Understanding the Intrinsic and Extrinsic Factors of ACL Injuries

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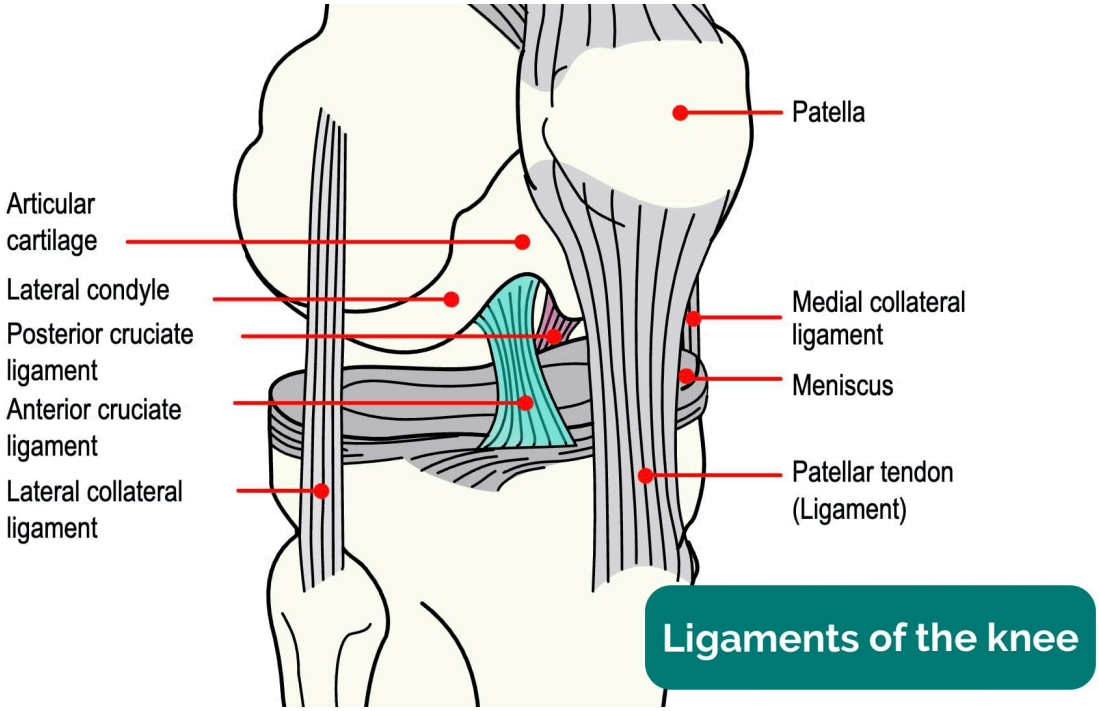
Abstract

ACL tears are a prevalent issue throughout all sports, sexes, and ages due to their harmful impact on an athlete's physical and mental well-being. This is the result of a variety of intrinsic and extrinsic factors. The intrinsic factors investigated in this paper relate to unique individual characteristics, such as ACL size, biomechanical movement, and amounts of different hormones. On the other hand, extrinsic factors refer to the outside environment around the athlete, including weather, playing surface, and footwear type. The combination of these factors impacts specific groups more than others. In particular, females are 3 to 6 times more likely to injure their ACLs than males, and soccer and basketball players are among the most susceptible to ACL injuries. The paper reviews why ACL injuries occur generally and how certain factors contribute to the disparity in injuries throughout multiple variables by collecting data and conclusions from past research. These conclusions are used to provide recommendations for injury prevention methods.

Introduction

The anterior cruciate ligament (ACL) connects the bottom of the femur to the tibia and provides stability to the knee area by regulating how much it can move. Despite its key role in the knee structure, the ACL is the most commonly injured ligament in the human body. In the United States, between 100,000 and 200,000 ACL injuries are recorded yearly (Siegel et al., 2012). These injuries are the result of the overextension, strain, or tear of the ACL and often cause serious physical and psychological damage, such as reduced knee stability and mental side effects of surgery. Athletes are particularly susceptible to sustaining these injuries due to the heightened chances of injury during exercise and sports.

The causes of these injuries are a variety of intrinsic and extrinsic factors that contribute to an athlete's predisposition to ACL injuries (Orchard et al., 2001). Intrinsic factors relate to personal physiological characteristics such as bone structure, hormonal changes, and genetic factors. In contrast, extrinsic factors describe environmental characteristics that are not uniquely related to the athlete. By using both approaches to discuss ACL injury, relations between intrinsic and extrinsic variables can be identified. Furthermore, these factors contribute to several important themes in ACL injury, such as the differences between male and female athletes and noncontact injuries. Girls and women are 3-6 times more likely to experience an ACL injury than boys and men, a result of a combination of social, hormonal, and structural patterns that differentiate them (Parsons et al., 2021). In addition, Boden et al (2010) state that almost 75% of ACL injuries are noncontact, which is largely due to abnormal biomechanical movements. It is important to understand these factors to prevent harm to athletes who suffer from these differences that cause traumatic consequences.



(Watson., 2020)

This paper aims to summarize the most relevant studies about factors in ACL injury to educate athletes on how they can avoid future injuries. Furthermore, the paper highlights sex differences in ACL injuries by discussing how intrinsic and extrinsic factors play a role in this relationship.

Understanding these differences is important in ensuring that both men and women get high-level care to prevent or fully recover from ACL injury. Creating equal treatment programs, deconstructing social stigmas, and understanding hormonal functions are among many possible actions that can help women stay healthy. This will also promote equality in athletic spaces, which are typically male-dominated, and give women higher chances of playing sports and staying healthy. Differing intrinsic and extrinsic factors have a significant impact on both male and female athletes and are equally important to discuss and prevent. It is important to understand intrinsic factors, such as ACL volume, to develop prevention methods based on specific factors. On the other hand, extrinsic factors are more easily prevented and should be limited rather than worked around. This paper will review a variety of types of intrinsic factors, such as anatomical, genetic, hormonal, and biomechanical factors before explaining and connecting social, sport-specific, environmental, and equipment-related extrinsic factors.

Intrinsic Factors

Anatomical and Genetic Predispositions

In a study by Chaudhari et al (2009), the contralateral volume of an ACL was identified as a significant factor in ACL injuries. Individuals with smaller ACLs are at a higher risk for injury

than those with an average or large size. In the study, 54 subjects were evaluated, half of whom had suffered non-contact ACL injuries whereas the other half were the uninjured control. The average volume of the control group's ACL was 2151 mm3. On the other hand, the average ACL size for the injured subjects was 1921 mm3. There was no significant difference between the age, height, or weight of the subjects, emphasizing how the volume of the ACL is directly correlated to an increased number of injuries. In women, weight and ACL volume have also been linked to each other. In the same study, the average difference in weight between the control group and the injured group was 5.6 kg, but the average for men was 1.6 kg. Weight influences on ACL size, which in turn changes the risk of injury.

Not only does the volume of an ACL impact injury rate, but the proportion of the intercondylar notch size to the ACL also influences the outcomes. Narrower intercondylar notches have been linked to an increase in the rate of ACL injuries (Siegel et al., 2012). The width of these notches is measured in notch width index (NWI), which is defined as the ratio of the interondylar notch's width to the distal femur's width (at the level of the popliteal groove). A lower NWI is connected to more negatively impactful injuries, as shown in a study that found bilateral injuries to have an average NWI of 0.1961 compared to acute injuries of 0.2248. However, intercondylar notches width is correlated with both ACL and PCL (posterior cruciate ligament) width, which indicates that these factors may have a more important effect on ACL injuries than the notches. Furthermore, there is no identified difference in the risk of having a small notch for men compared to women, as the average NWI is relatively similar for men and women.

In addition to the anterior connection to the intercondylar notch, the posterior slope of the tibial plateau is key to ACL injury. In normal cases, the slope ranges from -1° to 14° (Hashemi et al., 2011). Having a steeper posterior slope has been connected to a greater chance of injury, as milder and normal angles give more protection around the ACL. With a steeper slope, more shear force from the actions of deceleration and jumping is pushed onto the tendons and other structures surrounding the ACL. Increased stress and pressure have been known to massively increase the chance of injury. The depth of the medial tibial concavity, where the ACL is connected to the rest of the structure, also has a direct connection to injury. In the same paper by Hashemi et al (2011), they highlight how even a 1-millimeter decrease in depth of this cavity makes an ACL injury 3 times more likely. This is because, with a shallower plateau, the interlocking mechanism is more strained against the tibial translation. The posterior slope and the flatness of the tibial concavity not only independently harm the ACL, but are also deeply interconnected due to their proximity to each other.

After an ACL reconstruction surgery, more factors can increase the risk of a retear, such as age and type of tissue used in the reconstruction. An autograft is tissue taken from the body of the same person who is being operated on, whereas an allograft is tissue taken from other people. Kaeding et al (2015) reported that the odds of retearing the ACL post-surgery compared to tearing it the first time are almost the same if hamstring autografts were used in the reconstruction. However, if allografts were used, there was as much as a 5.2 times increase in the risk of retearing. This mostly applies at a younger age, as the odds of a retear are higher when the patient is younger and decrease by 0.09 every year after. Although this is consistent for both autografts and allografts, the starting point in these odds is higher for allografts than

hamstring autografts. As the years go on, the risk involving both of these tissue types eventually decreases enough to even out at around zero after several years.

Genetic history adds to possible predispositions for ACL damage, as summarized in a review paper by Smith et al (2012). ACL tear rates can be connected to a patient's familial connections regarding ACL tears. Patients with a torn ACL were found to be twice as likely to have a direct relative who has had the same injury than people without a tear. This may be because of family genetics relating to the structure of the ligament. The COL1A1 gene is associated with a protein found in the structures of tendons and ligaments. An abnormal amount of the CC and TT genotypes of this gene is associated with ACL tears (Smith et al., 2012). Injured patients who were studied concerning the COL1A1 gene had a 4 times more likely chance of having a family member with an ACL injury than a person without one. Despite these connections, there is little information on familial and genetic ties to ACL injury and more research is needed to verify this as a real risk factor.

Hormonal Predispositions

Although anatomical and genetic factors in men and women have important effects on ACL health, differing hormones in women compared to men leave them at a higher chance of sustaining an ACL injury. Hewett et al (2016) suggested in a review paper that hormonal factors play a large part in ACL injuries. During a woman's menstrual cycle, there is an increased amount of hormones released into the body, which has been found to alter the mechanics of the ACL and the area around it. These hormones cause increased laxity, which has been linked to a higher chance of sustaining an ACL injury. Laxity relates to the looseness of structures within the body, so an increased ACL laxity can cause a change in the mechanisms of the ACL itself and the knee area around it. Laxity is specifically associated with the midfoot loading mechanism and changing lower-body biomechanics, two factors that are important in the risk of an ACL tear because they make the body mechanisms less precise in the area around the ACL, which increases the risk of injury. This risk is especially prominent in the preovulatory phase of the menstrual cycle. The menstrual cycle's link to these injuries gives a possible reason as to why females have a 2 to 10 times greater rate of ACL injuries than males.

Another way the hormonal differences between males and females have been strongly linked to the disparity in ACL injury rates is seen in the link between increased injury and the estrogen and relaxin hormones. Estrogen is found in both sexes but exists in much greater quantities in females and plays an important part in the development of female characteristics. Relaxin is separate from estrogen, as it breaks down ligament tissue, but is also primarily found in females (Lin et al., 2018). This paper examined Dragoo et al's (2009) study, in which researchers treated guinea pigs with relaxin and estrogen. There was a control group, a group with only relaxin, and a group with both relaxin and estrogen. After 21 days of treatment, the group with both hormones saw a 13.6% increase in tibial displacement and the group with only relaxin saw a 12.8% increase. The significant increase when relaxin was present and the minimal increase when estrogen was present indicates that both hormones somewhat affect ACL injury chances, but relaxin is more influential. This is likely due to the discovery of relaxin receptors on the ACL. The destructive tendencies of relaxin being applied to the ACL lead to a

decrease in load-bearing abilities and an overall weaker ACL. Since both hormones have a larger presence in females than males, this indicates that the hormonal aspect of sex has a substantial impact on injury, particularly in the knee and ACL area.

Biomechanical Factors

In contrast to anatomical factors in ACL injuries, neuromuscular risk factors can be minimized with the right training. Neuromuscular factors relate to the ability to control body movement precisely, which gives a better chance of avoiding serious injury if done correctly. In Jagadeesh et al's paper (2016), control over the core and lower body is identified as a way to reduce the possibility of an ACL injury. Maneuvers such as cutting, changing direction, or deceleration have been identified as some of the biggest risks for causing ACL injuries, so being able to control how a body moves in these situations is important for staying healthy. In the situation of moving from a valgus knee position, body control is helpful to avoid getting into this position because the knee will be abnormally positioned. Generally, abnormal rotations of the hip, hip flexion, and other lower body functions close to the ACL have also been connected to injury. For example, the act of landing commonly causes the ACL to tear or become injured. An unusual landing position, typically a double leg stance, increases the strain that ground force has on knees, which has been shown to increase injury risk.

Four types of movement are listed as causes of ACL injury in Hewett et al (2010)'s paper: ligament dominance, quadriceps dominance, leg dominance, and trunk dominance. These are all closely interlinked due to their shared influence and similarities. Firstly, ligament dominance is when an athlete is forced into a difficult landing position that causes the leg muscles to have to absorb high amounts of force in a short period of time, thus increasing stress on leg ligaments. The center of mass has to control more force, which forces the knee into unsafe positions. Quadriceps dominance also relates to the effect of muscles on ligaments. When performing a mechanism that forces the knee into an unsafe position, the quadriceps in a leg contract to give more support to the knee. However, the muscle contracting also puts more stress on the ACL, increasing the risk of injury immensely. Furthermore, leg dominance occurs when too much weight is put onto one leg. This also puts stress on important ligaments and parts of the leg during cutting, planting, and landing mechanisms. This noticeably happens to people with asymmetric muscles, or people with more muscle on one side because they have both a greater force and greater torque. Lastly, trunk dominance also has to do with movement. This occurs when an athlete moves and is not able to control their torso in a three-dimensional space. This is correlated with a disturbance and excess movement of the trunk when the athlete has a higher body weight and center of mass. The importance of being able to controlled movement heightens the need for better training and balance programs to prevent injury. Additionally, these four types of movement are common but not limited to women, which gives another reason as to why women have a higher ACL injury rate than men.

The structure of the knee in females requires that they have a more practiced way of movement to avoid ACL injury compared to their male counterparts. In particular, landing position greatly affects the risk of injury, as women are understood to land in a straighter position than men with inadequate knee and hip flexion. Vosanian et al (2013) highlight the importance

of landing at a normal angle. Minimally flexed knees usually land at a 5-20 degree angle, a big difference compared to the ideal flexion angle of around 60 degrees. Due to their different landing position, women are more likely to land with a lower angle than men. Furthermore, during landing or deceleration, women tend to rotate their hips and tibia more than men, which increases the frequency of abnormal positioning of the knee, or knee valgus. To partially alleviate this problem, athletes must increase knee stability by learning proper landing techniques and building muscle around the knee area to add support to the area around the ACL. Hamstring strength is especially important in preventing injury because it works as a force against the displacement of the knee or tibial structure. A study mentioned by Vosanian et al (2013)'s paper monitored female soccer players who were told to practice balancing on one leg for an increasingly difficult amount of time. The group that didn't practice this had 70 ACL injuries, a significant amount compared to the other group's 10 injuries. As seen in the study, balancing and other forms of practicing correct biomechanical forms are directly connected to the reduced risk of sustaining an ACL injury.

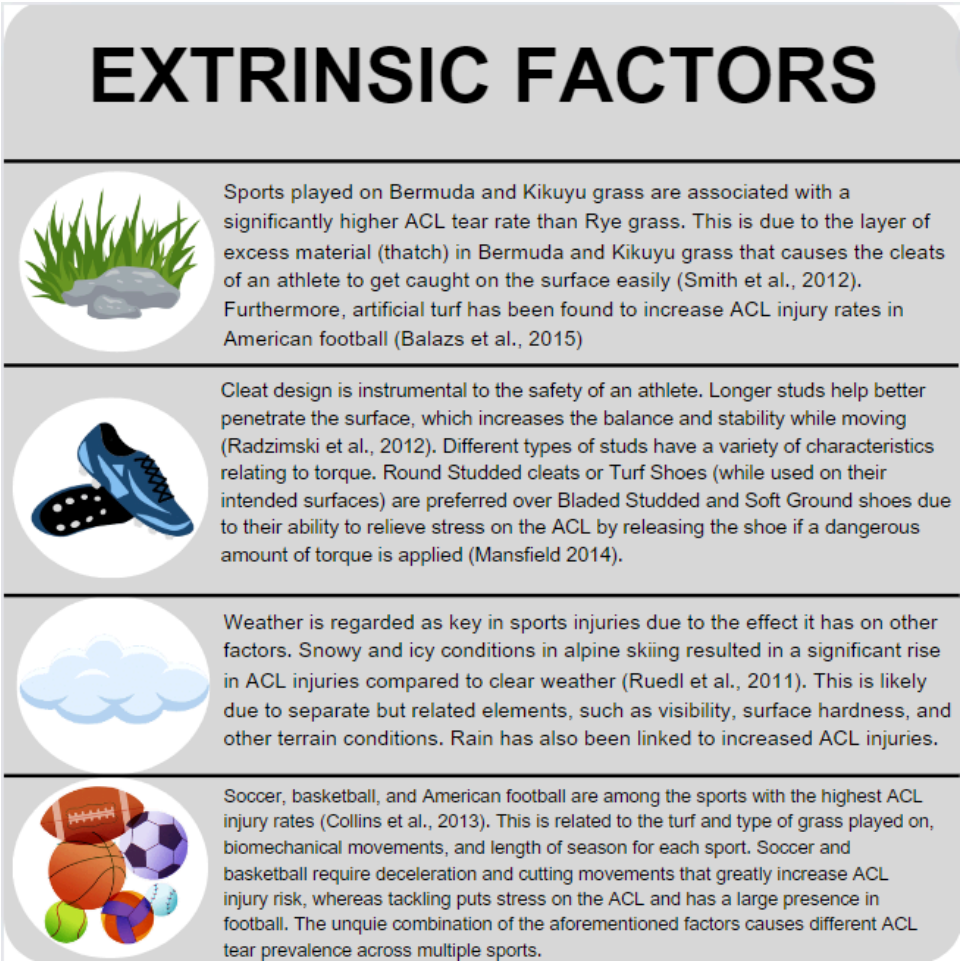


Figure 1. Extrinsic Risk Factor Categories
The figure above provides a brief summary of the main extrinsic risk factors influencing ACL tear prevalence and their causal pathways.

Extrinsic Factors

Social Factors

Despite the many biological and hormonal factors that contribute to the increased rate of ACL injury in females compared to males, social and environmental circumstances also greatly affect the chances of women sustaining these injuries. Parsons et al (2021) summarize how the overall availability and structure of training programs, such as gyms, heavily prioritize men's behaviors over women's. These can not only promote learned behaviors that negatively impact the chances of sustaining an ACL injury, but also allow for a new norm for how women should exercise to spread. The culture around female athletes in the gym encourages having a thin body shape over being physically strong enough to limit injuries.

A study by Coen et al (2018) reflected this in its interviews of everyday gym attendees who were asked questions about their gym routines. A male interviewee explained his preference for lifting heavy weights to build muscle by linking it with wanting to seem more masculine. On the other hand, a woman who was interviewed said that she typically lifts lighter weights because she didn't want to build too much muscle so she could obtain her desired physique. This difference between muscle building in men and women highlights a widespread reason why women have a higher ACL tear rate than men, as it is widely agreed upon that more muscle decreases the chances of sustaining such an injury.

Some aspects of sports are intentionally different due to gender, such as the length of the game, availability of the sport, or physicality of the game. In professional tennis, men's matches are 3 to 5 sets long, whereas women's matches are only 2 to 3 sets long. This results in male tennis players typically playing for much longer than their female counterparts, which brings the potential for them to experience more fatigue and more possibilities of injury than women. Furthermore, some behaviors in sports are more encouraged in men than women, specifically that athletes should play aggressively (Parsons et al., 2021). This is reflected in American football's widespread availability to men compared to scarce football leagues for women. Although flag football is a growing sport for women, it does not allow tackling and other aggressive behaviors that men's football is known for. This pushes the idea that men should act in a more violent way than women. Most of these behaviors that men are encouraged to do are risky in terms of injury, such as how tackling has been linked with ACL injury. Additionally, due to these masculine traits being valued in sporting culture, many women have started acting according to these ideals. This has led to these women making themselves vulnerable to the injury risks that come with this behavior.

Level of Play, Length of a Season, and Sport-Specific Factors

The difference between club, high school, college, and professional athletics are examples of increasing the intensity of a sport through multiple levels. Athletes must undergo a more intense schedule, training schedule, and level of play. As these playing levels become more competitive, the risk of ACL injury grows substantially. Beynnon et al (2014) conducted a study that observed and compared data from collegiate and high school athletes relating to ACL

injury. In high school sports, the researchers found a rate of 0.061 ACL injuries per 1,000 people. On the other hand, collegiate data showed a rate of 0.150 injuries per 1,000 people. This data included both men's and women's athletics through various sports, although the increased injury rates in collegiate sports are consistent while considering the outside factors, such as the sport being played. This indicates that the extrinsic factors in ACL injury typically act independently from each other, although they can be linked. For example, some sports need specific surfaces that tend to affect injury rates. However, these factors do not combine to heighten each other. As players compete in increasingly competitive levels of play, their chances of serious injury also grow concerningly, possibly due to more physicality, less time between competitions, or more intense practices. This harms the athlete's health and the fan's entertainment.

Along with an increased level of intensity, playing in a higher level of sport extends the length of a season. Although fatigue, which increases as the season progresses, has been associated with high rates of sports injuries, a study by Anderson et al (2019) shows that ACL injuries are less common during the late parts of a sports season. Instead, injury peaked during the regular season and decreased during the postseason. The study collected data from basketball, lacrosse, and soccer players about when their ACL injuries occurred: during the preseason, regular season, or postseason. Using combined information from all three sports and both sexes, the data showed a rate of 1.34 injuries per 10,000 athlete exposures during the regular season. Both the preseason and regular season data were less than this, as postseason play had a rate of 0.78 injuries per 10,000 athlete exposures. Myrick et al. (2019) concluded that as a season goes on, ACL volume increases (in female soccer players). This could explain for why the injury rate is lower during the postseason compared to the regular season, as smaller ACLs have previously been associated with a high chance of ACL injury. However, this does not explain why preseason data showed less ACL injury risk despite being earlier in the season and female athletes having smaller ACL volumes. One reason for this could be different tactics used in the preseason games that many coaches view as less important. The same study also examined the injury rates for athletes before and after halftime. The data showed a common trend in most sexes and sports, that post-halftime play posed a greater rate of ACL injury than before halftime. This indicates that fatigue could be more of a factor in individual games rather than affecting injuries throughout the season.

In addition to the level of play, the type of sport played adds more layers to ACL injury, specifically relating to the treatment of male and female athletes. Collins et al (2013) collected data about ACL injuries in high school boys and girls athletes throughout various sports. The results show how both men and women athletes are affected not by their sex, but also by the sport they play. This was measured by the rate of injury compared to athlete exposures (AE), which is any instance where an athlete participates in an activity that involves a risk of injury, such as a practice or a competition. Boys are shown to have a 4 times more likely chance of injuring their ACL while playing American football than any other boys' sport (rate of 11.1 injuries per 100,000 AE). On the women's side, the data showed that they are 2 times more likely to injure the ACL while playing soccer compared to any other women's sport (rate of 12.2 injuries per 100,000 AE). Furthermore, playing basketball or soccer as a woman shows a 4 times more likely chance of ACL injury compared to any other women's sport. This is due to the nature of these sports. For example, sports such as soccer and basketball require much more

biomechanical movements associated with injury than most other sports, such as cutting and deceleration mechanics. In males, American football involves being able to withstand tackles, which relates to the weight and force put on the knees during heavy contact, thus increasing ACL injury. Although these are intrinsic factors that cause injury, the type of sport is a broader topic because it includes factors other than body structure, such as playing surface or equipment used.

Environmental factors

Surface type has been shown to have a key effect on ACL injury rates. Smith et al (2012)'s review paper explained the connection between different types of grass used in the Australian Football League (AFL). In the study they reference, stadiums using Bermuda and Kikuyu grass were associated with a significantly higher ACL tear rate than those with Rye grass. Throughout the study, there were 22.4 non-contact ACL injuries per 1,000 games on Bermuda grass and 21.7 on Kikuyu grass, whereas Rye grass had 9.9 per 1,000 games. Bermuda and Kikuyu grass have notably thick layers of thatch between the grass blades and the soil. On the other hand, Rye grass has minimal amounts of thatch. This is important because thatch brings excess material to the playing surface, such as straw or leaves, which provides a high possibility of causing cleats to get caught in the ground. If these cleats get caught, this can cause sudden biomechanically unsafe movements, which heightens risks for injury. However, due to the locations and times in which the study was conducted, some data could be altered because of outside factors such as rainfall, evaporation, or time of day. Despite this, there is a staggering difference in the ACL tear rates on the variation of grass types.

Discussions of the safety of artificial turf have long been a popular topic among researchers and consequently have been the subject of many studies. Balazs et al (2015) collected 10 related studies and analyzed them to understand the relationship between artificial turf and ACL injury. Of these studies, 4 were focused on soccer and 6 were about American football. Four of the studies about football (with 768 ACL injuries involved) found increased ACL injury rates while playing on artificial turf. In contrast, none of the soccer studies found a difference between grass and turf. Not only does this suggest that artificial turf affects ACL tear rates, but also that sport type plays a role. However, due to the complexity of the studies as a result of them being done in unrelated settings, more research is needed to confirm these findings. Many variables were uncommon throughout these studies, such as competition, sex, and turf type. Furthermore, there were athlete-specific variables that were more difficult to track, such as playing position or play type in American football. Despite this, the data shows some connection between ACL injuries and artificial turf, which aligns with existing research findings.

Another way the environment affects athletics and injury risks is through the dangerous influence of the weather. Poor weather, including rain, snow, or sleet, has been closely linked to most sports injuries, although it particularly affects ACL injuries. Ruedl et al (2011) collected data from female skiers who had injured their ACLs and a control group. 41.9% of the injured skiers had been hurt on icy terrain. Not only does this further show how the playing surface negatively impacts ACL injury rates, but also explains why this surface became so bad, which is because of the icy weather conditions. Furthermore, 9.8% of the injured athletes skied during

snowfall, whereas the control group only did so 1.1% of the time, and sunny days had the least injuries. The type of snow also plays a role, as the study showed a lower injury risk on slushy or grippy snow. Although active snow days are harmful to exercise during, certain types of snow are more impactful than others. To limit the risk of injury, skiers should aim to exercise during clear periods. Although this study focused on a sport that commonly has extreme weather, this conclusion can be applied to most sports. Bad conditions are caused by poor weather and can lead to other unsafe circumstances, such as damaging the playing surface or causing low visibility. Rainy circumstances are common in many sports and are commonly accepted to also be dangerous to athletes.

Equipment

Outdoor sports played on grass or turf, such as soccer, baseball, or American football, have a notable extra risk that other sports don't have to consider: cleat design. Although other sports that aren't impacted by cleats have issues regarding shoe functionality, cleats are unique because they must be designed to consider the safety risks involved with the different surfaces on which they are used. This is done by incorporating spikes or studs on the bottom of the sole. Their main purpose is to regulate the traction between the shoe and the surface they are being used on. Increased distribution and number of these studs decreases stress on one part of the shoe and improves the athlete's stability, which is important for their biomechanical movement and overall health (Radzimski et al., 2012). Penetration of the surface is another key function of cleats, as more penetration allows for a better grip and balance for the athlete. Limited cleat height has been linked to increased penetration. Furthermore, weather can change the quality of penetration due to more ground stiffness limiting this. Overall, these factors mainly impact the axial rotation of the knee and lower leg, which has been closely linked with ACL injury due to the effect on loading force. 500 N is the most rotational force that can be safely put onto this area, so cleat design is critical to consider because of the risk of injury associated with areas that the cleat regulates.

Specifically, the type of stud on the bottom of the shoe has a large impact on the torque and stability generated, which has been linked to ACL injury risk. A study by Mansfield (2014) generalized all cleats into 4 types: Round Studded, Turf Shoe, Bladed Studded, and Soft Ground. These are characterized based on the type and shape of the studs on the shoe. The study evaluated the maximum torque created between the shoe and the surface and found that Round Studded and Turf shoes are statistically similar based on maximum torque. They produced lower torque levels than the other two, which were also found to be similar to each other. This is due to the design and size of the studs. For example, Soft Grounds produced more traction and a high maximum torque due to having deeper studs, which increases the surface area that comes into contact with the playing surface. In all of the cases examined, the surface that the shoes were tested on made a difference because they perform differently on surface types that the cleats are not intended to be used on. Overall, the study found that Round Studded cleats or Turf Shoes are best for relieving stress on the ACL (when used on their intended surfaces of grass or turf) because they produce a good amount of traction while also being able to slip if a dangerous amount of torque is applied, thus reducing the risk of injury in the knee and ACL area.

Conclusion

Although both intrinsic and extrinsic factors influence ACL injury rates, they cause damage in different ways. Intrinsic factors relate to player-specific causes, such as biomechanics and bone structure, whereas extrinsic factors are caused by the athlete's environment. Increased exposure to and prevalence of these factors cause female athletes to be 3-6 times more likely to injure their ACLs than male athletes.

On a hormonal level, the menstrual cycle causes changes in chemical concentrations, resulting in ACL laxity. Specifically, relaxin is influential because it causes tibial displacement and weakens the ACL, increasing the chance of injury. Regarding knee structure, decreased protection of the ACL and knee area is also associated with increased injury risk. Specifically, larger contralateral ACL volume, narrower intercondylar notch size, and steeper posterior slope of the tibial plateau all significantly affect the chance of injury. Furthermore, injured subjects with a COL1A1 gene were more likely to have a family member with an ACL tear, indicating that genetics and family history play an important role in ACL injury.

Although biomechanical risk factors can be reduced, they are still considered intrinsic due to the uniqueness of individual athlete movement. Cutting movements, changing direction, and deceleration are widely understood to be among the most dangerous mechanisms for ACL health. Uncontrolled movements are harmful because they increase the chance of moving in an abnormal position. ACL injury is associated with ligament, quadriceps, leg, or trunk dominance. If the knee is in an unsafe position, muscles in the knee contract, which increases stress on the ACL. To maximize safety during sports, an athlete must have high balance and a controlled center of mass. Women in particular are susceptible to unsafe landing positions, which increases ACL injury rates. After repair surgery, retear risks considerably increase if allograft tissue is used during surgery rather than autograft tissue.

Other factors that have to do with the environment are considered extrinsic rather than specific to an individual. Gyms and other available training programs typically prioritize male behaviors and disregard females, which can cause unhealthy habits and stigmas to be formed in women. One of these stigmas is the belief that women should have thin bodies and little muscle. This decreases the overall physical wellness of many female gym users, which then raises the chances of ACL tears and other sports injuries. Furthermore, specific sports change parts of the game based on gender. This is typically detrimental to men, as they have to play longer games in tennis and overall are encouraged to be more aggressive than their female counterparts. The intensity of the sport played also increases over multiple levels of sports, as professional and collegiate athletes have notably higher ACL injury rates compared to high school athletes.

Sports with dangerous biomechanical movements, such as soccer and basketball, increase opportunities for ACL damage. Certain sports require different environments and equipment, demonstrating the connectivity of ACL risk factors. Games played on Bermuda or Kikuyu grass can be more dangerous than ones played on Rye grass, due to the high amounts of thatch that cause cleats to get stuck on the surface. In addition to artificial turf, sport related,

environmental, or player-specific variables have also been linked to high injury rates in American football. Cleat design is another important factor in injury rates, due to the close connection it has with both the player and the surface. Traction is instrumental in maintaining safe stability in an athlete, which is why stud height and cleat type are important to consider. Round Studded, Turf Shoe, Bladed Studded, and Soft Ground are four basic types of cleat, and Round Studded cleats or Turf Shoes are optimal for balancing safety and performance because of the amount of traction they allow.

Despite many clear connections in the research, limitations in the data affect the validity of some of the conclusions. Throughout much of the research, the demographics of the participants were mostly young adult athletes and the data limits extrapolation to different ages. Furthermore, there were some conflicting reports, specifically about artificial turf. Many papers claim that turf is an important risk factor in ACL injuries, but one data set asserted that it is only a factor in American football. Therefore, more specific research is needed to justify this claim. Another limitation was the amount of sports researched. Most papers took data from soccer, basketball, or American football due to these sports having a high prevalence of ACL injuries. This contributes to a decreased understanding of ACL injury mechanisms in less affected sports, such as tennis. In turn, this is harmful for athletes in these sports because there is less understanding about how injuries in their sport can happen and how to prevent them.

To minimize the risk of ACL tears, athletes and coaches must consider the preventable factors to create prevention strategies. Training programs can be utilized to teach proper biomechanics to reduce injury due to unsafe movements. Furthermore, athletes should use Round Studded cleats or Turf Shoe on their intended surfaces and have long studs on the cleats to maximize safe torque and stability. Games should be played on safe surfaces, such as Rye grass and Bermuda grass. Turf and Kikuyu grass should be avoided. It is unrealistic to examine every athlete’s internal anatomy to be aware of intrinsic risk factors, but females can track their menstrual cycles to know when their knee laxity is high and educate themselves on how that affects ACL injury chances. Female athletes should be taught about their higher chances of injury. More research is needed to verify findings, particularly in the areas aforementioned as limitations. Furthermore, spreading awareness to athletes would help them be more intentional about prevention methods, which could decrease overall ACL injuries.

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