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Brace Use for ACL Injury Prevention in Soccer: Impacts on Rehabilitation and Performance

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ABSTRACT

ACL injuries are extremely common, especially in soccer, and often require extensive and invasive treatment such as surgery. Braces are almost always used to provide support and stability to the knee during the recovery period, following injury, and for preventative purposes. Additionally, braces aid the patient by preventing excessive movement and rotation that can further damage the ligament.

This review article aims to explore the use of braces in the prevention and recovery of ACL injuries, especially in soccer. In addition to the physiology and biomechanics of the ACL, this article will also discuss the factors that contribute to ACL injuries including gender, playing surface, and neuromuscular traits. It will also explore the different types of braces and their unique functions and role in injury prevention and rehabilitation. With more research, we can move towards a future where ACL injuries in soccer could become a rarity rather than a common concern.

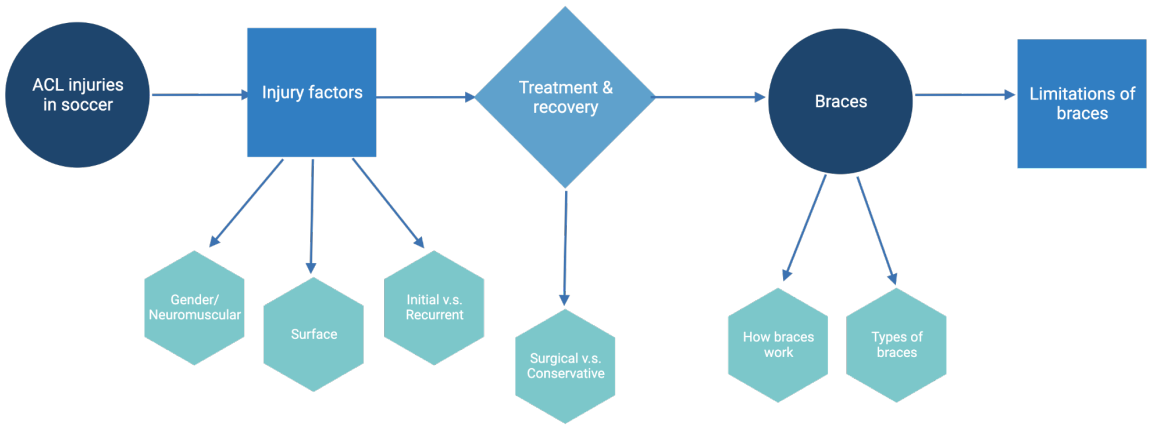

Figure 1. Overview of article topics. The figure shows what topics this paper will cover and the order. Created with BioRender.com.

Introduction

ACL injuries have a reported incidence of 100,000 to 200,000 in the US every year [6]. Anterior Cruciate Ligament (ACL) injuries are a common occurrence in soccer due to the sudden movements and unique actions required, such as those involved when defending. These injuries significantly affect an athlete's ability to participate in their sport and can hinder an athlete's performance when they return. After undergoing the common ACL injury treatment, ACL reconstruction surgery, only 55% of athletes return to competitive sports [21].

The ACL is located in the center of the knee, which is one of the most complex joints in the human body and is composed of three bones. The knee also includes various tendons and the meniscus, a c-shaped pad of cartilage located between the tibia and the femur [1].

The knee contains four major ligaments, pictured below. Ligaments are made of connective tissue that has strong collagen fibers. The most commonly injured ligament, the anterior cruciate ligament, prevents the femur from sliding too far backward and the tibia from sliding forward. It also limits rotational knee movement and excessive knee extension [15]. It plays a crucial role in stabilizing the knee during quick changes of direction, which is particularly important in sports. The ACL is an extremely strong ligament with tensile strength (maximum stress it can bear before breaking when being stretched and pulled) of about 495 pounds [10].

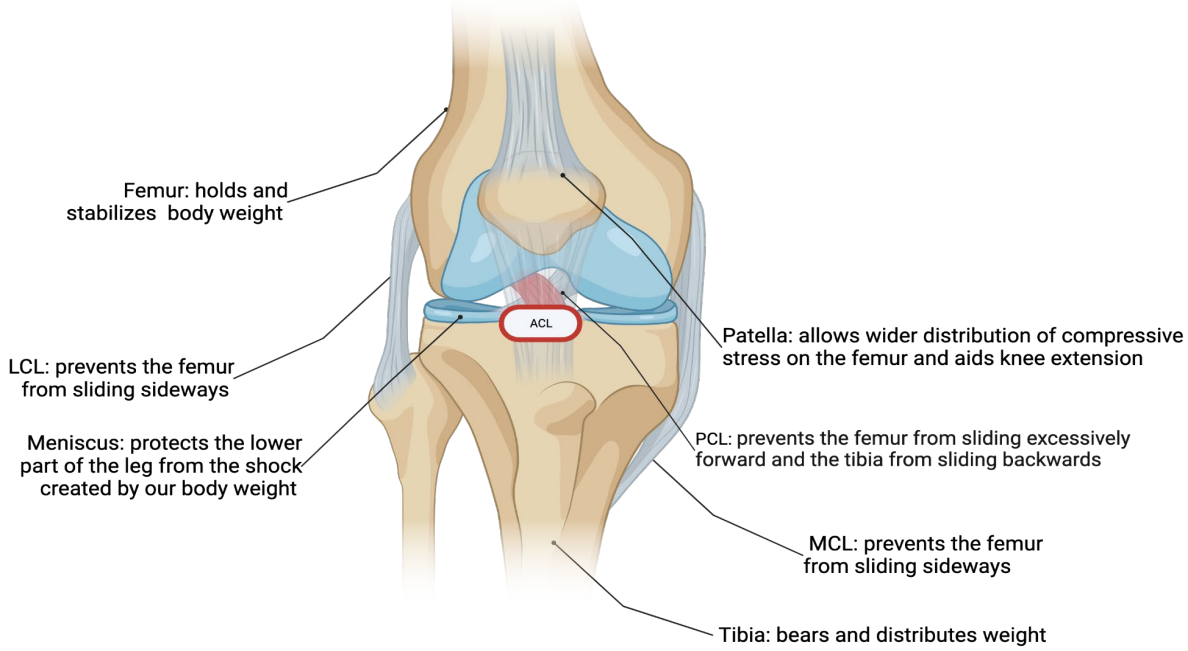

Figure 2. Physiology of the knee. The figure shows where the major ligaments and bones are located within the knee and their basic function. The figure highlights the location of the ACL in red. Created with BioRender.com.

ACL Injury in Soccer

Soccer is one of the most common sports that can result in ACL injury. Among the estimated 177,747 soccer-related ACL injuries that were reported nationally, the most common means of injury was rotation around a planted foot/inversion (46.0%). 77% of the total injuries required surgical intervention [13]. Oftentimes in soccer, a player making contact with another player leads to a high risk of injury. Interestingly, non-contact injuries

were predominantly higher than contact injuries in the study. These findings suggest that soccer players are most susceptible to ACL injury when they are pivoting or making quick movements. It is, however, important to note that these statistics were drawn from self-reported data, which could bias the results [13].

A more rigorous method to study ACL injuries and subsequently draw more compelling conclusions is to have healthcare professionals review video footage of the injury occurring. A study found that 73% of ACL injuries occurred when the opposing team had the ball and the injured athlete was defending [5]. Interestingly, females were more likely to be defending when they were injured compared to their male counterparts. The most common playing actions were tackling in defensive positions (51% of injuries) and cutting (15% of injuries) [5]. Cutting refers to when a player makes a quick, sharp change of direction. From this, it can be concluded that a soccer player is most at risk for an ACL injury when they are defending, especially tacking. It is important to note that Brophy and colleagues' study is limited concerning their conclusions due to the small sample size (N = 55) and the somewhat incomplete information on the athletes regarding age and history of previous ACL injury and or surgery [5].

Another study conducted with solely professional female athletes corroborated this claim that ACL injuries are most common when players are defending. When reviewers evaluated each video, they found that most injuries occurred with no player contact. When assessing the game situation, 49% of injuries happened while the player was tackling [11]. In soccer, a tackle is an attempt to steal the ball while the opposing player has the ball close to them, usually resulting in contact. This action typically occurs when the injured player is approaching the opponent intending to tackle. This percentage, while not as high as the one gathered in the Brophy study, shows a positive correlation between defending and ACL injury. The next most common situation was when the player was regaining balance after kicking (19%) and when a player was being tackled by an opponent (11%) [11]. Lucarno didn't comment on the likelihood of a player getting injured while regaining balance, making the two studies hard to compare. The second study admitted that there were limited camera views, possibly leading to false conclusions or missed details. Another important thing to note is the small sample size of 35 for the study. Overall, both studies draw a compelling conclusion that the most common game situation in which ACL injuries occur is when the athlete is defending, specifically tackling [11].

Causes/Factors

Gender Factors

One of the most prominent and well-researched factors affecting ACL injury risk is gender. This is due to many different biological differences such as puberty, natural movements, and muscle strength/asymmetries. Women naturally move differently than men, in ways that increase their risk of an ACL injury. One example of this is that women tend to position their bodies in a more upright stance with their knees straight [7]. Athletes are most vulnerable to ACL injury when their leg is straight due to the decreased flexibility and ability to absorb shock. This position also causes women to more easily lose balance and their center of gravity during quick changes of direction or other movements. Women's knees and hips also move at different angles than men's, and their muscles support their joints differently [7]. Another factor is the differences in the hamstring/quadriceps strength ratio. Women tend to have weaker hamstrings compared to their quadricep muscles. In contrast, men's hamstring strength is dominant to their quadriceps. Due to decreased hamstring strength, women's knee joints are less stable when moving, especially when jumping, landing, and changing direction. In some cases other muscles may have to compensate if an individual's hamstrings are too weak to do their role, further increasing the imbalance. Another factor is that women tend to have a bigger imbalance relative to men when comparing the strength of their dominant and non-dominant legs in soccer. A study reviewing the risk of injury when defending found that 74% of non-contact ACL injuries occurred in the dominant leg of male soccer athletes compared with 32% of females, meaning that most females experience a non-dominant leg ACL tear [5].

ACL injury risk increases significantly at 12 to 13 years of age in girls. This is due to growth spurts, and rapid increases in body weight, height, and bone length triggered by the onset of puberty. The tibia and femur grow at an especially fast rate during puberty, causing greater torque, the amount of force that causes an object to rotate around the pivot point [12]. These rapid biological changes cause muscular control to be more difficult, especially the higher center of mass due to the increase in height. This causes the body to be less stable during movements while it is getting used to the new structure [12]. Overall, the many biological differences between males and females contribute to a higher risk of ACL injury in females, with puberty playing a huge role in the risk of injury in young girls.

Surface Factors

Turf fields have gained popularity as a substitute for natural grass due to the low maintenance requirements and ability to withstand adverse weather conditions. This change to turf soccer fields could be causing more ACL injuries, as the friction, cushion, and texture are different. Turf has evolved a lot since it was first developed in 1966. The majority of fields played on now are made of third-generation turf. This type of turf is composed of longer fibers and a granular material that fills the spaces between them. Specifically, turf is unforgiving because it has less give than grass, which causes athletes to absorb more force caused by their movements and therefore increases injury risk. Nationally, there were 389,320 ACL injuries reported during the school years from 2007 through 2019, 183,586 of them being caused by participation in soccer. Of the 177,747 individuals who reported the playing surface of their injury, 40.4% occurred on artificial turf, 58.5% on natural grass, and 1% of cases on other surfaces. The study concluded that ACL injuries were 53% more likely to occur on artificial turf than natural grass in girls' soccer, but there was no significant association found in boys' soccer [13].

Numerous studies support these findings such as those conducted by the NCAA. The study also mentioned that the species of grass played on would affect the injury rate. While there was no numerical data to support this, they concluded that Perennial Ryegrass was associated with fewer ACL injuries than Bermudagrass [13]. It can be deduced that the length and thickness of the grass would play an important role in injury risk due to the friction. Overall, it is apparent that the nature of turf, including its friction and lack of cushioning properties, is a contributing factor to ACL injury risk.

Initial vs. Recurrent Injuries

When someone has injured their ACL once, the probability of injuring it again is significantly higher than those with no history of ACL injury. This is likely due to the patient returning to activity too quickly, their knee never regaining its full strength, and residual damage to the ligament or surrounding muscles. A study collected data from athletic trainers of collegiate and high school athletes. There were a total of 705 injuries reported, 644 of them being first- time injuries and 61 being recurrent. Compared to first-time injuries, the probability of a recurrent injury occurring through non-contact means was 2.8-4.5 times more likely depending on the season [17]. This shows a strong correlation between having a history of ACL injury and the probability of injuring your ACL again. It is clear from the study that prior ACL injury has a substantial effect on one's possible future injuries.

Treatments

Conservative/Non-Surgical Treatment

When an individual experiences an ACL injury, they, along with their doctors must decide if surgery is required and or the best treatment plan. This choice of treatment will depend on such factors as the patient's age, activity level, and the severity of the injury. If it is decided that surgery is not required, the patient goes through a rehabilitation process with an emphasis on physical therapy. Many experience significant muscle loss due to the time (usually around three months) one must take off from their normal activities. Through physical therapy, the patient strengthens their ACL and the muscles around it. One of the most important muscles to focus on is the hamstrings, as they play a crucial role in stabilizing the knee when the ACL is vulnerable [2]. Other forms of rehabilitation include ice and or heat therapy and the use of anti-inflammatory drugs such as ibuprofen. Eventually, patients ease into their desired activities, usually wearing a brace.

Surgical Treatment

Oftentimes, surgery is required for ACL injuries. This is due to the extreme damage usually done to the ACL and the instability this creates. If the patient's situation, which depends on the intent of future activity and damage to their knee, makes ACL repair possible, it will be done as it is a smaller procedure that only involves cutting into one area. On the other hand, if the patient's ACL is too damaged or they intend to return to a high level of competition or activity, then reconstruction is normally recommended. This procedure involves a graft from another part of the body, almost always taken from the patellar tendon or hamstring tendons. This graft can be taken from the patient or another person (allograft). The vast majority of these grafts are taken from cadavers that have been closely examined for potential infectious diseases, including HIV. The graft is attached to the knee, most commonly using screws but alternatively using staples, sutures, or buttons.

Following surgery, braces play a crucial role in managing the patient's pain and stabilizing the knee. The patient is usually on crutches for a week with a postoperative brace. The patient then switches to a less extreme brace, allowing them more movement. Four to eight months after the surgery, the patient slowly returns to full activity. The qualifications for return include having normal muscle strength, no swelling, and full range of motion. In most cases, patients wear a brace when initially returning to their activities. Complications of the surgery are rare but do sometimes occur. These include loss of motion of the knee and continual pain and swelling despite significant time after the surgery. These cases are unlikely, and in most cases, surgery allows the patient to return to their daily activities with no pain. Following the rehabilitation process, about 85% of patients return to their previous level of activity with no restrictions [2]. It is important to note that there are many reasons for one not to resume their original activity level that are not related to their physical health.

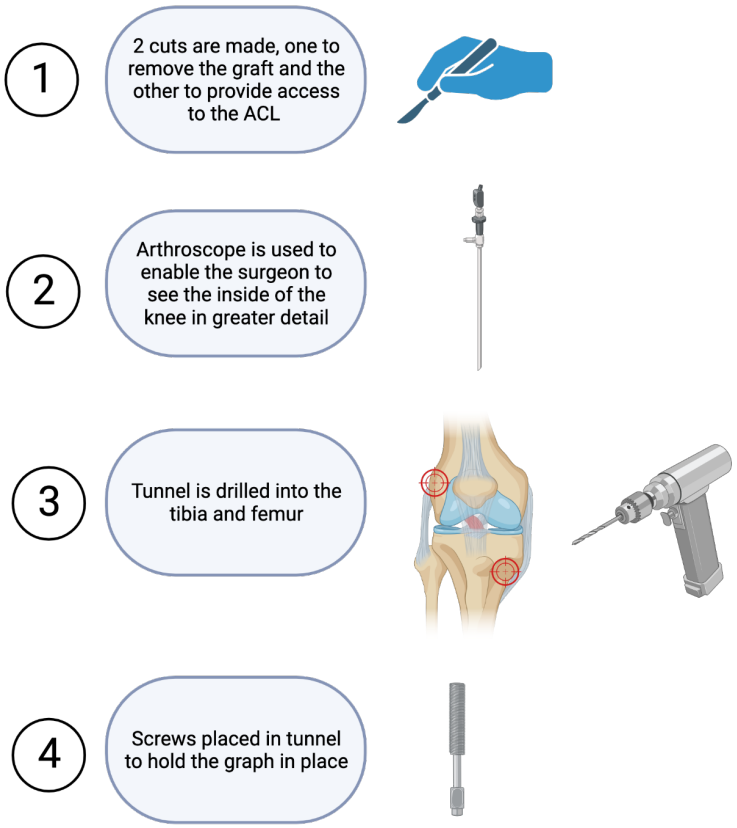

Figure 3. ACL Reconstruction Surgery. The figure shows a brief overview of the steps taken in the surgery. Created with BioRender.com.

How Braces Work

Rehabilitation paths can differ depending on the individual's treatment plan, but braces play a crucial role in both scenarios. There are many different kinds of braces including prophylactic, functional, and rehabilitative. Patients commonly use knee braces directly following their injury and surgery and when they return to their normal activities. Braces accelerate the recovery process by relieving pain and allowing patients to return to activity much sooner than they otherwise would. This is due to the support, stabilization, and compression they provide. Knee braces can protect the injury point from tibial forces up to 140 Newtons [18]. 9 newtons is approximately equal to the weight of 2 pounds. Additionally, they allow the user to confidently return to their activities, limiting hesitation and anxiety about returning to normal movements. This is especially important in sports when being hesitant can lead to further injury. An example of this is in soccer when unconfidently going into tackles leads to a high risk of injury. Braces continue to evolve in their capabilities, the most recent innovation being the integration of technology in braces.

Types of Knee Braces

Rehabilitative Braces

Rehabilitative braces are by far the biggest and most bulky. This is because their primary job is to protect a recently injured ACL. They are designed to help patients regain strength in their muscles while protecting the knee. They limit harmful knee movement and alleviate pain when the patient is recovering from an injury. These braces are usually used directly following a knee injury or surgery. They are usually made up of a significant amount of hard parts and limit range of motion. Many of the braces are semi-rigid and contain systems such as the "air bladder system" which uses air pressure to take some of the weight off the knee. Many of these braces are hinged, and some can be locked. Locking the brace disallows the knee from extending or bending beyond the settings the user sets. This feature is especially useful in preventing harmful movements. A study monitored the effects of hinged knee braces using sensors. 5 healthy males performed a series of tasks with and without wearing a brace. The results showed that the hinges in the knee brace can absorb up to 18% of the force and 2.7% of the torque at the knee [4]. This proves the immense benefits hinges can have in alleviating pressure from a vulnerable knee.

Functional Braces

Functional braces are designed to support the knee after the athlete is injured. Unlike rehabilitative braces, these braces are usually used after the patient has regained full range of motion. They normally contain a hard component that can limit certain movements and/or alleviate stress on a certain part of the knee. The hard components such as cables, tensioning systems, and spring-loaded pads absorb the shock created by movements and stabilize the knee. The soft components such as a sleeve help promote muscle activity by applying pressure on certain areas. Braces can also counteract dangerous movements, such as changing direction or bending/extending the knee excessively, that could potentially harm the ACL and reduce unwanted forces [9]. Another study corroborated this evidence by analyzing 14 patients recovering from ACL reconstruction surgery. By monitoring their walking pattern/gait over the two months following their surgery, they concluded that functional braces helped in improving gait mobility in patients [14].

Prophylactic Braces

Prophylactic braces are preventative braces that decrease the risk of ACL injury. This means they are mainly used when the athlete isn't injured. These braces are typically worn by athletes who are at high risk for an ACL injury. The braces are usually constructed with soft material and are designed to restrict excessive forward, backward, and rotational movement. This keeps the ligament from twisting or bending too far [20]. The level of intensity of the brace can differ depending on the individual. These braces were originally designed solely to protect the knee from contact injuries, but have evolved and can alter muscle function and knee mechanics. A study examined the effect prophylactic braces have on the knee. Researchers conducted the study with 10 men and 10 women, aged 18-30, and they found that the brace reduced muscle forces in the quadriceps, calf muscles (specifically the gastrocnemius), and the soleus. These muscles and the hamstring muscle play the biggest roles in preventing ACL injury. Interestingly, the study showed that with a prophylactic brace, subjects' hamstring function and muscle force did not differ when they didn't have the brace. The study also concluded that prophylactic braces reduce impact when landing from a jump, and restrict knee hyperextension, and knee valgus, which is the inward collapse of the knee [8]. Overall, prophylactic braces provide athletes with a proactive approach to reducing ACL injury risk.

Figure 4. Different types of braces. The figure shows examples of the three main types of knee braces and labels key components of them, including their function (photos adapted from Orthomen, Bauerfeind, and Brace Ability). Created with BioRender.com.

Disadvantages/Limitations of Braces

While braces provide immense benefits for those suffering from injury by allowing them to return to activities more quickly and safely than they would normally, some studies suggest that braces may not benefit the patient. A meta-analysis concluded that there were no significant long-term outcome differences (swelling, range of movement, muscle bulk, patient satisfaction with the result, function, pain) between patients who wore knee braces and those who didn't. They found that many studies suggested that during the early postoperative stages of rehabilitation, patients who didn't wear braces had better knee function [19]. Another study supported the claim that braces do not benefit the patient by comparing the translation, or movement/displacement, of the tibia relative to the femur when patients were wearing and not wearing braces. When analyzing their data, they found no difference in translation between the two test groups [3]. Additionally, a different study examined the joint movement and angular impulse values ("twisting" of the knee when a force is applied) when using braces and found that the braces they tested did not alter either of these [16].

One question that arises when examining the limitations of braces is limited adjustability. Most braces have size options but do not provide an ideal fit for each individual's knee, and patients may struggle to size themselves correctly. Additionally, many braces are not gender specific and do not account for the physiological difference between men and women. This could cause the brace to not adequately support each patient correctly.

Discussion/Conclusion

ACL injuries are extremely prevalent in soccer and most commonly occur when the player is defending. An athlete is at the highest risk of ACL injury when they are tackling the opposing player. Women injure their ACLs more than men due to biological factors affecting muscle strength ratios and natural movements. Girls are most susceptible to ACL injury during puberty. Their rapid physiological changes cause muscular control to be more challenging. Another factor influencing ACL injury is the playing surface. It can be concluded that injuries are more frequent on turf rather than grass due to the different texture and friction, and the type of grass also plays a role in affecting injury rates. Individuals who have injured their ACL once are significantly more likely to have their ACL injured again than those who have no history of ACL injury.

Braces play a crucial role in preventing recurrent injuries and during the recovery process. The three main types of brace; rehabilitative, functional, and prophylactic each have a unique benefit to the patient. However, some studies suggest that braces do not benefit the patient in preventing injury and/or assisting the recovery process. Although the majority of studies support brace use as a form of injury prevention and recovery, the effectiveness of braces remains unclear and is a topic of further research. Many studies conducted are limited in value due to their small sample size.

More research is required to evaluate not only the effect braces have but also innovations that can improve the braces we have available today. Within these innovations, braces customized to accommodate the distinct biomechanics of women's body movements could offer a potential breakthrough in the realm of injury prevention. As technology continues to evolve, we can expect further integration of innovative features into braces, enhancing their effectiveness and comfort for the patient. Additionally, braces might start to more noticeably differ depending on one's size, age, and gender. Another important factor when considering accessibility to braces is cost. As many braces, especially rehabilitative braces, can be very costly, there is a need for research aimed at identifying alternative materials and refining manufacturing processes. These exciting innovations will reduce the number of injuries worldwide and empower athletes to return to their sports, even after big setbacks.

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