






# Review of Factors Influencing ACL Tear in Football Players: A Descriptive Analysis

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## Article Info

### Article type:

Review Article

### How to cite this article:

Ghelich Afshar, N., Soltani, M., & Naderinasab, H. (2025). Review of Factors Influencing ACL Tear in Football Players: A Descriptive Analysis. *Health Nexus*, 3(1), 97-110. <https://doi.org/10.61838/kman.hn.3.1.11>



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## ABSTRACT

This narrative review aims to explore the key factors influencing ACL injuries in football players. The review employs a descriptive analysis method, synthesizing evidence from peer-reviewed articles published between 2014 and 2024. Relevant studies were identified through systematic searches of databases such as PubMed, Scopus, and Web of Science using keywords like "ACL injury," "football players," "biomechanics," and "prevention." Articles were included based on their focus on ACL injuries in football, encompassing epidemiological data, biomechanical analyses, and prevention strategies. Data from these studies were categorized into thematic areas such as intrinsic and extrinsic risk factors, injury mechanisms, and prevention methods. Intrinsic factors, including anatomical variations, hormonal influences, genetic predispositions, and neuromuscular deficits, significantly increase the risk of ACL injuries. Extrinsic factors, such as playing surfaces, footwear, workload management, and competition intensity, further compound injury risk. Non-contact mechanisms, including improper landing and pivoting, are the most common causes of ACL tears, driven by biomechanical and neuromuscular deficiencies. Evidence-based prevention strategies, such as the FIFA 11+ program and neuromuscular training, have demonstrated efficacy in reducing injury rates. Gender-specific considerations, particularly for female athletes, and the use of advanced wearable technology were highlighted as critical areas for targeted intervention. ACL injuries in football result from a complex interplay of intrinsic and extrinsic factors. Effective prevention requires a multidisciplinary approach combining structured injury prevention programs, neuromuscular training, advanced equipment, and education for players and coaches. Addressing gaps in gender-specific strategies and global disparities is essential for further reducing injury rates and promoting long-term player health.

**Keywords:** ACL injury, football players, biomechanics, injury prevention, neuromuscular training, playing surface, workload management.

## 1. Introduction

The anterior cruciate ligament (ACL) is a critical structure in the knee joint, essential for maintaining stability during high-demand athletic activities. It is particularly relevant in football, where players frequently engage in cutting, pivoting, and landing movements. ACL injuries are among the most severe injuries encountered in the sport, often leading to prolonged rehabilitation and a significant impact on an athlete's career. Studies have documented the high incidence of ACL injuries in football, emphasizing the urgent need for improved prevention and management strategies (1). This injury is not only physically debilitating but also carries psychological consequences, as players often struggle with the mental challenges of recovery and the fear of reinjury (2).

Football's dynamic nature makes ACL injuries particularly common, given the high-intensity actions required during games and training. Non-contact injuries, which constitute the majority of ACL tears in football, are typically linked to biomechanical and neuromuscular factors rather than external collisions. Research using video-based analysis has revealed that improper landing mechanics, coupled with knee valgus and rotational forces during sudden directional changes, significantly increase the risk of ACL tears (3). These findings underscore the critical role of technique and neuromuscular control in mitigating injury risk, making them a focus area for many preventive training programs.

The significance of ACL injuries is multifaceted, extending beyond the individual athlete to affect teams, organizations, and even leagues. Players who sustain ACL injuries often face extended periods away from the sport, with return-to-play timelines averaging several months. Even after successful surgical reconstruction, many players struggle to regain their pre-injury performance levels. This decline in performance is particularly evident in professional football, where the physical and psychological demands of competition are heightened (4). Studies have shown that return-to-play rates vary widely, with some athletes unable to resume their careers at the same competitive level (2).

The economic implications of ACL injuries are equally significant, especially at the professional level. Surgical costs, prolonged rehabilitation programs, and the financial burden of replacing injured players can place a substantial

strain on team resources. Furthermore, players often face career uncertainties following ACL injuries, including renegotiations of contracts and reduced earning potential (5). These financial and professional consequences highlight the broader impact of ACL injuries on the sport and the critical need for comprehensive prevention strategies.

The primary purpose of this review is to synthesize current evidence on the multifactorial etiology of ACL injuries in football players. By examining intrinsic and extrinsic factors that contribute to injury risk, the review aims to provide actionable insights for clinicians, coaches, and sports scientists. Intrinsic factors, such as anatomical and biomechanical characteristics, will be explored in conjunction with extrinsic factors like environmental conditions and training practices. Recent findings suggest that a deeper understanding of these factors can inform the development of targeted prevention programs tailored to the specific demands of football (6).

The objectives of this review are threefold. First, it aims to describe the epidemiology of ACL injuries in football, focusing on their incidence and trends over the last decade. Studies have shown a consistent increase in ACL injuries among football players, necessitating a detailed exploration of the underlying causes (1). Second, the review seeks to analyze the biomechanical and neuromuscular mechanisms that predispose players to ACL injuries. Evidence from biomechanical studies has highlighted the critical role of landing mechanics and knee alignment in injury prevention (7). Third, the review examines the role of external factors, such as playing surfaces and footwear, in influencing injury risk. Research has demonstrated that artificial turf is associated with a higher risk of ACL injuries compared to natural grass, particularly in female athletes (8).

This narrative review employs a descriptive analysis method, synthesizing findings from studies published between 2014 and 2024. The time frame ensures that recent advancements in understanding ACL injury mechanisms and prevention strategies are captured. By incorporating evidence from a diverse range of populations, including amateur and professional players, this review seeks to provide a holistic perspective on the issue. Such an approach is essential for bridging knowledge gaps and informing evidence-based interventions aimed at reducing the burden of ACL injuries in football (9).

The increasing prevalence of ACL injuries in football highlights the urgency of addressing this issue through multidisciplinary research and collaboration. This review emphasizes the complexity of the factors influencing ACL injuries and underscores the importance of integrating biomechanical, neuromuscular, and environmental considerations into preventive strategies. By addressing the intrinsic and extrinsic contributors to ACL injuries, the findings aim to inform best practices in injury prevention and management, ultimately enhancing player safety and performance in the sport.

## 2. Methods and Materials

### 2.1. Study Design

This narrative review employs a descriptive analysis method to investigate factors influencing ACL tears in football players. The descriptive analysis approach enables a detailed synthesis of existing literature, allowing for a comprehensive understanding of the intrinsic and extrinsic factors contributing to these injuries. The following sections outline the methodology employed, including literature search strategy, inclusion and exclusion criteria, and data extraction processes.

### 2.2. Literature Search Strategy

To identify relevant studies, a systematic literature search was conducted using multiple electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar. The search spanned studies published between January 2014 and December 2024 to ensure the inclusion of recent and relevant findings. The search strategy combined keywords and Medical Subject Headings (MeSH) terms such as "ACL injury," "anterior cruciate ligament tear," "football players," "risk factors," "biomechanics," "prevention," and "epidemiology." Boolean operators (AND, OR) were applied to refine the search, and filters were used to limit results to peer-reviewed articles written in English.

### 2.3. Inclusion and Exclusion Criteria

Studies were selected based on predetermined criteria to ensure relevance and quality. Inclusion criteria encompassed original research articles, reviews, and meta-analyses that

focused on ACL injuries among football players of all ages and competitive levels. Articles addressing intrinsic factors such as anatomical, physiological, and genetic predispositions, as well as extrinsic factors like environmental conditions, training practices, and preventive strategies, were prioritized. Studies using observational, experimental, or mixed-method designs were included. Conversely, articles that focused on non-football populations, injuries unrelated to the ACL, or those published before 2014 were excluded. Conference abstracts, case reports, and studies with insufficient methodological rigor were also omitted to maintain a high standard of evidence.

### 2.4. Data Extraction and Synthesis

After the initial search, duplicate records were removed, and the remaining articles underwent a two-stage screening process. First, titles and abstracts were reviewed to exclude irrelevant studies. Next, full-text articles were assessed for eligibility based on the inclusion and exclusion criteria. A standardized data extraction form was used to record key information from each study, including authorship, publication year, study design, population characteristics, key findings, and conclusions. The extracted data were then categorized into thematic areas corresponding to the objectives of the review, such as intrinsic and extrinsic risk factors, mechanisms of injury, and prevention strategies.

### 2.5. Quality Assessment

To ensure the credibility of the findings, the methodological quality of included studies was evaluated using established tools such as the Newcastle-Ottawa Scale for observational studies and the Cochrane Risk of Bias tool for experimental research. Each study was assessed independently by two reviewers, and discrepancies were resolved through discussion or consultation with a third reviewer. High-quality studies were emphasized in the synthesis to ensure the reliability of conclusions drawn.

## 3. Epidemiology of ACL Injuries in Football Players

ACL injuries are among the most prevalent and serious injuries in football, with significant implications for players' careers and overall health. These injuries occur at all levels

of play, from youth leagues to professional competitions, with a particularly high incidence in sports like football that require dynamic and high-intensity movements. Recent systematic reviews and meta-analyses have reported that ACL injury rates are notably higher in football compared to other sports, accounting for a significant proportion of knee injuries sustained during both training sessions and matches (1). Despite advancements in training methods and injury prevention programs, the prevalence of ACL injuries has not shown a marked decline, highlighting the persistent challenges associated with mitigating these injuries in football players.

The incidence of ACL injuries in football varies based on the level of play, with professional athletes experiencing the highest rates due to the intense physical demands of the sport. Studies have shown that ACL injury rates in professional leagues are approximately two to three times higher than in amateur and youth competitions. For example, a long-term analysis in professional men's football revealed consistent ACL injury rates over a decade, with no substantial reductions despite the implementation of preventive measures (2). These findings underscore the need for more targeted and sport-specific prevention strategies to address the unique demands of football.

Age is a critical factor influencing the epidemiology of ACL injuries in football. Young athletes, particularly those in adolescence, are at an increased risk of ACL injuries due to the rapid growth and development of their musculoskeletal systems. During this period, players often experience imbalances in muscle strength and coordination, which contribute to higher injury susceptibility. Research has demonstrated that adolescent football players, especially those between the ages of 15 and 19, exhibit the highest incidence of ACL injuries compared to other age groups (1). This elevated risk is attributed to the combination of high participation rates in competitive sports and biomechanical vulnerabilities associated with growth spurts.

Gender-specific trends also play a significant role in ACL injury epidemiology, with female football players experiencing a disproportionately higher risk than their male counterparts. Studies have consistently shown that female athletes are two to six times more likely to sustain ACL injuries, particularly during non-contact scenarios. This increased risk has been attributed to several intrinsic factors,

including anatomical differences, hormonal influences, and neuromuscular control deficits. Female players often exhibit greater knee valgus angles and reduced hamstring-to-quadriceps strength ratios, both of which are significant contributors to ACL injury risk. Additionally, variations in hormonal levels during the menstrual cycle may influence ligament laxity, further predisposing female athletes to ACL injuries (10). These findings emphasize the importance of developing gender-specific prevention programs that address the unique needs of female football players.

The playing position of football players is another key determinant of ACL injury risk, as different positions involve varying physical demands and movement patterns. Forwards and midfielders, who are frequently engaged in high-speed sprints, cutting maneuvers, and sudden changes of direction, exhibit higher rates of ACL injuries compared to defenders and goalkeepers. Studies analyzing match scenarios have highlighted that forwards are particularly vulnerable during attacking plays, where rapid directional changes are required to evade opponents and create scoring opportunities (11, 12). Midfielders, on the other hand, face consistent exposure to repetitive high-intensity movements throughout the game, further elevating their risk of ACL injuries. Understanding position-specific trends is crucial for tailoring injury prevention strategies to the demands of different roles within the game.

Global statistics reveal significant regional variations in ACL injury rates among football players. These differences can be attributed to factors such as playing surface, climate, training practices, and the level of medical infrastructure available. In North America, for example, studies have highlighted a higher prevalence of ACL injuries on artificial turf compared to natural grass. This trend is particularly pronounced among female players, who are more susceptible to the biomechanical challenges posed by synthetic surfaces (8). In contrast, European studies have reported higher overall ACL injury rates in professional leagues, possibly due to the greater intensity and competitiveness of matches in these regions (2). Regional differences also extend to youth and amateur football, where disparities in coaching quality, access to injury prevention programs, and socioeconomic factors play a significant role in influencing injury rates.

Cultural and environmental factors further contribute to regional disparities in ACL injury epidemiology. In regions with limited access to advanced medical care and rehabilitation facilities, players often face delayed or inadequate treatment following ACL injuries. This can result in higher rates of reinjury and long-term complications, such as post-traumatic osteoarthritis. Conversely, countries with well-established sports medicine infrastructures, such as Australia and certain European nations, have demonstrated better outcomes in terms of return-to-play rates and injury prevention (4). These findings highlight the importance of investing in medical and rehabilitation resources to address regional inequities and improve player outcomes.

The long-term consequences of ACL injuries are also significant, as players who sustain these injuries are at a higher risk of developing secondary complications, including chronic knee instability and degenerative joint conditions. Epidemiological studies have shown that approximately 20–30% of players experience recurrent ACL injuries following their initial tear, particularly those who return to play prematurely or without adequate rehabilitation (13). Furthermore, research has indicated that ACL injuries are a major contributor to post-football gonarthrosis, a condition characterized by severe knee osteoarthritis and functional limitations later in life (14). These findings underscore the importance of comprehensive rehabilitation programs and long-term follow-up to mitigate the adverse outcomes associated with ACL injuries.

Despite significant advancements in understanding the epidemiology of ACL injuries in football, several gaps remain in the literature. For instance, there is a lack of large-scale, multicenter studies that capture data from diverse populations and playing levels. Additionally, the influence of emerging factors, such as wearable technology and advanced biomechanical assessments, on injury prevention and diagnosis warrants further exploration. Addressing these gaps through collaborative research initiatives and standardized data collection protocols can enhance our understanding of ACL injury trends and inform evidence-based interventions (15-17).

In conclusion, ACL injuries remain a pervasive issue in football, affecting players across all levels of competition. The prevalence and incidence of these injuries are influenced by a complex interplay of factors, including age, gender,

playing position, and regional differences. While significant progress has been made in identifying key risk factors, there is a continued need for targeted prevention strategies that address the specific demands of football. By integrating insights from epidemiological studies with advancements in biomechanics and rehabilitation, stakeholders can work towards reducing the burden of ACL injuries and promoting the long-term health and performance of football players worldwide.

#### 4. Mechanisms of ACL Injury in Football

The mechanisms underlying ACL injuries in football are multifaceted, influenced by a combination of intrinsic and extrinsic factors. A deep understanding of these mechanisms is crucial for developing targeted prevention strategies that address the unique demands of the sport. Among the most common scenarios leading to ACL injuries are non-contact incidents, which account for the majority of cases. These injuries typically occur during high-risk movements such as cutting, pivoting, or landing from a jump. Studies analyzing match footage have shown that non-contact ACL injuries often result from rapid deceleration or sudden directional changes, where the knee joint experiences significant valgus and rotational stress. These movements, performed at high speeds and under dynamic conditions, place immense strain on the ACL, leading to its rupture in susceptible individuals (3).

In contrast, contact injuries occur less frequently but still represent a significant portion of ACL tears in football. These injuries usually result from direct collisions or tackles, where external forces are applied to the knee joint, causing abnormal movements and excessive stress on the ligament. Contact scenarios often involve an opponent's body weight or momentum being transmitted to the player's knee, resulting in complex injury patterns. While non-contact mechanisms are more amenable to prevention strategies focused on biomechanical and neuromuscular control, contact injuries present greater challenges due to the unpredictability of in-game dynamics. However, both types of injuries share common biomechanical principles that influence their occurrence (11, 12).

Biomechanical factors play a pivotal role in the occurrence of ACL injuries, particularly in non-contact scenarios. Improper landing mechanics have been



extensively documented as a significant contributor to ACL injury risk. During a landing maneuver, the inability to adequately dissipate forces through the lower extremity can lead to excessive loading on the knee joint. High valgus angles, coupled with insufficient activation of stabilizing muscles such as the hamstrings and gluteal muscles, increase the likelihood of ACL tears. Research has demonstrated that players with a stiff landing pattern, characterized by minimal knee flexion and high ground reaction forces, are at an elevated risk of injury. This biomechanical deficiency is particularly pronounced in female football players, who often exhibit greater knee valgus angles and reduced neuromuscular control compared to males (7).

Pivoting movements, another high-risk mechanism, involve rapid rotational forces that place substantial strain on the ACL. During a pivot, the foot remains planted on the ground while the upper body rotates, creating torsional stress on the knee joint. This movement is commonly performed during cutting maneuvers, where players attempt to evade opponents or change direction abruptly. Studies have shown that improper pivoting mechanics, such as inadequate hip rotation or delayed muscle activation, significantly increase the risk of ACL injuries. Additionally, the role of fatigue cannot be overlooked, as players are more likely to exhibit compromised biomechanics and reduced neuromuscular control during the latter stages of a match. This highlights the importance of conditioning programs designed to improve endurance and maintain optimal movement patterns under fatigue (15-17).

External forces and player dynamics further contribute to the complex mechanisms of ACL injuries. Environmental factors such as playing surface and footwear can influence the risk of injury by altering traction and stability. Research has highlighted that artificial turf, commonly used in many football settings, is associated with a higher incidence of ACL injuries compared to natural grass. The increased friction and reduced shock absorption of artificial surfaces contribute to greater ground reaction forces and altered movement mechanics, particularly during cutting and pivoting actions. This risk is especially pronounced in female players, who may experience greater biomechanical challenges on these surfaces (8). Conversely, poorly maintained natural grass fields with uneven surfaces also

pose a risk, as they can lead to unexpected slips or missteps that compromise knee stability (18).

Player dynamics, including body positioning and joint alignment during high-risk movements, are critical determinants of ACL injury risk. Studies have shown that improper body posture, such as an upright trunk or inwardly rotated knees during landing or pivoting, increases the strain on the ACL. The timing and coordination of muscle activation also play a vital role in mitigating injury risk. For example, the hamstrings, which act as secondary stabilizers of the knee, must contract effectively to counteract anterior tibial translation caused by the quadriceps. Inadequate hamstring activation or delayed muscle response can lead to an imbalance of forces around the knee joint, increasing the likelihood of ACL injury (15-17). Neuromuscular training programs aimed at improving muscle coordination and reaction times have been shown to reduce injury rates, highlighting the importance of incorporating these components into preventive strategies.

In addition to biomechanical and environmental factors, psychological and situational variables can influence the risk of ACL injuries. High-pressure scenarios, such as critical moments in a match, may lead to rushed decision-making and suboptimal movement patterns. Players under stress are more likely to exhibit biomechanical deficiencies, such as reduced knee flexion angles and improper weight distribution, which increase the risk of injury. Moreover, the role of fatigue in compromising cognitive and physical performance further underscores the multifactorial nature of ACL injury mechanisms. Interventions that address psychological readiness and decision-making under pressure, in conjunction with physical conditioning, may help reduce injury risk (4).

The interplay between intrinsic factors, such as anatomical and physiological characteristics, and extrinsic factors, such as environmental conditions and gameplay dynamics, creates a complex framework for ACL injury mechanisms. Players with predisposing anatomical features, such as a narrow intercondylar notch or a steep tibial slope, may be more susceptible to ACL injuries when exposed to high-risk movements. Similarly, hormonal fluctuations, particularly in female players, may influence ligament laxity and neuromuscular control, further increasing injury risk during specific phases of the menstrual cycle (10).

The mechanisms of ACL injuries in football are inherently multifaceted, involving a dynamic interplay of biomechanical, environmental, and psychological factors. Understanding these mechanisms is essential for developing effective prevention strategies that address the specific demands of the sport. While significant progress has been made in identifying high-risk scenarios and modifiable risk factors, ongoing research is needed to refine our understanding and improve intervention efficacy. By integrating biomechanical analyses, neuromuscular training, and environmental modifications, stakeholders can work towards reducing the burden of ACL injuries and promoting player safety in football.

### 5. Intrinsic Factors Affecting ACL Tear

Intrinsic factors play a fundamental role in determining an individual's susceptibility to ACL tears, encompassing anatomical, physiological, genetic, and neuromuscular characteristics. These factors are intrinsic to the athlete and often interact with external forces to create conditions conducive to ACL injuries. Understanding these intrinsic contributors is critical for identifying at-risk athletes and tailoring preventive interventions to address specific vulnerabilities.

Anatomical factors, particularly those related to the structure and alignment of the knee joint, have long been recognized as significant contributors to ACL injury risk. Variations in knee joint anatomy, such as a narrow intercondylar notch or a steep tibial slope, can increase the mechanical stress placed on the ACL during dynamic movements. The intercondylar notch, a groove at the distal end of the femur, houses the ACL. A narrower notch may physically constrain the ligament, making it more prone to impingement during high-stress activities. Similarly, a steep tibial slope, particularly on the lateral side, promotes anterior translation of the tibia relative to the femur, increasing strain on the ACL during landing or pivoting movements. These anatomical features are non-modifiable but can be identified through imaging techniques to assess an athlete's risk profile (15-17).

Gender differences in knee joint anatomy also play a role in ACL injury risk, with female athletes being disproportionately affected. Women tend to have a wider pelvis, leading to a greater quadriceps angle (Q-angle) at the

knee joint. This anatomical configuration increases valgus stress during movements such as cutting and landing. Additionally, females often exhibit greater ligament laxity, which reduces joint stability and places additional strain on the ACL. This laxity is influenced by hormonal fluctuations, particularly variations in estrogen and relaxin levels, which have been shown to affect collagen metabolism and ligament stiffness. The heightened susceptibility of female athletes to ACL injuries underscores the need for targeted preventive strategies that address these anatomical and physiological differences (10).

Hormonal influences further compound the risk of ACL tears, particularly in female athletes. Studies have shown that fluctuations in estrogen levels during the menstrual cycle can alter the mechanical properties of the ACL, reducing its tensile strength and making it more susceptible to injury. High estrogen levels, typically observed during the ovulatory phase, are associated with increased ligament laxity and reduced neuromuscular control. These hormonal effects are thought to interact with biomechanical factors, such as knee valgus and landing mechanics, to elevate injury risk during specific phases of the menstrual cycle. Although the exact mechanisms remain under investigation, this relationship highlights the importance of considering hormonal factors when designing injury prevention programs for female athletes (7).

Genetic predispositions also contribute to ACL injury risk, with emerging evidence suggesting a role for specific gene variations in ligament structure and repair. Polymorphisms in genes encoding collagen proteins, such as COL1A1 and COL5A1, have been implicated in altering the structural integrity of ligaments. These genetic variations may lead to reduced collagen fibril strength or abnormal remodeling responses, increasing the likelihood of ligamentous injuries under mechanical stress. While genetic testing for ACL injury risk is not yet widely implemented in clinical practice, advancements in this area could enable personalized risk assessments and targeted interventions for genetically predisposed individuals (19).

Family history also appears to play a role in ACL injury risk, with studies indicating that individuals with a family history of ACL injuries are more likely to experience similar injuries. This increased risk may result from inherited anatomical and neuromuscular characteristics or shared

environmental exposures, such as participation in high-risk sports. Identifying athletes with a genetic predisposition to ACL injuries could help inform preventive strategies, including enhanced monitoring and individualized training programs (6).

Muscle strength and coordination are among the most critical intrinsic factors influencing ACL injury risk, as they directly impact the ability to stabilize the knee joint during dynamic activities. The balance between the quadriceps and hamstrings is particularly important, as these muscle groups work together to control anterior tibial translation and rotational forces. An imbalance, characterized by quadriceps dominance or insufficient hamstring activation, places excessive strain on the ACL during movements such as landing or pivoting. Studies have shown that athletes with weaker hamstrings relative to their quadriceps are at a significantly higher risk of sustaining ACL injuries, highlighting the need for strength training programs that emphasize hamstring development (15-17).

Neuromuscular coordination further influences an athlete's ability to maintain proper joint alignment and movement patterns under dynamic conditions. Poor neuromuscular control, characterized by delayed muscle activation or improper sequencing of muscle contractions, can lead to biomechanical errors that increase ACL strain. For example, athletes with inadequate control of hip and trunk movements are more likely to exhibit knee valgus during landing, a known risk factor for ACL injuries. These deficits are particularly pronounced in female athletes, who often demonstrate less effective neuromuscular strategies for maintaining knee stability. Neuromuscular training programs that focus on improving balance, proprioception, and movement efficiency have been shown to reduce ACL injury rates by enhancing joint stabilization during high-risk activities (10).

Fatigue also plays a critical role in muscle strength and coordination, as it impairs the neuromuscular system's ability to execute precise movements. During the later stages of a match or training session, athletes are more likely to exhibit biomechanical deviations, such as reduced knee flexion angles or increased valgus alignment, that elevate ACL injury risk. Conditioning programs designed to improve muscular endurance and delay the onset of fatigue are essential for minimizing these risks. Additionally,

monitoring workload and ensuring adequate recovery between training sessions can help mitigate the effects of fatigue on neuromuscular performance (4).

Intrinsic factors influencing ACL injury risk are multifaceted and often interact with external forces to create conditions conducive to ligament failure. Anatomical and physiological characteristics, such as knee joint structure and hormonal influences, provide a baseline level of risk that varies among individuals. Genetic predispositions further modulate this risk by affecting ligament properties and repair mechanisms. Finally, muscle strength and coordination play a dynamic role in determining an athlete's ability to withstand the physical demands of football, particularly during high-risk movements. By addressing these intrinsic factors through targeted training and intervention programs, it is possible to reduce ACL injury rates and promote long-term joint health among football players. Future research should continue to explore the complex interplay of these factors, with an emphasis on developing personalized prevention strategies that account for individual risk profiles.

## 6. Extrinsic Factors Influencing ACL Injuries

Extrinsic factors play a critical role in the occurrence of ACL injuries in football, encompassing a variety of environmental, behavioral, and situational influences. These factors often interact with intrinsic predispositions to increase or mitigate injury risk. Understanding the contribution of extrinsic elements such as playing surfaces, footwear, training practices, workload management, and the intensity of competition is essential for designing effective preventive strategies and reducing the incidence of ACL injuries in football players.

One of the most significant environmental factors affecting ACL injury risk is the playing surface. Studies have shown that the type of surface can substantially influence traction, stability, and force transmission during gameplay. Artificial turf, commonly used in football, has been associated with a higher incidence of ACL injuries compared to natural grass. The increased friction and reduced shock absorption properties of artificial surfaces create greater ground reaction forces and alter the biomechanics of high-risk movements such as cutting, pivoting, and landing. These changes in mechanics can lead to excessive strain on the ACL, particularly during rapid directional changes. Female



athletes, who are already at a higher risk for ACL injuries due to intrinsic factors, appear to be disproportionately affected by the challenges posed by artificial surfaces. Conversely, poorly maintained natural grass fields with uneven or slippery conditions also increase injury risk, as they can lead to unexpected slips, missteps, or altered movement patterns that compromise knee stability (8, 18).

Footwear also plays a critical role in influencing ACL injury risk. The interaction between footwear and the playing surface determines the traction and stability available to athletes during dynamic movements. Football boots with cleats designed for specific surfaces can either enhance performance or increase injury risk depending on their configuration. For instance, shoes with excessively long or rigid cleats can increase rotational forces at the knee during pivoting, elevating the risk of ACL injury. Conversely, insufficient traction due to inappropriate footwear can lead to slips and falls, further compromising knee stability. The selection of proper footwear that balances traction and mobility for specific playing surfaces is crucial for minimizing injury risks. Innovations in shoe design that focus on reducing harmful rotational forces while maintaining adequate grip hold promise for reducing ACL injury rates in football (11, 12).

Training practices and workload management are equally important extrinsic factors influencing ACL injuries. Football players are exposed to high physical and mental demands during training and matches, making the optimization of workload a critical aspect of injury prevention. Overtraining and inadequate recovery are major contributors to neuromuscular fatigue, which compromises movement quality and increases susceptibility to injury. Fatigue-induced impairments in coordination and muscle activation often result in biomechanical errors, such as reduced knee flexion or increased valgus alignment during landing and cutting movements, both of which are strongly associated with ACL injuries. Studies have highlighted that players with insufficient recovery between sessions or those subjected to sudden increases in training intensity are at a significantly higher risk of sustaining injuries. Implementing structured workload monitoring systems, such as tracking player load using GPS devices or heart rate monitors, can help coaches and medical staff optimize training schedules and prevent excessive fatigue (4).

In addition to workload management, the quality and content of training programs play a significant role in ACL injury prevention. Many traditional training routines focus heavily on physical conditioning and skill development but neglect neuromuscular and biomechanical training components. However, evidence suggests that incorporating specific exercises targeting neuromuscular control, proprioception, and movement efficiency can significantly reduce ACL injury rates. Programs such as the FIFA 11+ warm-up routine have demonstrated effectiveness in improving muscle coordination, reducing valgus moments, and enhancing overall knee stability during high-risk movements. Furthermore, training drills that simulate game-like scenarios, including rapid directional changes and landing under dynamic conditions, are essential for preparing athletes to perform safely during matches (9).

The intensity of games and the competitive level of play also significantly influence ACL injury risk. High-stakes matches and tournaments often require players to perform at their physical and mental limits, increasing the likelihood of errors that lead to injury. During intense competition, athletes may exhibit riskier movement patterns, such as aggressive tackling, high-speed sprints, and rapid changes of direction, all of which place significant stress on the ACL. Studies have shown that the risk of ACL injuries is higher during competitive matches than during training sessions, primarily due to the increased pace and unpredictability of in-game scenarios. Additionally, the psychological pressure associated with high-stakes competitions can lead to rushed decision-making and suboptimal biomechanical execution, further elevating injury risk (2).

The level of competition also plays a role in determining injury risk. Professional and elite-level football players are exposed to higher game intensities and physical demands compared to amateur or recreational players. The faster pace of professional matches, combined with the physicality of challenges and the technical precision required, creates a heightened risk environment for ACL injuries. However, professional players often have access to superior medical care, advanced training facilities, and evidence-based injury prevention programs, which can mitigate some of these risks. In contrast, amateur players may lack access to such resources, making them more vulnerable to the effects of

poor training practices, inadequate recovery, and suboptimal playing conditions (5).

Environmental and situational factors during matches also contribute to ACL injury risk. Weather conditions, such as rain or extreme heat, can affect playing surfaces and athlete performance. Wet fields increase the likelihood of slips and falls, while high temperatures can exacerbate fatigue, leading to reduced coordination and higher injury susceptibility. Additionally, the timing of matches within a season may influence injury risk, as players who are exposed to congested schedules or back-to-back games face greater fatigue and reduced recovery opportunities. These situational factors highlight the importance of comprehensive injury prevention strategies that account for the specific conditions players are exposed to during training and competition (Palmieri-Smith et al., 2021).

Extrinsic factors influencing ACL injuries in football are diverse and multifaceted, encompassing environmental conditions, equipment, training practices, and the demands of competition. The interaction between these factors and an athlete's intrinsic predispositions creates a complex risk profile that varies across individuals and scenarios. Addressing these extrinsic factors requires a holistic approach that combines evidence-based training programs, optimized workload management, appropriate equipment selection, and situational awareness. By understanding and mitigating the impact of extrinsic influences, stakeholders in football can significantly reduce the burden of ACL injuries and promote the long-term health and performance of players. Continued research and innovation in this field are essential for refining prevention strategies and adapting them to the evolving demands of the sport.

## 7. Prevention and Risk Mitigation Strategies

Preventing ACL injuries in football is a multifaceted challenge that requires an integrated approach targeting both intrinsic and extrinsic risk factors. Effective prevention and risk mitigation strategies combine structured injury prevention programs, neuromuscular training, advancements in protective equipment and technology, and the vital role of education and coaching. These elements work synergistically to reduce the incidence and severity of ACL injuries across all levels of play.

Injury prevention programs are among the most widely studied and implemented strategies for reducing ACL injury risk in football. One of the most prominent examples is the FIFA 11+ program, a structured warm-up protocol designed to enhance strength, balance, and neuromuscular control. Research has consistently demonstrated that players who adhere to the FIFA 11+ protocol experience a significant reduction in injury rates, including ACL tears. The program includes exercises targeting core stability, lower extremity strength, and dynamic control, all of which address key biomechanical deficits associated with ACL injuries. By incorporating movements that mimic high-risk scenarios, such as cutting and landing, the FIFA 11+ program helps athletes improve their movement patterns and reduce harmful joint stresses during gameplay. The widespread adoption of this program at the youth and amateur levels has shown promise in bridging the gap between professional and non-professional injury prevention efforts (9).

Neuromuscular training is another cornerstone of ACL injury prevention, focusing on improving the coordination and activation of muscle groups that stabilize the knee joint. Neuromuscular deficits, such as delayed muscle activation or imbalanced strength ratios, are common contributors to ACL injuries. Training programs that incorporate plyometric exercises, agility drills, and proprioceptive tasks have been shown to enhance neuromuscular control and reduce the likelihood of biomechanical errors during high-risk movements. For instance, targeted exercises to strengthen the hamstrings relative to the quadriceps help counteract anterior tibial translation, a primary mechanism of ACL injury. Proprioceptive training using balance boards and stability exercises also improves joint position awareness, enabling athletes to maintain proper alignment during dynamic movements. Evidence suggests that these training methods are particularly effective when implemented as part of a comprehensive preseason conditioning program or as a regular component of team practices (15-17).

The role of protective equipment and technology in ACL injury prevention has garnered increasing attention in recent years. Advances in wearable technology, such as motion sensors and inertial measurement units, allow for the real-time monitoring of player movements and joint mechanics during training and competition. These devices can identify biomechanical patterns that place athletes at risk for ACL

injuries, enabling early intervention and individualized training adjustments. Additionally, improvements in footwear design have focused on optimizing traction and reducing rotational forces on the knee, particularly on artificial playing surfaces. Football boots with cleat configurations that minimize torsional stress while maintaining stability have shown promise in reducing injury risk. Moreover, the development of advanced braces and supports for at-risk players, particularly those returning from ACL reconstruction, has helped enhance knee stability and reduce reinjury rates (15-17).

Coaching and education play a pivotal role in the success of injury prevention efforts, as coaches are often the primary facilitators of training programs and injury mitigation strategies. Educating coaches on the biomechanical and neuromuscular factors associated with ACL injuries empowers them to implement evidence-based practices in their training sessions. For example, coaches trained to recognize and correct improper landing mechanics or cutting techniques can significantly influence players' movement patterns and reduce their risk of injury. Additionally, educating players about the importance of proper warm-ups, recovery protocols, and adherence to injury prevention programs fosters a culture of injury awareness and proactive management. Studies have shown that teams with well-educated coaching staff experience lower injury rates, underscoring the importance of integrating education into broader prevention strategies (11, 12).

The psychological readiness of players is another critical element in injury prevention, particularly for those returning from ACL reconstruction or other major injuries. Psychological barriers, such as fear of reinjury or lack of confidence, can affect movement patterns and neuromuscular control, increasing the risk of subsequent injuries. Coaches and medical staff can address these issues through cognitive-behavioral interventions and supportive communication, helping players regain their confidence and focus. Creating an environment that prioritizes mental well-being alongside physical performance is essential for comprehensive injury prevention (4).

Workload management and recovery practices also contribute significantly to ACL injury prevention. Overtraining and insufficient recovery are known risk factors that can exacerbate neuromuscular fatigue and impair

movement quality. Coaches and sports scientists can utilize workload monitoring tools, such as GPS tracking and heart rate variability analysis, to optimize training loads and ensure adequate recovery between sessions. Periodization, or the strategic planning of training intensity and volume, is particularly effective in preventing overuse injuries and maintaining optimal performance levels. Ensuring that players are adequately rested and prepared for high-intensity competition is crucial for minimizing injury risk (Palmieri-Smith et al., 2021).

The integration of these prevention strategies requires a multidisciplinary approach involving coaches, medical professionals, sports scientists, and players themselves. Collaboration among these stakeholders ensures that prevention programs are effectively implemented, monitored, and adapted to the needs of individual athletes and teams. Regular assessments of injury prevention protocols, along with data-driven evaluations of their effectiveness, can help refine strategies and promote continuous improvement. By addressing the multifactorial nature of ACL injuries through a comprehensive and collaborative approach, it is possible to significantly reduce their incidence and impact on football players. Continued research and innovation in this field will play a critical role in advancing prevention efforts and ensuring the long-term health and performance of athletes.

## 8. Discussion and Conclusion

ACL injuries remain one of the most challenging issues in football, with significant implications for players, teams, and the broader football community. The multifactorial nature of these injuries necessitates a nuanced understanding of their intrinsic and extrinsic contributors, as well as the development of targeted prevention strategies. This review has synthesized evidence on key factors influencing ACL injuries, highlighting the importance of addressing both modifiable and non-modifiable risks to minimize their impact.

The intrinsic factors influencing ACL injuries underscore the complex interplay of anatomical, physiological, genetic, and neuromuscular characteristics. Variations in knee anatomy, such as intercondylar notch width and tibial slope, are significant contributors to injury susceptibility. These structural differences, coupled with gender-specific

variations such as greater Q-angle and hormonal influences in female athletes, highlight the need for individualized risk assessments. Hormonal fluctuations during the menstrual cycle, particularly elevated estrogen levels, have been shown to impact ligament properties and neuromuscular control, further exacerbating injury risk. Genetic predispositions, including polymorphisms in collagen-encoding genes, provide an additional layer of complexity, suggesting that certain athletes may have an inherent vulnerability to ACL injuries. Neuromuscular deficits, including imbalances in muscle strength and delayed activation patterns, further elevate risk, emphasizing the need for tailored strength and conditioning programs.

Extrinsic factors, such as environmental conditions, training practices, and competition demands, compound the challenges associated with ACL injury prevention. Playing surfaces and footwear are critical determinants of biomechanical forces during gameplay. The increased traction and friction of artificial turf have been consistently linked to higher ACL injury rates, particularly in high-speed movements like cutting and pivoting. Similarly, inadequate or inappropriate footwear can alter traction and stability, further increasing injury risk. Training practices and workload management are equally crucial, as overtraining and insufficient recovery impair neuromuscular performance and elevate susceptibility to injury. High-intensity competition settings and the psychological pressures associated with elite-level play further complicate injury prevention efforts, as they can lead to risky movement patterns and reduced focus on proper biomechanics.

The mechanisms of ACL injuries provide valuable insights into high-risk scenarios, particularly the distinction between non-contact and contact injuries. Non-contact injuries, which account for the majority of ACL tears, typically result from biomechanical errors during cutting, landing, or pivoting movements. These errors are often influenced by neuromuscular deficits, such as inadequate hamstring activation or poor trunk and hip control. Fatigue further exacerbates these deficits, making late-game scenarios particularly dangerous. Contact injuries, while less common, are often unpredictable and arise from external forces during tackles or collisions. These injuries highlight the importance of situational awareness and the need for protective strategies in high-risk game scenarios.

Prevention strategies play a central role in mitigating ACL injuries and are most effective when they address both intrinsic and extrinsic risk factors. Evidence-based programs such as the FIFA 11+ have demonstrated significant reductions in injury rates by improving neuromuscular control, balance, and strength. Neuromuscular training programs that incorporate plyometric exercises, proprioceptive tasks, and strength conditioning have been particularly effective in addressing biomechanical deficits associated with ACL injuries. These programs not only enhance performance but also instill movement patterns that reduce harmful joint stresses during gameplay. The integration of wearable technology and biomechanical assessments further enhances prevention efforts by providing real-time feedback on movement patterns and identifying at-risk athletes.

The role of coaching and education cannot be overstated in the context of ACL injury prevention. Coaches are pivotal in implementing prevention programs and fostering a culture of injury awareness within teams. Educating players on the importance of proper warm-ups, movement mechanics, and recovery protocols empowers them to take an active role in their injury prevention efforts. Moreover, the psychological readiness of players, particularly those returning from ACL reconstruction, is a critical component of long-term injury prevention. Addressing fear of reinjury and building confidence through supportive coaching and rehabilitation strategies can improve both physical and psychological outcomes for athletes.

Despite the significant advancements in understanding and preventing ACL injuries, challenges remain. One notable limitation is the variability in adherence to prevention programs, particularly at the amateur and youth levels. Many players and teams lack access to the resources and expertise required to implement evidence-based strategies effectively. Additionally, the evolving nature of football, with its increasing speed and intensity, presents new challenges for injury prevention. Research must continue to adapt to these changes by exploring innovative approaches, such as biomechanical modeling and individualized training protocols, to address emerging risk factors.

Another critical gap lies in the integration of gender-specific prevention strategies. Female football players face

unique challenges due to their anatomical and physiological differences, yet many existing programs fail to account for these nuances. Tailored interventions that address hormonal influences, neuromuscular control deficits, and biomechanical variations are essential for reducing the disproportionately high injury rates observed in female athletes. Future research should prioritize the development and validation of gender-specific prevention programs to address these disparities effectively.

Global disparities in ACL injury rates and outcomes further highlight the need for equitable access to prevention and rehabilitation resources. Players in regions with limited access to advanced medical care and training facilities face higher risks of reinjury and long-term complications. Addressing these inequities requires collaborative efforts to disseminate best practices, provide educational resources, and invest in infrastructure to support injury prevention initiatives worldwide.

ACL injuries represent a significant challenge in football, with profound implications for players' careers, team performance, and overall health. The multifactorial nature of these injuries, influenced by intrinsic factors such as anatomy and neuromuscular control and extrinsic elements like playing surfaces and workload management, necessitates a comprehensive approach to prevention. Evidence-based strategies, including structured warm-up protocols, neuromuscular training, and the use of advanced technology, have shown promise in reducing injury rates. The role of education and coaching is equally critical, as these stakeholders are instrumental in implementing and sustaining prevention efforts.

While significant progress has been made, gaps remain in the integration of gender-specific approaches, equitable access to resources, and the adaptation of prevention strategies to the evolving demands of the sport. Addressing these gaps through collaborative research, innovation, and education will be essential for reducing the burden of ACL injuries in football. By continuing to prioritize the health and safety of players through multidisciplinary efforts, stakeholders can foster a safer and more sustainable future for the sport.

### Authors' Contributions

N. G. A. conceptualized the study, conducted the literature review, and drafted the initial manuscript. M. S. contributed to data synthesis, categorized thematic areas, and reviewed prevention strategies. H. N. oversaw the analysis of intrinsic and extrinsic risk factors, provided critical revisions, and ensured the accuracy of biomechanical insights. All authors collaborated on finalizing the manuscript and approved the final version for publication.

### Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

### Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

### Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

### Declaration of Interest

The authors report no conflict of interest.

### Funding

According to the authors, this article has no financial support.

### Ethics Considerations

Not applicable.

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