Modifiable Risk Factor Assessment and Mitigation Strategies for Non-contact Anterior Cruciate Ligament Injury in Female Footballers: A Literature Review

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Abstract:

Background: Non-contact anterior cruciate ligament injuries are more prevalent among female soccer participants. These injuries pose significant challenges to their sports careers and have implications for their mental well-being. The recovery process post-surgery for such injuries tends to be prolonged and can have adverse effects on their physical state. Studies suggest that factors contributing to non-contact anterior cruciate ligament injuries can be classified as either modifiable or non-modifiable, with modifiable factors encompassing internal and external components. It is imperative to comprehend these modifiable risk factors and employ efficient strategies and cutting-edge technologies for outcome assessment to mitigate the occurrence of ACL injuries in this specific demographic. **Objective:** current literature review was undertaken to identify potential risk factors and outcome measures, with the objective of developing evidence-based strategies and methodologies that cater to the specific needs of female soccer athletes. Sources/methods: The study utilized online databases such as Scopus, Web of Science, and SportDiscus, aiming to extract pertinent sources from articles, reviews, theses, and dissertations. The sources were meticulously filtered based on established inclusion and exclusion criteria. A total of 90 research papers were examined, from which 52 papers were ultimately selected. Conclusion: The study concluded that the assessment of modifiable risk factors, including core strength, neuromuscular components, and methodologies employing machine learning, alongside functional tests integrated with artificial intelligence, will enhance the precision of prevention strategies, which should concentrate on these identified factors.

Keywords: ACL, Modifiable Risk Factor, Injury prevention, IMU

Introduction:

ACL is the most challenging ligament in the knee for a sports person, mainly players involving Lower limb sports, the most injured sports were identified as football, basketball, and volleyball[1]. Predominantly Gender wises it has been said that females are 2 to 10 ratio more prone than males as cited in one study observed the occurrence of ACL injury for five years in that they observed the female in football and basketball is average of 0.31 and 0.29 per 1000 respectively whereas the male is 0.07 per 1000 in basketball, one of study reveals that narrow femoral condyle, wider pelvis[2] and hormonal changes, but they lack to prove. ACL where the mechanism of injury in football is mostly noncontact and during landing on a single leg or pivoting.[10,46,47] The risk factors have been identified as modifiable and nonmodifiable. Nonmodifiable risk factors such as previous injury, alignment defect, and anatomical, and hormonal implications which is difficult to adopt in prevention strategies. As we referred the literature, shows that the modifiable risk factors for non-contact ACL injuries in female football players are multi-factorial and comprise biomechanical, and neuromuscular factors predominantly involving muscle imbalance, or muscle weakness, poor conditioning, abnormal landing mechanics, as well as extrinsic factors such as footwear, playing surface and playing condition,[3] the modifiable risk factor which can be altered by adopting strategies. Understanding and evaluating the modifiable risk factors associated with ACL injuries is crucial in developing targeted strategies and measures to improve performance and reduce the incidence of these debilitating injuries.[4] The evaluation methods play a key role in understanding the nature of risk factors, hence understanding the nature and we can chart out that implementing effective warm-up strategies tailored to the specific needs of female football players can play a pivotal role in injury prevention and overall athletic performance.[5]

Additionally, the effectiveness of warm-up strategies goes beyond simply preparing the body for physical exertion; it also addresses certain factors like Biomechanical mainly landing techniques and their Role in the mechanism of injury another factor address is neuromuscular control which covers dynamic stability, core stability, muscle contraction strength and explosive strength which are all crucial in mitigating the risk of ACL injuries.[3]

This review aims to narrate a comprehensive understanding of the modifiable risk factors and certain evaluating tools associated with non-contact ACL injuries in female football players, the tools or measures it addresses are landing error score system using an Inertia measuring unit, core stability test, functional movement screening, isokinetic, EMG, Y Balance test. While understanding the interplay of various risk factors and the underlying mechanisms of ACL injury, this review seeks to equip coaches, athletic trainers, and healthcare professionals with the knowledge required to implement targeted interventions and warm-up protocols that can effectively mitigate the prevalence of ACL injuries in female football players.

Method:

A thorough literature review was undertaken to explore the effects of warm-up exercises on modifiable risk factors linked to non-contact ACL injuries in athletes. The review encompassed studies focusing on the impact of warm-up interventions on neuromuscular control, muscle strength, coordination, and biomechanical aspects associated with non-contact ACL injuries. Initial searches were performed across various databases such as PubMed, Web of Science, and SPORTDiscus, using specific terms like "warm-up exercises," "non-contact ACL injury

prevention," "neuromuscular control," "muscle strength and coordination," and "biomechanical factors."

Inclusion Criteria

The selected studies concentrated on modifiable risk factors, evaluation, and warm-up approaches for non-contact ACL injuries within female football players. They examined the effectiveness of tailored prevention programs designed to address individual athlete requirements. The research also delved into the impact of different training elements, particularly neuromuscular training, balance training, core stability and landing technique, on injury prevention among female football players.[6,7] The studies encompassed diverse settings, including youth leagues, college teams, and professional clubs. Moreover, the study included both quantitative and qualitative analyses offering insights into female football players' perspectives and experiences regarding injury prevention strategies, as well as assessments of long-term effects related to prevention programs.[9]

The review incorporated experimental and observational studies, systemic reviews, and umbrella reviews evaluating the influence of warm-up exercises on modifiable risk factors and their assessment for non-contact ACL injuries in athletes.

Exclusion Criteria

Studies not focusing on non-contact ACL injuries in female football players were excluded. Additionally, studies lacking a comprehensive evaluation of modifiable risk factors and strategies to mitigate risks were not considered. Studies with inadequate sample sizes or methodological rigor were also excluded, along with articles not in English and research conducted in sports or activities outside of football, volleyball, and basketball.

Discussion

When considering the risk factors of non-contact ACL injuries in football, as mentioned in the introduction, there are modifiable and non-modifiable factors. This study primarily focuses on modifiable risk factors. According to reviews, modifiable risk factors associated with ACL injuries include intrinsic factors such as neuromuscular and biomechanics, particularly muscle weakness/imbalance, poor conditioning, and abnormal landing mechanics, as well as extrinsic factors like footwear, playing surface, and playing conditions.

The mechanism of non-contact ACL injury is influenced by various factors, with the most significant factors being a combination of factors such as dual planar eccentric loading of the knee during single limb supported landing, rapid quadriceps contraction, and the antagonistic lines of action between the patella tendon and ACL. In female footballers, the identified mechanism is related to biomechanical factors such as a small knee flexion angle, great posterior ground reaction force, and quadriceps muscle force, all of which are significant ACL loading mechanisms.[4] Moreover, differences in whole-body kinematics during single-leg landings, including ankle, hip, and trunk flexion angles, play a role in ACL injury risk, with rearfoot landings potentially explaining the higher injury rate among females.[9]

The **neuromuscular** component plays a role in controlling the postural and core muscles during maximal sports activity.[10,43] Several studies have highlighted the importance of the neuromuscular component in the prevention of non-contact ACL injuries, particularly focusing

on knee flexor and extensor preactivation, core body control, lower extremity proprioception, and muscle strength imbalances that predispose individuals to ACL ruptures.[11,12] Studies suggest that addressing neuromuscular deficits through targeted training protocols can enhance athletic performance and decrease the likelihood of ACL injuries, especially in high-risk sports like soccer and basketball.[10,13,14]

Muscle imbalance is considered one of the primary factors leading to ACL injury. Factors such as dynamic knee valgus, knee flexor and extensor preactivation, and neuromuscular imbalances can contribute to ACL injury.[15,16] Reduced preactivation of knee flexors and increased activation of knee extensors have been associated with ACL ruptures, emphasizing the importance of neuromuscular control and muscle balance.[10,17] Specifically, the hamstring quadricep ratio is a crucial factor for ACL injury. Studies suggest that imbalances in the H/Q ratio can increase vulnerability to ACL injuries.18 Maintaining an optimal balance between hamstring and quadriceps strength is essential for knee joint stability and injury prevention.[19,20] Additionally, a functional H/Q ratio not less than 0.9 during knee flexion and extension, considering eccentric-concentric muscle actions, has been proposed as a more accurate measure to assess knee muscle strength balance and reduce injury risk.[20] Therefore, monitoring and improving the H/Q ratio through targeted exercises and training programs can be beneficial in preventing ACL injuries and enhancing overall knee joint stability.

Core stability's significance is evident in the realm of lower limb kinematics, particularly in its role in enhancing knee kinematics. It effectively facilitates energy transfer and stabilizes the trunk during functional tasks, thereby contributing to improved player performance and reduced injury risks.[21,22] According to research, the incorporation of core stability exercises can help minimize ACL injuries associated with core muscle imbalances.

Dynamic Knee Valgus (DKV) refers to the outward movement of the leg, resulting from muscle imbalances, which can exert excessive stress on the knee joint ligaments. Studies indicate that DKV is commonly observed in competitive sports such as football and basketball, especially during activities like landing and cutting, increasing the likelihood of ACL injuries, particularly in females due to anatomical differences.[23] Research suggests that the alignment of the tibial slope is a critical factor in DKV, with steeper lateral tibial slopes being identified as a potential cause of ACL injuries.[24,25,26] Furthermore, other contributing factors include an increased Q angle, hip abductor weakness, poor hip or postural control, excessive lateral trunk flexion, knee flexion exceeding 30 degrees, and a deficit in the Hamstring-Quadriceps Ratio.[27] To address this issue, experts recommend implementing proper landing techniques to mitigate excessive DKV, along with strategies focused on core stability, hip abductor strength, and ankle stability, particularly in sports like football and basketball.[24,28]

Proprioception plays a crucial role in non-contact ACL injuries by influencing movement patterns and joint stability. Tasks involving rapid movements, landing, and pivoting challenge knee stability, necessitating good proprioception to efficiently control neuromuscular responses.[7,29] A deficiency in proprioception can serve as a contributing factor to non-contact ACL injuries. Moreover, impaired or inadequate proprioception can lead to delayed motor responses, negatively impacting the ability to adapt to environmental changes and potentially predisposing individuals to non-contact ACL injuries.[30,31] The study emphasizes the importance of proper proprioception for joint stability and recommends enhancing proprioception to prevent non-contact ACL injuries effectively.[49]

Outcome measures are essential for identifying the underlying factors contributing to non-contact ACL injuries. Several modifiable risk factors were identified in the study, including dynamic knee angle (adduction angle and knee flexion angle) and ground reaction force, which are considered potential predisposing factors. Other modifiable risk factors discussed include muscle imbalances, balance, and landing techniques. The study utilized various outcome measures such as Inertia Measuring Units for assessing the Landing Error Score System, isokinetic testing, the Star Excursion Balance Test, and the Functional Movement Scale to identify susceptible risk factors for non-contact ACL injuries.

The Inertia Measuring Unit (IMU) stands out as a prominent and reliable tool for measuring angular velocity and linear acceleration. IMU identification of risk factors predisposing to non-contact ACL injuries during landing is crucial. It is also utilized to determine the progression during the rehabilitation process. IMU, in conjunction with the Landing Error Score System, has been integrated.[32,33,34,35] The use of IMUs positioned on the tibia has shown strong correlations with knee variables relevant to the risk of ACL injuries, assisting in the assessment of ACL injury risk in field settings. Furthermore, the application of Machine Learning methods to predict sports injuries has significantly increased the success rate, demonstrating high accuracy in the identification of injury risk factors in athletes and potentially aiding in injury prevention strategies.[36,37,50] The combination of AI and IMU technology will enhance the precision in identifying risk factors.[38] When considering other tools or scales, studies have suggested a few options such as the Functional Motor Scale (FMS), core stability, co-contraction of hamstrings and quadriceps, and balance. Delving deeper into FMS, it is a valid tool for identifying fundamental movements in athletes and assists in pinpointing movement control during dynamic tasks. Research has indicated that deficits in perceptual-motor function, especially in postural control, may persist in individuals with contact ACL injuries, resulting in slower lower extremity visuomotor reaction times. The FMS can be valuable in identifying perceptual-motor control, and its further utilization as an outcome measure can aid in outlining the progression of related preventive measures. [39,52] The hamstring-quadriceps ratio is crucial in identifying the co-contraction factor for predicting non-contact ACL injuries, as previous studies have highlighted that the eccentric hamstring and concentric quadriceps ratio is one of the measurements to be assessed using isokinetic or EMG methods.[18,20]

Balancing is a critical component to evaluate for non-contact ACL injuries, as studies suggest that the Y Balance and Star Excursion Balance Test are reliable tools in predicting non-contact ACL injuries. When discussing the Star Excursion Balance Test, its dynamic nature in multiple planes of movement is highly significant in predicting non-contact ACL injuries in football players. Incorporating both the Y Balance and Star Excursion Balance tests may enhance the accuracy in prediction.[7,40]

Strategies to mitigate risk factors involve identifying the factors and tools to pinpoint the risk factors of non-contact ACL and knee injuries in female football players.[51] As for the remedies, most studies have adopted preventive exercise protocols that are integrated into warm-up routines during the preseason or season. The most popular protocols, based on systematic reviews, include FIFA 11+, Harmo Knee, and Knee Injury Prevention Protocol.[7,41,42,47,48] These studies emphasize the incorporation of neuromuscular co-contraction of the spine, hip, and knee, as well as dynamic cutting exercises while addressing eccentric hamstring and concentric quadriceps exercises. Additionally, any landing errors should be identified and corrected. When discussing the types of warm-up exercises recommended, they include specific stretching, both static and dynamic, strengthening using body weight and resistance from

gravity, forward, backward, and sideways jogging, jumping and pivoting with a knee flexion angle exceeding 30 degrees, as well as challenging static and dynamic balance exercises, hopping on alternate legs.[43,44] The exercise duration prescribed ranged from a minimum of 15 minutes to a maximum of 25 minutes, with a recommended frequency of at least 6 weeks to three months and a frequency of 3 to 5 times a week. The recommended seasons for training were primarily during the training season, particularly the pre-season. [31,45]

Limitations of the study include the inability to investigate the effects of training on the prevention of non-contact ACL injuries in various geographical locations.
Furthermore, the study is deficient in its examination of the long-term follow-up of injury prevention programs.

Moreover, the study has offered only a superficial examination of the utilization and effectiveness of Artificial Intelligence in identifying modifiable risk factors and implementing its use in prevention programs for non-contact ACL injuries.

Recommendations for Subsequent Research: The literature underscores the intricate nature of non-contact ACL injuries among female football players and elaborates on numerous approaches to pinpoint modifiable risk factors for such injuries. Furthermore, it delves into various prevention programs tailored to address these factors. Given the insights gained from this study, it is recommended for future research endeavors to explore the integration of Artificial Intelligence alongside inertia measuring units and other outcome measures. This integration aims to enhance the effectiveness and efficiency of injury prevention programs. Additionally, future studies should emphasize the efficacy and sustainability of the injury prevention pathway. Moreover, it is imperative for research to be conducted across diverse geographical locations.

Conclusion

In the final analysis, this study concludes certain findings.
Noncontact ACL injuries are more prevalent among soccer and basketball athletes. When considering gender, females are the demographic most impacted. The adjustable risk factor pertains to neuromuscular, core strength, technique, and proprioception, and can be pinpointed through the combined use of outcome measures such as IMU, isokinetic core stability, and star excursion balance. The adjustable risk factors can be alleviated by integrating a suitable injury prevention regimen, taking into account the effective exercises, frequency, duration, and specific timing within the season. Moreover, the research concludes that a prolonged follow-up period is necessary to determine the effectiveness of mitigating risk factors.

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