, flexibility in the right hip flexor muscle group could predict flexibility in the left hip flexor muscle

group. The relationship between hip flexor and hamstring muscle group flexibility within either the same or opposite leg was weak, indicated by the low Pearson Correlation Coefficients.

Table 1- Correlation Matrix

	R Flex	L Ham	R Flex	L Flex
R Ham	r =1.0000 p = 0.0	r = 0.5981 p = 0.0001	r = -0.3838 p = 0.0059	r = -0.4410 p = 0.0014
L Ham	r = 0.5981 p = 0.0001	r = 1.0000 p = 0.0	r = 0.2114 p = 0.1405	r = -0.2836 p = 0.0460
R Flex	r = -0.3838 p = 0.0059	r = -0.2114 p = 0.1405	r = 1.0000 p = 0.0	r = 0.8679 p = 0.0001
L Flex	r = -0.4410 p = 0.0014	r = -0.2836 p = 0.0460	r = 0.8679 p = 0.0001	r = 1.0000 p = 0.0

Demographically, of the 50 participating football athletes, 24 (48%) were classified as the starter for their position. This means they played in a least 50 percent of the available opportunities. The remaining 26 (52%) had a back-up role during the games, although during practice all participants attempted approximately the same repetitions per position. The line position players (offensive line, defensive line, and linebackers) had 28 participants, or 56%, while skill position players (running backs, defensive backs, receivers, etc.) had 22 participants, or 44 % of the sample.

Flexibility Measurements

Average range of motion (ROM) for passive knee extension, measured in degrees, did vary slightly, although the difference was not significant. A knee in full extension received a zero degree measurement, motion beyond this point was not considered. When reporting measurements, higher numbers indicated less flexibility of the muscle.

For the right hamstring, participants that experienced injury had 13.88 degrees of range of motion and non-injured participants had 8.79 degrees ($t = 1.78$, $p > .05$). The injured athlete participant group's left hamstrings had an average of 7.75 degrees, while non-injured participants had 7.79 degrees of range of motion ($t = -.01$, $p > .05$). With regards to the hip flexor muscle groups, potential measurements ranged from a zero degree starting point up to fifty-five degrees. Beyond this point ROM was affected by accessory rotation of the back/pelvis. The measurements were then converted from the fifty-five degree end point to a zero degree end point. Again, a higher number indicated less flexibility. The injured group's right side measurement showed an average flexibility of 20 degrees and the un-injured group had a 17.67 degree range of motion figure ($t = .58$, $p > .05$). The left side injured group had an average ROM of 17.38 degrees and un-injured left hip flexor muscles had a 16.17 degree average ROM ($t = .40$, $p > .05$).

Questionnaire Responses

Each participant that experienced an injury was given a questionnaire (See APPENDIX VI) about possible contributing mechanisms to the injury. While no participants had experienced a hamstring strain within the past year, four had a prior history of hamstring strains and twelve had no prior history. Eight of the sixteen injuries kept the athlete out of full activity for zero to two days, while six athletes were out for more than one week. In a subjective pain rating from 1 – 10, responses ranged from one to ten with nine players rating a seven or higher. Seven of the nine were able to continue playing immediately following the occurrence. When asked how long until they felt fully

healed, four said within one week, while nine reported three weeks or more. One of the sixteen had not recovered by the end of the study period.

All participants had been involved in a lower extremity-strengthening program. On a subjective 1 – 10 scale, all reported they were working minimally at a level five with seven participants recording a ten, or the most effort possible. Concerning sleeping habits, thirteen of the sixteen were getting normal hours. One participant-recorded six hours a night, the remaining fifteen all had seven or more hours a night. All participants' felt they were eating a normal diet and most (13/16) were eating at normal times. No participant had made any significant changes to their diet within the period of the study. Supplements to the normal diet were being taken by all but five of the participants. Of interest, ten of the sixteen were using creatine. Regarding water availability and ingestion, thirteen of sixteen felt they were getting enough. When asked what time period during the practice/game the injury occurred six said the first quarter, three said the second, four said the third and three said the fourth quarter of the practice or game. Fourteen of the sixteen felt they stretched adequately before the injury occurred. Seven considered themselves flexible and nine considered themselves inflexible. The questionnaire dealt with the athletes' subjective interpretation of the factors related to their hamstring strain. No objective results could be taken from the survey.

The values for both correlational analyses in this study only involved hamstring and hip flexor muscle groups. It is not within the scope of this study to translate or predict similar relationships involving other muscle groups.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This study was designed to investigate if hamstring and hip flexor flexibility related to hamstring injury in collegiate football players. Specifically, it was to test the common belief that muscle strain can be reduced or eliminated by having increased flexibility or range of motion. The statistics showed no relationship between flexibility and injury rate. When examining the range of motion (ROM) of both the injured and non-injured participants, differences did exist between the group averages. These differences were not statistically significant. The injured participant group did have less flexibility in both hamstring and hip flexor muscle groups, although not a statistically significant decrease in flexibility of these muscles, as explained in the results chapter.

Discussion of Results

The present study was conducted over the course of a competitive football season at the collegiate level. Beginning with preseason two-a-day practices throughout the last game, the period was fifteen weeks. Fifty athlete participants completed the study. Of these fifty, sixteen participants became injured. Flexibility measurements were taken within the first week of the preseason and again at approximately halfway through the competitive season. All injuries, with the exception of one, occurred within the first half of the season. There were no season-ending injuries over the course of the study.

According to the statistical results, the null hypothesis was retained saying that there is no relationship between amount of flexibility and rate of injury.

The measurement technique and procedure had a great influence on the accuracy of this research study. If the goniometer was misplaced or misread even slightly, readings would be inaccurate. An effective flexibility evaluation, along with accurate measurement, was needed to insure actual range of motion. The anatomical landmarks used for the reading of the goniometer must have been carefully identified and double-checked for accuracy. For these reasons, one tester was used throughout the study for all flexibility evaluations. Each measurement was double-checked for the same amount of degrees on the goniometer.

The connection, or relationship, between flexibility and injury rate is widely assumed to be true. When a muscle becomes strained, it no longer can reach its before-injury ROM amount. The muscle (in this case, hamstring) now has a decreased amount of flexibility. To return the muscle group back to pre-injury condition, flexibility must be restored. Research, such as that of Worrell et al. (1991) has shown that as a muscle becomes strained, it both loses flexibility and is more likely to become re-injured. For this type of example, it is true that as the muscle gains flexibility it is less likely to become injured. This is not the case when dealing with healthy muscle tissue. This study, along with others such as Orchard et al.(1997), Worrell and Perrin (1992), and Macera (1992) as discussed in the review of literature, have failed to show a relationship between flexibility and injury rate. The primary reason this relationship is regarded as true is that "it seems to made sense" because we all have heard it for so long. These statements need to be eliminated because they are not being proved through research.

This is not to say flexibility is unimportant. A muscle with greater range of motion has greater potential to generate strength. Worrell et al.'s work in 1994 has shown this relationship. The greater amount a muscle can lengthen, or relax, the greater the force production because of the increased contraction distance. The greater the contraction, the more force or strength a muscle can produce. Through the agreement that a muscle with greater ROM (flexibility) has the potential for greater strength output, due to the increased amount of contraction, it can be inferred that injury to a healthy muscle is indirectly related to flexibility. This thought states that because of the muscle's increased strength; a muscle is prevented from initially becoming injured. This belief is highly subjective without evidence of the relationship through research.

Conclusions and Recommendations for Further Study

There are a number of suggestions for future research between flexibility and injury rate. This additional research would be helpful to further identify the different contributing mechanisms of muscle strain and how to reduce or eliminate those factors:

I. A longer period of evaluation to allow for changes in individual participants' overall flexibility and what effect that had on injury occurrence.

II. A period of one year might be helpful to include the off-season, the spring season and summer conditioning.

III. Research as to what time of year or kind of activity is most closely related with hamstring pulls.

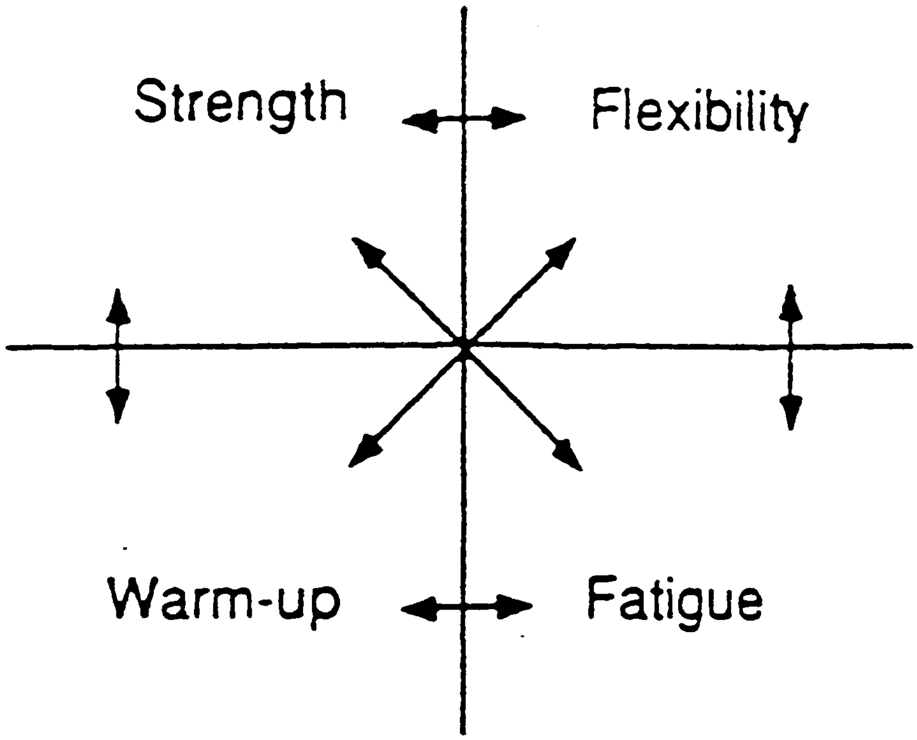
IV. Research with other muscle groups or participant populations could be done comparing results to the present study.

V. Research to identify strength deficits or imbalances and those measurements related to both flexibility and/or injury rates.

In summary, the present study revealed no correlation between flexibility and injury rate. As Sallay, Friedman, Coogan, and Garrett (1996) have explained through their research, an adequate warm-up that proceeds the exercise period is important in preventing muscle strains. This can lead to confusion between the terms of warm-up and flexibility and the relationship of each term in prevention of muscle strain. It is important for the athlete to be at his certain available range of motion, rather than working to increase his overall flexibility, to prevent muscle strains. Any attention to increasing flexibility should be directed at its potential implications with strength gains, rather than prevention of injury.

APPENDIX I

HAMSTRING INJURY MODEL



MULTIPLE FACTOR HAMSTRING INJURY MODEL

WORRELL & PERRIN

APPENDIX II

HUMAN SUBJECT PROTOCOL

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

DATE: August 21, 1998

TO: Joseph Slat (KIN)
M/S 3034

FROM: Dr. John Young, Chair
Biomedical Sciences Committee

RE: Expedited Review of Human Subject Protocol:
"Relationship of Hip Flexor and Hamstring Flexibility to Injury Rates of Muscle Strains in Collegiate Football"
OSP #: 504s0898-071x

The protocol for the project referenced above has been reviewed and approved by an expedited review by the Institutional Review Board Biomedical Sciences Committee. This protocol is approved for a period of one year from the date of this notification and work on the project may proceed.

Should the use of human subjects described in this protocol continue beyond a year from the date of this notification, it will be necessary to request an extension.

If you have any questions or require any assistance, please contact Marsha Green, IRB Secretary, at 895-1357.

cc: B. Mangus (KIN-3034)
OSP File

Office of Sponsored Programs
4505 Maryland Parkway • Box 451037 • Las Vegas, Nevada 89154-1037
(702) 895-1357 • FAX (702) 895-4242

APPENDIX III

INFORMED CONSENT FORM

CONSENT FORM

PURPOSE

You are being asked to participate in a research study. The purpose of this study is to show the relationship between muscle flexibility and occurrence of injury. Participants will be evaluated for flexibility amounts in their hip flexor and hamstring muscle groups. Participants will then be tracked throughout the football season to record any hamstring muscle injuries that may occur. Participants will be re-evaluated approximately halfway through the season, to note any changes in flexibility. The study will last throughout the season for a period of four months.

RISKS

Because of the procedures involving only flexibility measurements, the risks are minimal to none. Your participation and results form this study will remain confidential. Any identification will be through participant identification numbers only.

QUESTIONS

Any questions that may come up will be answered at any time to your satisfaction by any of the following sources:

Joe Slat	895-4035
Dr. Brent Mangus	895-3158
Office of Sponsored Programs	895-1357

PARTICIPATION

Participation in this study is voluntary. At no time will you be asked to do something against your will. You are free to withdraw this consent and discontinue participation in this research study at any time.

CONSENT

By signing below, you will indicate that you understand what is involved and have decided to volunteer as a research participant in this study. You will be given a copy of this form of consent.

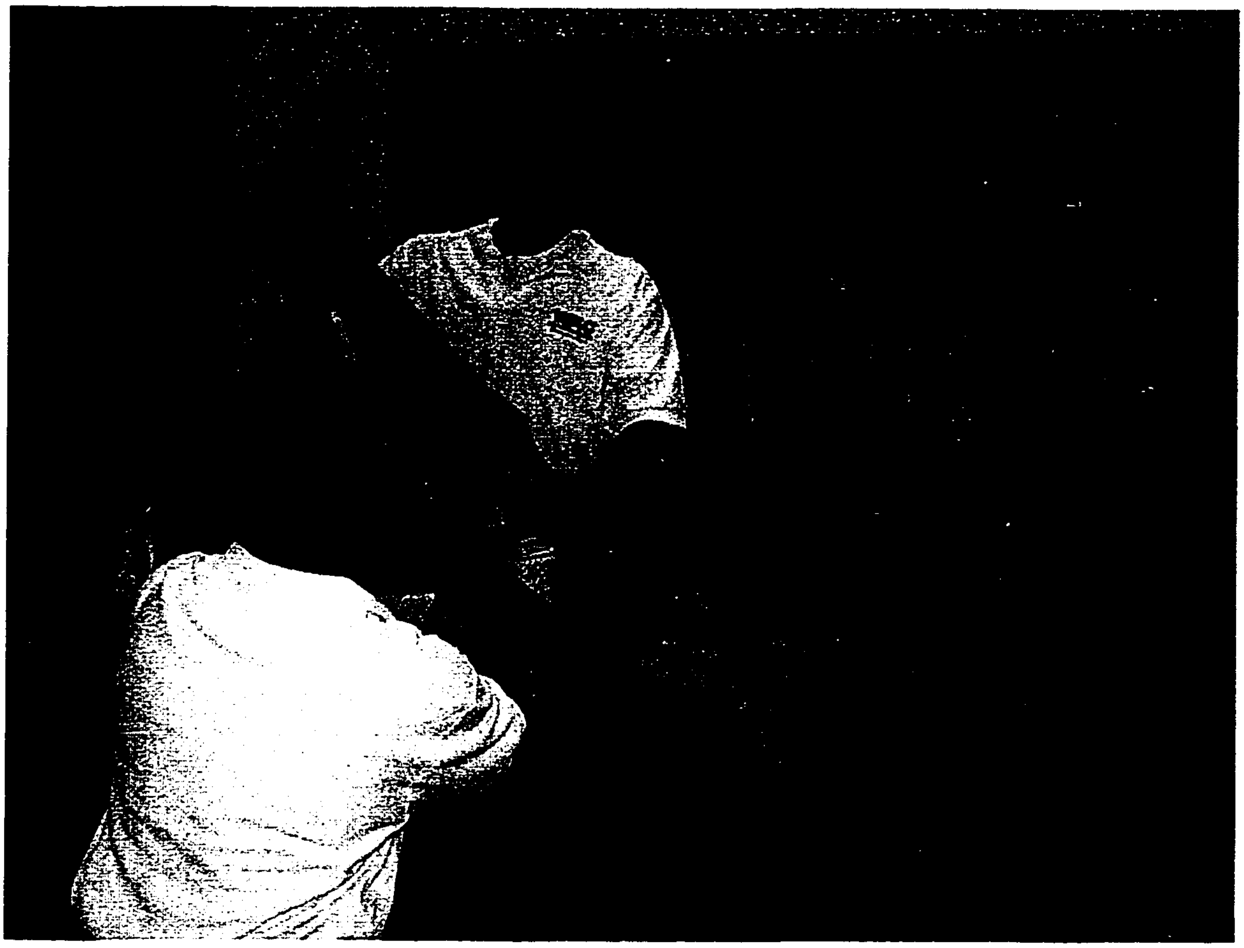
__________ ____________________ ____________________

Date Name of Participant Signature of Participant

APPENDIX IV

PROCEDURE FOR MEASUREMENT

HAMSTRING MEASUREMENT PROCEDURE



HIP FLEXOR MEASUREMENT PROCEDURE

APPENDIX V

DATA SET AND STATISTICS OUTPUTS

Participant	Right Ham	Left Ham	Right Flex	Left Flex	Right Injury	Left Injury
1	6	0	27	17	0	1
2	4	1	22	11	0	0
3	0	0	0	0	0	1
4	3	3	13	15	0	1
5	0	4	21	14	0	0
6	15	2	33	26	0	1
7	12	8	20	17	0	0
8	20	17	15	20	1	0
9	30	15	23	17	0	0
10	20	10	23	23	1	0
11	7	6	15	7	1	0
12	13	15	15	16	0	0
13	9	9	5	9	0	0
14	4	3	14	12	0	0
15	4	1	13	20	0	0
16	10	0	6	17	0	1
17	13	6	26	22	0	0
18	0	0	30	20	0	0
19	5	7	36	25	1	0
20	4	4	2	3	0	0
21	10	10	37	37	0	1
22	0	0	18	21	0	0
23	6	7	14	11	1	0
24	6	4	21	14	0	0
25	14	11	4	7	0	0
26	12	11	25	24	0	0
27	15	17	21	17	0	0
28	3	2	0	6	0	0
29	1	5	18	13	0	0
30	13	12	33	30	0	0
31	6	1	7	6	0	0
32	7	3	10	8	0	0
33	31	26	29	28	0	0
34	8	42	10	15	1	1
35	23	22	37	24	1	0
36	9	9	10	15	0	0
37	11	6	28	23	0	0
38	1	0	20	13	0	0
39	1	1	9	13	0	0
40	7	7	9	14	0	0
41	2	5	12	12	0	0
42	13	12	24	22	0	0
43	7	7	12	9	0	0
44	4	6	28	21	0	0
45	22	5	10	12	1	1
46	10	8	29	28	0	0
47	25	27	22	23	0	0
48	13	8	35	36	0	0
49	11	3	10	12	0	0
50	10	1	1	3	0	0

SAS OUTPUT PROGRAM
The LOGISTIC Procedure

Data Set: WORK.HAMSTR
Response Variable: RINJURY
Response Levels: 2
Number of Observations: 50
Link Function: Logit

Response Profile

Ordered Value	RINJURY	Count
1	0	42
2	1	8

Model Fitting Information and Testing Global Null Hypothesis BETA=0

Criterion	Intercept Only	Intercept and Covariates	Chi-Square for Covariates
AIC	45.967	46.986	.
SC	47.879	52.722	.
-2 LOG L	43.967	40.986	2.981 with 2 DF (p=0.2253)
Score	.	.	3.291 with 2 DF (p=0.1929)

Analysis of Maximum Likelihood Estimates

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
INTERCPT	1	2.5538	0.9321	7.5068	0.0061	.	.
RHAM	1	-0.0813	0.0505	2.5926	0.1074		
RFLEX	1	-0.00013	0.0424	0.0000	0.9975		

Association of Predicted Probabilities and Observed Responses

Concordant	= 68.2%	Somers' D	= 0.381
Discordant	= 30.1%	Gamma	= 0.388
Tied	= 1.8%	Tau-a	= 0.104
(336 pairs)		c	= 0.690

SAS OUTPUT PROGRAM
The LOGISTIC Procedure

Data Set: WORK.HAMSTR
Response Variable: LINJURY
Response Levels: 2
Number of Observations: 50
Link Function: Logit

Response Profile

Ordered Value	LINJURY	Count
1	0	42
2	1	8

Model Fitting Information and Testing Global Null Hypothesis BETA=0

Criterion	Intercept Only	Intercept and Covariates	Chi-Square for Covariates
AIC	45.967	49.838	.
SC	47.879	55.574	.
-2 LOG L	43.967	43.838	0.129 with 2 DF (p=0.9374)
Score	.	.	0.130 with 2 DF (p=0.9371)

Analysis of Maximum Likelihood Estimates

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
INTERCPT	1	1.8800	0.9189	4.1857	0.0408	.	.
LHAM	1	0.00919	0.0526	0.0306	0.8612	0.040990	1.009
LFLEX	1	-0.0174	0.0496	0.1235	0.7252	-0.077787	0.983

Association of Predicted Probabilities and Observed Responses

Concordant	= 54.5%	Somers' D	= 0.101
Discordant	= 44.3%	Gamma	= 0.102
Tied	= 1.2%	Tau-a	= 0.028
(336 pairs)		c	= 0.551

t-Test: Two-Sample Assuming Equal Variances

RIGHT LEG

	Hamstrings	*Hamstrings*
Mean	13.875	8.785714286
Variance	63.83928571	53.34320557
Observations	8	42
Pooled Variance	54.87388393	
Hypothesized Mean Diff.	0	
df	48	
t Stat	1.780978265	
P(T<=t) two-tail	0.081244575	
t Critical two-tail	2.01063358	

t-Test: Two-Sample Assuming Equal Variances

RIGHT LEG

	Hip Flexors	*Hip Flexors*
Mean	20	17.66666667
Variance	120	105.5447154
Observations	8	42
Pooled Variance	107.6527778	
Hypothesized Mean Diff.	0	
df	48	
t Stat	0.582973484	
P(T<=t) two-tail	0.562640167	
t Critical two-tail	2.01063358	

t-Test: Two-Sample Assuming Equal Variances

LEFT LEG

	Hamstrings	*Hamstrings*
Mean	7.75	7.785714286
Variance	203.0714286	44.61149826
Observations	8	42
Pooled Variance	67.7202381	
Hypothesized Mean Diff.	0	
df	48	
t Stat	-0.011250385	
P(T<=t) two-tail	0.991070312	
t Critical two-tail	2.01063358	

t-Test: Two-Sample Assuming Equal Variances

LEFT LEG

	Hip Flexors	*Hip Flexors*
Mean	17.375	16.16666667
Variance	114.5535714	51.50813008
Observations	8	42
Pooled Variance	60.70225694	
Hypothesized Mean Diff.	0	
df	48	
t Stat	0.402039731	
P(T<=t) two-tail	0.689439466	
t Critical two-tail	2.01063358	

APPENDIX VI

QUESTIONNIARE

Injury questionnaire
CONFIDENTIAL: for my use only, please answer honestly and accurately

NAME ______________________________

Did you experience a hamstring injury this past season? Y N

Have you experienced any hamstring injury within the past year? Y N

Have you experienced any hamstring injury ever before? Y N

How much time (# of practices or games) did you miss due to the injury? __________

Can you rate the pain from the injury from 1 (least) to 10 (most)? __________

Were you able to continue playing immediately following the injury? Y N

Approximately how long after the injury until you felt 100%? ____________

At the time of injury, were you involved in any leg-strengthening program? Y N

How hard had you been working with the strengthening program, 1-10 (least-most)? ________

Had you been sleeping normal hours? Y N How many hours per night? _________

Had you been eating a normal diet? Y N At normal times? Y N

Concerning your diet, had you recently added or stopped eating anything? Y N If yes, please list. ____

Had you been taking any vitamins or supplements? Y N If yes, please list __________
____

Was enough water available to you during your activity? Y N

Had you been drinking water at regular intervals? Y N

During what period in practice/game did the injury occur (1st, 2nd, 3rd, 4th quarter)? ________

Had you stretched/warmed-up your hamstrings before the injury occurred? Y N

In your opinion, do you consider yourself flexible? Y N

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