Anterior Cruciate Ligaments; a literature review on why women have increased susceptibility to ACL tears with a prevention program

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Abstract

The introduction of Title XI in 1972 saw women's participation in extracurricular activities and high-level sports exponentially increased. This increase in participation also meant an increase in women sustaining injuries. Sports injuries such as; ankle sprain, plantar fasciitis, shin splints, patellofemoral pain syndrome, and anterior cruciate ligament (ACL) tears and ruptures became common among female athletes. Among these injuries, ACL ruptures and tears account most significant differences when comparing injury risk between men and women. Studies have shown that women are at a two to eight time’s greater risk of tearing or rupturing their ACL when compared to their male counterparts. These differences stem from a number of factors that are seen as hormonal, anatomical, neuromuscular and biomechanical differences. Additionally, the goal of this literature review will be to address why females are more susceptible to ACL injuries and to provide information on the mechanism of injury, methods of reconstruction, statistics, and provide a prevention plan that can be utilized before a competitive event or integrated into a gym routine.
The Anatomy

In order to understand why women tear their ACL at higher rates, we must first understand the anatomy of the knee and the components that coincide with ACL injuries. This information will be useful in formalizing a prevention plan. The knee joint, which is considered one of the most important and largest joints in the human body, is responsible for movements such as running, walking, jumping and bearing our own weight. The knee joint is classified as a hinge joint, which permits extension, flexion, and some slight internal & external rotation of the knee. Three components make up the knee joint. Component one is the femur bone also known as the thigh bone. This bone serves as an attachment point for all the hip and thigh muscle groups that act on the lower half of the leg. Importantly, the femur is one of the strongest bones in the human body as it must withstand the immense force from surrounding muscle groups and the weight of a person. The femur is connected to the pelvis, the hip, via a ball & socket joint. A notable detail about this joint is that the head of the femur sits deep in the socket in order to help with stability (Fig.1).
Figure 1: Depicts the attachment site of the femur (thighbone) and pelvis. The head of the femur also known as the ball is connected to the acetabulum (socket). This is otherwise known as the hip joint and was designed to bear weight and give stability. This picture was taken from Orthoinfo.Aaos.org.
The head of the femur also known as the ball is connected to the acetabulum, the socket. This attachment forms a 120-degree angle in most people to make walking efficiently. Figure was taken from Orthoinfo.Aaos.org. In addition to having a deep socket, the hip joint is also encapsulated by ligaments called the iliofemoral, pubofemoral, and ischiofemoral ligaments for stability and security. This attachment via the head of the femur and hip joint creates a 120-degree angle that makes walking more efficient. The lower half of the femur is attached to two bones that form the lower leg. The first bone is the tibia; this is your shin bone, and it is attached to the femur via a ligament called the medial collateral ligament (MCL). The attachment site for the MCL is the medial femoral condyle of the femur to the medial tibial condyle (Fig.2).

**Figure 2:** In this figure, we see the important tendons and ligaments that keep our knee joint in place and give us stability. Two out of the three knee joint components are also shown, including the Patellofemoral joint and the attachment of the femur to the two lower bones via the mcl and LCL. Figure was taken from Johns Hopkins Medicine.
The second bone is the fibula; this is attached to the femur via the lateral collateral ligament (LCL). The LCL is attached at the lateral femoral epicondyle and ends at the head of the fibula (Fig.2). The job of the LCL is to avoid any varus stress across the knee that could result in a torn LCL. In other words the LCL prevents the knee from buckling outwards.

Similarly to LCL, the MCL job is to prevent the knee from bending inwards via valgus stress which is inward force (Fig.3).

**Figure 3:** Above we see the two types of forces, Varus (B) and valgus (C). (A) Is the knee under normal or no forces. Forces B and C can cause injuries to important ligaments such as the LCL, MCL, and the ACL. Figure was taken from science direct.com.
The second component of the knee joint is the patellofemoral joint and is made up of three parts: the patella, quadriceps tendon, and patellar tendon. The patella, which is considered the kneecap, is connected to the quadriceps muscle via the quadriceps tendon and held in place by the patellar tendon that connects to the tibial tuberosity (Fig.2). The function of the patellofemoral joint is for protection, strapping the kneecap in place, and extension of the leg. Knee extension is possible due to the patella increasing the angle at which the quadriceps tendon can exert more force on the femur. This is an important function because it allows us to extend our legs when walking and running. The final component of the knee is the joint capsules, which functions as housing for synovial fluid, the shock absorber our meniscus, and two major stabilizing ligaments called the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) (Fig.4).
The posterior cruciate ligament is located behind the ACL and runs across forming an X, hence why the ligaments are called cruciate. “The PCL is connected to the anterolateral aspect of the medial femoral condyle and the posterior aspect of the tibial plateau. The PCL functions as one of the main stabilizers of the knee joint and serves primarily to resist excessive posterior translation of the tibia relative to the femur” (Logterma et al. 2018). In other words, the PCL prevents the tibia from sliding back when a force to the front of the knee is applied. PCL injuries do occur but are significantly less than ACL injuries. “There are about 200,000 ACL injuries per year in the United States, whereas only 3% of the injured knees have a PCL disruption” (Naraghi and White, 2014). A possible explanation is the PCL being much larger and stronger than the ACL.
due to it being splinted by two other small ligaments and it being extra-synovial or having extra synovial fluid space. Being extra synovial allows the ligaments to have more space for better blood circulation.

After the PCL we get to the final major ligament and the focus point of this paper: the ACL. The ACL is located right in front of the PCL and originates from the lateral femoral condyle, ending in the middle of the intercondylar area (Fig. 4). The way the ACL is attached allows it to be a major stabilizer in the knee and in kinematics that involve angular and rotational movement. Additionally, the ACL prevents the tibia from sliding too far forward. As mentioned before, the ACL is a commonly injured ligament in the knee. Mechanisms that cause these tears are seen as a sudden stop, planting and cutting wrong, a tackle, and suddenly slowing down & then suddenly taking off. Injuries are broken down into either non-contact or contact cases. “The most common are the non-contact injuries, caused by forces generated within the athlete’s body while most other sport injuries involve a transfer of energy from an external source. Approximately 75% of ruptures are sustained with minimal or no contact at the time of injury” (physiopedia contributors, 2014). An example of a non-contact tear would be the case of a 21-year-old female soccer player at Kalamazoo College. This female athlete had a previous injury, a torn Achilles tendon. Her first game back from this injury; the athlete was running back to make a tackle. When she plants to make the tackle, her feet stop but her body continues, this causes her hyperextend and twist her knee resulting in full-thickness tear involving the ACL and some bone contusion involving the pivot shift bone. On the other hand, “contact related ACL tears account for 25% of cases” (physiopedia contributors, 2014). These injuries occur when a force such as a
football tackle is exerted lateral to medial on the knee causing the ligament to tear. An example of this is the case of a first year soccer player on the Kalamazoo College men's soccer team. This player tore his ACL by going to a challenge with his left leg extended, the opponent then kicked the side of his femur which resulted in his femur and tibia colliding and catching his ACL. With this in mind, sports commonly linked with ACL tears are soccer, football, volleyball, basketball, tennis and many more. Knowing which sports are commonly linked with ACL injuries will help us in creating sport specific exercises that will target a niche muscle group or tell us which group of athletes are susceptible and what are common at risk factors.

The Lachman test is widely used to detect an ACL tear. The test is performed by stabilizing the femur with one hand and the other hand on the tibia; once this is done, the hand located on the tibia pulls the tibia anteriorly while stabilizing the femur (Fig. 5).

**Figure 5:** Above is a diagram of how the Lachman test is performed on individuals. This test should only be performed by medical professionals. Figure was taken from research gale.com.
A positive test will show an increased forward translation of the tibia. If the ACL is still attached it will prevent this forward movement. MRI or magnetic resonance imaging is used in further diagnosis of ACL and to check for severity of injury. Regardless of the cause, the tear will be given a grade from 1 to 3. Grades refer to the severity of the tear. A grade 1 tear, ranks the lowest in severity, and is when the ligament is mildly stretched but still provides adequate stability to the knee joint according to Hopkins Medicine. Grade 2, or partial tears, are classified by the ligament being loose and showing signs of damage. Additionally, episodes of instability are associated with a partial tear. The highest grade one can receive is 3; this is the most severe tear and is classified as so when the ligament is completely torn and no longer provides stability to the knee. Once a grade 3 tear occurs, the athlete will often hear a popping sound at the time of the tear, swelling, inability to bear weight on the leg, and instability in the knee joint (Fig.6).
**Figure 6:** Depicts the three grades that are given to ACL tears. Grade 1 is slight stretching of the ligament, as a result it becomes loose. In grade 2, the ligament is loose and some partial tears can be seen, this is also the least common among tears. Grade 3 is a total tear where the ligaments are no longer one whole piece rather the ligament is cut in half. Figure was taken from quaro.com.
The Numbers and difference between Male and Females

The anterior cruciate ligament (ACL) is the most commonly injured knee ligament. “In the United States there are between 100,000 and 200,000 ACL ruptures per year, with an annual incidence in the general population of approximately 1 in 3,500, although the actual incidence may be higher” (Friedreg, 2019). This rate can fluctuate depending on the type of sport, gender, and age of the athlete. For example, age plays a role; the most active period of someone’s life is the 15-23 year range, meaning the older people get the less likely they are to tear their ACL due to inactivity. Of course, there are always exceptions such as active older adults that do not fall in this category. Regarding sports; soccer, football, volleyball, basketball, and soccer are among the top offenders of ACL tears in men and women. According to Joseph et al “The highest rates of ACL injury per 100,000 AEs were reported for girls' soccer (12.2), football (11.1), and girls' basketball (10.3), whereas the lowest ACL injury rates were seen in boys' basketball (2.3) and baseball (0.7). Most boys' ACL injuries were sustained while playing football (71.2% of boys' ACL injuries), followed by soccer (17.2%), basketball (5.5%), wrestling (4.1%), and baseball (2.0%)” (Joseph et al. 2013). For males football is the top offender, due to the nature of the sport e.g. a player falling or tackling another athlete's knees. Not much can be done to prevent a 300-pound lineman from falling on or tackling another athlete. The biggest difference between ACL injury rates is among men and women playing the same sports. It is well known and documented that women are at a higher risk, two to eight times higher, than their male counterparts. These differences get even more drastic when looking at individual sports. For example; the previously mentioned study stated “As for women; soccer is seen as the top offender with (53.2%)” (Joseph et al. 2013). Additional studies also state that soccer and basketball increases the rate of
incidence in women. “The incidence of females to male is 3.5 times greater in basketball and 2.8
times greater in soccer” (Raines et al. 2017). Even at the institution of Kalamazoo College, there
is a clear difference in how many females have torn their ACL versus how many males have
torn their ACL. The 2018-2019 season; soccer, football, volleyball, and basketball teams saw a
total of five people tear their ACL during the season, of the five, four were female athletes and
one was a male athlete. Two of the four females were volleyball player, one was a basketball
player, and the fourth was a soccer players.

These differences between men and women stem from a number of factors, including
hormonal, muscular structure, anatomical differences, femoral notch, and biomechanical factors.
Cho et al states that, “The categories of risk factors were anatomic, environmental, hormonal,
and biomechanical. Neuromuscular and anatomical factors appear to be the most important
reason for the higher rate of ACL injuries in females compared to males” (Cho et al. 2014).
Neuromuscular factors such as weakness in glutes, thighs, hips, and core stability have been
associated with ACL injuries. According to Smith et al, “It is hypothesized that “deficits in core
neuromuscular control can cause unstable behavior and allow for a higher probability of injury
throughout the kinetic chain” (Smith et al. 2012). The core and the muscle group within it are
responsible for maintaining stability and the transfer of energy from larger to smaller body parts.
A poor core stability and control could put an athlete in an at risk position. In other words, the
athlete could be off balance when he or she is planning, cutting, or suddenly stopping resulting in
a torn ACL. Furthermore, anatomical structures such as femoral notch, which is where the ACL
is attached, tibial geometry, and laxity and alignment of knee joints are plausible reasons why
women have higher rates of ACL tears. Studies looking at femoral notch have revealed that
women have a significantly smaller notch width when compared to men. The study conducted by Smith et al states, “This is believed to be a problem because in certain movements the ACL can become impinged thus increasing the risk of a tear. Although, it is unclear whether it is the notch itself, the volume of the ACL, or a combination of both that increases the risks” (Smith et al. 2012).

Another component that could give insight to why women are more susceptible is the laxity and alignment of the knee joint. An increase in knee joint laxity, e.g. how flexible a ligament or tendon is, has been correlated with an increased risk for a torn ACL. Related studies have shown that women have a greater knee joint and overall joint laxity than men: “Females have greater knee and general joint laxity than males. The use of the KT-1000 arthrometer to measure anterior-posterior knee joint laxity is a popular technique and specific to the ACL. Increased generalized joint laxity is a risk factor for ACL injury in both males and females, and increased AP knee joint laxity (KT-1000) is associated with increased risk of injury”(Smith et al. 2012). A possible explanation to increased laxity in females are female related hormones that affect muscle, bone, and other connective tissue. A study conducted by Faryniarz et al revealed that, “Estrogen and relaxin receptors have been found in the human female ACL” (Faryniarz et al. 2006). These hormones are believed to increase the laxity of a ligament, which in return increases the risk of rupturing an ACL. Other studies suggest that the increased laxity in females Anterior cruciate ligament is due menstruation. Dehghan et al. 2016 states; “there may also be an association between ACL injuries and stages of menstrual cycle. Occurrence of ACL injuries during the ovulatory phase (mid cycle) is more frequent than the luteal phase. During this period, estrogen and relaxin levels are high; therefore, activation of the estrogen and relaxin receptors
may be increased” (Dehghan et al. 2016). Additionally, biomechanics of an athlete play a role in increasing the risk of female susceptibility. “Laboratory studies have shown that females land from a jump and perform cutting and pivoting maneuvers with less knee and hip flexion, increased knee valgus, increased internal rotation of the hip coupled with increased external rotation of the tibia, and increased quadriceps muscle activation” (Smith et al. 2012) These movements all cause excessive force on the ACL ligament increasing the risk of a tear. Women, when performing actions such as, running, jumping, and planting; they tend to land with their knees `Turned in” and are not as “bent” and run with a “rigid” posture (Dr. Galland). On the bright side, with the help of prevention training and proper guidance the biomechanical and neuromuscular addressed to help reduce the possibility of injury.
Reconstruction process

Once an ACL has been torn, the athlete will either undergo surgery or, depending on the severity of the tear, will not undergo surgery and be sent to a physical therapist for rehabilitation. If an athlete decides to have surgery or their physician requests it, the rupture ligament is replaced with a graft tendon. Two types of grafts are used: autografts and allografts. Autografts are grafts that are harvested from the athlete’s body and allografts are taken from cadavers. Each graft has its own pros and cons; for example, surgery time is greatly reduced when using allografts because the replacement tendon is already sterilized and prepared for the surgery. The downside to using allografts is that donor tissue might not be readily available, and the price of allografts are significantly higher than autografts according to Desio sports medicine. According to a primary physician on Desio sports medicine website; Allografts can be rejected by one’s own body (Dr.Desio). This will cause an immune response against the graft tendon since it’s a “foreign” object, causing the graft not to heal properly and resulting in failure. On the other hand, autografts practically remove the risk of rejection and failure due to the graft tendon being from the athlete’s own body. Cons of autografts are site morbidity, multiple incisions, and a prolonged surgery time. The extended time is required due to having to harvest and process the graft before reconstruction of the ACL can begin.

Regardless of the type of graft, the graft tendon will come either from the hamstring tendon, patellar tendon, or quadriceps tendon (Fig.7). The type of graft used will depend on
patient factors: “Patient factors including skeletal maturation, gender, activity, and preference are also taken into account for graft selection” (Ochi et al. 2016). That being said, the group that is being targeted in this paper is active collegiate athletes and the end goal for most of these athletes is a complete return to high activity levels. “Complete return to preinjury or higher activity level is one of the goals for patients who desire to participate in sports after ACL reconstruction. However, the best graft choice for return to sports has not been addressed because not only the reconstructed knee function but many other factors, such as fear of re-injury, attenuated motivation in competitive sports, change in lifestyle, and difference in criteria for return affect the postoperative activities” (Ochi et al. 2016). In our case, the most commonly used graft for active collegiate athletes is patellar tendon graft. “Patellar tendon graft (BPTB) has been widely used in the primary surgical reconstruction of the ACL due to its strength, stiffness, potential for bone integration, and biomechanical studies on cadavers have shown that the middle third of the BPTB graft has an initial strength and stiffness comparable to, or maybe even greater than, those of the native ACL” (Cerulli et al. 2013). Similarly, the hamstring tendon (HT) graft has been shown to have similar outcomes and tensile strength to BPTB, but a common issue with both grafts is donor site morbidity. Donor site morbidity refers to the possible complication at the site where the graft was taken from.
Once a graft has been chosen, the athlete will undergo ACL reconstruction surgery with open surgery and arthroscopy. “Before the ACL reconstruction process begins, your surgeon will examine your knee arthroscopically, and repair any additional damage to the knee, such as a torn meniscus, or worn articular cartilage” (Sharma, MD). Once this is done, the reconstruction producers can be carried out. The start of the surgery is marked by the surgeon making two incisions where the tunnels for the graft ACL will be drilled. Using a motorize device called a shaver, the ruptured ACL is removed and the surrounding area is cleaned of any remaining debris, as seen in the figure on the right. The attention is now directed to the graft. If one chooses
an allograft, the graft will be already sterilized and harvested; autografts require the tendon to be harvested, sterilized, and processed. This can be seen in the figure below in figures 8, 9, and 10.

Figures 8, 9, &10: starting from top left to right is figure 8 and 9. The bottom figure is figure 10. Figure 8 depicts the surgeon checking and clearing out the torn ACL. A medical shaver is used to remove the damaged ACL. Figure 9, is the harvesting of the autograft. This specific graft is a patellar tendon graft. Figure 10, show the replacement graft prep and sterilized. These figure were taken from Sharma. MD.
Once the graft tendon has been harvested, drilling of the tunnel can now be done. The drilling is done by using a medical drill that is directed by a drill guide (not shown) in order to assure precise drilling (Fig. 11).

![Figure 11: Above, the drilling site of the canal where the replacement graft will be housed and anchored at. Figure was taken from Sharma, MD](image)

The drilling of the canal is done by using a medical drill. These tunnels will serve as the anchoring point for the graft ACL. “The graft is then placed through the tibia, through the knee joint, and into the femoral drill hole” (Sharma.MD). Screws are placed at both ends of the tunnels in order to secure the graft in place (Fig.12).
Once the tendon has been secured into place, the procedure is practically done, and the surgeon sutures the incisions up and prepares everything for post operation. The average recovery time for an ACL reconstruction is 6-9 months which includes extensive physical therapy work to return to a high level of play. Non-Surgical procedures do not require surgery rather they require extensive physical therapy to work on stabilizing and strengthening surrounding muscle groups. Many physical therapy flow charts have athletes doing prevention and recovery exercises. In all, it is important to realize that with modern medicine ACL tears are becoming less and less career ending injuries and more season ending injuries.
Why Women?

More previously mentioned, female athletes are at a two to eight time’s greater risk of tearing their ACL than male athletes. This increase is due to a number of physiological and biological differences between males and females that put female athletes at a disadvantage. This discrepancy alone should be enough reasoning to focus on female athletes and to create a prevention plan for females. Additionally, the research also indicates that the implementation of prevention programs significantly reduces the risk of ACL tears. During 1999, Hewett et al conducted a study on the effects of neuromuscular training with male and female high school sports teams such as soccer, volleyball, and basketball. The 6-week program included exercises that focused on plyometric, weight training, and proper jumping and landing technique. Which resulted; “The incidence of serious knee injury was 2.4 to 3.6 times higher in the untrained group than in the trained group, depending on whether the sport of volleyball was included. Untrained female athletes were 4.8 to 5.8 times more likely than male athletes to suffer a knee injury, and trained female athletes were 1.3 to 2.4 times more likely than male athletes to suffer a knee injury. These results indicate that neuromuscular training may decrease injury risk in female athletes” (Hewtt et al. 1999). Although these numbers are small and the study was not randomized, it still has significance; that prevention programs that include multifactorial approaches may minimize the risk in female athletes. This is of course assuming the athlete follows the program and is disciplined enough to stick to the prevention program. In any case; the simple fact that women have physiological and anatomical hurdles that cause them to have
higher rates of ACL tears should be more than enough reasoning to focus on women, especially when studies reveal that the risk can be reduced with prevention programs.

This was not the only reason why this prevention program is focused on female athletes. Personally, I have been lucky enough to shadow athletic trainers and physical therapists that have worked with female athletes who have torn their ACL. This experience has shown me first-hand the physical and mental demand an ACL tear has on an athlete. I’ve seen athletes cry due to pain, fear of not knowing if they'll be able to play again, and frustration of wanting to get back to a high level of play. Additionally, I am close friends with some of these female athletes that have torn their ACL at Kalamazoo College and each time I speak to them there's a sense of doubt in their voice when they speak about the recovery process or their overall status. Being a former collegiate athlete, having a sense of doubt meant not performing well. Having said that it felt as if athletes had no hope of returning from the injury and that is what resonated with me. Having this in mind, one can easily see why the emphasis is being put on female athletes. Additionally, even if this program does not get used, at least it is raising awareness to an issue that can often be overlooked in the fast paced world of collegiate sports. Overall I would say the coupling effect of personally seeing the mental and physical effects, research evidence what these female athletes go through the recovery process and the vast difference of risk between females and male was enough motivation to focus on female athletes.
The Prevention Plan

When synthesizing a prevention plan; a few key factors were taken into consideration. Physical therapist Theresa Chiaia states; “Successful injury prevention programs may differ in specific exercises and drills but they share a common focus: improving flexibility, strength (particularly of the core, hips, and legs), balance, agility, and your ability to jump and land safely. Having this in mind the muscle groups that should be targeted when working on those key factors are core, quadriceps, hamstring, calves, glutes, and hips”(Chiaia T, 2009)(Fig.13).

![Image of muscle groups](image)

**Figure 13:** Above, a figure of each muscle group and function are shown. The muscle groups targeted in this prevention program are core, hip, glutes, hamstring, quadriceps, and calf muscles. Figure was taken from Neurokinetic Therapy.

The strengthening of said muscle; will allow for better dispersion of forces throughout those muscles rather than on the knee. That being said, the goal is to strengthen the surrounding
muscles, which will allow for forces that act on the knee to be better dissipated and absorbed by those targeted muscle groups.

Glutes and hips are important in preventing ACL tears, because they prevent the knee from deviating inward from exercises or movements that cause valgus stress on the knee. This means that movements such as jumping, planting, changing direction, and landing all are causes of valgus stress. A weak or lack of control and stability in the hip and glutes will not be able to properly prevent the knee from deviating inward, in return increasing the risk of tearing your ACL. Muscles such as the core are responsible for stabilizing the body and balance. This allows us to move in any direction without falling over or being off balance in movement like running, changing direction, cutting, and landing on one leg. Being off balance in any of these movements could increase the risk of your ACL being torn. Therefore a strong and solid core is necessary in prevention programs. Hamstrings are important; “There is evidence showing that female athletes who suffered an ACL injury subsequent to strength testing, had reduced hamstring but not quadriceps strength and conversely, those who did not go on to ACL injury had adequate hamstring strength (Myer et al. 2009)”. This is due to the hamstring acting on the tibia and pulling it backward, which serves as a dynamic protector of the ACL, according to physiotherapist Benjamin Wright (Wright B, 2017). This means that weakened hamstring will not be able to pull the tibia back effectively, which in return lowers the ability to reduce the stress on the ligament when the leg is extended outward. If we target the hamstring we must also target the quadriceps muscle as both of these muscles work in close synergy, working together to perform a movement such as running. We also do not want to have a muscle imbalance between these two muscles as this will cause one muscle group to over compensate for the weaker one,
increasing the risk of the muscle being injured. The calves’ muscles play a vital role in facilitating plantarflexion and assist in knee extension, meaning they help with movements such as running, walking, and jumping. That being said, having weak or weakened calf muscle will lead to improper running, walking, and jumping technique further increasing the risk of a torn ACL.

The prevention program below is broken into two parts, both parts focus on targeting those key muscle groups but have different approaches. The first part of the program will focus on warming up and getting those important muscles ready for a competitive match or event. It will also focus on improving proper biomechanics in movements such as jumping, landing, cutting, and changing direction. The second part of the program focuses on muscle building and strengthening of those key muscle groups. This part of the program can be slightly customized as many of them can be increased in difficulty by adding more weight. In all the proposed prevention program attempts to take every female athlete into consideration, but will work for one person might not work for someone else. That being said it is important to discuss with a Physical Therapist or athletic trainer if this program is the right fit for you.

(The hard copy will have the prevention program after this page. I couldn't figure out how to transfer from word doc to google without messing up the font and formatting)
Conclusion

In summary, this literature review’s goal was to inform the reader on why women are more susceptible to ACL injuries. Factors such as hormones that cause women to have loose ligaments, poor neuromuscular control and development, anatomical differences such as wider hips and Q-angels, and poor biomechanics have correlated with a greater risk of ACL injury. Some factors such as; anatomical, hormonal, and some neuromuscular factors are prevalent in females due to predetermined evolutionary hurdles. On the other hand, factors such as; poor neuromuscular control and development and biomechanics can be addressed and worked on to mitigate the risk of ACL injuries. That being said, this literature review has an additional component; which is to provide a two-part prevention program that can be used prior to a competitive event as a warm up or to be integrated with a workout plan. Overall with the advances in the medical field and technology, ACL injuries are more or less season ending injuries rather than career ending injuries.
Annotated Bibliography

   - This article gave information on the Posterior Cruciate Ligament. This information gained from this article was used to draw composition points between the ACL and PCL. This information was important to show why PCL injuries are less common than ACL injuries.

   - This article provides statistics on how often ACL injuries occur when compared to PCL injuries. The article also gave the total number of PCL tears from total number of knee injuries.

   - This webpage gave useful information on the mechanism of injuries when it comes to ACL injuries. Additionally it breaks down each type of mechanism of injury and gives it a percentage of how often those mechanisms of injuries caused ACL tears.

   - This source was useful as it provided useful information on the total number of ACL ruptures per year and a rate of incidence in the general population. Additionally it provided statistics on ACL injuries.

   - This article gave additional information on the difference between male and females with respect to ACL injuries. It also reinforced important points in this paper.

   - This article played an important part in providing risk factors that cause women to have higher rates of ACL injuries than their male counterparts. It also gave me additional sources to reinforce those factors.
   - This article was used to provide more information on certain factors that cause women to be more likely to ACL injuries. One factor is hormones, certain hormones, which are talked about in this article case women have less bone mass density and produce less red blood cells.

   - This article provided important information on the difference in rates of ACL injuries between male and females’ athletes. This source also broke it down to specific sports and highlighted the higher at risk sports in male and females

   - This book was useful in giving more information on ACL injuries additionally it had similar structure to this paper.

    [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4295687/#b9-18-24]
   - This paper gave me additional information on other hormones that might cause women to have a higher risk of tearing their ACL. This paper was also used to reinforce the idea that women have a higher risk of tearing their ACL.

    [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4282454/#b21]
   - This source provided useful information on the steps of ACL reconstruction surgery and provided useful images to go along with the step by steps and process of ACL reconstruction.

   - This article was useful in providing information on how the important muscles that are correlated with ACL work and what happens to them when an ACL injury occurs. It also gave insight on why these muscles should be targeted in ACL prevention plans.

   - This website was used in providing information on the differences of autografts and allografts. These are the two main types of graft used in the ACL surgeries.

- This website provided more evidence and factors that support the fact that women have higher rates of ACL tears and why these rates are higher than their male counterparts.
Abstract:
The purpose of this program is to help minimize the risk of ACL injuries in females. This TWO-PART program focuses on key muscle groups associated with ACL injury risk such as core, hip, glutes, calves, quads, and hamstrings. Additionally, the program also works on proper biomechanical techniques. This program is split into two parts: one for pre-game and one for Pre/during/post workout.

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PRE-GAME:

The first part of this prevention program is to be completed before a game and integrated with a pre-game warm up. The focus is to get the muscles firing and warmed up for a competitive game. These exercises target the hips and glutes, hamstring, quadriceps, core, and calves. These muscles are important in executing movements that are correlated with ACL injuries such as jumping, cutting, landing, and sudden stops. Additionally, these 5 exercises also help with certain biomechanical differences that female athletes face when playing sports. Biomechanical factors such as landing with knees valgus, relying on outside leg instead of the inside cutting leg, and poor jumping and landing technique are all factors that increase the risk of tearing ones ACL. This program can be done as a team or individually.
ACL PREVENTION

PREGAME OPTION

Exercise 1 – Resistance Banded Body Dashes (1x10)

Using a heavy-duty resistance band, hand one end to a teammate or tie resistance band around a sturdy pole.

1. Begin the exercise by starting in an athletic position. (when the resistance band is tight and begins to pull you back is when you begin to return to starting position)

2. Dash to the right, return to start position.

3. Dash to the left and return to start position.

4. Dash to the center, and return to the start position. (This is one set, do 10).

Tips:

Touch the ground to focus more on your “cutting inside leg” and to help improve your technique.

Purpose: Works on proper cutting technique, Women rely on their outside leg when cutting which increases the risk of an ACL tear.
ACL PREVENTION

PREGAME OPTION

Exercise 2 – Side shuffles (2x10)

(1) Start in an athletic position

(2) Leading with one-foot shuffle to the left or right 5 times

(3) Then switch sides. Make sure to lean and hold for a few seconds

(4) Return to resting position after switching sides

Purpose: Works on warming up the lower half of your body, as well as serving as a functional exercise to help with cutting and planting.

Tips:

Just like the body dashes before, make sure to maintain proper technique through the whole exercise to maximize the effect.
ACL PREVENTION

PREGAME OPTION

Exercise 3 – Scissor jumps (1x20 or 2x10)

(1) Begin this exercise by squatting as seen in the second picture.

(2) After this Jump.

(3) While jumping, switch the leg and land firmly. Do 10 on each leg. Make sure your knee does not deviate inward/medial or make sure your knee does not go past your toes.

Purpose: Works on warming up the hip, quads, and hamstring. Also works on planting and proper landing technique.

Tips:

It’s better to take it slow and flow a proper range of motion to get the most out of this exercise. Focus on planting firmly and maintaining a strong core for stability.
ACL PREVENTION

PREGAME OPTION

Exercise 4 – Skiers (2x10)

(1) Begin this exercise by standing on one leg or both.
(2) Jump across and land firmly with your other (single leg)
(3) Hold landing for a few seconds and then repeat the process again. Make sure you maintain good balance and stability. Emphasis should be on the technique rather than quantity

Purpose: Works on proper jumping and landing technique. Stability and balance.

Tips:

Focus on quality over quantity, work on balance and stability, so if this means take it slow then so be it. Make sure your knee does not go inward.
ACL PREVENTION

PRE-GAME OPTION

Exercise 5 – 3 step decelerations (1x50-70%, 1x90-100%)

(1) Start by sprinting at desire speed for about 20 yards
(2) Right before the end perform a 3-step deceleration as indicated above in figures 3,4, and 5. Make sure to exaggerate the chopping motion to get the most out of this exercise.

Purpose: Helps with proper stopping technique and preload cutting/ weight bearing leg.

Tips:

Swinging your arms when performing the 3-step deceleration will help with proper technique.
PRE/DURING/POST WORKOUT OPTION:

The second portion of this prevention program focuses on strengthening those previously stated muscle. Strengthening of those muscles allow for better dispersion of forces that are being acted upon the knee. An added component to this part of the prevention program is that the difficulty can be increased by adding weights. This ability to add weights contribute the focus on further strengthening important muscle groups.
ACL PREVENTION
PRE/DURING/POST-WORKOUT OPTION

Exercise 1 – Clams with leg extension (1x10 each leg)
(1) Place a resistance band around your knees and lay down side ways. Pull your knees up to a 90-degree angle.
(2) Begin the exercise by opening your top leg like a clam, hold for a few seconds.
(3) After this extend your leg out, hold for a few seconds. Make sure you do not let the resistance band snap your leg down.
(4) Once this is completed pull your leg back and return to start starting position

Purpose: Targets hips and glutes, quads, and hamstring

Tips:
To increase the difficulty of this exercise, add weights to your ankles, use a tighter resistance band, or reduce the speed in which you open and extend the leg.
Exercise 2 – Rocking Calves Raises (1x10)

(1) Begin this exercise by rocking onto your heels.
(2) Shortly after rocking onto your heels rock onto your toes to activate your calf muscle and then repeat it again.
(3) Right after you rock on your toes for the second time jump, make sure to not bend your knees.

**Purpose:** Targets the calve muscles, which often get overlooked in ACL prevention programs.

**Tips:**
To increase difficulty, use dumbbells, ankle weights, or a barbell. Also, do not add too much weight, it’s better to have a full contract rather than struggle with a weight.
ACL PREVENTION

PRE/DURING/POST - WORKOUT OPTION

Exercise 3 – Glute Bridges (1x10)

(1) Begin this exercise by laying down, as seen in the first figure.

(2) Squeezing your glutes, pull your body level so that it is a level plane. Hold this position for a few second, your body should not sag at any point must be rigid and solid.

(3) Once this is done, return to resting position.

Purpose: Targets the hip glutes, hamstring, core, and quads.
A very good exercise.

Tips

To increase the difficulty, add weights to the mid-section, do single leg w/ ankle weights, or add a barbell with weights onto your mid-section.
ACL PREVENTION

PRE/DURING/POST - WORKOUT OPTION

Exercise 4 – 4-way hip (1x10 on each leg)

(1) Place a resistance band around your feet. Additionally, ankle weights or a pulley machine can be used as an alternative.

(2) Starting with one leg, move the starting leg laterally return to starting position.

(3) With the same leg go out forward, backward, and upward thrust, returning to resting position after each time.

Purpose: Targets many of hip and glutes muscle that often get overlooked in prevention programs or in general

Tips

To increase the difficulty, add ankle weights or use a heavier duty resistance band. Also keep your back straight and in line with the leg that is being worked on.
ACL PREVENTION

PRE/DURING/POST - WORKOUT OPTION

Exercise 5 – Split Squats (1x10)

(1) Begin this exercise by starting in the position demonstrated in the first figure.
(2) Squat with the one leg, make sure your knee does not deviate medially/ inward and that it not over your toes. Hold it for a few seconds.
(3) Return to starting position.

Purpose: Targets quads, hips and glutes, and hamstring

TIPS:
Use dumbbells, squatting rack, or a barbell to increase the difficulty of the exercise.