# THE EFFECT OF PREVIOUS HAMSTRING INJURIES ON ACL INJURY RISK

by

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## Introduction

In the United States there are between 100,000 and 200,000 Anterior Cruciate Ligament (ACL) injuries per year, making it the most commonly injured ligament in the knee (Friedberg, 2016). There are many factors that increase the risk of injuring the ACL. Among these factors are anatomical factors such as knee laxity, the sport the athlete participates in, and the neuromuscular control of the knee joint (Shultz, 2015). Some of these injuries can be prevented but others are unavoidable because 60% of ACL injuries are non-contact related; meaning they happened because of some way that the athlete moved and not because they got hit by another player (Agel, 2016). The non-contact mechanism can be observed when there is a sudden deceleration of the body such as when the athlete is abruptly changing direction. The foot will plant into the ground and then the athlete will quickly go into a cutting motion by moving laterally. This may cause the ACL to tear due to extreme strain being put on the ligament when it attempts to stop excessive anterior movement of the tibia. It is typically common in sports such as soccer, football and lacrosse. The number of cases has increased over the years, in sports such as skiing, by almost 14% (Beynnon, 1998). This injury can be detrimental to athletes as well. It may take an athlete six months to a year to return to their sport but can also cause health problems in the future. ACL tears also lead to abnormal tibiofemoral joint kinematics, joint trauma, and early onset osteoarthritis (Beynnon, 1998).

ACL tears not only affect an athlete by removing them from play for at least a year but it can also predispose them to early-onset osteoarthritis. Osteoarthritis (OA) is an age-related disorder characterized by the loss of articular cartilage with degrees of osteophyte formation, subchondral bone change, and synovitis (Lohmander, 2007). In addition to age, family history, developmental conditions, and injuries to the joint such as an ACL tear can also lead to early-onset osteoarthritis (Lohmander, 2007). ACL tears that occur in people ages 20-30 years often report symptoms of early-onset osteoarthritis between the ages of 30 and 50 years old. In one particular study, 75% of female soccer players studied reported symptoms of OA just 12 years after their reconstructive surgery (Lohmander, 2007). Overall, the results of these studies have shown that not only are there devastating short-term effects, the long-term effects of an ACL tear can be debilitating and have long-term consequences. These reasons among others are why research needs to be done in order to learn how to prevent this injury.

## Background

### *Current State of Anatomical Risk Factors*

Risk factors associated with ACL injury are generally categorized into four main categories: hormonal, anatomical and structural, genetic, and neuromuscular. Anatomical risk factors can influence a person's likelihood to tear the ligament. For example, if there is laxity in the knee this may predispose an individual to the risk of injury. The amount of laxity in the knee varies greatly among individuals but it was found that knee laxity has been associated with the landing strategies that are considered "higher-risk" for injury (Shultz, 2015). Hormonal risk factors can play a part in this as well. Women tend to have acutely high knee laxity due to their high levels of estrogen during the menstrual cycle (Shultz, 2015). The hormone estrogen can have an effect on the collagen that makes up the ACL causing it to be altered. The hormone relaxin is also released into the body and studies have shown that it can have effects on the collagen metabolism. The collagen metabolism changes can lead to a less dense structure of the

ACL therefore causing laxity (Shultz, 2015). While these anatomical and hormonal risk factors are important they are typically viewed as non-modifiable. Thus, focusing on risk factors that are modifiable may have the greatest potential to reduce injury incidences.

Neuromuscular control is a risk factor for ACL injury that can be considered modifiable. Neuromuscular control is described as the body's ability to produce coordinated movement through muscle force production and reduction. Deficiencies in lower extremity neuromuscular control can lead to the knee joint being placed in vulnerable positions that can increase ACL strain. When there are deficits in neuromuscular control in the knee the likelihood of an ACL injury is much higher than if the neuromuscular control was normal (Shultz, 2015). An example of poor neuromuscular control in the lower extremity is when the knee may turn inward in a valgus knee formation during a squat when the knees are supposed to stay straight and parallel to the ground. This causes excess strain on ligaments of the knee and would require improvement of neuromuscular control of the hamstrings and quadriceps. Given that the quadriceps and hamstrings muscles are the primary muscles controlling the knee joint movement, an understanding of how these muscles normally function is critical to better interpret how potential neuromuscular deficiencies could affect ACL injury risk.

*Effects of Quadriceps and Hamstrings Muscle Function on ACL Strain*

The quadriceps and hamstrings have direct effects on the ACL as evidenced through both cadaver and in-vivo research. In cadavers, when there is an applied hamstrings load there will be significant decrease in ACL force; while when there is an applied quadriceps load the force on the ACL will increase, with the greatest effects being when the knee joint is in relatively extended positions (Beynnon, 1998). In-vivo research also has confirmed the role of the quadriceps and hamstrings in relation to the ACL (Beynonn, 1998). In a study done by Beynnon et al 1998, it was found that with an isometric contraction of the quadriceps muscle there was increased ACL strain (Beynnon, 1998). In comparison, when the hamstrings were coupled with quadriceps activation, there was a decrease in amount of strain on the ACL compared with isolated quadriceps activations. Hamstrings are also thought to enhance knee stability because they are responsible for controlling internal rotation and excessive varus forces; there by decreasing ACL strain during those movements (Bjordal, 1997). Overall, healthy hamstrings function to protect the ACL from injury by reducing ACL strain while the quadriceps act antagonistically to the ACL

*Evidence Suggesting Previous Hamstring Injury is a Risk Factor for ACL Injury*

The hamstring muscles are considered protagonists or "protectors" of the ACL. Therefore, if the hamstrings are deficient they may not be able to reduce the load on the ACL causing excessive ACL strain. In one study, hamstrings muscle structure was compared between people with and without hamstring injuries (Silder, 2008). MR imagining showed that in the subjects with injuries to their biceps femoris long head there was atrophy in the injured hamstring when compared bilaterally (Silder, 2008). Hamstring injuries are common and athletes sometimes return to play before they are fully healed (Silder, 2013). Another study showed apparent residual scarring in the injured hamstrings 5 months after injury. All of the MR images were taken after the injured participants had completed a supervised rehabilitation program and been cleared to play one month prior to the study. Therefore, the results demonstrate that even after being cleared to play with normal strength requirements being met the structural make-up of the hamstring may be comprised (Silder,2013). This can be detrimental because if the hamstring is deficient it can cause an increase in ACL strain making it more likely to tear. Because of these effects of previous injury on hamstring muscle structure and function, studies should be done to further investigate the relationship between previous hamstring injuries and ACL tears.

## Purpose

The purpose of this study is to determine if athletes with prior hamstring injury are at a relative higher risk of ACL injury compared to athletes without a history of hamstring injury.

## Hypothesis

It is our hypothesis that individuals with previous hamstring injuries are at higher relative risk of ACL injury compared to individuals without a history of previous hamstring injury.

## Methodology

This was a retrospective study. This study had University and Medical Center IRB approval as of August of 2017. Athlete injury histories were extracted over a period of the previous 6 years, from July 2011 to December 2016 by the Athletic Trainer. As part of normal clinical practice, the Athletic Trainer keeps record of injuries throughout the seasons. While going through these records the number of athletes who had a history of hamstring injuries, the athletes who had ACL injuries and the athletes that had both a hamstring injury and an ACL injury. In a separate spreadsheet for hamstring injuries, the grade of the strain, how long the athlete was out of play due to the injury, and which leg was injured and when it occurred was recorded by the Athletic Trainer (Table 1). Whether the hamstring injury was diagnosed by a doctor or an imagining technique was recorded as well (Table 1). For athletes with an ACL injury the mechanism of injury was recorded in a separate spreadsheet (Table 2). When athletes had both, the timeline of the injuries was recorded to see whether the hamstring injury came before or after the ACL tear. The athletes' data was organized into a 2 x 2 contingency table. The rows were divided into two groups: number of athletes with a history of hamstring injury and athletes with no history of hamstring injury. The columns were then divided into two as well: number of athletes with ACL injury and number of athletes with no history of ACL injury. The total number of athletes in each row will be added together to get a total. The total number of athletes competing across the 6-year timespan was determined by assessing sport rosters posted publicly at the beginning of the seasons. To determine the likelihood of injury in athletes, relative risk ratios were determined. The number in first column of the first row was divided by the total population number of the first row to calculate the proportion of injuries for athletes who had a previous hamstring injury and an ACL tear. This calculation was done for the first number in both rows. These proportions represent the risk of sustaining an ACL tear with a history of hamstring injury relative to the risk of ACL injury without a history of hamstring injury.

Table 1: Information recorded regarding hamstring injuries.

| | |
|---|---|
| Side of Body the Injury was on | Mechanism of Injury |
| Grade of Strain | Injury Confirmed by ATC or Physician |
| Days of Play missed | |

Table 2: Information recorded regarding ACL injury.

| | | |
|---|---|---|
| Side of Body | Days of Play Missed | Graft type used for surgery |
| Grade of Strain | Whether they had surgery | Mechanism of Injury |

## **Results**

Over a six-year period there were 274 unique players that participated in a total of 710 player seasons. During this time, there were 69 individuals that suffered hamstring injuries and 10 individuals suffered an ACL injury (Table 3). Five individuals suffered both an ACL injury and hamstring injury. In the group with a previous history of hamstring injury, zero individuals suffered an ACL injury. In the group of individuals without a previous history of hamstring injury, 9 suffered ACL tears. A total of 196 (72%) individuals had neither a ACL injury nor hamstring injury. In order to calculate relative risk, 0.5 was added to each number in the 2 x 2 contingency table (Table 3). The relative risk of having an ACL tear following a hamstring injury compared to individuals without a history of hamstring injury was 0.16 (95% CI= 0.01, 2.63). p=.198. Thus, the risk of sustaining an ACL tear following hamstring injury was effectively no different than individuals without a previous hamstring injury history.

In this study, there were zero players who suffered a hamstring injury that had a future ACL tear, but there were five individuals who had the presence of both injuries. Five players with an ACL injury later injured their ipsilateral hamstring. We conducted a follow-up analysis to determine if the risk of hamstring injury is relatively higher in individuals with a previous ACL tear compared to individuals without a history of ACL injury(Table 4). In the group without a previous history of hamstring injury, 69 individuals suffered a hamstring injury during the six-year period. The group with a previous history of ACL tear, had five individuals suffer a hamstring injury and 10 individuals not suffer a hamstring injury during the six year period. A total of 190 (69%) individuals had neither a previous ACL tear nor a hamstring injury. The relative risk of suffering a hamstring injury after a previous ACL tear was calculated to be 1.25 (95% CI= .59,2.63). p=.57. Therefore, the relative risk of suffering a hamstring injury after an ACL tear was no different than the risk of a hamstring injury without a previous history of an ACL tear.

TABLE 3:

| | No ACL Tear | ACL Tear | **Total** |
|---|---|---|---|
| Previous Hamstring Injury | 69.5 | 0.5 | 70 |
| Without Previous Hamstring Injury | 196.5 | 9.5 | 206 |
| **Total** | 266 | 10 | 276 |

TABLE 4:

| | No Hamstring Injury | Hamstring Injury | **Total** |
|---|---|---|---|
| Previous ACL Injury | 10 | 5 | 15 |
| No Previous ACL Injury | 190 | 69 | 259 |
| **Total** | 200 | 74 | 274 |

***Legend:** Each number in the cell represents the total number of unique athletes with that injury. These were the exact numbers used to calculate relative risk ratios.

## **Discussion**

The purpose of this study was to determine if athletes with a previous hamstring injury were at a relatively higher risk of ACL injury than those without a history of hamstring injury. We hypothesized that the relative risk of having an ACL injury would be higher if the athlete had a history of hamstring injury. This was found to not be true for this study. There were zero athletes that sustained an ACL injury following a hamstring injury. The relative risk of athletes with a previous hamstring injury suffering an ACL injury was determined to be no different to those without a previous hamstring injury. Rationale as to why a hamstring injury could theoretically influence ACL injury risk, the limitation that the study was only included male collegiate football players, and whether there were measures taken to prevent ACL injury during this study will all be evaluated in this discussion.

A previous hamstring injury could possibly lead to a future ACL injury for multiple reasons. One reason why it could be considered a risk factor is because the hamstring muscles are agonists of the ACL; the hamstrings assist in preventing anterior tibial translation. If the hamstrings are compromised they cannot decrease the load on the ACL well. Athletes often return to play with compromised hamstring muscles. For example, the Silder et al 2013 study was done to compare hamstring muscle structure between the injured and uninjured legs after rehabilitation and found this to be true (Silder, 2013). This theory that a previous hamstring injury increases an athlete's risk for a future ACL tear has also been discussed in Opar's article (Opar, 2014). Opar believes that mechanistically it makes sense that if the hamstrings have been compromised then the ACL has more stressed placed on it making it more likely to tear (Opar, 2014). It is plausible that in the current study that hamstring injuries occur in varying degrees of severity and that minor hamstring injuries are fully healed by the time the athlete's return to competition. The hamstring injuries were a limitation to this study due to no injury being excluded. On average athletes missed 7.9 days and some athletes did not even miss a full day of practice or a game.  Excluding some hamstring strains may have improved the study because many of the less severe hamstring injuries may not have left the muscle compromised long-term. If the hamstring muscle was not compromised long term then the hamstring injury would not have left the athlete predisposed to an ACL injury. Future studies are suggested to include hamstring injuries that are more severe such a grade 2 or 3 strain. Those injuries are more likely to return to play with compromised muscle structure.

Another factor that may have contributed to the results of this study may have been the population. This study's population included only collegiate male football players from one institution. This study's limitation led to females or other high-risk sports not being evaluated. It is reported in the literature that females are considered to be more at risk for tearing their ACL than males (Sutton, 2012). Including females in this study potentially could have given us more robust results related to our purpose strengthening the external validity of the study.  ACL injuries are also prevalent in sports such as soccer, basketball, and lacrosse not just football (Agel, 2016). In these sports, cutting and pivoting moves are prevalent. Not only are these sports high-risk for ACL injuries, hamstring injuries are also present due to the high stress on lower extremities. Future studies should look to include multiple sports that have a high risk of both hamstring and ACL injuries. Multiple institutions should also be included in order to further expand the population.

In this study only medical records of athletes were analyzed but not everything is included in medical records. For example, the records do not say what kind of work outs an athlete was doing or if the athlete wore prophylactic knee braces every practice. During this six year period that the records were taken from, there was no documentation about whether techniques were being used to prevent ACL injuries. Knee braces could have been used to protect against ACL injuries. Specifically, this football team does require the offensive line to wear prophylactic braces. These braces could have affected the study's outcome which could potentially have affected the results. However, these braces would not have significantly affected the outcome because hamstring injuries are more likely to occur in skill players such as receivers due to the greater amounts of cutting and sprinting they do. Since hamstring injuries occur predominantly in the skill positions the ACL injuries would have been more prevalent in those players as well compared to offensive linemen. Other techniques such as specific strengthening programs for muscles that stabilize that knee may have been done during the six-year period. Therefore, some techniques may have been done during this period to prevent ACL injuries that could have masked the effects of previous hamstring injury on ACL injury.

A final limitation to the study design itself. This research study was a retrospective study therefore we do not know anything about how severe or not severe the athletes' injury (hamstring) may have been. A prospective study should be done in the future so that researchers can palpate the site of the hamstring injury when it happens and when they return to play for any palpable divets or scar tissue, the researchers could manually test the athletes' strength before they return to play, or test their strength on a dynamometer. These would help to better understand the extent of hamstring "compromise" when returning to play.

## Conclusion

In this study, we hypothesized that individuals with a prior history of hamstring injury would be at a higher relative risk of ACL injury compared to athletes without a history of hamstring injury. The results of our study determined that athletes with a history of hamstring injury have the same relative risk of ACL injury as those without a history of hamstring injury. We believe this research question requires further consideration and evaluation. Future studies should consider expanding the population to include both females and males from multiple institutions and multiple high-risk sports such as soccer, football, and basketball. The grade of hamstring strains included in future studies should be limited to only more severe strains such as Grade 2 or Grade 3.

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