A Retrospective Study Investigating Knee Injury Risk Factors

A Thesis Presented
by
Mackenzie Ann Pierson
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NOTIFICATION OF IRB ACTION MODIFICATION APPROVAL

Date: April 13, 2015
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Principal Investigator(s): Rui Li
Department: Health Sciences
Address: 316 Robinson Hall 
Northeastern University

Title of Project: A Cross-Sectional Comparison of Knee Injury Risk Factors in Male and Female Athletes through Onsite Laboratory Testing and Questionnaires

MODIFICATION: a) project will now include retrospective data analysis of the women’s ice hockey, women’s basketball, women’s soccer, men’s ice hockey and men’s soccer from 2012 and 2013. Data have already been coded; b) Professor Li has re-assumed the role of PI from Professor Sceppa, who was temporarily named while Professor Li was on sabbatical.

Participating Sites: N/A
Original Protocol Approved: August 13, 2014
DHHS Review Category: Expedited #5
Informed Consents: N/A
Monitoring Interval: 12 months

APPROVAL EXPIRATION DATE: AUGUST 12, 2015

Investigator’s Responsibilities:
1. The informed consent form bearing the IRB approval stamp must be used when recruiting participants into the study.
2. The investigator must notify IRB immediately of unexpected adverse reactions, or new information that may alter our perception of the benefit-risk ratio.
3. Study procedures and files are subject to audit any time.
4. Any modifications of the protocol or the informed consent as the study progresses must be reviewed and approved by this committee prior to being instituted.
5. Continuing Review Approval for the proposal should be requested at least one month prior to the expiration date above.
6. This approval applies to the protection of human subjects only. It does not apply to any other university approvals that may be necessary.

C. Randall Colvin, Ph.D., Chair
Northeastern University Institutional Review Board

Nan C. Regina
Director, Research Integrity

Northeastern University FWA #: 4630
Acknowledgements

Throughout this study there have been many unexpected twists and turns. There are individuals that have assisted me throughout this process during those times that deserve special recognition.

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Finally I would like to thank my family: Marcia, Richard, Paul, Carol and Dave. You have always supported my dreams. I would not have been able to find success and make it to this point in my life without you. It was your endless love, support and encouragement that allowed me to find reckless optimism during tough times. You are the reason I have found success and peace in both this thesis and my life.
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Abstract

This retrospective study examined knee injuries in NCAA Division I athletes to assess potential knee injury risk factors. A secondary investigation occurred to determine if selected risk factors were associated with gender. Data were obtained from subject’s participating in women’s soccer, women’s basketball, women’s ice hockey, men’s soccer and men’s ice hockey from 2012-2013. All subjects were of college age during analyzed years. Two risk factors analyzed were found to be statistically significant (p > 0.05): Ankle Range of Motion (6.99, 0.01) and Straight Leg Raise (7.08, 0.02). One risk factor, Leg Raise Left (3.19, 0.76), was found to be marginally significant. Further investigation assessed risk factors for gender association to knee injury. No gender association was found.
Chapter I: Introduction

In the United States, a reported 80,000 – 250,000 knee injuries occur each year according to the American College of Sports Medicine (Hanaki-Martin & Swank, 2013). A unique subpopulation affected by lower extremity injuries is college athletes. A female college athlete is nine times more likely to suffer a knee injury than a male counterpart (Cimino, 2010). Women are between two and ten times more likely to suffer a knee injury, depending on sport, previous injury, as well as other testable factors (Cimino, 2010; Sigward & Powers, 2010; Hootman et al., 2007; Nagda et al., 2010; Cook & Burton, 2007). However, recent publications (Chorba et al., 2010; Drakos et al., 2010; Nagda et al. 2010 & Sigward & Powers, 2010) have reported an increased injury risk in female athletes of nine times that of male athletes. In 2014, the NCAA reported 12,500 knee specific injuries; the clear majority, 8,127, affected women (NATA, 2014). This drastic difference between genders sparks inquiry into why females are at a heightened risk.

With lower extremity injuries, specifically knee injuries, becoming increasingly prevalent, it is common for competing athletes to fear getting injured (Sigward & Powers, 2010). Becoming injured can prevent athletes from practicing, participating in games or may cause them to miss the entire season. If the injury is severe, the athlete is likely to lose valuable time (Hootman et al., 2007). It is common for college athletes to have attended camps and special training sessions prior to starting a college career (Hootman, 2007). Many athletes in Divisions I and
II also use athletic scholarships as a way to help reduce tuition. A minor injury can end the hours of work and result in financial stress for the athlete.

Injuries also have an adverse effect on teammates, coaches and athletic trainers. Athletes may allow the stress and fear of becoming injured to affect their own play. The team atmosphere and morale may be altered, especially if the injured athlete had a heightened role on the team such as a starter or captain. Coaches will have to modify line-ups, practices and plays if an athlete will not be returning to play. Correspondingly, athletic trainers will have extra responsibility through the treatment and rehabilitation of the injured athlete (Hanaki-Martin & Swank, 2013). This may take additional time away from competing athletes during the season.

When an athlete becomes injured, he or she requires more attention than an uninjured athlete. The uninjured athletes’ needs may get overlooked, as they often are more preventative in nature. This could lead to potential injuries later during the athletes’ current season resulting in increases in the financial impact of the injury, affecting more than just the injured athlete.

Lower extremity injuries are not entirely avoidable, but minimizing the likelihood of sustaining an injury is conceivable in future years. While there are preventative programs in place that have decreased the occurrence of knee injuries, sustaining preventative programs has not been successful. Encouraging sustainability and providing areas of growth within a preventative program will aid in decreasing the occurrence of knee injuries.

While it is important to understand the mechanism behind injuries, it is more important to identify the malleable risk factors as a key to prevent lower
extremity knee injuries in the future. It is vital to connect current statistical statuses of the athletes with past data to test for correlations with injury. This will assist in bridging the gap between injury and injury prevention. If researchers have the ability to identify and confirm risk factors in specific sports that can be addressed, altered, and sustained in athletic populations, it is more likely that the rate of lower extremity injuries would decrease.

**Statement of the Problem**

There is a lack of literature identifying reproducible, statistically significant risk factors for knee injuries in athletic populations. While it is known that in the general athletic population more females sustain knee injuries than their male equivalents, understanding the role specific risk factors play in injury is still unclear. An in-depth investigation is required to assess and identify the specified risk factors that may be associated with the prevalence of knee injuries among Division I athletes. If risk factors exist, the secondary investigation is to determine if they are gender associated.

**Scope of Study**

This study will provide a retrospective look at NCAA Division I athletic departmental standard pre-participation data and highlight associations to areas of interest that may be linked with injury for an athletic population. All data are from Northeastern University (NEU), located in Boston, MA. Data were obtained by the institution’s athletic training staff and examined using Microsoft Excel, version 14.2.0, and IBM SPSS, version 22. Data were collected from a total of 206 subjects over a two-year span, 2012-2013. The database provided includes standard
Functional Movement Screening (FMS) tests, other functional movement tests, and injury rates.

**Limitations**

Limitations of this study include technician error. The data were collected over a 2-year period with various medical staff. Standard methods and procedures were followed for all processed data; however, the variation of individual evaluators can cause differences in reported data. Specified data sets are incomplete, as more data were collected in the recent year, 2013, over the past year of 2012. Within the two-year sampling period, modifications were made to test protocols used for each athletic team. Certain functional movement tests followed University standard protocols, but due to changes between years, standard protocols may vary. Sample size was affected for analyzing specific teams and individuals due to missing and unrecorded data. Some subjects were not able to be analyzed due to these inconsistencies, which slightly decreased the total subject population. Athletes that had incomplete data sets were not used for data analysis.

Potential confounding variables could be the extent of training that each athlete experienced before being evaluated. If well-established form and technique are instilled prior to attending NEU, subjects may be less likely to suffer a lower extremity injury due to more advanced and efficient biomechanical movements. Previous lower extremity injuries are a predisposing factor as well. Previously suffering a lower extremity injury is a risk factor with the greatest correlation to sustaining another injury (Sigward & Powers, 2010). As data collection did not allow for previous injury to be recorded, an athlete may have sustained an injury
that was not recorded. Due to the lack of data about previous injury, campus medical staff may be unaware that an athlete is at a higher risk for a future injury. Having access to previous injury data along with current variables, would allow a regression equation that predicts those who will suffer a time loss injury.

Making associations from preexisting data is difficult, as the athlete is no longer available for testing. Proper data analysis is of extreme importance. This study used Microsoft Excel and IBM SPSS software to analyze all preexisting data. Variables that were assessed included sport, gender, injury prevalence, and varied functional movement screenings and tests. All data were gathered from the NCAA Division I athletic training department at Northeastern University, March 2015.

Examining preexisting conditions and showing correlations to injuries is limited in the current literature. Preexisting conditions include characteristics that are not malleable. Risk factors include conditions studies that may be associated with higher rates of injury or injury association. These risk factors may include specific preexisting conditions along with malleable characteristics. Many studies have assessed risk factors that may lead to injury. Finding statistically significant associations has been a challenge of previous injury studies. The goal of this study, within Northeastern University’s body of collected data, is to identify associations from risk factors to potential knee injuries and determining if those risk factors are gender specific.
Statement of Investigation

This study sought to examine risk factors that may be associated with knee injuries. This may assist in determining if specified risk factors could predispose athletes to knee injuries. Therefore, we hypothesize that risk factors are identified that may be associated with knee injury and that those risk factors will be gender specific.
Chapter II: Review of Literature

A reported 80,000 – 250,000 knee injuries occur each year according to the American College of Sports Medicine (Hanaki-Martin & Swank, 2013). Approximately 59% of those injuries affect athletes ranging from 15-25 years old, peak years in an athlete’s career (Hanaki-Martin & Swank, 2013). This equates to time sitting out for the athlete, practices and games missed, potential scholarship loss and increased medical costs. A common knee injury, especially among this age group, is a torn anterior cruciate ligament (ACL) (Cinimo, 2010). The total cost is averaged to be $11,500 to repair a torn ACL (Lewis, 2014). This can place a burden on a family, individual or college to cover the cost. It takes a limited amount of injuries, such as an ACL tear, for preventative programs to be worth the investment (Sigward & Powers, 2010). While striving for injury prevention is common in today’s training and weight rooms, the data collected through athletic departments is often not analyzed at all; this is especially true when trying to correlate risk factors with injury (Hootman et al., 2007). Identifying associations between risk factors and injury allows coaches and trainers to assist athletes to decrease the likelihood of sustaining a knee injury (Sigward & Powers, 2010).

Specific aspects of injury risk factors have had attention in the past, such as gender, strength imbalances and biomechanics of movement for an athlete; these have provided significant growth for future studies (Sigward & Powers, 2010, Hanaki-Martin & Swank, 2013, and Lewis, 2014). The aim of this review is to perform a critical analysis of injury rates, risk factors associated with knee injuries in NCAA Division 1 athletes and apply that knowledge to a new population, such as
younger athletes or an older, physically active population. Gender differences that include an in-depth examination of hormonal changes, strength differences between the hamstring and quadriceps, and landing biomechanics have provided insight into potential risks for injury. Applying what has been previously researched for knee injury risk factors to pre-existing data is what will occur for this study. A better understanding of these injury rates and risk factors will help in the treatment of patients with knee injuries and the development of interventions designed to prevent knee injuries.

**Predictors of Injury**

A Functional Movement Screening (FMS) is a comprehensive exam that assesses the quality of fundamental movement patterns to identify an individual's limitations or asymmetries. The fundamental movement pattern is a basic movement utilized to simultaneously test range of motion, stability and balance. The combination of the FMS requires strength, flexibility, range of motion (ROM), coordination, balance and proprioception in order to successfully complete the seven movement patterns. Each subject is scored from zero to three, on all seven screenings, based on what is considered normal movement. The scores can be summed and used as a composite, or screening tests can be used for individual assessment.

The FMS tests have been found to be significantly associated with predicting injury in recent years. For examination and comparison purposes, combination scores are normally used. The summation of overhead squat, leg raise, ankle range of motion, in-line lunge, and hurdle step have been associated with predicting knee
injuries in female athletes. Two studies, Kiesel et al., 2007 and Chorba et al., 2010, found a combined score of 14 or less was associated with a 4-fold increase in risk of lower extremity injury over the course of a competitive season in female collegiate athletes. It was also restated that compensatory fundamental movement patterns could increase the risk of injury in female college athletes. Having a screening test, like FMS, can help identify negative movement patterns so proper training can occur to help negate future injury.

**Ankle Range of Motion**

Determining significant associations between FMS tests and knee injuries proved scientifically taxing in the research field. Studies, like Kaufman et al., 1999, set out to determine associations with ankle range of motion and lower extremity injuries, but discovered that the height of the foot arch may be more associated with knee injury than ankle range of motion alone. The transfer of foot inversion to internal leg rotation was found to significantly increase injury with increasing arch height. However, Kaufman et al., did find associations with over flexible and stiff ankle joints having a higher association to knee injury for an athletic population (Kaufman et al., 1999).

Fong et al. (2011) investigated ankle ROM and implications of the body's biomechanical response. It was discovered that greater dorsiflexion ROM was associated with greater knee-flexion displacement and smaller ground reaction forces during landing, including a landing posture consistent with ACL injury risk while limiting the forces the lower extremity must absorb. This equates to clinical
techniques to increase plantar flexor extensibility and dorsiflexion ROM as they may be important additions to ACL injury prevention programs (Fong et al., 2011).

**Leg Raise**

There are many varying components that can affect and be affected by the risk factor of Leg Raise. The majority of studied influences come from hamstring and quadriceps functionality. Imbalances between the hamstrings and the quadriceps muscles generally cause issues biomechanically and have a potential to be highly associated with injury. The largest imbalances seen with knee injuries are inequalities in hamstring and quadriceps musculature (Sigward & Powers, 2010). Studies have concluded women are quadriceps dominant, while males are hamstring dominant. Women were found to be quadriceps dominant due to weakened hamstring strength, not because of improper training. This had more evidence when correlations were made for body weight, making this strength difference more significant (Anderson et al., 2001). Muscle activation is interwoven with muscular imbalances. The FMS test of Leg Raise can identify muscle imbalances and deficiencies. As men tend to be hamstring dominant, they also create peak hamstring power at much faster rates than female counterparts. This plays an important role in knee injuries, as the quadriceps muscle is an ACL antagonist. Due to the imbalance, the quadriceps may generate excess force, which places strain on the ACL as well as the entire knee joint. Hamstring strength counterbalances that excess force. However, when hamstring strength is lacking, which is true for many female athletes, it puts a higher strain on the knee (Sigward & Powers, 2010). Consequently, it could be related to higher injury rates among
female athletes (Anderson et al., 2001). Having a more complete description of the subject, such as including maximal effort testing done in the weight room for each subject’s sport would aid in a better understanding of the relationship between Leg Raise (FMS), strength, balance and power.

Currently, there are no direct studies that investigate the comparison between leg raise and its association to knee injuries.

**Financial Impact of ACL Injuries**

Annually, ACL reconstructive surgery costs the United States 10.1 billion dollars (Hame, 2009). While limited studies examine the cost burden that knee injuries place on varying populations, more emphasis should be placed on the financial implication, as knee injuries are prevalent in today’s society.

In 2012, Lau et al. investigated the management and cost of knee injuries at the Calgary Acute Knee Injury Clinic (C-AKIC) in Alberta, Canada. The goal of the study was to compare patients receiving care from two clinical pathways. These included the existing pathway (comparison group), which had 136 cases, and the new model (experimental group), which had 138 cases. All cases were patients who had sustained an ACL rupture and needed surgical treatment. It was found that the cost to each group varied significantly. The comparison group’s associated costs were $6,954.33, while the experimental group’s costs were $2,549.59. It was concluded that the C-AKIC was and is able to manage and treat knee injuries for a less associated cost while maintaining the same outcome of treatment. While the type of care was being evaluated, this study also included the discrepancies between care for patients who sustain knee injuries in terms of cost. This study suggests that
current practices of managing knee injuries in a clinical setting may need to reevaluate their current practice and management of knee injuries (Lau et al., 2012).

While the United States and Canada have differing medical care systems, it can be implied that there can be a potential change made to current care and management of knee injuries to make the process more cost effective for the patient.

In 2013, Mater et al. investigated the societal and economic impact of ACL tears in the United States. The study reported that the mean lifetime cost for a typical patient undergoing ACL reconstruction surgery was $38,121. This was compared with $88,538 for rehabilitation only, with no ACL reconstruction surgery. This equates to a mean incremental cost savings of $50,417 when comparing surgery and rehabilitation treatment strategies. As discussed, treatment plans of ACL rehabilitation only with no surgery reconstruction component are chosen to try and make an ACL injury more cost effective for the patient. This was found to be untrue as it is more cost effective, when taking future needs into account such as re-injury, future pain and medical attention, knee instability, etc., to perform ACL surgery. As the majority of ACL injuries occur in physically active, young people, making the most cost effective decision for the future should be considered for those who sustain an ACL injury (Mater et al, 2013).

Types of ACL reconstruction vary, depending on the severity of the injury and the type of treatment that the surgeon suggests. Currently the most popular options are varying forms of autografts and allografts. Autograft equates to a tendon or muscle being harvested from the patients’ own body. Allograft equates to the tendon or muscle being harvested from a cadaver. In 2010, a cost analysis was
performed that examined these two types of surgical procedures. One hundred fifty-five patients who underwent ACL reconstruction between 2001-20014 were examined. One hundred five patients underwent surgery with an autograft and 50 underwent surgery with an allograft. While no differences were found in related complications, the total cost varied. The autograft ACL (N=105) reconstruction was found to be $4,872 while the allograft ACL (n=50) reconstruction was found to be $5,465. The study concluded that each surgery was similar to each other in cost and the slight cost difference of the allograft outweighs the increased surgical time needed for harvesting an autograft (Nagda et al., 2010). This has potential to change the direction of research as it was found, in this study, that autografts might be the best option from a surgical and patient cost effective perspective. While this study reported a lower total cost for ACL reconstruction, no mention was made for rehabilitation costs.

It would be advantageous for more investigation to confirm potential ground breaking findings in knee injuries research. Previous studies have provided strong evidence for risk factors such as menstrual cycle, neuromuscular control and the cost benefit of specific surgical techniques relating to knee injuries. Previously established research has sparked further investigation into other risk factors that may contribute to knee injuries. The increase in information regarding risk factors for knee injuries assists in better preventive tactics to reduce knee injuries in many different populations.
Chapter III: Procedures

This chapter will provide a detailed account of the examination of data that was used for this study. The procedure was designed to investigate identifiable knee injury risk factors and determine if the gender differences contributed to knee injuries.

Subjects

The study population included participating athletes from Division I athletic programs. Specific sports include women’s basketball, soccer and ice hockey and men’s soccer and ice hockey. All athletes were of typical college age, 18-23 years old. Two years of data were analyzed which include the competition years 2012 and 2013. All subjects’ names were replaced with a code designed by the university’s athletic department. Proper procedures were taken with Northeastern University’s IRB to confirm use of data. Injury was defined as any pain or damage to the knee that required attention from athletic trainers and/or recorded time sat out from a sport.

Methods

Subjects who participated in women’s basketball, ice hockey and soccer and men’s soccer and ice hockey were selected due to the high prevalence of knee injury reported to the NCAA ISS (Hootman, 2007). Data for all subjects were accessed through Microsoft Excel, version 14.2.0 and IBM SPSS, version 22. The university’s athletic department created all Excel spreadsheets from 2012-2013.
Injury rates were assessed through reported injury during practices and/or games through the athletic training department. Injury was only recorded for this study if it involved the knee. For analysis purposes, subjects were initially separated by gender. Subjects were then separated by individual sport. Once a subject’s data were separated by gender and sport a comparison of injured subjects versus uninjured subjects was performed. This was to determine if there were crossover injured athletes from 2012 to 2013 competing season. If an athlete sustained a reported knee injury in 2012 and 2013, the subject was considered as a crossover athlete. Means and standard deviations were determined using standard statistical analysis once crossover athletes were determined.

An examination for each team was then performed that assessed a range of functional movement tests that were completed by the university’s medical staff. Standard procedures for finding averages, standard deviations, and levels of significance for each team occurred through Microsoft Excel and SPSS using the programs analysis. The range of tests that were examined varied as all recorded tests varied between years and teams. Standard protocol set by Gray Cook was followed for the Functional Movement Screenings. Tests included overhead squat, hurdle step, inline lunge, shoulder mobility, active straight-leg raise, trunk stability pushup, and rotary stability. The scoring system from 1-3 was used to identify level of functionality each athlete had for each movement. Functional Movement Screening (FMS) tests were examined for women’s basketball. Scores were assessed by examining the total FMS score for subjects who sustained an injury versus
subjects who did not sustain an injury. Scores were analyzed for the mean, standard deviation, and level of significance for injured and uninjured.

Women’s soccer, men’s soccer, women’s ice hockey and men’s ice hockey used function movement tests that were similar to a standard functional movement screening (FMS). Women’s basketball was the only team to have a complete FMS, with standard protocol completed. Both soccer and ice hockey subjects had functional movement exams, but no standard protocol was followed between teams and years of testing. Examinations that occurred for these teams include overhead squat, leg raise right and left (R&L), ankle range of motion (R&L) seated hip internal rotation (R&L), hip external rotation (R&L), prone internal rotation (R&L), prone external rotation (R&L), Y Balance tests, seated hip tests, hip abduction (R&L), and hip adduction (R&L). The overhead squat examination used FMS testing and scoring system. Leg raise also used standard FMS testing and scoring to evaluate athletes. Ankle ROM was assessed by FMS standard testing and scoring for women’s soccer in 2012 and men’s ice hockey 2013. An athletic training staff member using a tape measure for women’s soccer in 2013 and men’s ice hockey in 2012 assessed circular rotation. Scores were taken and rounded to the nearest whole inch.

All Y balances movement exams measurements for both the length of limb and direction of movement were recorded in centimeters. For assessing direction of movement, men’s soccer 2013 and women’s ice hockey 2012 used a Y Balance Test device devised for FMS testing. For men’s soccer 2012 and women’s ice hockey 2013, a technician used a tape measure for assessment. The tested athlete tracked movement in each desired direction (anterior, medial and lateral) on a pre-
established line. The technician took measurements at the point furthest reached by athlete.

All abduction and adduction tests were performed using a goniometer by a technician. No protocols were used to determine if the athlete was sitting or standing. Seated Hip IR and ER assessments used a goniometer and pre-established protocols FMS were followed for all athletes.

Scores were grouped by sport and then separated by injured or uninjured. Within those two groups for each sport, the average, standard deviation and significance level was determined.

**Analysis**

Microsoft Excel, version 14.2.0, and IBM SPSS, version 22, were used for all data analysis calculations. The method of comparing and analyzing the data results for each subject was performed by an evaluation of injury, gender, and sport through Microsoft Excel. SPSS was used to determine means, standard deviations and levels of significance. Comparisons varied for each team due to protocol variations. From this data, conclusions could be determined regarding injury rates, risk factors associated with knee injuries and potential predicative factors that contribute to a knee injury.
Chapter IV: Results & Discussion

The purpose of this study was to assess potential knee injury risk factors among Division I subjects. Specific aims were to test the hypothesis that established an investigation of risk factors correlated with knee injuries. A secondary investigation questioned if tested risk factors were gender specific. The intention of this chapter is to present the results and analysis that were described in Chapter 3. The chapter will interpret and discuss the results to explain the correlations and implications surrounding knee injuries and potential risk factors that may lead to future knee injuries. This chapter will also emphasize the importance of research and its limitations regarding knee injuries in an athletic population.

Rate of Injury

Summaries of injury rates are seen in Table 1. A total of 21 subjects in 2012 and 27 subjects in 2013 sustained knee injuries. In 2012, seven (19.3%) were female and in 2013, 19 (31.1%) were female. This is an 11.8% increase in female knee injuries among this select population. While the total population is small compared to other studies, the increase in injury is a concern. As female knee injuries rose between 2012 and 2013, male knee injuries decreased from 31.8% in 2012 to 23.3% in 2013.
Table 1

Summary of rates of injury in 2012 and 2013 competing years

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>2012 Competing Subjects (n=93)</th>
<th>2013 Competing Subjects (n=116)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sustained Injury</td>
<td>No Injury Reported</td>
</tr>
<tr>
<td>Women</td>
<td>7 (14.3%)</td>
<td>42 (85.7%)</td>
</tr>
<tr>
<td>Men</td>
<td>14 (31.8%)</td>
<td>30 (68.2%)</td>
</tr>
<tr>
<td>Total</td>
<td>21 (22.6%)</td>
<td>72 (77.4%)</td>
</tr>
</tbody>
</table>

Sport:

<table>
<thead>
<tr>
<th></th>
<th>2012 Competing Subjects</th>
<th>2013 Competing Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>W Soccer</td>
<td>2 (11.8%)</td>
<td>15 (88.2%)</td>
</tr>
<tr>
<td>M Soccer</td>
<td>6 (35.3%)</td>
<td>11 (64.7%)</td>
</tr>
<tr>
<td>W Ice Hockey</td>
<td>5 (20.8%)</td>
<td>19 (79.1%)</td>
</tr>
<tr>
<td>M Ice Hockey</td>
<td>8 (29.6%)</td>
<td>19 (70.4%)</td>
</tr>
<tr>
<td>W Basketball</td>
<td>0 (0%)</td>
<td>8 (100%)</td>
</tr>
</tbody>
</table>

Gender Specific Injury Rates

There was a difference in rates of injury among male and female subjects.

When compared to National Collegiate Athletic Association Injury Surveillance (NCAA ISS), this study's rates are much greater than the current rate increase of 1.3% annually for females (Hootman, et al. 2007).

As found in the NCAA ISS, male injury rates have not followed the same statistical increase. The rate of male knee injuries has increased by 0.6% annually (Hootman et al., 2007). When comparing male subjects, in 2012, 14 subjects sustained a knee injury, which equates to 31.8% of the entire reported male population sustaining a knee injury. However, in 2013, only eight male subjects sustained a knee injury, which is 14.5% of the reported male population. An inverse
relationship that is seen between male and female subjects during these years raises questions related to training protocols and previous injury status.

No significant risk factors were found to be gender specific due to the lack of impact of gender on tested risk factors such as strength tests or Q-angle tests that may have shown gender division. No testing incorporated height, weight, or strength, which can normally alter the results of tests based on gender.

**Significant Risk Factors**

After analysis of risk factors for this population, three risk factors were found to be significant or marginally significant: ankle range of motion right (AROMR) (F=6.99, p=0.10), leg raise left (LegRaiseL) (F=3.19, p=0.76) and straight leg raise (StLegRaise) (F=7.08, p=0.017). Significance was determined at a level equal to or less than .05. One-way ANOVA and Pearson’s bivariate correlation were analyzed to measure the significance.
Figure 1. Gender differences in Injury rates from 2012 and 2013 (p<0.05).

Figure 2. Statistically and marginally significant risk factors for knee injuries (p<0.05). Significance were determined using ANOVA, SPSS.

When risk factors were not combined and separated by year, five risk factors were determined significant or marginally significant: Leg Raise 13 (F=7.58,
KNEE INJURY RISK FACTORS

p=0.008), Hip Abduction Left 12 (F=2.98, p=0.089), Y Balance Medial Right 13 (F=5.27, p=0.025), Y Balance Medial Left 13 (F=5.75, p=0.020) and Y Balance Anterior Right 13 (F=4.82, p=0.032). This can be seen in Figure 3. Due to a lack of cohesion between years of testing, it’s likely that when separating the two years a higher level of significance was found due to the smaller sample size. When sample size increased, the significance was not statistically relevant.

Figure 3. Significant/marginally significant risk factors separated by year. (p<0.05)
Discussion

Two risk factors were identified with the highest correlation to knee injury: ankle range of motion and leg raise. As both factors impact knee mechanics, it is logical that both might play roles in the prevalence of knee injuries. There are numerous aspects of both risk factors that can be examined with greater detail.

When assessing ankle range of motion and the correlation to knee injury, a variety of explanations can be found in the literature. It should be noted that ROM and flexibility are not the same, nor can they be used interchangeably. ROM is viewed as an active assessment, while flexibility is a passive movement assessment (Hamill & Knutzen, 2003). If a lack of flexibility at the ankle occurs, more flexibility is needed at the knee to compensate due to lack of movement (Hirst et al., 2007). This extra compensation at the knee causes a higher than average translational force on the knee, increasing the likelihood of injury (Chorba et al., 2010). However, higher compressive and tensile forces on the knee can be seen if the ankle is over flexible. Greater muscular knee strength would be needed to maintain body alignment in order to return back to a controlled position. This may cause a redistribution of force on the femur or tibia. Compensating for these flexibility issues at the ankle can be especially stressful when an athlete is performing dynamic movements such as running, cutting, and jumping (Sigward, 2010). In general, impairment in ankle range of motion is likely to be a risk factor for knee injuries.

As in ankle range of motion, flexibility between the knee and hip may affect the risk of knee injuries, as seen from the data. A decrease in musculature flexibility
in both leg raise and straight leg raise has a higher correlation to injury (Steffen et al., 2001). Biomechanically, these findings are explained with varying points of concern. If there is a lack of flexibility in the hamstring, higher levels of force can be placed at the hip and knee due to a decrease in range of motion. The body compensates for a lack of movement by engaging movement from surrounding joints, which in this case equates to a higher likelihood of injury to the knee. Due to less flexibility in the hamstrings, full extension at the knee may not be possible due to these musculature limitations. Therefore, compensation of both ankle and hip places the knee in a more injury prone position.

As the hamstrings are agonists for knee flexion and the quadriceps are agonists for knee extension, both muscle groups play a critical role in movement that occurs at the knee joint. When there is movement at the knee, whether it is flexion, extension or a combination of each, the knee is placed in a vulnerable position for injury. As both muscle groups are important in all lower extremity movement for subjects, this is especially true for dynamic movements. During athletic and dynamic movements, various amounts of strain are placed on the knee as the tibiofemoral joint. As a subject goes through dynamic types movements, the knee ligaments are placed in varying degrees of vulnerability based on the position of the tibiofemoral joint and patellofemoral joint (Sigward, 2010).

Running, cutting and jumping are all activities that subjects incorporate into repetitive movements. Landing for subjects is a source for knee injury (Sigward, 2010). There are numerous components that are involved in landing and some factors that were tested play an important role. Flexibility, in terms of
musculature’s ability to lengthen as well as, joint range of motion in the hamstrings and quadriceps, can prevent an athlete from exhibiting proper landing mechanics. Not allowing the body to fully extend or flex is not advantageous in landing. As the body lands, a variety of compressive stresses and potentially shear forces are placed on each joint. When extended, or almost straight leg, knee landing results in serious deformation of the meniscus and cartilage and increases the risk of bone-to-bone contact (Sigward, 2010). This large compressive stress can lead to serious knee injury as the load exceeds the threshold of the joint and potentially the bone. If the stress placed on the knee exceeds the threshold of the joint, due to flexibility, strength deficits, or too high of an impact, injury is likely to occur.

In summation, three risk factors were identified as significant or marginally significant: ankle range of motion right, leg raise left, and straight leg raise. No gender differences were identified due to lack of gender’s impact for tested risk factors. Future studies could investigate identified risk factors with greater depth to determine if more specific findings could occur.

**Limitations**

There are several limitations that impacted the data utilized for this study. Due to the lack of standardized data collection among subjects, the data had inconsistencies so comparisons between years, teams, and subjects of potential risk factors and injury rates could be invalid. If standard protocols are not followed year to year, data will vary due to differing protocols, which results in a lack of cohesion. This made using the data for comparisons between years invalid. As of now, there is
no specific data collection protocol for athletes. If a standard protocol was defined, a better assessment of weaknesses could be identified and addressed.

There were variations in the data collection protocol for subjects in this study. If a standard protocol were defined, errors in data collection would have been minimized.

Data collection was limited to a two-year period. A larger data set could have provided additional information regarding predictive factors for knee injuries. Limitations for all injury studies are the prevalence of injury in a tested population. Having more subjects who sustained injury and a larger population to assess data may have yielded stronger correlations to tested risk factors.

There was also no record of data for previous injury or previous training. As a previous knee injury is the best predictor of another knee injury (Sigward, 2010), this data would be valuable. Collecting subjects’ experience in previous training before entering Northeastern would also be valuable. If certain subjects underwent body movement intensive training, this may help negate knee injuries, which could skew numbers.
Chapter V: Summary

The aim of this study was to perform an in-depth investigation that required the assessment of identifiable risk factors that may be associated with the prevalence of knee injuries among Division I athletes. An investigation of risk factors associated with knee injuries occurred. A second hypothesis investigated if those risk factors were gender related. Male subjects for this study participated in soccer and ice hockey and female subjects participated in basketball, soccer and ice hockey. Subjects were separated into injured and non-injured categories. Data were analyzed by sport, comparing the difference of testing outcomes between injured and non-injured athletes.

Results indicated that in 2012 there were 21 total knee injuries; seven (14.3%) injuries were from female teams. In 2013, more knee injuries occurred, a total of 27 (23.3%). Of the 27 total injuries, 19 (31.1%) were sustained by females. This is a rise in the rate of injury between 2012 and 2013 for female athletes. Within the two years of data, there were six athletes who sustained knee injuries: three female and three male.

In a sport-by-sport comparison, women’s basketball had the largest injury rate increase. In 2012 no knee injuries were reported. In 2013, six (54.5%) of the team sustained knee injuries. Other notable injury rates include men’s ice hockey. In 2012, eight (29.6%) knee injuries were reported. In 2013, this rate decreased dramatically to three (10.3%) reported injuries. Women’s soccer sustained two
(11.8%) injuries, but in 2013, the amount and rate of injury increased to 19 (31.1%) knee injuries.

Of the tested risk factors that were analyzed, three were found to be significant (All p values <0.05). No gender differences were seen within the testing data. When comparing this study to larger studies, such as the NCAA ISSS, it is likely that gender specific risk factors would have been able to be identified, but a lack of gender specified testing between years and sports made data unsuitable for direct comparison.

**Conclusions**

There were differences between the rates of injury for male and female subjects from 2012-2013. Three risk factors were found to yield significant results to be influencing factors for knee injury, ankle range of motion right, leg raise left, and straight leg raise. Therefore, the research hypothesis that risk factors would be identified is accepted. The second hypothesis that gender differences would be seen is rejected as no significant gender differences were found in subject data.

Based on the outcomes of this study, applications to clinical practice may be considered. Taking precautionary measures with subjects that show a poor range of motion in their dominant leg and significantly decreased flexibility in hamstrings could be primary screens for determining if a subject may sustain a knee injury. This type of clinical implementation may be most useful when already screening for functional movement patterns.
Future Directions for Research

While this study found no gender associations between risk factors and knee injuries, it identified many areas that could provide direction for future research and implications for higher quality data collection. Based on current research, it is known that current risk factors affect women with a higher rate of injury than men. Such risk factors include, but are not limited to, muscular imbalance between quadriceps and hamstring, landing mechanics and hormonal shifts. From this study, future research could focus on hip flexibility. Subjects showed an increased likelihood for injury when the hip was either too flexible or too stiff. Finding an acceptable value for flexibility could help decrease injury. If athletes could be evaluated for this specifically and compared to acceptable ranges, changes in training could help athletes strengthen hips. Stronger hips in an athlete give the athlete more power and control, which would aid in potential injury reduction.

More precise and consistent data collection is a necessity for further research regarding data. Comparisons and associations could be made if the same tests were administered to all athletes from year to year. Incorporating strength and conditioning assessments into standard testing procedures would greatly benefit future research. This would aid all athletes in reducing injury rates.

Injury prevention programs are a part of many athletic departments. Assessing each athlete’s proper form and stance could help in reducing injury. Athletes may have acquired unfavorable mechanics throughout the years of training. Retraining the body to use correct form will help reduce injury and future joint problems. Past evidence supports that knee injury prevention programs are
effective in preventing knee injuries. However, it is the continuing of such preventative programs that are an issue. Preventative programs must change and adapt to meet the changing needs of the athletes. Future research could investigate how changing an athlete from unfavorable movement patterns to favorable patterns. An investigation into how long it took an athlete to gain favorable patterns and how well the athlete sustained them could provide more insight into training.

Knee injuries plague thousands of athletes each year ranging from middle school to professional athletes. The high prevalence of knee injuries in athletics is something that many have come to expect and accept. This calls for change. Determining influencing factors that may be associated with knee injuries is a key component in lowering the rate of knee injuries. Assessing these factors for gender differences is also a necessity as females have higher rates of injury than males. A reduction of knee injuries is possible if proper steps, including funding and research, can occur. Implementation of significant research findings can alter knee injuries from the norm to the exception.
REFERENCES


APPENDIX A

Northeastern University IRB Human Subject Research Application

NOTIFICATION OF IRB ACTION
MODIFICATION APPROVAL

Date: April 13, 2015
IRB #: 14-08-02
Principal Investigator(s): Rui Li
Department: Health Sciences
Address: 316 Robinson Hall
Northeastern University

Title of Project: A Cross-Sectional Comparison of Knee Injury Risk Factors in Male and Female Athletes through Onsite Laboratory Testing and Questionnaires

MODIFICATION: a) project will now include retrospective data analysis of the women's ice hockey, women's basketball, women's soccer, men's ice hockey and men's soccer from 2012 and 2013. Data have already been coded; b) Professor Li has re-assumed the role of PI from Professor Sceppa, who was temporarily named while Professor Li was on sabbatical.

Participating Sites: N/A
Original Protocol Approved: August 13, 2014
DHHS Review Category: Expedited #5
Informed Consents: N/A
Monitoring Interval: 12 months

APPROVAL EXPIRATION DATE: AUGUST 12, 2015

Investigator's Responsibilities:
1. The informed consent form bearing the IRB approval stamp must be used when recruiting participants into the study.
2. The investigator must notify IRB immediately of unexpected adverse reactions, or new information that may alter our perception of the benefit-risk ratio.
3. Study procedures and files are subject to audit any time.
4. Any modifications of the protocol or the informed consent as the study progresses must be reviewed and approved by this committee prior to being instituted.
5. Continuing Review Approval for the proposal should be requested at least one month prior to the expiration date above.
6. This approval applies to the protection of human subjects only. It does not apply to any other university approvals that may be necessary.

C. Randall Colvin, Ph.D., Chair
Northeastern University Institutional Review Board

Nan C. Regina
Director, Research Integrity

Northeastern University FWA #: 4630