

Knee Injuries in Collegiate Athletes, a Review of Literature, and a Study of the Effects of Pre vs. Post Collegiate ACL Reconstruction in Division 1 Collegiate Athletes on Subsequent Knee Surgeries and Sports Career Length

By

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Contents	
Abstract:.....	4
Research Study: Pre vs. Post Collegiate ACL Reconstruction in D1 Athletes and Effects on Subsequent Knee Surgeries and Sports Career Length	5
Introduction.....	5
Methods	6
Overall Design	6
Population	6
Variables/Outcomes	6
Results.....	7
Discussion	9
Conclusions.....	11
Systematic Review: A review of knee injuries in collegiate athletes	12
Background:.....	12
Methods	13
Search Strategy	13
Inclusion and Exclusion Criteria.....	13
Quality Assessment.....	13
Study Synthesis.....	14
Results.....	14
Study Selection	14
Study Characteristics	15
Study Exposure and Outcome Measurement	15
Knee Injuries across Sports.....	16
Knee Injuries by Gender	16
Discussion.....	17
Acknowledgments:	18
References	19
Tables for the research paper:	20
Table 1: Injuries stratified by sport played.	20
Table 2: Overall Operation Rates.....	22
Table 3: Incidence of ACL Injury.....	23

Table 4: Athletes by Gender	24
Table 5: Stratification Breakdown by years played, year of injury, and total number of injuries	25
Table 6: Total Years Played after surgery and percentage of eligibility used	26
Table 7: Table of subsequent knee surgeries	27
Tables and Figures for the systematic review:	28
Table 1: Critical appraisal instrument used for the study	28
Table 2: Summary of study design characteristics	30
Table 3: Prevalence Rate of Knee Injuries by Sport and Gender	31
Figure 1: Search Results	32

Abstract

The direct annual economic burden of anterior cruciate ligament (ACL) injury exceeds 2 billion dollars (1). Additionally, it is known that knee injuries, particularly ACL injuries, increase the risk of osteoarthritis later in life (2). ACL and other knee injuries are common in athletics. These injuries often require reconstruction in addition to extensive rehabilitation before functions return at a pre-injury level (3). Though considerable research has been conducted regarding outcomes, a large knowledge gap exists in terms of injury risk factors, and targeted prevention programs. The development of successful preventive strategies cannot occur without an understanding of the mechanisms associated with knee injuries.

The goals of this master's paper are to define the prevalence of knee injuries and understand the outcomes of ACL injuries in collegiate athletes. The first part of the paper is an original research study examining whether previous ACL injury in high school athletics is a risk factor for subsequent graft failure and reoperation. The research question serves to examine the future health implications for high-level athletes who have suffered a prior ACL injury and undergone a subsequent reconstruction during their high school career. The second, more substantial portion of the paper is a mini-systematic review examining the epidemiology of knee injuries among collegiate athletes. These findings will help to increase our understanding of the epidemiology of knee injuries, and serve to guide potential interventions that could be developed to prevent knee injuries.

Research Study: Pre- vs. Post-Collegiate ACL Reconstruction in D1 Athletes and Effects on Subsequent Knee Surgeries and Sports Career Length

Introduction

Each year in the United States more than 25 million students are involved in high school sports, and an estimated 2.5 million adolescents visit emergency departments with sports related injuries (2). The knee is the second most commonly injured body site, and knee injuries are the leading cause of high school sports related surgeries (2). The anterior cruciate ligament (ACL) is particularly subject to damage from sporting activities, with seventy percent of ACL injuries occurring during athletic participation (4). Injuries to the ACL are most commonly seen in sports that require rapid stopping, cutting, and changes in direction, such as basketball and soccer (5). ACL injuries often require reconstruction or surgery in addition to extensive rehabilitation before function returns to a pre-injury level (6).

Many high school athletes who sustain an ACL injury continue to play at the collegiate level. Few studies have examined the implications of these injuries as these athletes continue their playing careers in collegiate sports. There is a paucity of information on how pre-collegiate injury affects reoperation rates, subsequent knee surgery rates, and career length in ACL reconstructed athletes who continue to play at the collegiate level.

The purpose of this study is to assess ACL graft survivorship and knee function in collegiate athletes from 1999-2009 who underwent a pre-collegiate ACL reconstruction compared to athletes who underwent an ACL reconstruction after matriculation in college. This study will help to understand if prior injury and reconstruction are risk factors for future injuries.

Methods

Overall Design

We conducted a retrospective chart review of Division 1 athletes at the University of North Carolina at Chapel Hill (UNC). We examined how previous ACL reconstruction affects re-injury rate, sports participation, and career length. This study was approved by the Institutional Review Board (IRB) of the Office of Human Research Ethics at UNC.

Population

The medical records for all Division 1 athletes who were on the roster at UNC from 2004-2009 and matriculated by 2006 were obtained. This sample included athletes who matriculated as far back as 1999 and were playing in the 2004 season. A total of 808 athletes were identified; of these, 16 charts were unable to be located or had missing data, for a final sample size of 792. From these records, we identified 25 athletes who had a pre-collegiate ACL reconstruction and 29 athletes who had an ACL reconstruction while playing in college.

Variables/Outcomes

Note was made of the initial injury and operation date, sport played, total years played, years played after initial reconstruction, gender, and of ipsilateral or contralateral knee reoperation. Surgical records were verified or obtained when possible. We assessed knee function and graft survivorship as a function of reoperation rates and years played.

Statistical Analysis

Statistical tests were performed with by a statistician using simple two-sample tests of proportions.

Results

A total of 329 female and 463 male athletes were included in the study. Athletes participated in one or more of the following NCAA sports: football, soccer, lacrosse, field hockey, track/cross country, swimming/diving, tennis, gymnastics, fencing, wrestling, softball, baseball, golf, rowing, and basketball. Only the sports with athletes who underwent ACL reconstruction are listed. The most common sport played by the post-matriculation ACL reconstruction athletes was football, while lacrosse was the most common sport played by the pre-collegiate reconstructed athletes. One of the athletes in the pre-collegiate ACL reconstruction group participated in both football and track. The injuries stratified by sport are shown in table 1.

Of the 29 athletes who underwent initial ACL reconstruction post-matriculation, 20 had no other knee operation while at UNC, while 9 had a revision or another knee surgery, and 1 athlete had 2 or more further surgeries. Of the 25 athletes who underwent pre-collegiate ACL reconstruction, 11 underwent no further surgery at UNC. Two underwent additional knee surgery before starting college. Fourteen underwent post-matriculation knee surgery, and another 6 underwent 2 or more knee surgeries after entering college.

There were 767 athletes entering UNC with no prior ACL injury; 29 had an ACL injury while at UNC, an incidence of 3.8%. Of the 25 athletes entering UNC with a prior ACL injury, 14 had a re-operation while at UNC, an incidence of 56.0%. This observed difference in injury incidence is highly significant ($p < .0001$).

There were 14 male and 15 female athletes who underwent post-matriculation ACL reconstruction, and 9 males and 16 females who underwent pre-collegiate reconstruction. Of the total number of athletes who underwent initial ACL reconstruction, females had a higher

incidence of reoperation at UNC in both the post-matriculation group (33% vs. 28%, $p = 1.0$) and the pre-matriculation group (69% vs. 33%, $p = 0.20$), though these differences were not statistically significant.

Of the injured athletes in both groups, a majority (83-89%) of them were able to complete 4 years of play. Those in the post-matriculation group tended to be injured later in their collegiate career. All athletes had a potential of 4 years of eligibility, but some played a total of 5 years.

Athletes who underwent pre-collegiate ACL reconstruction ($n=25$) played an average of 3.56 years and met 89% of their predicated 4 years of eligibility. However, the 14 pre-collegiate reconstructed athletes who underwent additional surgeries, were able to complete an average of 1.63 years of additional play, meeting only 62% of their remaining eligibility. The 25 post-matriculation athletes met 60-90% of their remaining eligibility depending on year that they were injured, and the 10 post-matriculation athletes who underwent subsequent surgeries met 0-100% of their remaining eligibility depending on the class year that they were injured. Shown in table 6. Some athletes with injuries received a medical redshirt and thus had another year of eligibility. According to National Collegiate Athletic Association (NCAA), redshirting refers to delaying or suspending an athlete's participation in order to lengthen his or her period of eligibility due to academic or medical reasons which allows the athlete to spread those four years of eligibility over five years. In a redshirt year, an athlete may attend classes at the college or university, practice with an athletic team, and dress for play but he or she may not compete during the game. We assumed that all athletes had a potential of 4 years of eligibility regardless of redshirting since it was not possible to determine the cause of redshirting.

Athletes who underwent pre-collegiate ACL reconstruction had more sequent surgeries overall, along with a greater incidence of contralateral ACL reconstruction compared to athletes undergoing post-matriculation ACL reconstruction. ACL revision both contralateral and ipsilateral was more common (n= 5, n=7 respectively) in athletes who underwent pre-collegiate ACL reconstruction compared to (n=3, n=1 respectively) athletes who underwent post-matriculation ACL reconstruction. Menisctomy both contralateral and ipsilateral was also more common (n=6, n=3) in Athletes who underwent pre-collegiate ACL reconstruction compared to athletes who underwent post-matriculation ACL reconstruction (n=0). Table 7 shows the number of different ipsilateral and contralateral knee procedures/surgeries performed on athletes who underwent additional surgery after the initial ACL reconstruction. Some athletes underwent multiple procedures during a surgery, and thus each procedure is counted separately.

Discussion

Athletes often suffer ACL injuries, which can result in significant morbidity. A previous study showed a detriment to the expected career in college football players who continued on to play in the National Football League (NFL) who underwent ACL reconstruction and/or Menisctomy (5). However, our research represents the first known attempt to compare outcomes and identify differences between Division 1 athletes who underwent an ACL reconstruction pre-collegiately, and athletes who underwent an ACL reconstruction after starting their college career. Our results show that athletes who underwent the initial ACL reconstruction pre-collegiately had worse outcomes. Additionally, the rate of ACL injury in athletes who had already undergone reconstruction was much higher when compared to athletes with no history of an ACL injury (56% vs. 3.8%, $p<.0001$).

It is known that up to 40% of patients having revision ACL reconstructions may be unable to return to the same level of sport or competition (6). Additionally, younger patients are at higher risk for a subsequent ACL reconstruction on either knee within one year (7). Thus it is not surprising that those in the pre-collegiate group required more additional knee surgery and were more likely to undergo revision, which negatively affected their rates of play in college. The rate of initial injury for the post-matriculation group was 3% compared to the 52% rate of re-injury in the pre-matriculation group . Thus, subjects in the pre-collegiate group are more likely to have a knee injury at UNC than are athletes with no pre-collegiate knee injury. Those athletes with post-matriculation repair have a higher rate of athletes playing meeting their percentage of eligibility and tended to have surgeries later in their career compared to athletes who underwent pre-collegiate reconstruction. Better training and follow up, access to physical therapy, and organized care for post-matriculation reconstructions may be factors explaining this occurrence.

Our research suggests that female athletes may have higher rates of subsequent knee surgery, particularly for athletes with a pre-matriculation injury (69% in females vs. 33% in males, $p=0.20$). A higher sample size may be necessary in this case to achieve statistical significance. Previous research has shown that female athletes are more susceptible to knee ligament injuries than male athletes performing the same activities (8). Anatomic, hormonal, neuromuscular, and biomechanical factors have been studied that help to explain the increase rate of ACL tears in female athletes (3, 9). The re-injury rate can also be attributed to these factors such as anatomical differences and differences in movement patterns between males and females.

The current study is a retrospective review of data from charts rather than a prospective cohort or randomized trial. Resultantly, the study can only suggest association and certainly does not demonstrate causation. Data on each surgery (for example, the type of graft used for ACL

reconstruction and surgical method) were not available, especially for pre-collegiate ACL reconstruction. We had no medical data on the actual cause for the end of each athlete's career, medical or otherwise if they did not complete 4 years of play. However, this is the first study examining at differences between athletes who underwent pre-collegiate and post-matriculation ACL reconstruction and the impact on subsequent knee surgery and career length.

Future study can be directed at developing prevention programs for high school athletes, and better post-surgical therapy and rehabilitation if an injury does occur. Additionally, documentation of the recovery after initial reconstruction such as return to sports and knee function is important. Failure to return to a similar level of activity may point toward technical error associated with the initial procedure, postoperative complications, or inadequate rehabilitation. If a re-injury is suspected, evaluation of knee performance after the original reconstructive procedure should be examined to determine if a new complaint is related to a separate re-injury or progressive degenerative pathologic changes (8).

Conclusions

ACL injury is a common athletic injury and it is one of the most commonly treated conditions of the knee (12). The injury and resultant surgery is accompanied by a large burden of suffering. With the increasing sports participation for adolescents, ACL injuries at a younger age are of important concern. Athletes who undergo reconstruction prior to starting their collegiate playing career have a higher rate of knee injury in college requiring reconstruction, and are less likely to play 4 years of Division 1 collegiate level sport compared to athletes who enter UNC with no previous knee injury.

Systematic Review: A review of knee injuries in collegiate athletes

Background:

Each year in the United States, more than 25 million students are involved in high school sports (2). Many of these high school athletes continue to play at the collegiate level. The increasing level of sports participation also leads to a greater number of sports related injuries.

The knee joint is reported to be the most commonly injured joint in young sports participants, and the structure of the knee joint and multidirectional forces encountered during sporting activities may explain why knee injuries occur so frequently and with such severity (3).

Approximately 20% of such injuries require surgery (13). Athletes who undergo knee surgery often require extensive rehabilitation before function returns to a pre-injury level (6). Pain and limited mobility may require long term management and lead to diminished future participation in sports (1, 14, 15). Additionally, such knee injuries are associated with long-term sequelae such as osteoarthritis later in life (16).

Prevention and rehabilitation of sports related knee injuries are key to improving overall outcomes. Some studies have examined injury risk factors (5, 10, 11, 17). Reviews of the epidemiology of knee injuries among high school athletes have also been published (3, 6).

However, a little is known regarding prevalence of sports related knee injuries in athletes playing at the collegiate level. Without an understanding of the common knee injuries in collegiate athletes, successful prevention strategies and better training methods cannot be developed.

Therefore, the aim of this review is to synthesize the epidemiological research on prevalence of knee injuries in collegiate athletes.

Methods

Search Strategy

We conducted the primary search in PubMed using MESH terms and key word searching of “sports AND athletic injuries AND knee AND university AND athlete.” A Controlled Vocabulary search was used in the other databases (Sports Discuss, EmBase, Web of Science). One reviewer (NV) assessed all possible studies at title, abstract, and if necessary, the full text level against the inclusion criteria (age group, epidemiological study design, language). Uncertainty of a study inclusion was discussed with a second reviewer (LH). From this list, the full text versions were reviewed, and the eligible studies were then included in the review.

Inclusion and Exclusion Criteria

To meet inclusion, articles had to be published in English and discuss the epidemiology of sports related knee injuries on collegiate level players. Cross sectional, retrospective, and prospective studies were eligible. Experimental studies, case reports, or narrative reports were excluded. Articles describing overall all rates of body injury without stratifying knee injuries into specific types were also excluded. Studies reporting on athletes younger than 18, in high school or playing at a professional level were excluded. Additionally studies not available in full text from any accessible (University of North Carolina at Chapel Hill Library Consortium) library source were excluded.

Quality Assessment

One reviewer (NV) performed an assessment of quality. A modified version of the sports epidemiological appraisal tool developed by Louw et al. was used (3). The table can be found in the appendix.

Study Synthesis

Details of the included articles were compiled in an evidence table, which was used to collect key elements for synthesis and comparison of the study details. The key data fields were, year of publication, country, study design, research question/objective, sample collection range, sample size, sample source, sample age range, gender, level of play, sport type, injury definition, expression of injury risk, knee injury rate, injury types, exposure, injury conditions, injury mechanism, risk factors for injury, and implications for prevention. To be able to make comparisons we grouped men's football and women's rugby as a similar sport.

Results

Study Selection

The initial search yielded 223 titles in PubMed, 59 in Sports Discuss, 2 in Embase, and 33 in Web of Science. From screening the title or abstract, 293 of the publications were excluded (Figure 1). The remaining 24 articles were reviewed at the full text level. 5 articles were identified from these with the potential to be included. Duplicate articles (N=3) were excluded. Of the 2 articles remaining, a search of related citations was performed in PubMed, yielding a total of 622 articles. After reviewing the title or abstract, 617 of these were excluded. The full text review of the remaining 5 studies yielded 3 publications that met the inclusion criteria. However, 2 of these were duplicates to the studies found in the initial search. Thus, the one study

found from the related articles search plus the 2 found from the initial search were included in the review (18-20).

Study Characteristics

All studies scored 15-16 points out of the total 29 possible with the appraisal tool. All of the studies were conducted in the United States and included various forms of collegiate athletes playing the following sports: soccer, basketball (18), football (19), and rugby(20). One of the studies evaluated players at the club level (20) while the others were elite level (18, 19). The sample sizes ranged from 332 (19) to over 900,000 (18). One study included both males and females (18), while the other two focused either on males or females (19, 20). Two of the studies clearly defined sports related knee injury as one that occurs as a result of participation in an organized practice or game, requires medical attention by an athletic trainer or physician, and results in restriction of the student athlete's participation (18, 20). A summary of the study design characteristics can be found in Table 2.

Study Exposure and Outcome Measurement

The injury prevalence rate was reported as injury rate per 1000 athlete exposures in two of the studies (18, 20), while the other studies (19) expressed the rate as injuries per player. An exposure was defined as one athlete participating in one practice or game where he or she is exposed to the possibility of an athletic injury (18, 20). The knee injuries addressed across the studies were collateral ligament injuries, meniscal injuries, patellar/tendon injuries, anterior cruciate ligament (ACL) injuries, and posterior cruciate ligament (PCL) injuries. The most common knee injuries were collateral ligament injuries and meniscal injuries (exposure rates of 0.62 – 0.24 for collateral ligament injuries and 0.43 – 0.19 for meniscal injuries) (Table 3).

Knee Injuries across Sports

The overall knee injury rates varied across the studies. We assumed that all athletes had a similar level of exposure since they were playing at a collegiate level. Knee injuries occurred in all of the sports, but soccer and football/rugby had a greater prevalence of knee injuries. The injury rate was 0.51 and 0.62 for collateral ligament in soccer and 0.40 and 0.24 for collateral ligament injuries in rugby/football for male and female athletes respectively. Male and female athletes playing soccer had a meniscal injury rate of 0.19 and 0.34 and a tendon injury rate of 0.21 and 0.30 respectively. The ACL injury rate in soccer for males and females, respectively, was 0.13 and 0.31 and 0.36 and 0.12 for rugby/football. The rate for PCL injuries in soccer was 0.04 for both male and female athletes. PCL injuries were the least prevalent in all sports (less than or equal to 0.04 in all sports). Athletes playing football/rugby also had a lower prevalence of tendon/patellar injuries than other sports (0.09 and 0.05).

Knee Injuries by Gender

Females had higher rates of most types of knee injuries compared to males. ACL and meniscal injuries were particularly more prevalent in females across the different sports. For ACL injuries the injury rates were 0.31 for soccer, 0.29 for basketball, and 0.36 for rugby. For meniscal injuries the injury rates were 0.34 for soccer, 0.29 for basketball, and 0.43 for rugby. Females also had a greater prevalence of collateral ligament injury, but only slightly higher than males rates of 0.62 for soccer, 0.28 for basketball, and 0.40 for rugby compared to 0.51 in males for soccer, 0.21 for basketball, and 0.24 for football in males. Females had a greater prevalence of patellar/tendon injuries in soccer and rugby. The injury rate was 0.30 compared to 0.21 for male athletes in soccer. For females playing rugby the rate was 0.09 compared to 0.05 for male

athletes playing football. Males had slightly more patellar/tendon injuries in basketball 0.26 compared to 0.24 for females. The prevalence of PCL injuries was the same in males and females except in rugby compared to football. Table 3 shows the comparison and rates of knee injury rates across the studies.

Discussion

Overall, we found that knee injuries often occur in collegiate sports, but the risk of sustaining a knee injury is relatively low per 1000 athlete exposures. The prevalence of most knee injuries is also much higher in females when compared to males. This finding was consistent across the three studies reviewed. This finding is in line with current research showing that female athletes are more susceptible to knee ligament injuries than male athletes performing the same activities (10). Collateral ligament and patellar/tendon injuries were more common in women playing soccer. ACL and meniscal injuries were more common in women playing rugby followed by those playing soccer. These sports are accompanied by a high rate of cutting and sliding maneuvers, which are associated with injury. Additionally, one paper found that women were more likely to sustain injury during noncontact, while men were more likely to sustain injury during contact with another player (18). The higher rate of injuries in the rugby players can possibly be attributed to the club level of play, since level club sports often do not have the same level of support and field maintenance as elite level sports players (20). These findings show that women are more likely to sustain knee injuries in high impact sports, which provides a target for prevention/education to try to limit these injuries. It is not possible to overcome all of the factors that predispose females to more injury than males, but movement modification strategies and other modifiable techniques may help to reduce the risk.

This review also shows that further research is needed on knee injuries in collegiate sports. Studies have been done examining the prevalence of knee injuries in high school and professional athletes, but our literature search only returned three articles that directly addressed the epidemiology of different types of knee injuries in collegiate level athletes. We found a few studies based on National Collegiate Athletic Association (NCAA) data that reported on overall body part injury, but these studies did not stratify the different types of injuries to that body part. Additional studies will help to gain a better understanding of the distribution of the types of knee injuries associated with particular collegiate sports, and based on such results, that better training and movement modification strategies can be implemented to prevent or limit the occurrences of the injuries.

The major limitation of this review is the low number of studies included, which limits the generalizations that can be made about the prevalence of knee injuries in collegiate athletics. However, this review synthesizes the available literature to provide targets for prevention. The paucity of literature on this topic represents a knowledge gap that needs to be filled. Future research on the epidemiology of knee injuries among college athletes will allow for stronger conclusions to be made regarding the potential strategies for prevention.

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Tables for the research paper:

Table 1: Injuries stratified by sport played.

Sport	Post-Matriculation ACL Reconstruction		Pre-Collegiate ACL Reconstruction	
	Total number of injured athletes playing sport	Percentage of athletes injured in the sport*	Total Breakdown of athletes	Percentage of athletes injured in the sport
Basketball	0	0%	4	0%
Softball	2	3%	1	10%
Baseball	0	0%	1	3%
Lacrosse	8	19%	6	32%
Field Hockey	4	3%	1	13%
Football	3	27%	8	10%
Swim/diving	0	3%	0	0%

Wrestling	0	5%	2	0%
Track	1	3%	1	3%
Soccer	4	5%	3	19%
Volleyball	0	3%	1	0%
Gymnastics	2	5%	1	6%
Rowing	1	0%	0	3%
Tennis	0	3%	0	0%

*The percentages represent the number of injuries divided by the total number of athletes who were injured in each group.

Table 2: Overall Operation Rates

Athletes who underwent primary ACL reconstruction after matriculation to UNC		
Total number of athletes with ACL Injuries	Athletes who underwent at least one re-operation	Athletes who underwent two or more re-operations
29	9	1
Athletes who Underwent Pre-Collegiate ACL Reconstruction		
Total number of athletes with ACL Injuries	Athletes who underwent at least one re-operation	Athletes who underwent two or more re-operations
25	14	6

Table 3: Incidence of ACL Injury

	No history of ACL injury	History of ACL reconstruction
Total	767	25
ACL Injuries	29	14
Incidence	3.8%	56.0%

Table 4: Athletes by Gender

Athletes who Underwent Post-Matriculation ACL Reconstruction			
Total Males		Total Females	
14		15	
Males with Reoperation		Females with Reoperation	
4	29%	5	33%
Athletes who Underwent Pre-Collegiate ACL Reconstruction			
Total Males		Total Females	
9		16	
Males with Reoperation at UNC		Females with Reoperation at UNC	
3	33%	11	69%

Table 5: Stratification Breakdown by years played, year of injury, and total number of injuries

		Number of Years Played in College Sports after primary ACL reconstruction					
		Total number injured	Four or more	Three	Two	One	Zero
Year of Injury	High School	25	19	3	2	0	1
	Freshmen	3	1	1	0	1	0
	Sophomore	3	0	1	1	0	1
	Junior	9	0	1	0	5	3
	senior	14	0	0	0	0	14

Table 6: Total Years Played after surgery and percentage of eligibility used

	Year Initially Injured				
	High School	Freshmen	Sophomore	Junior	Senior
Total Athletes	25	3	3	9	14
Average years played after injury	3.56	2.67	1.67	0.89	0
% of eligilgbilty used	89%	89%	83%	89%	N/A
Total Athletes with subsequent surgery after enrolling at UNC	14	3	1	2	3
Average years played after subsequent surgery	1.63	1.3	2	0.0	0
% of eligibility used assuming 4 years of potential eligibility	62.1	80%	100%	0%	N/A

Table 7: Table of subsequent knee surgeries

ACL Surgery			Other Ipsilateral Surgeries				Other Contralateral Surgeries				Minor Procedures		
Athletes who underwent post-matriculation ACL Reconstruction													
Revision	Contralateral Revision	Graft failure not revised	Menisectomy	OATS	Microfrx	Minor Procedure	Menisectomy	OATS	Microfrx	Minor Procedure	Debridement	synectomy	HWR
1	3	0	0	0	1	9	0	0	0	0	6*	1	2
Athletes who underwent pre-collegiate ACL Reconstruction													
Revision	Contralateral Revision	Graft failure not revised	Menisectomy	OATS	Microfrx	Minor Procedure	Menisectomy	OATS	Microfrx	Minor Procedure	Debridement	synectomy	HWR
7 (+1)**	5	1	6	1	0	10	3	0	2	0	5	1	4

* One post-matriculation athlete underwent multiple debridements due to infection

** One patient had graft failure but chose not to have it revised

Abbreviations: Microfrx = Micro Fracture Repair, OATS = osteoarticular transfer system, HWR = Hardware removal

Tables and Figures for the systematic review:

Table 1: Critical appraisal instrument used for the study

Question	Points
Study Design	
1. Is the study design stated	1
2. Is the study a retrospective/prospective study	1
3. Is recruitment of the sample stated	1
4. Is the objective of the study clearly stated	1
5. Is the definition of the study setting stated?	1
6. Are the following demographics addressed? - Age - Gender - Level of play	1 for each for a total of 3
7. Was exposure taken into account? - Sport played - Position played - Frequency of play - Practice and game situation - Playing surface - Level of competition - Previous injury - Other appropriate exposures	1 for each for a total of 8
8. Is injury clearly defined?	1
Results	
9. Are the following outcomes described? - Prevalence/incidence/rate - Injury type - Injury severity - Mechanism of injury - Loss of play - Other factors	1 for each for a total of 6
10. Are the outcomes measured in a equal, valid, and reliable way? - Validated measurement tool - Reliable data collection method - Standard method for data collection	1
Analysis	
11. Is the basic data well described?	1
12. Are descriptive statistics/odds ratios/relative risk ratios given?	1

13.	Are risk factors included in the analysis?	1
Overall assessment		
14.	Can the results be generalized?	1
15.	Do the authors state the applicability of the study to the target population, policy development, clinical practice, etc.?	1

Table 1 contains the appraisal tool used for the eligible articles. Each component contributes to 1 point with a possible total of 29 points.

Table 2: Summary of study design characteristics

Author	Year Published	Setting	Study Design	Measurement Tool	Country	Sports	Gender	Age Group	Sample Size
Arendt(18)	1995	NCAA college schools reporting to the injury surveillance system	retrospective	Data report	USA	Soccer and basketball	Males and Females	Undefined – College aged	M: 1,362,299 F: 948,646
Bradley(19)	2008	College Athletes at 2005 NFL Combine	retrospective	History and Physical	USA	Football	Males	Undefined – College aged	332
Levy(20)	1997	athletes who played club rugby from 1992-1994	retrospective	Questionnaires	USA	Rugby	Females	Undefined – College aged	810

Table 2 represents the key study design characteristics taken from the data collected from the eligible studies.

Table 3: Prevalence Rate of Knee Injuries by Sport and Gender

		Collateral Ligament Injury	Meniscal Injuries	Patallar/Tendon Injuries	ACL Injuries	PCL Injuries	Osteochondral injuries
Males							
	Soccer	0.51	0.19	0.21	0.13	0.04	Not reported
	Basketball	0.21	0.13	0.26	0.07	0.01	Not reported
	Football*	0.24	Medial: 0.05 Lateral: 0.10	0.05	0.12	0.01	0.02
Females							
	Soccer	0.62	0.34	0.30	0.31	0.04	Not reported
	Basketball	0.28	0.29	0.24	0.29	0.01	Not reported
	Rugby	0.40	0.43	0.09	0.36	0.03	Not reported

* Football injuries rate was based on injuries per player while all other rates are reported as rate per 1000 athlete exposures.

Table 3 shows the prevalence rate of knee injuries by sport and gender.

Figure 1: Search Results

