EXERCISE & SPORT NUTRITION REVIEWS

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Factors that affect ACL injury risk and possible protection

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Abstract: ACL injuries are the most devastating to an athletes career. Not only does the injury immobilize you for the first couple of months after surgery, but you must also teach your body how to function normal again. There are several factors that can contribute to an increased risk of injury to the ligament. There are two types of factors: modifiable (quadriceps strength, hamstrings strength, angle flexion of the hip, and axial compression forces due to improper form) and unmodifiable factors (Gender, family history, and genetic predisposition). There are also many different ways to lessen the impact of most of these factors. For modifiable factors, one can increase quadriceps and hamstrings strength to create more stability in the knee, decrease hip angle flexion to increase flexibility and range of motion, and improve their form to lessen the load on the ACL from axial compression forces. Unmodifiable factors are a little trickier to fix. Because these deal with genetic factors and skeletal structure there is not much one can do outside of surgery. The athlete can make sure to do a proper warm up to get the body ready for physical activity or wear proper equipment to counteract some of the structural defects of the body. A knee brace is a great tool to use before and after an ACL injury. The brace with add extra stability in the knee and prevent the tibia from moving too far anteriorly or posteriorly to the femur. While these prevention strategies are working for the present athlete, there is still much room for future research.

Keywords: ACL, Injury, Repair, Genetics, Influencing Factors, and Protection

1. Introduction

An Anterior Cruciate Ligament (ACL) tear is one of the most detrimental injuries that can occur to an athlete. The ACL helps stabilize the knee by preventing the tibia from slipping out in front of the femur while also limiting the allowed amount of rotation of the knee. If an athlete were to tear this it would be extremely difficult to compete at a high level and increases the chance of further injury, like the cartilage in the knee, if not repaired immediately. Although this does not happen often to most athletes it is still a cause for concern and it is important to know more about this injury to prevent it. The purpose of this review is to identify factors that can have an impact on an individual's chance of injuring their ACL and possible ways to prevent future damage.

2. Methods

A comprehensive review of the information was made by using the PubMed database of the US National Library of Medicine of the National Institutes of Health to search for articles relating to the subject of interest. The search was done using the keywords: ACL, injury, repair, genetics, influencing factors, and protection. The articles that were chosen were picked from a database of over 700 articles.

3. ACL injury and repair

3.1. Anatomy of ACL and injury

The ACL is one of the most important ligaments in the knee. The ligament connects from behind the femur to the front of the tibia. Its main function is stability of the knee; more specifically, preventing the tibia from shifting anteriorly (in front of) to the femur [1]. It takes an extreme amount of force to rupture the ligament, but if one was to tear the ACL then the integrity of the knee's stability is lost. It makes everyday movements, even walking, difficult and can lead to injury in other parts of the body. If the ACL is not repaired in time then the cartilage in the knee can be degraded from the constant moving of the tibia. The ligament in the knee is avascular, meaning that there is no blood flow being supplied to structure. The ligament has to be extremely

strong to absorb the constant force generated from movement. To make sure that the knee is strong enough, it limits the amount of blood vessels in the structure and increases the amount of tough connective tissue. Because of this, if the ligament is injured then it cannot heal by itself.

3.2. ACL Repair

Due to the fact that the ACL cannot repair itself like muscular tissues, it must be repaired through surgery (see Figure 1). ACL reconstruction is done by creating a graft from either the hamstring or the patella tendon [2]. During the surgery the surgeon will drill holes on the superior anterior area of the tibia and at the posterior inferior area of the femur. Next the graft is pulled through the holes and fused to the bone, creating a new ACL ligament. To make sure the new ligament heals properly to the bone the patient is placed in a locked brace for 1-2 weeks. After that time they may start physical therapy to initiate movement and build strength back in the leg. The recovery process takes 6-8 months, depending on how well physical therapy goes and muscle strength before the surgery [2].

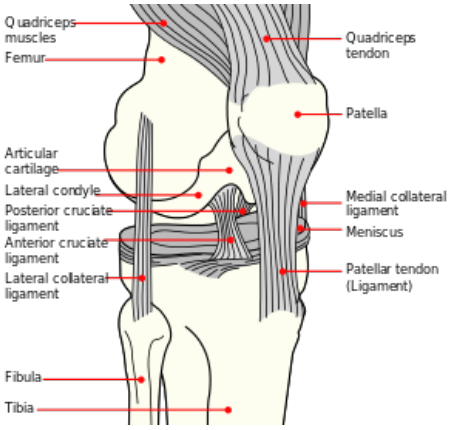

Figure 1. ACL reconstruction surgery. From Wiki Commons.

4. Modifiable Factors that Influence ACL injury

4.1. Quadriceps

It has been theorized that for open kinetic chain activity, such as swimming and kicking, the hamstrings are primary ACL agonists and the quadriceps are the main ACL antagonist [3]. For activities such as running, jumping, and walking (closed kinetic chain activities) it has been thought that the quadriceps are the main ACL protagonist [4]. So it is safe to assume the quadricep muscles are important for ACL stability and protecting the ligament from injury. A study by Marko Bodor [4] looked at the force vectors of different muscles acting on the knee. In the research there was an emphasis on closed and open kinetic chain situations and how the quadriceps responded to both types of movements. During both kinetic chains, when the knee extends due to quadricep contraction there are forces acting on the origin (femur) and insertion (tibia) of the muscle. The difference is during the open chain the hamstrings are generating more force, which lessens the work load of the quadriceps. In closed kinetic chains, when the knee extends the quadriceps are the main agonist of the motion and generate the most force. These two chains support the claim that the quadriceps are important for ACL support, but also "that during closed kinetic chain activities, the quadriceps protects the ACL regardless of the activity of the hamstrings" [4]. Most tears of the ligament occur during activities that include walking, running, or jumping (all closed kinetic chain situations). With this information it can be assumed that quadriceps are the main protagonist of the ACL and play an important role in its protection [4]. It is imperative to keep the quadriceps in good health and muscular strength. Any compromise of the muscle can lead to an immediate increase in risk of tearing the ACL.

4.2. Hamstrings

The hamstrings have been linked to the protection of the ACL. While the quadriceps are nearly twice as strong as the hamstrings [5] if the hamstring muscles were to give out then the quadriceps would absorb all the force from physical movement. Since the quadriceps are the primary protagonist in the protection of the ACL [4] if they begin to fatigue then the ACL is put at a greater risk of injury. Because of this it is important to maintain both quadriceps and hamstring muscle strength. However, an excessive increase in hamstring strength could have a negative impact on the ligament. In a study by E.B. Simonsen et al. [6] isometric contractions of a side-cutting maneuver were measured by EMG. The EMG result showed that the quadriceps were the main contractors with a co-contraction by the hamstrings [6]. It has been speculated that if the hamstrings were to increase in strength and size then it would make it difficult to perform the side-cutting maneuver in the experiment and other movements like it. This would decrease the efficiency of the movement and possibly increase the load on the ACL. While a decrease in hamstring strength would increase the load on the quadriceps and increase the risk of injury of the ACL if the quadriceps start to fatigue, an excessive increase in strength could decrease the range of motion (ROM) and increase the risk of injury.

4.3. Hip Angle

It has also been shown that hip rotation is correlated with a higher risk of ACL rupture. Video analysis done by Boden et al. [7] showed that individuals who experienced ruptured ACL injuries had higher hip flexion angles when they come in contact with the ground (50.1 degrees versus a normal 25.8 degrees). This type of hip angle would put the torso in more a posterior position to the knee and increase strain on the ACL. It has also been shown that there is a correlation between low hip rotation ROM and higher possibility of ACL failure [8]. When landing from a jump it is important to have good position and proper form. If an individual has restricting hips that put the body in a posterior position in reference to the knee then it can cause the tibia to shift anteriorly upon impact. The ACL prevents excessive anterior movement of the tibia in orientation to the femur [1]. If there is too much force acting on this anterior movement then the ACL could give and tear completely. Being able to increase ROM of the hips will put the torso in good position and allow the body to absorb that force in more places than just the knee. Distributing the load throughout the body puts less strain on the ACL and protects against injury.

4.4 Axial Compression Force

In recent studies it has been confirmed that excessive axial compression force on the tibiofemoral joint causes an increased strain on the ACL [9] [10]. This is especially true in the shift from non-weight bearing to weight bearing forces. A study by Meyer et al. [11] looked at microscopic cracks between the cartilage and bone in the knee caused by compressive forces. These damages correlated with MRI results the showed damage to the microscopic damage of the ACL. In most athletic activities, a decrease in efficiency from bad form can cause an increase in forces that can be avoided with correct positioning. Over time these microscopic damages done to the ACL can add up until there is a complete rupture. Most often complete failure of the ACL can occur in ranges of 1,812 N to 2,659 N [12]. With excessive axial compression of the knee, that complete failure can happen at 2,900 N to 7,800 N [13]. It is recommended to improve the efficiency of movements so that an athlete may decrease both the load on the ACL and any chance of failure of the ligament.

5. Unmodifiable Factors that Influence ACL Injury

5.1 Gender

Differences in gender can affect the baseline risk of ACL injury. It has been identified that female athletes have an increased chance of injuring the ACL [14] [15]. Female athletes are 3.5 times more likely to tear and ACL in basketball and 2.67 times more likely in soccer compared to male athletes [14]. Right not very little is known about the differences in sexes and any correlation between ACL injuries in males and females. One research conducted by Muneta et al. [16] took measurements from the cadavers of Japanese knees to determine a link between notch size and ACL ruptures. Regardless of the gender it was shown that those with smaller notch sizes had a greater risk of injury [15] [16]. However, a study done by Sheiboume et al. [17] reported a correlation between intercondylar width of the femur and ACL ruptures. The data showed that female athletes were discovered to have narrower notches than males [17]. One last possibility to the high risk of injury in females versus males is that females tend to have thinner ACLs that high higher levels of flexibility than males [14]. Although these structural differences cannot be change it just means that females have to be more cautious than males when performing physical activity. They must make sure their bodies are ready for physical activity with proper warm ups to decrease stiffness and increase range of motion (ROM).

5.2 Family Predisposition and Genetics

Family predisposition could be a cause of ACL injuries in some individuals. Two case studies have been conducted to answer the question as to whether family predisposition can have an effect on ACL injuries [14, 18, 19]. The first case used a questionnaire to determine a correlation to ligament injuries to primary relatives [19]. This experiment showed that subjects were 35% more likely to injury their ACL if they had a primary family member with previous history of ACL tears. The experiment by Flynn et al. [18] proved that those who injured their ACL were twice as likely to have a family member with an ACL injury than those in the control group (those who have not torn their ACL).

There are 3 genetic factors that all have an influence on ACL tears. One group of researchers published 4 different articles that identify each gene and their relationship to the injury. One gene (COL1A1) encodes a protein chain within type I collagen, a major structural component of ligaments [14]. An underrepresentation

of the genotype increases the risk of injury to the ACL [20]. The COL5A1 has been linked to the tearing of the ACL in females [21]. This gene, found in ligaments and tendons, codes a protein chain in type V collagen [14]. The third gene, COL12A1, codes a protein chain in type XII collagen; thought to control fibril diameter of ligaments [22]. An overrepresentation of this gene limits the ligaments ability to change its diameter based on different forces and increases its chance of injury. The table below is a summary of the different data found in articles throughout this section.

Table 1. Genetic genes correlated with ACL injury. From [14].

Reference	Study Design	Participants	Injured Cases	Risk Factors
Flynn [18}	Matched-Case Contol	342	171	Family history of ACL tear
Haner [19]	Matched-Case Control	54	31	Family history of ACL tear

6. Possible Prevention of Injury

6.1 Modifiable Factors

The modifiable factors above, such as hamstring and quadricep strength as well as hip flexibility, can easily be fixed so that the probability of injury decreases substantially. As stated earlier the hamstrings and quadricep muscles are important for stability of the knee and reducing the load of force on the ACL [23]. By maintaining these muscles they will be more inclined to resist fatigue and prevent unnecessary compression on the knee. Also keeping up with daily stretching of the hip flexors can improve their angle of flexion. By increasing ROM there will ultimately be less anterior shifting of the tibia [1]. If you limit the tibia from shifting there will be rubbing of the bone on the ACL, since shear force is the number one injury factor of the ACL, this will exponentially diminish any chance of injury [1].

6.2 Unmodifiable Factors

Unmodifiable factors are harder to fix. Unfortunately, there are some asymmetrical features of the knee that cannot be fixed with just strength and flexibility. Although these features cannot be repaired without some type of extensive surgery, a brace will prevent excessive anterior movement of the tibia past the femur {24}. This will decrease the shear load of the knee during weight bearing and non-weight bearing movements [24]. It has been tested that knee braces can decrease the lateral blow to the knee during activity by 20-30% [25]. Even though the braces cannot change the asymmetrical features of an at risk knee, it can prevent or dampen injury with stability and absorbing forces due to high activity. One unmodifiable factor that most people over look is the weather. Colder weather can increase muscle stiffness and increase risk of injury. It is best to get a proper warmup to prepare the body and wear the appropriate clothing to overcome the cold climate.

7. Summary and Practical Applications

Genetic predisposition can play a huge role in determining your chances of tearing your ACL. If an individual has a family history of the injury, then it is wise to take precautionary measures to attempt to decrease the odds of tearing it yourself. Although you cannot alter the unmodifiable factors discussed above, you can use extrinsic tools to shift the favors. Braces are a great tool to use as they keep the knee in line and lower the odds of error from the skeletal structure, footwear with good shock absorbing abilities can help lower the force pounding on the ligament, and doing a short warmup routine can aid in getting the body ready for intense physical activity.

Modifiable factors are easier to control. Strengthening the quadriceps and hamstring muscles will allow the force generated through activity to be distributed to places other than the ACL. They will take the force created from lateral movements and take it upon themselves to limit the strain on the ACL. If the hips are too tight they limit the ROM of the entire body and can increase the load in places that otherwise wouldn't have much strain during exercise. Opening up the hips and allowing them to move freely can increase the stiffness of the ACL, increasing the amount of force that can be absorbed before strain onset occurs. Researchers are still looking for more answers on how to alter the unmodifiable factors, but until then it is up to the athletes to take care of their body. Listen to the signs and know how to repair your body. ACL injuries are avoidable, if you take precautionary measures to maintain your health and strength.

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