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Determining The Rate Of Ipsilateral And Contralateral ACL Rupture Following ACL Reconstruction Surgery In Males And Females: A Systematic Review

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DETERMINING THE RATE OF IPSILATERAL AND CONTRALATERAL ACL RUPTURE FOLLOWING ACL RECONSTRUCTION SURGERY IN MALES AND FEMALES: A SYSTEMATIC REVIEW

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ABSTRACT

Title: Determining the rate of ipsilateral and contralateral ACL rupture following ACL reconstruction surgery in males and females: A SYSTEMATIC REVIEW

Introduction: The ACL is one of the two intraarticular ligaments within the knee joint that provides stabilization and resists against anterior translation of the tibia on the femur and rotation. There are many risk factors that may predispose an athlete to an ACL tear or increase their risks, however excessive motion at any plane may cause an ACL rupture. Over the last decade, several research studies have found that the rate of ACL tears following reconstruction surgery has increased compared to previous decades. . **Objective:** The primary objective of this systematic review was to determine the rate of ipsilateral and contralateral ACL ruptures following ACL reconstruction surgery in both males in females. **Background:** A literature search was performed using PubMed, Medline, Academic Search Premier, and CINAHL databases. Twelve articles met inclusion criteria and minimum score on the Modified Downs and Black for Study Quality checklist. All articles included in this systematic review include findings on the incidence of rupture rates on both the ipsilateral and contralateral ACL tears including percentages within the last 12 years and included both males and females within their study design. **Results:** Comparison of twelve studies included 6,901 post-operative ACL reconstruction patients, 57% male and 43% female. Patients were followed for an average of 6.9 years, with a follow-up windows ranging from 1 year to 15 years. The ipsilateral ACL re-rupture rate was 6.07% and contralateral ACL re-rupture rate was 6.89%. Overall

rate of re-rupture following ACL reconstruction is 12.97% with a range of 5.96% to 35.8%. **Conclusion:** Post-operative ACL reconstruction patients have nearly a 13% risk of sustaining another ACL injury. Studies that followed patients for longer period of time reported higher injury rates comparatively. The research suggests that patients are more likely to tear their contralateral ACL compared to the ipsilateral following ACL reconstruction. Future longitudinal studies are needed to further examine risk of rupturing the ipsilateral or contralateral ACL following an ipsilateral reconstruction surgery, as well as, investigating possible risk factors for re-rupturing the ACL. **Key Words:** Anterior Cruciate Ligament, Reconstruction, Re-rupture rate

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Introduction

Empirical research in sports medicine has shown the prevalence of anterior cruciate ligament (ACL) ruptures has increased over the last two decades. [1] Surgical intervention to reconstruct the ACL is a necessity to return to static stability to the knee joint and allow for the restoration of function. [2] The ACL is one of the two cross ligaments that restricts unwanted anterior tibial translation and rotation of the knee joint. Over the last two decades, ACL research has focused on the prevention, treatment, rehabilitation, and return to play following ACL reconstruction. In addition, there has been increasing interest in examining re-rupture to the surgical repaired ACL, as well as the contralateral ACL.[3,4] Research has uncovered many risk factors that increase the chances of an individual sustaining an injury to the ACL.

There are many risk factors that may predispose a physically active individual to an ACL tear. There are different factors that affect one's susceptibility to ACL tears; including joint laxity, Quadricep muscle dysfunction, hamstring to quadricep strength ratio, high knee abduction, small femoral condylar notch widths, genetics and biomechanical and neuromuscular deficits.[5] There are also different risk factors that affect diverse populations. For example, a female population has different risk factors regarding their anatomical differences[6,7,8] and menstrual cycle. [5,9,10] However excessive motion at any plane may cause an ACL rupture. An ACL can be ruptured by collision, contact, limited contact and non-contact sports through the process, of jumping, turning, or cutting.[11,12] These mechanisms may result in a full or partial tear of the ACL, surgical intervention to restore the stability and function of the knee is often the treatment of choice.

Following ACL tears most patients opt for an arthroscopic ACLR surgery. [13] Depending upon patients' goals there are different graft types to choose from all of which have pros and cons. These grafts can be from a donor or one's own tissue. After the surgery a certain protocol most be followed to rehabilitate the knee joint and the surrounding muscles.

Postoperative care is crucial in the rehabilitation process following anterior cruciate ligament reconstructive surgery. Weight bearing of the recovering limb is suggested to occur as soon as possible, this can happen with or without the use of crutches depending on your surgeon's preference. [14,15,16] The rehabilitation process involves your surgeon, physical therapist and one's self and working together. Most young athletes' goals for rehabilitation is return to sport so depending upon patients' goals, the rehabilitation process may be different. However, all physical therapy programs should follow a safe progression program with pain free motions in order to reduce the risk of re rupturing the ACL.

Several research studies have reported conflicting re-rupture rates following ACLR over the past decade. Just like how some populations can be at a higher risk for primary ACL tears, the same is true for the incidence for re-rupturing following ACLR. Based on the literature, women and individuals who return to activity under 9 months are at an increased risk of further injury to the ACL graft or contralateral ACL. [4] Although there is no available literature on risk factors leading to re-rupture or re-injury, the literature suggests that the primary risk factors related to the initial injury may be relevant. [5] This systematic review will explore the incidence rates of ACL tears following reconstructive surgery while discussing the findings from 12 included studies.

Objective

The primary objective of this systematic review was to determine the rate of ipsilateral and contralateral ACL ruptures following ACL reconstruction surgery in both males in females. The secondary purpose was to investigate the rate of ipsilateral compared to contralateral ACL injury following the initial ACL rupture.

Research Question

What are the incidence rates of ipsilateral and contralateral ACL ruptures following ACL reconstruction surgery in both males and females?

Literature Review

In the United States, it has been observed that the incidence of anterior cruciate ligament (ACL) tears are on the rise, this influences the incident rates of re- rupture or contralateral tears after reconstruction.[17] A study from 2007 stated there is an annual increase in ACL tears of 1.3%.[17] Hogea et al.,[18] states that ACL tears happen between 100,000 and 200,000 a year in the United States alone. Women have a higher incidence rate compared to men involved in the same sport [19,20] especially through a non-contact mechanism. [6] Researchers show that women are two to eight times more likely to tear their ACL.[5,11,19,21,22] The ACL is an important ligament within the knee joint.

ACL Structure and Function

The knee joint is one of the largest joints and must support the majority of one's weight, making the ACL a crucial support to the knee.[18] The ACL is one of two cross ligaments within the knee that help stabilize the joint and allows for a greater range of motion (ROM) and slight rotation. The ACL is the major anterior tibial translation and rotation ligament.[23] The ACL is made up of dense connective tissue with two bundles,

anteromedial bundle (AMB) and posterolateral bundle (PLB). These work together through the knees ROM with different tensioning patterns to prevent tibial translation and excessive rotation.[22] The other cruciate ligament is the Posterior (PCL), it keeps the tibia from posteriorly displacing the femur.[24] These ligaments help prevent injury to the knee by stabilizing the joint and preventing excessive motion.

Mechanism of Injury (MOI)

Mechanism of injury is the process in which an injury may occur. An ACL can be ruptured by collision, contact, limited contact and non-contact sports through the process, of jumping, turning, or cutting.[11,12] Collision sports involve contact with other opponents and objects. Contact sports means that contact between objects and opponents is allowed. Limited contact sports discourage the use of contact. Non- contact sports do not anticipate there to be any contact.[12]

Contact injuries include a direct force to the knee by a fixed object, this may include an opponent. A fixed object may involve another player or a piece of equipment. Researchers believed that contact sports would lead to the most ACL tears[25] but many non-contact sports such as gymnastics has observed many ACL tears.[12] Landis et al.,[21] states that non-contact ACL tears are at a rate of 70-84%. Overall, excessive motion at any plane can lead to a ligamentous injury.[5] There are many risk factors that may predispose an athlete to an ACL tear or increase their risks.

ACL Rupture Risk Factors

There are different factors that affect one's susceptibility to ACL tears; including joint laxity, Quadricep muscle dysfunction, hamstring to quadricep strength ratio, high

knee abduction, small femoral condylar notch widths, genetics and biomechanical and neuromuscular deficits.[5]

Quadricep muscle dysfunction, can be described as weakness and inadequate central muscle activation. Following ACLR, women have been shown to have a decreased ability for the knees to absorb shock.[26] This is due to muscle imbalances such as hamstring to quadricep strength ratio. A decrease in hamstring strength with an increase in quadriceps strength can lead to an increased risk for ACL tears.[7,26,27]

Knee abduction movement (KAM) is a mechanism where knees face outwards away from the body, when drop jump landing; this increases one's risk for a primary ACL rupture.[21,12, 28] Knee flexion and valgus motions was measured during a drop jump landing to determine high KAM which is any score over 21.74 nanometers. Myer et al., found that any KAM of 25.3 increased subsequent ACL tears by 6.8%.[27]

There are some genetic disorders that affect one's laxity in their joints which is a known risk factor of ACL tears; however, more research has to be done to understand the full effects of genetics.[5] Two genetic disorders that interfere with collagen such as Ehlers Danlos and Marfan's syndrome are inherited diseases that affect laxity.[5] Various genetic variants have been studied to try and determine the link between genetics and ACL ruptures. It has been noticed that if a relative of yours has had an ACL tear then you are more predisposed to tearing your ACL. Researchers are not exactly sure why this is, which is why more research is needed.[29]

Biomechanical and neuromuscular deficits can increase risk for an ACL tear. Biomechanical deficits include poor body mechanics while in functional movements, this

can be due to improper form due to lack of strength or poor posture. Neuromuscular deficits are due to improper nerve functioning that leads to muscles. [6]

Poor landing mechanics with increased valgus torque at ground landing places more stress on ACL causing it to be a risk factor especially in the female population.[6] Valgus torque can be described as the rotational aspect of knees angulating towards the midline ("falling" inward"). Hip abductor and adductor muscles play a role in one's knee positioning. Strong hip adductors muscles can pull knees inward causing poor biomechanics because hip abductor muscles are weaker. Women have smaller joint angles and larger joint movements compared to men when landing after jumps or cutting movements that also predispose them to injuring their knees.[30] Hewett et al.,[5] states that the mechanism for men and women may differ especially with regards to dynamic knee positioning.

A woman's menstrual cycle may affect her susceptibility to ligament injuries such as a torn ACL through increased joint laxity within the knee.[5,9,10] Joint laxity can be characterized as a decrease in stiffness in one's musculoskeletal tissues in and surrounding joints. A woman's joints tend to be laxer due to estergon[31], allowing for decreased stiffness of ligaments and, therefore, increase one's risk of tearing their ACL.[9,22] A women's knee laxity changes over the course of their menstrual cycle. These changes are due to women's fluctuating hormone levels, the most important hormone to affect laxity being estrogen.[22,31] During a woman's ovulatory phase there is a 17% seen decrease in knee stiffness which in return results in lower knee laxity making the ACL more vulnerable to ACL tears.[5,22,32] During the menstrual cycle the preovulatory phase

has been noted to be the highest risk for ACL tears. [5,9,10,19] The menstrual cycle may be a risk factor for women due to the fluctuations of hormones that influence knee laxity.

Q-angle, pelvic width, and intercondylar notch width (INW) are other biomechanical risk factors that more specifically relate to women.[6,7,8] A Q-angle is the measurement of pelvic width that is found by drawing a line from the anterior-superior iliac spine of the pelvis to the patella (kneecap) and from the patella to the tibial tubercle. Women tend to have larger Q- angles compared to men due to greater pelvic widths. Pelvic widths are the distance from the top of the right iliac spine to the left iliac spine, also known as your hip width. Women with larger Q-angles tend to place more stress on their knees which increases their risk for ACL tears.[8] Intercondylar notch width, is the distance between the two protrusions of the distal end of the femur. Women are more susceptible to have a narrower INW compared to men. Smaller INW are seen to increase a woman's odds for an ACL tear.[5,8] Anterior Cruciate Ligament tears often require interventions, especially for athletes looking to return to their sports.

Anterior Cruciate Ligament Reconstructions (ACLR)

Most ACL tears are followed by surgical reconstructions.[30] ACL reconstructions are a repair of the ACL using a graft. Grafts are typically chosen to try and mimic the native ACL to its best ability for proper anatomical and biomechanical function in a safe fixation manner with limited recovery time.

All ACL surgeries are now done arthroscopically. Arthroscopic procedures are minimally invasive surgery, using both an arthroscope, an endoscope that are inserted through a small incision. An arthroscope is an instrument that can be inserted into a small entry point to operate on the joint. An endoscope is a small camera and light attached to a

narrow hole that transmits pictures of inside your joints to a TV monitor. Arthroscopic procedures still require you to go under anesthesia, even though it's not a major open surgery.[13]

There are different graft types that can be used; bone patella tendon bone (BPTD), hamstrings, quadriceps tendon, intra-articular brace (IAB).[33] BPTD, consists of using the patellar tendon and fixing it to the patella using a piece of bone from your shin. Another option is to use a part of the hamstring or quadricep tendon. The hamstring has better outcomes compared to the BPTB, surgeons use the gracile and semitendinosus which has a greater cross-sectional area and allows for a 69% return to pre-surgery levels. The quadriceps tendon was used back in 1979 but did not see great outcomes so it remained unpopular. IAB is the use of a brace within the knee.[33]

Grafts can be autograft, synthetic, or allografts. Autograft are the most reliable approach as it uses one's own body tissues to repair the ACL which reduces the chance of rejection of the graft. This option also allows for shorter surgical and recovery time. Synthetic grafts are grafts that are made, they must be referred to as IAB as it is an artificial graft and is reserved for patients who meet specific criteria. This option also is a reduced surgical time and recovery but is not very common or popular due to poor outcomes when they were first in use. Allografts are donors from cadavers, this graft type has a higher risk for rejection of the graft but has a faster surgical and recovery time compared to autografts.[33] Following ACLR surgery patients must follow a certain protocol for recovery based on graft type and personal goals.

Postoperative Care

Postoperative care is different depending on the graft type used during surgical reconstruction of the ACL; however, most ACLR patients will wear a locked knee brace for 3 weeks while walking and are able to unlock it to complete exercises to regain knee flexion of 90 degrees. The brace is typically recommended to be used for two months.[14] Weight bearing should happen as soon as possible following surgery depending upon surgical techniques and graft types this can happen right away whereas other types require you to use crutches to allow for only 50% weight bearing. Surgeons also suggest patients follow RICE: rest, ice, compression, and elevation. This will help to reduce swelling of the knee joint.[15]

The duration of rehabilitation following ACLR may vary depending upon the graft type. However, rehabilitation of ACLR consists of postoperative weight bearing, strengthening the quadriceps, regaining full range of motion (ROM), and neuromuscular training through Physical therapy (PT). Throughout rehabilitation movements should be completed in a pain free range of motion. Rehabilitation should not be on a structured timeline of return to sport. Johnson et al., states that the primary goal of rehabilitation is regaining quadricep strength; however, readiness to return to sport should be about more than how much force one can produce.[16] Rehabilitation should be safely progressed to challenge each individual patient.

Rehabilitation of the ACL following ACLR usually occurs a week or two after, through a physical therapy program. Programs are typically split into different phases. There are four general phases, followed by return to sport. Phase one involves early postoperative care focusing on minimizing pain and regaining some ROM. Phase two

involves strengthening activities and neuromuscular control. Phase three is an in-depth strengthening program where patients start plyometrics, agility, running. Phase four is fine toning strength and neuromuscular control with regards to specific sports. These phases allow for a safe return to sport.[15,16] As previously mentioned allografts may be rejected leading to a re- rupture of the ACL[40]; however, re-ruptures may occur following ACLR with synthetic and autografts as well.

Re-rupture Rates

Over the last decade the rate of ACL tears following reconstruction surgery has increased and is the highest it has seen.[34] Hewett et al.,[5] states that return to sports following ACL tears puts one at a 15-25 times greater risk for rupture of either the ipsilateral or contralateral ACL. Researchers have also found that women are at a higher susceptibility rate to injury following ACLR[14] and they are at a higher risk for contralateral ruptures[5,26,35] ; female athletes are at a 2-8-fold for ruptures compared to males.[11,19] Bell et al.,[10] suggests that hormones may be a strong risk factor for a woman's increased risk of contralateral tears. Adolescents between the ages of 10 and 25 are another population that is at an increased risk for contralateral ACL tears following ACLR.[36] If one favors their contralateral limb once they return to their sport it is observed to increase one's risk for tearing their uninjured limb and this deficit can last up to two years.[5] Re-rupture rates may have increased over the past decade due to changes in the rehabilitation process. These statistics are showing that the rehabilitation process is failing a large segment of patient populations.[36] With more ACL tears, prevention is key both prior to and following an ACLR.

Prevention

Preventative measures are key to decreasing the incidence rate of ruptures following ACLR. However, prior to preventative programs, rehabilitation should focus on more than just quadricep strength. Faulty movement patterns should be identified and corrected, having poor biomechanics for intervention will only increase risks for ACL re-ruptures.[3] Implementing prevention programs can be challenging once they are fully understood due to individuals having to adhere to a program. Patients adherence to such programs can be challenging due to extensive requirements of time and involvement needed to prevent ACL injuries.[5] Many researchers have found that implementing neuromuscular and proprioceptive training can decrease one's risk for ACL injuries, especially in a women's population.[11,5,30]

Neuromuscular training may reduce one's incidence rate of re injury by 50%.[5,30] Training that incorporates plyometrics, balance and strength may provide adequate injury prevention.[5] As previously discussed, women are at a higher risk for ACL tears this may be due to a women's hormonal fluctuations throughout the menstrual cycle. Oral Contraceptive Pills (OCP) were investigated to see if this form of birth control influences a protective effect on a women's ACL due to the changes in the levels of hormones produced with the pill. Both Chidi-Ogbolu and Barr[22], and Herzberg et al.,[9] found a 20% reduction in ACL ruptures with OCP users compared to non OCP users. This systematic review analyzed 12 included studies that discussed the incidence rates of re-ruptures of the ipsilateral ACL or the contralateral ACL.

Methods

Cochrane handbook for systematic review guidelines were followed when conducting and reporting this systematic review. The Cochrane handbook is the official guidelines for preparing and completing a systematic review on the effects of interventions of healthcare. This tool prepares guidelines on how to conduct the methodical section of a systematic review including; Review planning, study search and selection, data collection, bias risk assessment, statistical analysis, GRADE and results interpretation.[37]

Search Strategy

An electronic search was conducted on second ACL tears on either the ipsilateral or contralateral knee following a reconstruction. The databases of PubMed (1990, 2019), Medline (1990, 2019), academic search premier (1990, 2019), CINAHL (1990, 2019) were searched for full text, on humans with the following combinations of search terms: *Anterior Cruciate Ligament, Reconstruction, graft failure, females, males*. A broad search was used to identify articles that discussed the ACL injury that resulted in 2,273 articles that fit the search terms. The article titles and abstracts were examined for relevance. In addition to the electronic searches, professionals in the field were asked to suggest further citations and references from review articles were examined, which included six new articles. The search was completed in September 2019 with a total of 2,279 articles to be reviewed for inclusion and exclusion criteria. 2,267 articles were excluded from this systematic review due to duplicate articles, not reporting both genders, not available in full text, not specific on what graft was injured, contralateral or ipsilateral.

Selection Criteria

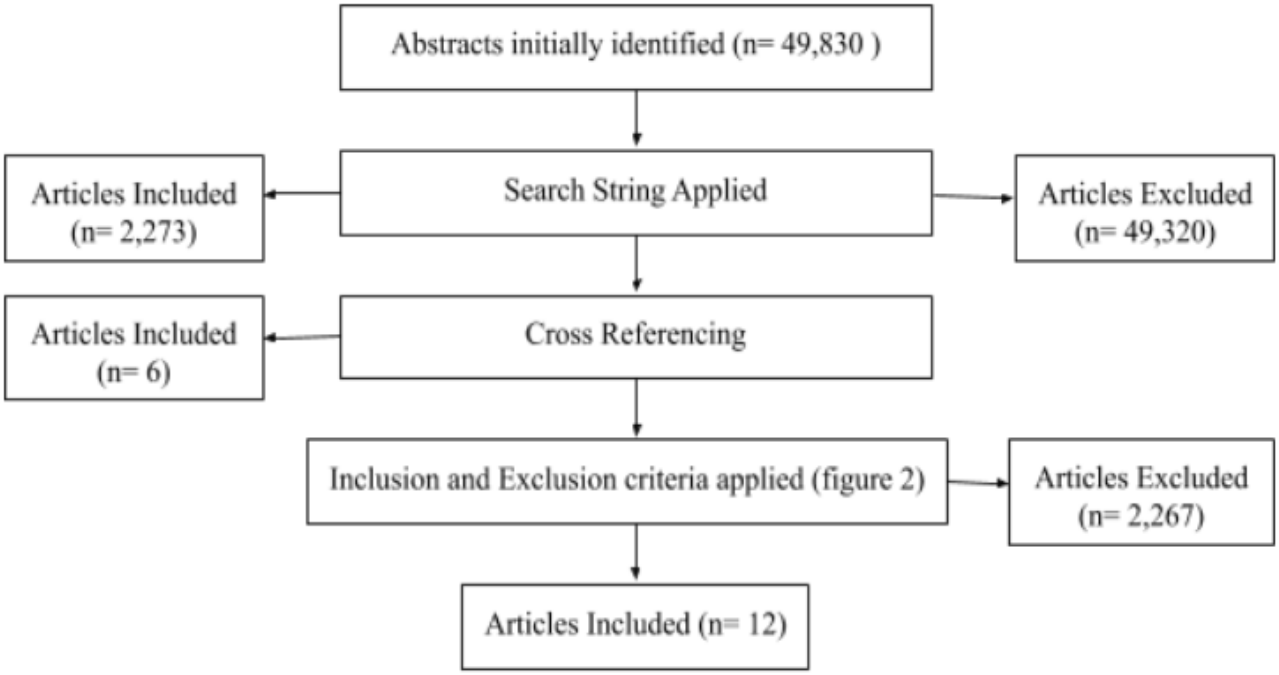
Given the large number of articles found, an initial screening of articles was conducted for inclusion. Articles were screened by title, author, abstract, then full text according to inclusion and exclusion criteria. All articles included in this systematic review include findings on the incidence of rupture rates on both the ipsilateral and contralateral ACL tears including percentages within the last 12 years and included both males and females within their study design. Exclusion criteria included; all articles that did not meet the above inclusion criteria, written in another language besides English, narrative reviews, or clinical commentaries. The process of the literature search can be outlined in Table and Figure 1.

Table 1. Literature Search

	Total N	Total N After Filters	1990-1999 N	2000-2009 N	2010-2019 N	Totals of all years
PubMed	25,665	564	61	169	333	
Medline	10,067	353	22	67	264	
Academic Search Premier	9,135	36	0	7	29	
CINAHL	4,963	184	3	13	168	

Total	49,830	1,137	86	256	794	2,273

Figure 1. Flow Chart of the Literature Review Process



Risk of Bias

The methodological reliability of the papers included was analyzed and tested using the Revised Downs and Black Checklist (Table 2). This test is a checklist that contains 13 "yes (Y)" or "no (N)" questions used to evaluate: 1) the potential sources of bias in non-randomized or cohort studies, 2) the reliability of a study, and 3) recommends the use of a study in the context of public health.[39] The questions were designed to test the reliability of the research, external validity, bias in the sample, uncertainty and

selection bias, and study strength. A larger total number shows more satisfied items and thus less chance of bias in papers.

Table 2. Modified Downs and Black for Study Quality checklist

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Kaeding et al., [40]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	12
Shelbourne et al., [41]	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N/A	N	N	9
Salmon et al., [42]	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	11
Webster, Feller et al., [43]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N/A	N	N	10
Webster et al.,[44]	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	11
Morgan et al.,[45]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N/A	N	N	10
Wright et al.,[46]	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N/A	N	N	9
Bourke et al.,[47]	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N	N	N	8
Leys et al.,[48]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N/A	N	N	9
Mae et al., [49]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N/A	N	11
Drogset and Grøntvedt[50]	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	N	8
Paterno et al., [35]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N/A	N	N	9
Average Quality of														10.5

studies													

Data Extraction

For each study, sample size was reported at baseline and follow-up time. From each source the; author, year of publication, the total number of participants in follow up (N), how many males and females participated, follow period, ipsilateral (IL) rupture, IL percentage, contralateral (CL) rupture, CL percentage were all extracted and inputted into a chart for further analysis. The primary variables derived include the number or percentage of ipsilateral injuries to the graft, and the number of contralateral injuries to ACL. The data that was extracted from each included study is shown in Table 3.

Data Synthesis

On average from the 12 included articles it is seen that following ACL reconstructions participants are seen to have an 8.54% incidence rate of rupture of the ipsilateral graft compared to a 10.54% contralateral injury.

Table 3. Data Extracted from each Included Study

Author	Year	N	Male	Female	Follow up Period (yrs.)	ILR	ILR %	CLR	CLR%
Kaeding et al., [40]	2015	2,488	1365	1123	2	105	4.4	84	3.5
Shelbourne et	2009	1,415	863	552	5	61	4.3	75	5.3

al., [41]									
Salmon et al., [42]	2005	612	383	289	5	39	6	35	6
Webster, Feller et al., [43]	2014	561	370	191	3	25	4.5	42	7.5
Webster et al.,[44]	2016	316	229	125	3-10	57	18	56	17.7
Morgan et al.,[45]	2016	242	138	104	>15	27	11.2	33	13.6
Wright et al.,[46]	2007	235	125	110	2	7	3	7	3
Bourke et al.,[47]	2012	200	100	100	15	33	16.5	15	7.5
Leys et al.,[48]	2012	179	95	85	15	22	12.29	34	18.99
Mae et al., [49]	2014	149	78	71	5	7	4.7	11	7.4
Drogset and Grøntvedt[50]	2002	94	45	55	8	11	11.7	15	15.96
Paterno et al., [35]	2012	63	21	42	1	4	6	12	19
Averages						33.16	8.54	34.91	10.54

Results

The comparison of the twelve studies included 6,901 post-operative ACL reconstruction patients of which, 57% male and 43% female. Patients were followed for an average of 6.9 years, with a follow-up windows ranging from 1 year to 15 years. The ipsilateral ACL re-rupture rate was 6.07% and contralateral ACL re-rupture rate was

6.89%. Overall rate of re-rupture following ACL reconstruction is 12.97% with a range of 5.96% to 35.8%.

Table 4. Descriptive Statistics

Total n	6901
Male (%)	3967 (57)
Female (%)	3039 (43)
IL rupture (%)	419 (6.07)
Cl rupture (%)	476 (6.89)

Conclusions

It has been observed that there has been a higher incidence rate of re injury following ACLR over the past two decades.[3] Post-operative ACL reconstruction patients have nearly a 13% risk of sustaining another ACL injury. Wright et al.,[46] found that following ACLR individual had a 50% greater chance of tearing the contralateral ACL compared to the ipsilateral ACL. Other studies showed that there was almost an equal chance of rupturing one's ACL on either side.[42,44] Keading et al.,[40] was the only study who found that their subjects had a higher incidence rate for ipsilateral tears. The rest of the studies that were included had a higher percentage of contralateral tears.[35,41,43,45,47,48,49,50] The evidence from this systematic review points to similar findings

of one having a higher incidence rate of a contralateral tear compared to the ipsilateral ACL, but only by a small percentage on the average of all 12 included studies.

When we look at the numbers across all studies that met inclusion criteria the rate of IL ruptures was 6.07% and CL ruptures was 6.89%, this may seem low at first look but is consistent when you look at the large n studies. Studies with lower population sizes yielded larger rupture rates and therefore provided outliers of rupture percentages. This is a limitation, having smaller sample sizes cause the rupture rates to be higher due to those who rupture their ACL would account for a bigger percentage of the total population. The smallest n was 63 participants and resulted in a 6.00% ipsilateral rupture and a 19% contralateral rupture rate. [36] The largest n was 2,488 which yielded a 4.40% IL rupture and a 3.5% CL rupture. The CL rupture rate of 19% in comparison is higher. However, when you take out some of these outliers and average the data percentages you see that the percent on average is lower for both CL and IL rates and together is about 13%. Paterno et al., [3] found that athletes returning to sport are a population that are at a high risk for ACL tears following ACLR. Athletes who return to sport (RTS) are at a 29.5% chance of re-rupturing the ipsilateral ACL or contralateral ACL following ACLR compared to a population of young athletes with no prior history of an ACL injury. 20.5% of the 29.5% re-rupture rates is seen to be contralateral ruptures and 9% are ipsilateral ACL tears following ACLR. This study included more female individuals sustaining a contralateral ACL tear, 23.7% compared to males, 10.5% within 24 months of RTS. [3] Sequentially those athletes who return to sport to soon are at a higher risk especially if returning prior to 9 months post operation. For every month a patient waits before RTS there is a 51% reduction in risk of rupture following ACLR.[4] Studies that

followed patients for a longer period reported higher injury rates comparatively. It appears that the chance of an ACL re-rupture to either IL or CL increases with a longer follow up period; this may have to do with them being exposed to more risk factors over time.

This higher incidence of ACL tears due to a certain population, the graft type chosen for repair, the surgical process or the work of one surgeon alone, the rehabilitation process, poor biomechanics that causes stress on the knee, difference of female anatomical structures, and/or returning to one's sport too soon; despite preventive measures and risk factors[5], there are some ACL injury situations that are uncontrollable.

Higher re-rupture rates may be due to a more specified population such as a population of all athletes who return to play. This population would be at a higher risk due to wanting to return to their sports as soon as possible and therefore stress their knees. Webster et al.,[44] found that the younger population is at a higher risk for a contralateral tear. Younger patients are more likely to return to sport; therefore, older individuals are at a lower risk for re-tear due to fewer of them returning to their sports compared to younger athletes.

Keading et al.,[40] found that allografts had a higher rate of rupturing than other grafts used for reconstructive surgery. This author also had a cohort of surgeons conducting the surgeries. This goes to show that surgical techniques are similar and that it is not one surgeon that is turning out a high percentage of ruptures following ACLR.[40] Future research is needed as this is becoming a bigger issue in the world of exercise science especially in the younger athletic population.

Keading et al.,[40] found that there was no significant difference between males and females and their incidence rates for rupturing their ACL; with a 4.6% rate for males and a 4.1% for females. Therefore, this may suggest that although women have different risk factors compared to males, they may not put them at an increased risk for ACL tears compared to males. Although it has been analyzed that women have a higher rate for ACL tears[26] and some studies found that women are at an increased risk for contralateral tears following ACL reconstructive surgery. [5,26,35]

The same risk factors that exposed one to a primary ACL injury are still present following ACLR surgery. These risk factors also affect the contralateral knee especially for those who may choose to favor their non injured limb. During rehabilitation the focus may be solely placed on the injured limb, so the contralateral knee is weakened. Therefore, when an athlete returns to sport their contralateral limb may be at an increased risk for a rupture. [4]

Clinical Implications

Sports medicine health care professionals who provide patient care to individuals who have sustained an ACL injury should understand the risk of re-injuring the ipsilateral or contralateral ACL when returning to activity or sport. In 2014, Paterno et al., [3] found a re-rupture rate of either the ipsilateral or contralateral ACL in individuals who returned to sport within 12 months of surgery to be 29.5%. The results of this study were higher than any other previously published study, due to inclusion criteria limited to only individuals that returned to sport who are at higher risk of re injury compared to individuals who never resume competitive physical active. .[3] The results of this systematic review indicated a 13% risk of re- rupture, however not all of these studied examined individuals

who returned to sport following ACLR. Patients who return to sport before 9 months post ACLR had a 51% greater chance of re-rupture compared to those who returned to sport after 9 months. [4] Individuals who return to sport with quadricep weakness have a 40% rupture rate if returning with quadriceps weakness. For each 1% increase in quadricep strength the injury rate decreases by 3%. [4] Although 13% is still a high rupture rate of ACL's following reconstruction; this shows that prevention is necessary to reduce the rate of sequential ACL ruptures.

Current systems are failing regarding rehabilitation.[36] Rehabilitation programs are focusing too heavily on quadriceps strength and time and are leaving out other risk factors. Clinicians need to be focusing on creating and implementing a comprehensive program that has standards with measurable outcomes on what is important to strengthen and prevent future ACL injuries. Clinicians should employ objective functional outcome measures to gather data throughout the rehabilitation process that can inform return to sport discussions. Burgi et al., [51] reviewed 209 studies and found that 85% of the studies used time as a primary criterion for RTS following ACLR. Out of the 209 studies 129 reported athletes returned to sport between 6 and 9 months. Preventative programs should not focus on just one aspect nor be focused around a specified timeframe.

Returning to sport used to be a timeframe of at least a year and now it can be seen that return to sport can be as early as a couple of months for athletes itching to return. Brophy et al., [52] claims that athletes believe they should be able to return to sport within 4- 5 months from ACLR and that the "best" surgeons can ensure athletes return sooner. Clinicians should educate patients on the risks of returning to sport too early and the increased risk of ipsilateral ACL or contralateral ACL ruptures they would be

subjected to. Criteria of what needs to be met for an athlete to return to sport should also be discussed to athletes in order to explain the consequences of not returning near optimal performance. Asymmetrical quadricep strength should be assessed and ipsilateral strength should be comparable to that of the contralateral knee. [4] Research into preventative measures for risk factors need to be considered to reduce this high incidence of ACL tears following reconstructive surgery. [42] All risk factors for ACL tears must be fully understood and taken into consideration during the rehabilitation process and be continually implemented into training for athletes' during their preseasons. When athletes are returning to sport, they must minimize all potential risk factors associated with their populations to reduce their chances of another ACL tear.

Neuromuscular training has been seen to be most successful for the reduction of ACL tears. If we can understand and implement neuromuscular prevention programs following ACLR we should also implement similar programs into preseason trainings to decrease the rate of primary ACL ruptures. [5,11,25] However future research is still needed in order to be able to create a comprehensive rehabilitation program that incorporates neuromuscular training that can prevent ACL injuries and decrease the rate of re-tears.

Paterno et al., [3] and Grindem et al., [4] have reported significantly higher ACL re-injury rates following ACLR compared to previously published research. Why are we still seeing an increase if we have preventive programs that are implemented? This is an aspect of research that is still trying to be understood. There are many risk factors that can contribute to a rupture of the ACL. These risk factors may not all be incorporated into a cohesive prevention program which may be why incidence rates are still high with prevention programs in place. More research should focus on creating a well-balanced

preventative program that encompasses all risk factors that affect ACL tears. Also, future research may want to include studies focusing on whether different populations should implement different programs due to their population and predisposition risk factor.

Gupta et al., [53] suggested that following ACLR, re-injury to the ipsilateral ACL may be just another ACL tear rather than a failure of the new graft. This is due to the idea that following a successful ACLR, the graft should act as your native ACL. Following 12 months post operation it has been observed that incidence rates for ipsilateral ACL injury is less than that of contralateral ACL; therefore by 12 months an ipsilateral ACL should reach ligamentization and act as a native ACL. Following ACLR, ipsilateral ACL injuries may just be a re-tear of the ACL compared to a rupture of the surgical graft. Re-rupturing the ACL prior to 12 months post ACLR may be due to graft weakness during the rehabilitative process before the ligament has the proper time to heal and fully be incorporated into the knee joint. This is a newly published study as of 2019 and future research is needed to continue understanding duration from surgery is needed for full ligamentization of the ACL graft and when clinicians can classify it as a re-tear.

Future research describing the process of how to implement prevention strategies to decrease secondary ACL injuries are needed. Future longitudinal studies need to further examine the risk of rupturing the ipsilateral or contralateral ACL following an ipsilateral reconstruction surgery, as well as, investigate possible risk factors for re-rupturing the ACL.

References

1. Abram, S. G., Price, A. J., Judge, A., & Beard, D. J. (2019). Anterior cruciate ligament (ACL) reconstruction and meniscal repair rates have both increased in

the past 20 years in England: hospital statistics from 1997 to 2017. *Br J Sports Med*, bjsports-2018.

2. Barber-Westin, S., & Noyes, F. R. (2019). Return to Sport After Primary ACL. *Return to Sport after ACL Reconstruction and Other Knee Operations: Limiting the Risk of Reinjury and Maximizing Athletic Performance*, *15*, 79.
3. Paterno, M. V., Huang, B., Thomas, S., Hewett, T. E., & Schmitt, L. C. (2017). Clinical Factors That Predict a Second ACL Injury After ACL Reconstruction and Return to Sport: Preliminary Development of a Clinical Decision Algorithm. Orthopaedic journal of sports medicine, 5(12), 2325967117745279. doi:10.1177/2325967117745279
4. Grindem, H., Snyder-Mackler, L., Moksnes, H., Engebretsen, L., & Risberg, M. A. (2016). Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study. British Journal of Sports Medicine, 50(13), 804–808. doi: 10.1136/bjsports-2016-096031Hewett, T. E.,
5. Myer, G. D., Ford, K. R., Paterno, M. V., & Quatman, C. E. (2016). Mechanisms, prediction, and prevention of ACL injuries: Cut risk with three sharpened and validated tools. Journal of orthopaedic research : official publication of the Orthopaedic Research Society, 34(11), 1843–1855. doi:10.1002/jor.23414
6. Zazulak, B. T., Ponce, P. L., Straub, S. J., Medvecky, M. J., Avedisian, L., & Hewett, T. E. (2005). Gender Comparison of Hip Muscle Activity During Single-Leg Landing. Journal of Orthopaedic & Sports Physical Therapy, 35(5), 292–299. doi: 10.2519/jospt.2005.35.5.292

7. Myer, G., Ford, K., Barber Foss, K., Liu, C., Nick, T., & Hewett, T. (2009). The Relationship of Hamstrings and Quadriceps Strength to Anterior Cruciate Ligament Injury in Female Athletes. Clinical Journal Of Sport Medicine, 19(1), 3-8. doi: 10.1097/jsm.0b013e318190bddb
8. Mohamed, E. E., Useh, U., & Mtshali, B. F. (2012). Q-angle, Pelvic width, and Intercondylar notch width as predictors of knee injuries in women soccer players in South Africa. African health sciences, 12(2), 174–180. doi:10.4314/ahs.v12i2.15
9. Herzberg, S. D., Motu'apuaka, M. L., Lambert, W., Fu, R., Brady, J., & Guise, J. M. (2017). The Effect of Menstrual Cycle and Contraceptives on ACL Injuries and Laxity: A Systematic Review and Meta-analysis. Orthopaedic journal of sports medicine, 5(7), 2325967117718781. doi:10.1177/2325967117718781
10. Bell, D. R., Blackburn, J. T., Hackney, A. C., Marshall, S. W., Beutler, A. I., & Padua, D. A. (2014). Jump-landing biomechanics and knee-laxity change across the menstrual cycle in women with anterior cruciate ligament reconstruction. Journal of athletic training, 49(2), 154–162. doi:10.4085/1062-6050-49.2.01
11. Donnell-Fink, L. A., Klara, K., Collins, J. E., Yang, H. Y., Goczalk, M. G., Katz, J. N., & Losina, E. (2015). Effectiveness of Knee Injury and Anterior Cruciate Ligament Tear Prevention Programs: A Meta-Analysis. PloS one, 10(12), e0144063. doi:10.1371/journal.pone.0144063
12. Montalvo, A., Schneider, D., Webster, K., Yut, L., Galloway, M., & Heidt, R. et al.,. (2019). Anterior Cruciate Ligament Injury Risk in Sport: A Systematic

Review and Meta-Analysis of Injury Incidence by Sex and Sport Classification. *Journal Of Athletic Training*, *54*(5), 472-482. doi: 10.4085/1062-6050-407-16

13. Wilkerson, DO, R. (2019). Arthroscopy - OrthoInfo - AAOS. Retrieved 1 November 2019, from https://orthoinfo.aaos.org/en/treatment/arthroscopy/
14. Chachula, L., Cameron PhD, ATC, LTC, K., Svoboda, MD, and LTC, S., & Owens, MD, B. (2019). Postop bracing after ACL reconstruction | Lower Extremity Review Magazine. Retrieved 19 November 2019, from https://lermagazine.com/article/postop-bracing-after-acl-reconstruction
15. Cavanaugh, J. T., & Powers, M. (2017). ACL Rehabilitation Progression: Where Are We Now?. Current reviews in musculoskeletal medicine, 10(3), 289–296. doi:10.1007/s12178-017-9426-3
16. Johnson, A. K., Palmieri-Smith, R. M., & Lepley, L. K. (2018). Contribution of Neuromuscular Factors to Quadriceps Asymmetry After Anterior Cruciate Ligament Reconstruction. Journal of athletic training, 53(4), 347–354. doi:10.4085/1062-6050-463-16
17. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. J Athl Train. 2007;42(2):311.
18. Hogea, G. B., PĂTRAŞCU JR, J. M., SĂNDESC, M. A., Bredicean, A. C., Nussbaum, L. A., Hogea, L. M., ... & Chiriac, S. D. (2018). The utility of indirect imagistic signs in the diagnosis of anterior cruciate ligament ruptures. Rom J Morphol Embryol, 59(3), 741-745.

19. Beynnon, B. D., Bernstein, I. M., Belisle, A., Brattbakk, B., Devanny, P., Risinger, R., & Durant, D. (2005). The Effect of Estradiol and Progesterone on Knee and Ankle Joint Laxity. *The American Journal of Sports Medicine*, 33(9), 1298–1304.
20. Little, D., Thompson, J. W., Dubois, L. G., Ruch, D. S., Moseley, M. A., & Guilak, F. (2014). Proteomic differences between male and female anterior cruciate ligament and patellar tendon. PloS one, 9(5), e96526. doi:10.1371/journal.pone.0096526
21. Landis, S. E., Baker, R. T., & Seegmiller, J. G. (2018). NON-CONTACT ANTERIOR CRUCIATE LIGAMENT AND LOWER EXTREMITY INJURY RISK PREDICTION USING FUNCTIONAL MOVEMENT SCREEN AND KNEE ABDUCTION MOMENT: AN EPIDEMIOLOGICAL OBSERVATION OF FEMALE INTERCOLLEGIATE ATHLETES. *International journal of sports physical therapy*, 13(6), 973–984.
22. Chidi-Ogbolu, N., & Baar, K. (2019). Effect of Estrogen on Musculoskeletal Performance and Injury Risk. *Frontiers in physiology*, 9, 1834. doi:10.3389/fphys.2018.01834
23. Anterior Cruciate Ligament (ACL) - Structure and Biomechanical Properties. (2019, August 28). *Physiopedia, .* Retrieved 17:49, October 22, 2019 from https://www.physiopedia.com/index.php?title=Anterior_Cruciate_Ligament_(ACL)_-_Structure_and_Biomechanical_Properties&oldid=221062.

24. Logterman, S., Wydra, F., & Frank, R. (2018). Posterior Cruciate Ligament: Anatomy and Biomechanics. Current Reviews In Musculoskeletal Medicine, 11(3), 510-514. doi: 10.1007/s12178-018-9492-1

25. Agel, J., Arendt, E., & Bershadsky, B. (2005). Anterior Cruciate Ligament Injury in National Collegiate Athletic Association Basketball and Soccer: A 13-Year Review. *The American Journal Of Sports Medicine*, *33*(4), 524-531. doi: 10.1177/0363546504269937

26. Kuenze, C. M., Hertel, J., & Hart, J. M. (2014). Quadriceps muscle function after exercise in men and women with a history of anterior cruciate ligament reconstruction. *Journal of athletic training*, *49*(6), 740–746. doi:10.4085/1062-6050-49.3.46

27. Myer, G. D., Ford, K. R., Di Stasi, S. L., Foss, K. D., Micheli, L. J., & Hewett, T. E. (2015). High knee abduction moments are common risk factors for patellofemoral pain (PFP) and anterior cruciate ligament (ACL) injury in girls: is PFP itself a predictor for subsequent ACL injury?. British journal of sports medicine, 49(2), 118–122. doi:10.1136/bjsports-2013-092536

28. Hewett TE, Myer GD, Ford KR, et al.,. Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. Am J Sports Med. 2005; 33:492–501. [PubMed: 15722287]

29. Kaynak, M., Nijman, F., van Meurs, J., Reijman, M., & Meuffels, D. E. (2017). Genetic Variants and Anterior Cruciate Ligament Rupture: A Systematic Review.

Sports medicine (Auckland, N.Z.), 47(8), 1637–1650. doi:10.1007/s40279-017-0678-2

30. Ortiz, A., Capo-Lugo, C. E., & Venegas-Rios, H. L. (2014). Biomechanical deficiencies in women with semitendinosus-gracilis anterior cruciate ligament reconstruction during drop jumps. *PM & R : the journal of injury, function, and rehabilitation*, *6*(12), 1097–1106. doi:10.1016/j.pmrj.2014.07.003
31. Shultz, S. J., Sander, T. C., Kirk, S. E., & Perrin, D. H. (2005). Sex differences in knee joint laxity change across the female menstrual cycle. *The Journal of sports medicine and physical fitness*, 45(4), 594–603.
32. Park, S. K., Stefanyshyn, D. J., Loitz-Ramage, B., Hart, D. A., and Ronsky, J. L. (2009). Changing hormone levels during the menstrual cycle affect knee laxity and stiffness in healthy female subjects. *Am. J. Sports Med.* 37, 588–598. doi: 10.1177/0363546508326713
33. Cerulli, G., Placella, G., Sebastiani, E., Tei, M. M., Speziali, A., & Manfreda, F. (2013). ACL Reconstruction: Choosing the Graft. Joints, 1(1), 18–24.
34. Eckenrode, B. J., Carey, J. L., Sennett, B. J., & Zgonis, M. H. (2017). Prevention and Management of Post-operative Complications Following ACL Reconstruction. Current reviews in musculoskeletal medicine, 10(3), 315–321. doi:10.1007/s12178-017-9427-2
35. Paterno, M. V., Rauh, M. J., Schmitt, L. C., Ford, K. R., & Hewett, T. E. (2012). Incidence of contralateral and ipsilateral anterior cruciate ligament (ACL) injury after primary ACL reconstruction and return to sport. *Clinical journal of sport*

medicine : official journal of the Canadian Academy of Sport Medicine, *22*(2), 116–121. doi:10.1097/JSM.0b013e318246ef9e

36. Paterno M. V. (2015). Incidence and Predictors of Second Anterior Cruciate Ligament Injury After Primary Reconstruction and Return to Sport. Journal of athletic training, 50(10), 1097–1099. doi:10.4085/1062-6050-50.10.07
37. Hewett T, Ford KR, Hoogenboom BJ, Myer GD. Understanding and Preventing ACL Injuries: Current biomechanical and epidemiologic considerations - Update 2010. North Am J Sports Phys Ther. 2010;5(4):234-251.
38. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). Cochrane Handbook for Systematic Reviews of Interventions version 6.0 (updated July 2019). Cochrane, 2019.
39. Downs SH Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health.* 1998;52(6):377-384.
40. Kaeding, C., Pedroza, A., Reinke, E., Huston, L., & Spindler, K. (2014). Risk Factors and Predictors Of Subsequent ACL Injury After ACL Reconstruction: Prospective Analysis Of 2801 Primary ACL Reconstructions. *Orthopaedic Journal Of Sports Medicine, 2*(7_suppl2), 2325967114S0004. doi: 10.1177/2325967114s00046
41. Shelbourne, K. D., Gray, T., & Haro, M. (2009). Incidence of Subsequent Injury to Either Knee within 5 Years after Anterior Cruciate Ligament Reconstruction with Patellar Tendon Autograft. *The American Journal of Sports Medicine*, 37(2), 246–251. https://doi.org/10.1177/0363546508325665

42. Salmon, L., Russell, V., Musgrove, T., Pinczewski, L., & Refshauge, K. (2005). Incidence and Risk Factors for Graft Rupture and Contralateral Rupture After Anterior Cruciate Ligament Reconstruction. Arthroscopy: *The Journal Of Arthroscopic & Related Surgery*, 21(8), 948-957. doi: 10.1016/j.arthro.2005.04.110

43. Webster, K. E., Feller, J. A., Leigh, W. B., & Richmond, A. K. (2014). Younger Patients Are at Increased Risk for Graft Rupture and Contralateral Injury After Anterior Cruciate Ligament Reconstruction. *The American Journal of Sports Medicine*, 42(3), 641–647. https://doi.org/10.1177/0363546513517540

44. Webster, K. E., & Feller, J. A. (2016). Exploring the High Reinjury Rate in Younger Patients Undergoing Anterior Cruciate Ligament Reconstruction. *The American Journal of Sports Medicine, 44*(11), 2827–2832. https://doi.org/10.1177/0363546516651845

45. Morgan, M., Salmon, L., Waller, A., Roe, J., & Pinczewski, L. (2016). Fifteen-Year Survival of Endoscopic Anterior Cruciate Ligament Reconstruction in Patients Aged 18 Years and Younger. *The American Journal Of Sports Medicine*, 44(2), 384-392. doi: 10.1177/0363546515623032

46. Wright RW, Dunn WR, Amendola A, et al.,. Risk of tearing the intact anterior cruciate ligament in the contra-lateral knee and rupturing the anterior cruciate ligament graft during the first 2 years after anterior cruciate ligament reconstruction: a prospective MOON cohort study. *Am J Sports Med.* 2007; 35:1131–1134. [PubMed: 17452511]

47. Bourke, H., Gordon, D., Salmon, L., Waller, A., Linklater, J., & Pinczewski, L. (2012). The outcome at 15 years of endoscopic anterior cruciate ligament reconstruction using hamstring tendon autograft for 'isolated' anterior cruciate ligament rupture. *The Journal Of Bone And Joint Surgery. British Volume, 94-B*(5), 630-637. doi: 10.1302/0301-620x.94b5.28675

48. Leys, T., Salmon, L., Waller, A., Linklater, J., & Pinczewski, L. (2011). Clinical Results and Risk Factors for Reinjury 15 Years After Anterior Cruciate Ligament Reconstruction. *The American Journal Of Sports Medicine*, 40(3), 595-605. doi: 10.1177/0363546511430375

49. Mae, T., Shino, K., Matsumoto, N., Yoneda, K., Yoshikawa, H., & Nakata, K. (2014). Risk factors for ipsilateral graft rupture or contralateral anterior cruciate ligament tear after anatomic double-bundle reconstruction. *Asia-Pacific Journal Of Sports Medicine, Arthroscopy, Rehabilitation And Technology,* 1(3), 90-95. doi: 10.1016/j.asmart.2014.05.001

50. Drogset, J., & Grøntvedt, T. (2002). Anterior Cruciate Ligament Reconstruction with and without a Ligament Augmentation Device. *The American Journal Of Sports Medicine,* 30(6), 851-856. doi: 10.1177/03635465020300061601

51. Burgi, C. R., Peters, S., Ardern, C. L., Magill, J. R., Gomez, C. D., Sylvain, J., & Reiman, M. P. (2019). Which criteria are used to clear patients to return to sport after primary ACL reconstruction? A scoping review. *British Journal of Sports Medicine,* 53(18), 1154–1161. doi: 10.1136/bjsports-2018-099982

52. Brophy, R. (2018). Return to Play and Future Anterior Cruciate Ligament Injury Risk after Anterior Cruciate Ligament Reconstruction in Soccer Players. *The Anterior Cruciate Ligament.* doi: 10.1016/b978-0-323-38962-4.00127-2

53. Gupta, R., Malhotra, A., Sood, M., & Masih, G. D. (2019). Is anterior cruciate ligament graft rupture (after successful anterior cruciate ligament reconstruction and return to sports) actually a graft failure or a re-injury? *Journal of Orthopaedic Surgery*, *27*(1), 230949901982962. doi: 10.1177/2309499019829625