

International Journal of Sport Studies for Health

Journal Homepage



Identifying Key Factors Influencing Hamstring Muscle Strains in Football Players: A Narrative Review with Descriptive Analysis



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Article Info

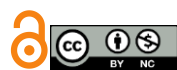
Article type:

Review Article

How to cite this article:

Ghelich Afshar, N., Soltani, M., & Naderinasab, H. (2025). Identifying Key Factors Influencing Hamstring Muscle Strains in Football Players: A Narrative Review with Descriptive Analysis. *International Journal of Sport Studies for Health*, 8(1), 64-78.

<http://dx.doi.org/10.61838/kman.intjssh.8.1.8>



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ABSTRACT

Objective: This study aimed to explore the key intrinsic and extrinsic factors contributing to hamstring muscle strains in football players.

Methods and Materials: A narrative review approach was employed, synthesizing findings from peer-reviewed articles published between 2010 and 2024. A descriptive analysis was conducted to evaluate trends, gaps, and variations in the literature on hamstring strains. Data were extracted from studies focusing on intrinsic factors (e.g., muscle imbalances, flexibility, injury history) and extrinsic factors (e.g., training load, playing conditions, coaching methods), as well as prevention and rehabilitation approaches, including eccentric strengthening, neuromuscular training, and workload management.

Findings: The review revealed that intrinsic factors such as muscle strength imbalances, limited flexibility, and prior injury history are significant contributors to hamstring strains, while extrinsic factors, including high training loads, artificial playing surfaces, and inadequate coaching practices, exacerbate injury risk. Evidence-based interventions, such as Nordic hamstring exercises, dynamic warm-ups, and load monitoring, effectively reduce injury rates and recurrence. However, gaps in the literature were identified, including the role of genetic predisposition and the long-term impact of rehabilitation programs. Variations in the implementation and adherence to prevention strategies were noted across teams and competitive levels.

Conclusion: Hamstring strains in football are a multifactorial issue requiring a holistic approach to prevention and rehabilitation. Addressing both intrinsic and extrinsic factors through individualized and evidence-based strategies can significantly reduce injury incidence and recurrence.

Keywords: Hamstring strains, football injuries, injury prevention, eccentric strengthening, risk factors, rehabilitation, load management, flexibility, neuromuscular training.

Article history:

Received 20 September 2024

Revised 23 November 2024

Accepted 04 December 2024

Published online 01 January 2025

1. Introduction

Hamstring muscle strains are among the most common injuries in football, affecting players across all levels of competition. These injuries often occur during high-speed activities such as sprinting, sudden directional changes, or overstretching, all of which are integral to the demands of football. The repetitive nature of these actions places substantial strain on the hamstring muscles, making them highly susceptible to injury. Research indicates that hamstring injuries have steadily increased in prevalence over the years, with some studies reporting a 4% annual rise in professional football settings (1-3). This trend highlights the persistent and growing challenge that these injuries pose to players and teams.

In addition to their prevalence, hamstring strains have significant implications for football clubs, players, and medical teams. These injuries often result in considerable time away from training and matches, disrupting team performance and individual progress. For professional clubs, the financial burden of managing injured players, including medical expenses and rehabilitation programs, is substantial. Furthermore, the recurrence of hamstring injuries remains a pressing concern, as many players return to play without fully addressing the underlying risk factors. Evidence suggests that prevention programs, such as eccentric strengthening exercises, can effectively reduce injury rates, yet adoption of these evidence-based practices remains inconsistent across elite teams (4). This gap between research and practice underscores the importance of understanding the factors contributing to hamstring injuries.

Addressing hamstring muscle strains is critical not only for maintaining peak athletic performance but also for protecting the long-term health of football players. Injuries that are not adequately treated can lead to chronic issues such as reduced range of motion, muscle imbalances, and persistent pain. For professional players, repeated injuries may jeopardize their careers, while for amateur players, the consequences often result in decreased participation or early retirement from the sport. The recurrence of hamstring injuries also presents challenges for rehabilitation protocols, as repeated strains are associated with a heightened risk of long-term complications (5). Therefore, the need for targeted injury prevention and management strategies is paramount.

The objectives of this review are to synthesize current knowledge on hamstring muscle strains in football players and to evaluate the effectiveness of existing prevention and rehabilitation strategies. One key focus of this review is the

identification of intrinsic risk factors, such as muscle strength imbalances, flexibility deficits, and a history of prior injuries. These factors have been consistently linked to increased susceptibility to hamstring strains (6). Another critical focus is on extrinsic factors, such as the intensity of training loads, playing surfaces, and coaching methodologies. These external influences play a pivotal role in injury occurrence and are often more modifiable than intrinsic factors (7). Understanding how these factors interact is essential for designing effective injury prevention programs.

This narrative review adopts a descriptive analysis approach to integrate findings from studies conducted between 2010 and 2024. By examining contemporary research, this review captures the latest advancements in understanding hamstring injuries, including insights into biomechanics, injury mechanisms, and training practices. The inclusion of diverse study populations, ranging from amateur players to elite professionals, ensures that the findings are relevant across different levels of football. For example, recent studies have highlighted the role of acute-to-chronic workload ratios in predicting hamstring injury risk, suggesting that monitoring training intensity is crucial for injury prevention (8). Additionally, biomechanical studies have provided valuable insights into the relationship between sprinting mechanics and hamstring strain susceptibility (9).

The broader scope of this review also includes an evaluation of current prevention and rehabilitation strategies. Research has shown that specific exercises, such as the Nordic hamstring exercise, can significantly reduce the risk of hamstring injuries by strengthening the muscles during eccentric contractions (10). Moreover, individualized rehabilitation programs that address the unique needs of each player have been found to improve recovery outcomes and reduce recurrence rates (11). By consolidating these findings, this review aims to provide actionable insights for players, coaches, and medical professionals.

In conclusion, this study aims to bridge the gap between research and practical application in the management of hamstring muscle strains in football. By identifying key risk factors, synthesizing evidence-based prevention strategies, and highlighting gaps in the literature, this review seeks to contribute to a more comprehensive understanding of this prevalent issue. The ultimate goal is to enhance the performance, health, and career longevity of football players through improved injury prevention and management practices.

2. Methods and Materials

2.1 Study Design

This narrative review utilized a descriptive analysis method to identify and synthesize key factors influencing hamstring muscle strains in football players. The study was designed to provide an in-depth understanding of both intrinsic and extrinsic risk factors contributing to these injuries. The narrative approach allowed for the integration of diverse sources, including epidemiological studies, clinical research, and biomechanical analyses, offering a holistic view of the subject. The review focused on research published between 2010 and 2024 to ensure the inclusion of contemporary findings and advancements in the field.

2.2 Search Strategy and Data Sources

The literature search was conducted using several prominent electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar. A combination of keywords and Medical Subject Headings (MeSH) terms were employed to maximize the search scope. Keywords included "hamstring strain," "football injuries," "muscle injury risk factors," "biomechanics of hamstrings," and "injury prevention in athletes." Boolean operators (AND, OR) were used to refine the search strategy. The search was limited to peer-reviewed articles published in English between January 2010 and December 2024 to maintain consistency and relevance.

2.3 Inclusion and Exclusion Criteria

The inclusion criteria for this review comprised original research articles, systematic reviews, meta-analyses, and clinical trials that directly addressed hamstring strains in football players. Studies focusing on epidemiology, biomechanics, injury mechanisms, risk factors, prevention, and rehabilitation were prioritized. Articles involving athletes from other sports were excluded unless they provided significant insights applicable to football players. Non-peer-reviewed sources, editorials, and studies published before 2010 were also excluded to ensure the reliability and timeliness of the findings.

2.4 Data Extraction and Analysis

Relevant studies were selected through a multi-step process. Titles and abstracts were first screened to identify potentially relevant articles. Full-text reviews were then

conducted to determine eligibility based on the inclusion and exclusion criteria. Key information extracted from each study included the study design, sample size, population characteristics (e.g., age, gender, level of play), identified risk factors, and key outcomes. Data synthesis involved thematic analysis, which grouped findings into categories such as intrinsic factors (e.g., muscle imbalances, flexibility) and extrinsic factors (e.g., training load, playing conditions). This categorization facilitated a clear descriptive analysis of the factors influencing hamstring strains.

2.5 Quality Assessment

The quality of the included studies was evaluated using established tools such as the Newcastle-Ottawa Scale (NOS) for cohort studies and the Cochrane Risk of Bias Tool for randomized controlled trials. Each study was assessed for methodological rigor, sample representativeness, and the validity of outcomes. Only studies meeting a minimum quality threshold were included in the review, ensuring that the findings were drawn from robust and reliable research.

3. Epidemiology of Hamstring Strains in Football

Hamstring strains are a significant concern in football, accounting for a substantial proportion of all muscle injuries in the sport. Studies indicate that hamstring strains represent approximately 12-16% of all injuries reported during professional football seasons, with variations depending on the level of play, age group, and gender. These injuries are particularly prevalent during competitive matches, where the physical demands are heightened. Research examining the epidemiology of football injuries has consistently highlighted hamstring strains as one of the most common and recurrent types of muscle injuries, emphasizing their impact on player availability and team performance (1-3).

The incidence of hamstring injuries in football is strongly linked to the dynamic nature of the sport, which requires repeated high-speed running, acceleration, and deceleration. Epidemiological studies have shown that the majority of hamstring strains occur during sprinting or other activities that involve sudden changes in speed and direction. For example, one analysis reported that over 80% of hamstring injuries in elite football occurred during high-speed running, often in the late swing phase of the gait cycle when the hamstrings are under peak tension (9). These findings underline the importance of understanding the specific biomechanical and physiological demands placed on the

hamstrings during football-related activities to develop effective prevention strategies.

While hamstring injuries are prevalent across all levels of play, the incidence appears to increase with the intensity of competition. Professional players are particularly at risk due to the high physical and psychological demands of elite football. Studies have reported that the annual incidence of hamstring injuries in professional footballers ranges from 4 to 7 injuries per 1000 hours of match play, a figure significantly higher than that observed in amateur or recreational players. This elevated risk is attributed to factors such as greater match intensity, more frequent training sessions, and higher cumulative workloads. In contrast, amateur players often experience lower injury rates but may face longer recovery times due to limited access to advanced medical and rehabilitation resources (4).

Differences in hamstring injury rates are also observed across age groups, with older players being more susceptible to these injuries. Age-related declines in muscle strength, flexibility, and neuromuscular control are thought to contribute to the increased vulnerability of older players. Research indicates that players over the age of 30 have a significantly higher risk of sustaining hamstring strains compared to their younger counterparts. This age-related risk is compounded by the fact that older players often experience slower recovery and higher recurrence rates, making injury prevention and management particularly critical for this demographic (5).

Gender also plays a role in the epidemiology of hamstring injuries, with differences in both incidence and risk factors between male and female players. While the overall prevalence of hamstring strains is higher in male footballers, recent studies have highlighted an increasing burden of these injuries in women's football. This trend is attributed to the rapid growth and professionalization of the women's game, which has led to higher physical demands and more intense training regimens. However, women may also face unique risk factors, such as differences in muscle architecture, hormonal influences, and movement patterns. For instance, research has shown that women's football teams often have higher rates of hamstring injuries related to inadequate training loads and suboptimal recovery protocols, underscoring the need for tailored injury prevention strategies (1-3).

The recurrence of hamstring injuries is another critical aspect of their epidemiology. Players who have previously sustained a hamstring strain are at a significantly higher risk of reinjury, often within the first year of returning to play.

Studies have reported recurrence rates as high as 30-40% in professional football, with the majority of reinjuries occurring within the first two months after the initial injury. This high recurrence rate is often attributed to inadequate rehabilitation, premature return to play, and failure to address underlying risk factors. For example, players who return to play without fully restoring muscle strength and neuromuscular control are particularly vulnerable to reinjury (6).

Environmental and contextual factors also influence the epidemiology of hamstring injuries in football. Playing surfaces, weather conditions, and match schedules can all impact injury risk. Research has shown that matches played on artificial turf are associated with a higher incidence of hamstring strains compared to those on natural grass. Similarly, congested match schedules, such as those during tournament seasons, increase the risk of injuries due to inadequate recovery between games. These findings highlight the importance of considering external factors when developing injury prevention strategies and managing player workloads (12-14).

A closer examination of injury patterns within specific populations provides additional insights into the epidemiology of hamstring strains. For example, youth players often experience a different injury profile compared to adults. While the incidence of hamstring injuries is generally lower in younger players, the impact on their development and long-term participation in football can be significant. Youth injuries are often linked to growth-related issues, such as muscle imbalances and reduced flexibility during periods of rapid growth. Addressing these factors through targeted training and conditioning programs is essential for reducing injury risk in young players (15).

In conclusion, the epidemiology of hamstring strains in football underscores their significant impact on players and teams across all levels of the sport. The high incidence, recurrence rates, and associated risk factors highlight the need for a comprehensive approach to injury prevention and management. Understanding the specific epidemiological trends, including differences across age groups, genders, and competitive levels, is essential for tailoring strategies to reduce the burden of hamstring injuries in football. By addressing these challenges, stakeholders in the sport can enhance player health, performance, and career longevity, ultimately contributing to the continued growth and success of football worldwide (16, 17).

4. Anatomy and Biomechanics of Hamstring Muscles

The hamstring muscle group, located in the posterior compartment of the thigh, consists of three primary muscles: the biceps femoris, semitendinosus, and semimembranosus. These muscles originate from the ischial tuberosity of the pelvis and insert at various points on the tibia and fibula. The biceps femoris, which is further divided into long and short heads, plays a pivotal role in providing both hip extension and knee flexion. The semitendinosus and semimembranosus contribute to similar functions but differ in their specific attachment points and mechanical properties. Collectively, the hamstring muscles function as biarticular structures, spanning both the hip and knee joints, which makes them particularly susceptible to injury during high-intensity football activities that involve rapid and repetitive joint movements (Lee et al., 2017).

The anatomy of the hamstring muscles is characterized by a high proportion of type II fast-twitch fibers, which are well-suited for explosive actions such as sprinting and jumping. However, this composition also renders the hamstrings more prone to fatigue and strain, especially during prolonged or high-intensity physical exertion. The biceps femoris is the most frequently injured muscle within the hamstring group, primarily due to its unique anatomical structure and biomechanical demands. Its long head spans both the hip and knee joints, making it highly vulnerable to eccentric overload during activities such as deceleration and directional changes. Furthermore, the biceps femoris is often subject to greater mechanical strain than the other hamstring muscles during high-speed running, which contributes to its predisposition to injury (5).

The biomechanical role of the hamstring muscles during football-related activities is multifaceted and essential for optimal performance. During sprinting, the hamstrings function as primary stabilizers of the lower limb, providing both hip extension and knee flexion. These muscles play a critical role in the terminal swing phase of the gait cycle, where they decelerate the forward motion of the tibia and prepare the leg for ground contact. This phase places significant eccentric stress on the hamstrings, as the muscles are required to lengthen under high tension to control limb movement. Studies have shown that eccentric contractions are a primary mechanism for hamstring injuries, as they generate the highest levels of muscle tension and are particularly susceptible to fatigue-induced strain (9).

In addition to sprinting, the hamstring muscles are heavily engaged during kicking, which is another common action in football. The kicking motion involves a complex interplay of hip flexion and knee extension, both of which place the

hamstrings under significant mechanical strain. During the backswing phase of a kick, the hamstrings stretch to accommodate hip flexion and prepare for the subsequent explosive forward motion. This rapid transition from a lengthened to a contracted state can result in excessive tensile forces, particularly if the muscles are fatigued or lack adequate flexibility. Biomechanical analyses have demonstrated that kicking-related hamstring strains often occur during the late backswing phase, when the muscles are subjected to peak elongation (11).

The mechanisms underlying hamstring strains are multifactorial and involve a combination of intrinsic and extrinsic factors. Intrinsic factors, such as muscle imbalances, poor flexibility, and inadequate neuromuscular control, are well-established contributors to injury risk. For instance, an imbalance between the strength of the hamstrings and the quadriceps muscles can create uneven loading patterns during high-intensity activities, increasing the likelihood of strain. Similarly, deficits in flexibility can limit the range of motion required for effective sprinting or kicking, leading to excessive tension on the hamstring muscles during these actions. Neuromuscular control is another critical factor, as improper activation patterns or delayed muscle firing can compromise the hamstrings' ability to stabilize the lower limb during dynamic movements (18).

Extrinsic factors, including training load, playing conditions, and recovery protocols, also play a significant role in the occurrence of hamstring strains. High training and match workloads, especially when combined with insufficient recovery periods, can lead to muscle fatigue and decreased capacity to absorb mechanical stress. Fatigue has been identified as a major risk factor for hamstring injuries, as it impairs the muscles' ability to generate force and maintain coordination during high-speed actions. Research has shown that players are more likely to sustain hamstring strains during the later stages of matches, when fatigue is most pronounced. Moreover, external conditions such as playing on artificial turf or uneven surfaces can further exacerbate the risk of injury by altering movement mechanics and increasing the demands on the hamstring muscles (12-14).

Recurrent hamstring strains are often the result of inadequate rehabilitation or premature return to play, which fails to address the underlying biomechanical and physiological deficits. Studies have highlighted the importance of restoring eccentric strength and neuromuscular coordination during the rehabilitation

process to reduce the risk of reinjury. Players who return to play without achieving full recovery of these parameters are significantly more likely to experience a recurrent strain. Additionally, structural changes within the muscle, such as scar tissue formation or altered fascicle length, can compromise the hamstrings' mechanical properties and increase susceptibility to reinjury. Recent research has demonstrated that eccentric strengthening exercises, such as the Nordic hamstring exercise, are effective in promoting optimal muscle adaptation and reducing the likelihood of recurrence (10).

In conclusion, the anatomy and biomechanics of the hamstring muscles play a central role in their susceptibility to strain injuries in football. The biarticular structure of the hamstrings, combined with their high proportion of fast-twitch fibers and involvement in explosive movements, makes them particularly vulnerable to mechanical stress and fatigue. Understanding the specific functions of the hamstrings during sprinting, kicking, and other football-related activities is essential for identifying the mechanisms that contribute to injury risk. By addressing both intrinsic and extrinsic factors, including muscle imbalances, fatigue, and playing conditions, stakeholders in football can develop more effective prevention and rehabilitation strategies to mitigate the burden of hamstring strains and enhance player performance and safety.

5. Intrinsic Factors Contributing to Hamstring Strains

Intrinsic factors play a significant role in the susceptibility of football players to hamstring strains. These factors are inherent to the individual and encompass a variety of physical, physiological, and genetic traits that influence the functionality and resilience of the hamstring muscles. Understanding these factors is essential for developing personalized prevention and rehabilitation strategies, particularly in a sport as physically demanding as football.

One of the most well-documented intrinsic factors contributing to hamstring strains is muscle strength imbalance, particularly the ratio of strength between the quadriceps and hamstrings. This ratio, often referred to as the quadriceps-to-hamstring (Q:H) ratio, is a critical determinant of lower-limb stability during high-intensity activities such as sprinting and kicking. A disproportionate Q:H ratio, where the quadriceps are significantly stronger than the hamstrings, places excessive stress on the posterior thigh muscles during eccentric contractions. This imbalance

is especially problematic during the terminal swing phase of sprinting, as the hamstrings must counteract the forward propulsion generated by the quadriceps. Research has consistently shown that players with a low Q:H ratio are at a heightened risk of sustaining hamstring strains, underscoring the importance of strength symmetry in injury prevention (5).

Flexibility and range of motion are equally important intrinsic factors. Limited flexibility in the hamstring muscles can restrict the range of motion required for effective performance during football activities. For instance, inadequate flexibility may lead to excessive tensile forces on the hamstrings during rapid hip flexion and knee extension, as seen in kicking or sprinting actions. Players with reduced hamstring flexibility are less capable of withstanding the mechanical demands of these movements, increasing their risk of strain injuries. Flexibility deficits are often attributed to factors such as muscle stiffness, inadequate stretching routines, and previous injuries that result in scar tissue formation. Studies have demonstrated that regular flexibility training, particularly through dynamic stretching and neuromuscular exercises, can significantly improve range of motion and reduce injury risk in football players (18).

A history of previous hamstring injury is another prominent intrinsic factor that predisposes players to recurrent strains. Once a player sustains a hamstring injury, the affected muscle is often left with residual weaknesses, altered neuromuscular coordination, and scar tissue, all of which compromise its structural and functional integrity. These deficits can persist even after the player has returned to play, creating a vicious cycle of recurrent injuries. The risk of reinjury is particularly high within the first few months following the initial strain, highlighting the need for comprehensive rehabilitation programs that address both strength and neuromuscular control. Research indicates that players who undergo targeted eccentric strengthening exercises, such as Nordic hamstring exercises, exhibit lower rates of reinjury compared to those who follow traditional rehabilitation protocols. This finding emphasizes the importance of incorporating advanced therapeutic techniques into recovery programs (10).

Age is another intrinsic factor that significantly influences the risk of hamstring strains. Older players, particularly those over the age of 30, are more prone to these injuries due to age-related declines in muscle elasticity, strength, and recovery capacity. The cumulative wear and tear on the hamstring muscles over years of high-intensity play also contributes to this increased vulnerability.

Furthermore, older players often require longer recovery times and face higher recurrence rates, making injury prevention and management particularly crucial for this age group. Studies have highlighted the need for tailored training regimens that focus on maintaining muscle strength, flexibility, and neuromuscular function in aging players (6).

Genetic factors may also play a role in the predisposition to hamstring strains, although research in this area is still emerging. Variations in genes associated with muscle composition, tendon elasticity, and collagen structure have been hypothesized to influence an individual's susceptibility to strain injuries. For example, certain genetic markers are thought to affect the proportion of fast-twitch muscle fibers in the hamstrings, which are more prone to fatigue and injury during high-intensity activities. While the exact mechanisms remain unclear, these findings suggest that genetics could be an important consideration in the development of personalized injury prevention strategies (7).

Other physiological factors, such as fatigue and neuromuscular control, also contribute to the risk of hamstring strains. Fatigue impairs the muscles' ability to generate force and maintain coordination, particularly during the later stages of matches when the physical demands are highest. Neuromuscular control deficits, such as delayed muscle activation or improper movement patterns, further exacerbate this risk by reducing the hamstrings' ability to stabilize the lower limb during dynamic actions. Research has shown that players who exhibit poor neuromuscular control are more likely to sustain hamstring strains, emphasizing the need for training programs that enhance proprioception and movement efficiency (16, 17).

In conclusion, intrinsic factors such as muscle strength imbalances, limited flexibility, previous injury history, age, genetics, and other physiological characteristics play a central role in the development of hamstring strains in football players. Addressing these factors through targeted prevention and rehabilitation strategies is essential for reducing the incidence and recurrence of these injuries. By focusing on individual risk profiles and incorporating evidence-based interventions, medical teams and coaches can better protect players from the physical and psychological challenges associated with hamstring strains, ultimately enhancing their performance and career longevity (11).

6. Extrinsic Factors Contributing to Hamstring Strains

Hamstring strains in football are not solely influenced by intrinsic factors; extrinsic factors play a significant role in determining injury risk. These external variables encompass aspects such as training load, environmental conditions, equipment, and coaching methods. Understanding these elements is essential for developing comprehensive injury prevention strategies that address the broader context in which players train and compete.

One of the most critical extrinsic factors is the management of training load and intensity. The balance between overtraining and undertraining significantly impacts a player's susceptibility to hamstring strains. Excessive training loads, especially when combined with inadequate recovery periods, can lead to muscular fatigue, reducing the hamstring muscles' ability to withstand mechanical stress. Fatigue impairs neuromuscular coordination, which is crucial for maintaining proper movement patterns during high-intensity activities such as sprinting or kicking. Conversely, undertraining can also elevate injury risk by leaving players insufficiently prepared for the physical demands of competitive matches. Research has shown that players with inadequate conditioning are more likely to experience muscle strains when exposed to sudden increases in workload. Monitoring training intensity through tools such as acute-to-chronic workload ratios has proven effective in minimizing these risks, as it helps coaches and medical staff tailor training programs to individual players' needs (8).

Environmental conditions, including the playing surface, are another important extrinsic factor. The type and condition of the surface on which football is played can significantly influence the risk of hamstring injuries. Matches and training sessions conducted on artificial turf have been associated with higher injury rates compared to natural grass. Artificial surfaces often generate greater friction and stiffness, which can alter movement mechanics and increase stress on the hamstring muscles during sprints, sudden stops, and changes in direction. Similarly, uneven or poorly maintained grass fields can exacerbate the risk by causing unpredictable foot placements and joint angles. Weather conditions, such as extreme heat or cold, can further impact muscle performance and increase injury susceptibility. For instance, cold weather is known to reduce muscle elasticity and flexibility, while high temperatures can accelerate fatigue, both of which heighten the risk of strain injuries (12-14).

Footwear and equipment considerations also play a pivotal role in the occurrence of hamstring strains. The

design, fit, and condition of football boots are crucial in determining the forces transmitted through the lower limbs during play. Boots that provide inadequate support or have improper cleat configurations can increase the mechanical demands on the hamstring muscles, particularly during rapid accelerations and decelerations. Footwear that fails to match the specific playing surface can exacerbate these effects. For example, wearing boots designed for firm ground on soft or wet surfaces can lead to instability and increased risk of muscle strain. Equipment such as compression garments and protective padding has also been studied for its potential to reduce injury risk, although findings remain inconclusive. Nonetheless, ensuring that players use well-fitted and appropriate footwear for the conditions is a fundamental aspect of injury prevention (19).

Coaching and training methods are perhaps the most controllable extrinsic factors influencing hamstring injury risk. The structure and content of training sessions, as well as the communication between coaches and medical teams, directly impact players' physical preparation and injury resilience. Inadequate warm-up routines, for example, can leave muscles insufficiently prepared for the demands of high-intensity actions, increasing the likelihood of strain. Warm-ups that incorporate dynamic stretching and progressive activation exercises have been shown to enhance muscle readiness and reduce injury risk. Similarly, training programs that emphasize eccentric strengthening exercises, such as Nordic hamstring exercises, have demonstrated efficacy in improving the hamstrings' capacity to withstand high loads. However, the implementation of such evidence-based practices is not always consistent, even at the elite level. Studies have highlighted gaps in the adoption of injury prevention protocols, particularly among teams with limited access to advanced sports science resources (4).

The scheduling of training sessions and matches also influences injury risk, as players subjected to congested match calendars are more likely to experience fatigue-related injuries. Tournament formats that require players to compete in multiple matches within a short timeframe often lead to insufficient recovery periods, which is a major contributor to hamstring strains. Recovery protocols, including sleep, nutrition, and active recovery sessions, play a critical role in mitigating these risks. Additionally, communication between coaches, fitness staff, and medical teams is essential to ensure that training intensity and recovery strategies are appropriately aligned with each player's physical condition and workload (20).

In conclusion, extrinsic factors such as training load, playing conditions, equipment, and coaching practices are integral to understanding the risk of hamstring strains in football. These factors are often modifiable and provide valuable opportunities for intervention. By optimizing training regimens, ensuring appropriate footwear, maintaining quality playing surfaces, and adopting evidence-based coaching methods, teams can significantly reduce the incidence of hamstring injuries. Addressing these external variables in tandem with intrinsic factors is essential for developing a holistic approach to injury prevention and ensuring the health, performance, and longevity of football players (11).

7. Risk Assessment and Injury Prevention Strategies

Effective prevention of hamstring strains in football requires a comprehensive approach that incorporates risk assessment, tailored exercise protocols, and systematic workload management. The implementation of evidence-based strategies has been shown to significantly reduce the occurrence of these injuries, particularly when they are integrated into team routines and individualized for players based on their risk profiles.

The use of screening tools to identify players at risk of hamstring strains is a cornerstone of modern sports medicine. These tools assess factors such as muscle strength, flexibility, previous injury history, and neuromuscular control to determine the likelihood of injury. One commonly employed measure is the hamstring-to-quadriceps strength ratio, which evaluates the balance between these muscle groups. A low ratio indicates a disproportionate reliance on quadriceps strength, which increases the mechanical load on the hamstrings during high-intensity activities. This imbalance is a well-documented risk factor for strain injuries. Screening also includes assessments of eccentric hamstring strength, which is critical for resisting the high forces experienced during sprinting. Tools like isokinetic dynamometers and functional movement screening tests are widely used to evaluate these parameters. These tests not only identify at-risk players but also guide the development of targeted interventions to address specific deficits (5).

Warm-up routines and stretching protocols are fundamental components of injury prevention strategies. Warm-ups prepare the body for the demands of physical activity by increasing blood flow to muscles, enhancing joint mobility, and activating neuromuscular pathways. Dynamic warm-up exercises, such as high knees, leg swings, and

bounding drills, have been shown to effectively activate the hamstring muscles while improving flexibility and coordination. Stretching, particularly dynamic stretching, plays a crucial role in enhancing the hamstrings' range of motion, reducing the likelihood of strain during explosive movements. Static stretching, while less effective as a warm-up component, can be beneficial when incorporated into post-training or rehabilitation programs to maintain long-term muscle flexibility. Research has demonstrated that players who regularly engage in structured warm-up routines experience significantly fewer hamstring injuries, highlighting the importance of consistency and adherence to these protocols (18).

Strengthening programs are another critical aspect of hamstring injury prevention. Exercises that focus on eccentric muscle contractions, such as Nordic hamstring exercises, have gained widespread recognition for their effectiveness. Eccentric contractions involve the controlled lengthening of the muscle under tension, which strengthens the hamstrings and improves their ability to withstand high mechanical loads. The Nordic hamstring exercise, in particular, has been extensively studied and shown to significantly reduce the incidence of hamstring strains in football players. This exercise targets the entire hamstring muscle group and enhances both strength and neuromuscular control. Regular inclusion of eccentric strengthening exercises in training regimens not only reduces injury risk but also improves overall athletic performance by enhancing the hamstrings' capacity to generate force during sprinting and jumping (10).

Load management and recovery strategies are equally important for minimizing the risk of hamstring injuries. Football players are exposed to varying physical demands throughout the season, including intense training sessions, competitive matches, and travel schedules. Monitoring and managing these workloads are essential to prevent overtraining and fatigue, which are major contributors to hamstring strains. The acute-to-chronic workload ratio is a widely used method for tracking player load, providing insights into how recent training intensity compares to long-term averages. Maintaining an optimal ratio helps ensure that players are neither underprepared nor overstressed, reducing the likelihood of injury. Recovery strategies, including active recovery sessions, proper hydration, and adequate sleep, are also crucial for maintaining muscle health. Massage therapy, foam rolling, and cold-water immersion are additional recovery modalities that have been

shown to alleviate muscle soreness and enhance recovery after high-intensity activities (8).

The integration of these strategies into a cohesive injury prevention program requires collaboration between coaches, medical staff, and players. Consistent communication and monitoring are vital to ensure that interventions are effectively implemented and adapted to individual needs. Teams that adopt a multidisciplinary approach, combining screening, warm-ups, strengthening exercises, and workload management, are more likely to achieve sustained reductions in hamstring injury rates. Such programs not only improve player health and availability but also enhance overall team performance by minimizing disruptions caused by injuries (16, 17).

In conclusion, risk assessment and injury prevention strategies for hamstring strains in football are multifaceted and require a combination of screening tools, structured warm-up routines, targeted strengthening programs, and effective load management. These approaches, when implemented consistently and tailored to individual player profiles, can significantly reduce the incidence of hamstring strains and improve the overall well-being of athletes. By prioritizing these evidence-based practices, football teams can foster a safer and more productive training environment, enabling players to perform at their best throughout the season (4).

8. Treatment and Rehabilitation Approaches

The effective management and rehabilitation of hamstring injuries are critical for minimizing time away from sport, ensuring safe return to play, and preventing recurrence. The process requires a structured approach, beginning with acute management and progressing through targeted rehabilitation phases, with an emphasis on long-term strategies to address underlying risk factors.

Acute management of hamstring injuries focuses on minimizing the extent of tissue damage and controlling inflammation. Immediately following an injury, the principles of rest, ice, compression, and elevation (RICE) are often employed to reduce swelling and pain. Rest is essential to prevent further strain on the affected muscle, while ice application helps to constrict blood vessels and limit inflammation. Compression and elevation work in tandem to control swelling and promote healing. In some cases, nonsteroidal anti-inflammatory drugs (NSAIDs) may be used to manage pain, although their use should be carefully monitored to avoid delaying the natural healing process.

During the acute phase, avoiding activities that exacerbate pain is crucial, as premature loading of the injured muscle can prolong recovery and increase the risk of complications (5).

Once the acute phase has subsided, rehabilitation becomes the primary focus. The initial stages of rehabilitation emphasize restoring range of motion, reducing pain, and gradually reintroducing load to the injured muscle. Gentle stretching and low-intensity isometric exercises are typically introduced to maintain muscle function without causing further damage. These exercises also stimulate blood flow to the affected area, which aids in tissue repair. As the player progresses, eccentric strengthening exercises are incorporated to rebuild the hamstrings' capacity to withstand high mechanical loads. The Nordic hamstring exercise, for example, is widely recognized for its ability to improve eccentric strength and has been shown to significantly reduce reinjury rates when used during rehabilitation programs (10).

Neuromuscular training is another critical component of rehabilitation. Hamstring injuries often result in altered movement patterns and neuromuscular deficits, which can increase the risk of reinjury if not addressed. Proprioceptive exercises, such as balance training and agility drills, are incorporated to improve coordination and stabilize the lower limb during dynamic activities. These exercises help retrain the nervous system to activate the hamstrings efficiently, ensuring that the muscle group can effectively respond to the demands of football-related actions. Rehabilitation programs also focus on correcting any biomechanical issues that may have contributed to the initial injury, such as improper sprinting mechanics or poor lumbopelvic control (16, 17).

The final stages of rehabilitation are designed to prepare the player for a safe return to play. This phase includes sport-specific drills that replicate the intensity and complexity of match conditions. Sprinting, cutting, and kicking exercises are introduced to test the hamstrings' ability to perform under stress. Monitoring tools, such as strength assessments and functional movement tests, are used to evaluate the player's readiness to return to competition. Return-to-play criteria typically include pain-free performance of high-intensity activities, restoration of strength and flexibility to pre-injury levels, and the absence of compensatory movement patterns. Adhering to these criteria is essential for minimizing the risk of reinjury, as premature return to play is a leading cause of recurrent hamstring strains (6).

Long-term strategies to prevent recurrence are integral to the management of hamstring injuries. Players with a history of hamstring strains are at a significantly higher risk of reinjury, often due to residual deficits in strength, flexibility, or neuromuscular control. To mitigate this risk, ongoing strengthening programs are recommended, with a particular focus on eccentric exercises. Regular performance of the Nordic hamstring exercise, for example, has been shown to maintain muscle strength and reduce the incidence of reinjury. Flexibility training is also emphasized to ensure that the hamstrings can accommodate the full range of motion required for football-related activities. Dynamic stretching and yoga are often incorporated into training routines to enhance flexibility and reduce muscle stiffness (18).

Load management is another critical aspect of long-term prevention. Overtraining and inadequate recovery are major contributors to hamstring injuries, particularly during periods of congested match schedules. Monitoring tools, such as GPS tracking and workload ratios, are used to optimize training intensity and ensure that players are not exposed to excessive physical stress. Recovery protocols, including massage, foam rolling, and cryotherapy, are also employed to facilitate muscle repair and reduce the risk of fatigue-related injuries. Adequate nutrition and hydration further support recovery and overall muscle health, contributing to long-term injury prevention (8).

Education plays a vital role in preventing hamstring injury recurrence. Players, coaches, and medical staff must be aware of the risk factors associated with hamstring strains and the importance of adhering to evidence-based prevention and rehabilitation protocols. Workshops, training sessions, and individualized feedback are used to enhance awareness and promote best practices. By fostering a culture of injury prevention, teams can reduce the burden of hamstring strains and improve player performance and longevity (4).

In conclusion, the treatment and rehabilitation of hamstring injuries involve a multi-phase approach that addresses both the immediate effects of injury and the long-term factors that contribute to recurrence. Acute management focuses on minimizing tissue damage and inflammation, while rehabilitation aims to restore strength, flexibility, and neuromuscular function. The integration of sport-specific drills and rigorous return-to-play criteria ensures a safe transition back to competition. Long-term strategies, including ongoing strengthening programs, load management, and education, are essential for preventing

reinjury and maintaining the health of football players. By implementing these comprehensive approaches, teams can effectively manage hamstring injuries and enhance the overall well-being and performance of their athletes (16, 17).

9. Descriptive Analysis of Key Studies

The body of research on hamstring injuries in football provides valuable insights into their causes, prevention, and treatment. A synthesis of key studies reveals recurring themes, identifies gaps in the literature, and highlights variations in the effectiveness of different approaches to managing these injuries. By critically analyzing the findings, it becomes possible to understand the strengths and limitations of current strategies and to identify areas where further research is required.

Several studies have consistently emphasized the role of muscle strength imbalances, particularly the hamstring-to-quadriceps strength ratio, as a critical factor in hamstring strain injuries. Research involving elite football players has demonstrated that a low strength ratio significantly increases injury risk, particularly during high-intensity activities such as sprinting and kicking. This finding underscores the importance of strength assessments and targeted interventions to correct imbalances. While many studies have validated the efficacy of eccentric strengthening exercises, such as Nordic hamstring exercises, in addressing these imbalances, variations exist in how these exercises are implemented within training regimens. Some studies suggest that the frequency and intensity of these exercises are not standardized, leading to inconsistencies in their preventive effects across different teams and populations (5).

Flexibility and range of motion have also been the focus of numerous studies, with many identifying deficits in hamstring flexibility as a significant risk factor for strains. Research has shown that limited flexibility can increase tensile stress on the hamstring muscles during rapid movements, making them more susceptible to injury. Interventions such as dynamic stretching and proprioceptive neuromuscular facilitation have been explored to address this issue. While these techniques have demonstrated effectiveness in improving flexibility, studies have noted that their benefits are often short-lived without regular practice. Furthermore, there is limited consensus on the optimal stretching protocols, including the duration and frequency required to achieve long-term benefits. This lack of standardization represents a gap in the literature that warrants further investigation (18).

The role of previous injury history in hamstring strain recurrence has been a prominent theme in the literature. Studies have consistently reported that players with a history of hamstring injuries are at a significantly higher risk of reinjury, often within the first few months of returning to play. This increased risk is attributed to factors such as residual muscle weakness, scar tissue formation, and altered neuromuscular coordination. Rehabilitation programs that incorporate eccentric strengthening exercises and neuromuscular training have shown promise in reducing recurrence rates. However, variations in the duration and content of these programs remain a challenge, as some studies report suboptimal adherence to recommended protocols among players and medical teams. The need for individualized rehabilitation strategies that address player-specific deficits has been highlighted as a critical area for improvement (10).

Environmental factors, such as playing surfaces and match schedules, have also been explored in the literature. Studies have indicated that matches played on artificial turf are associated with a higher incidence of hamstring injuries compared to natural grass. The increased friction and stiffness of artificial surfaces are thought to alter movement mechanics and place additional stress on the hamstrings. Similarly, research has shown that congested match schedules, which allow insufficient recovery time between games, significantly increase injury risk. These findings underscore the importance of considering external factors when developing injury prevention strategies. However, there is a lack of longitudinal studies that systematically examine the interaction between environmental conditions and other risk factors, leaving a gap in understanding how these variables contribute to injury risk over time (12-14).

Trends in the literature highlight the growing recognition of the importance of neuromuscular training in injury prevention and rehabilitation. Proprioceptive exercises, balance training, and agility drills have been shown to improve neuromuscular control and reduce the likelihood of hamstring strains. These exercises are particularly effective when combined with eccentric strengthening programs, as they address both strength and coordination deficits. However, studies have noted that neuromuscular training is often underutilized in team settings, particularly at the amateur and semi-professional levels. This underutilization reflects a broader challenge in translating research findings into practical applications, especially in resource-limited contexts (16, 17).

Comparative analyses of prevention strategies have revealed variations in the effectiveness of different approaches. For example, studies on eccentric strengthening exercises consistently report significant reductions in injury rates, particularly among players who adhere to structured programs. In contrast, the effectiveness of flexibility training appears to be more variable, with some studies reporting limited benefits in reducing injury risk. These discrepancies may be due to differences in study design, participant characteristics, and intervention protocols. Similarly, research on the impact of load management strategies has shown mixed results, with some studies emphasizing their importance in preventing fatigue-related injuries, while others highlight the challenges of implementing these strategies in practice. The lack of consensus on optimal training loads and recovery periods remains a significant limitation in the literature (8).

Gaps in the literature also include the limited exploration of genetic and physiological factors that may predispose players to hamstring injuries. While some studies have hypothesized that variations in muscle fiber composition and tendon elasticity could influence injury risk, empirical evidence in this area is sparse. Furthermore, there is a need for more research on the long-term effects of rehabilitation programs, particularly in terms of preventing reinjury and enhancing performance. Most studies focus on short-term outcomes, leaving questions about the sustainability of these interventions unanswered (7).

In conclusion, the descriptive analysis of key studies on hamstring injuries in football reveals important findings, trends, and gaps. While significant progress has been made in identifying risk factors and developing prevention strategies, variations in the effectiveness of these approaches highlight the need for standardized protocols and individualized interventions. Addressing gaps in the literature, such as the role of genetic factors and the long-term impact of rehabilitation programs, will be crucial for advancing the field and reducing the burden of hamstring injuries in football. By synthesizing existing knowledge and identifying areas for further research, this analysis provides a foundation for improving injury prevention and management practices in the sport (4).

10. Discussion and Conclusion

Hamstring strains in football remain a prevalent and challenging issue, significantly affecting players' performance and career longevity. This review highlights the

multifactorial nature of hamstring injuries, emphasizing the interplay between intrinsic and extrinsic factors, as well as the importance of evidence-based prevention, treatment, and rehabilitation strategies. The discussion integrates findings from key studies, identifies gaps in the literature, and explores implications for future research and practice.

The findings underscore the importance of addressing intrinsic factors such as muscle strength imbalances, flexibility deficits, and previous injury history. Muscle strength imbalances, particularly a low hamstring-to-quadriceps ratio, are among the most well-documented risk factors for hamstring strains. This imbalance places excessive stress on the hamstrings during eccentric contractions, especially in high-intensity activities like sprinting. Eccentric strengthening exercises, such as the Nordic hamstring exercise, have consistently been shown to improve strength ratios and reduce injury risk. However, variations in their implementation, adherence, and effectiveness across different populations highlight the need for standardized protocols tailored to individual needs. Similarly, deficits in flexibility and range of motion contribute to increased tensile stress on the hamstrings during rapid movements. While dynamic stretching and neuromuscular techniques have demonstrated effectiveness, their benefits are often short-lived without consistent practice, emphasizing the need for ongoing flexibility training (5, 18).

Previous injury history is another critical intrinsic factor, as players with a history of hamstring strains face a significantly higher risk of recurrence. This increased risk is often attributed to residual deficits in muscle strength, scar tissue formation, and neuromuscular dysfunction. Comprehensive rehabilitation programs that address these deficits, particularly through eccentric strengthening and neuromuscular training, are essential for reducing recurrence rates. However, adherence to rehabilitation protocols remains a challenge, as many players and teams fail to fully address underlying issues before returning to play. This highlights the need for improved education and communication among players, coaches, and medical teams to ensure adherence to evidence-based practices (10).

Extrinsic factors, including training load, playing surfaces, and coaching methods, also play a significant role in hamstring injury risk. The balance between training load and recovery is particularly critical, as both overtraining and undertraining can increase the likelihood of injury. Monitoring tools, such as GPS tracking and acute-to-chronic workload ratios, have proven effective in optimizing training

loads and minimizing fatigue-related injuries. However, practical challenges, including resource limitations and varying levels of expertise, can hinder the implementation of these tools, particularly in amateur and semi-professional settings. Additionally, the impact of environmental factors, such as playing surfaces, has been well-documented, with artificial turf posing a higher risk for hamstring injuries compared to natural grass. Addressing these external conditions through appropriate footwear, maintenance of playing surfaces, and scheduling adjustments is crucial for reducing injury risk (8, 12-14).

The integration of prevention strategies, such as structured warm-ups, eccentric strengthening, and neuromuscular training, has shown promise in reducing hamstring injury rates. Dynamic warm-ups that include progressive activation exercises have been found to enhance muscle readiness and flexibility, while eccentric strengthening programs target the hamstrings' ability to withstand high mechanical loads. Neuromuscular training, including balance and agility exercises, addresses coordination deficits and enhances movement efficiency. However, the implementation of these strategies varies widely across teams, with gaps in adoption and consistency even at the elite level. This variability underscores the importance of standardized prevention programs that can be adapted to different contexts while ensuring adherence and effectiveness (4).

Despite these advances, significant gaps remain in the literature and practice. For instance, the role of genetic and physiological factors in hamstring injury risk is still poorly understood. Emerging research suggests that genetic variations in muscle composition and tendon properties may influence susceptibility to strains, but empirical evidence in this area is limited. Longitudinal studies that explore these factors in relation to injury prevention and performance outcomes are needed to provide a more comprehensive understanding of hamstring injuries. Additionally, the long-term effects of rehabilitation programs on reinjury rates and overall performance are not well-documented. Most studies focus on short-term outcomes, leaving questions about the sustainability and scalability of these interventions unanswered (7).

The need for individualized and context-specific approaches to injury prevention and rehabilitation is another critical area for future research and practice. While standardized protocols provide a foundation for reducing injury risk, they must be adapted to account for individual player characteristics, such as age, gender, playing position,

and previous injury history. For example, older players may require targeted interventions to address age-related declines in muscle elasticity and recovery capacity, while female players may benefit from strategies tailored to their unique biomechanical and hormonal profiles. Similarly, players in different positions face varying physical demands, necessitating position-specific training and recovery protocols (1-3).

Education and awareness are also essential for improving adherence to prevention and rehabilitation strategies. Players, coaches, and medical teams must understand the importance of evidence-based practices and their role in reducing injury risk. Workshops, training sessions, and individualized feedback can enhance awareness and promote a culture of injury prevention within teams. Additionally, fostering collaboration between researchers, clinicians, and practitioners can facilitate the translation of research findings into practical applications, ensuring that prevention strategies are accessible and effective across different levels of football (20).

In conclusion, hamstring strains in football are a complex and multifactorial issue that requires a holistic approach to prevention, treatment, and rehabilitation. This review highlights the importance of addressing both intrinsic and extrinsic factors, including muscle strength imbalances, flexibility deficits, training load, and environmental conditions. Evidence-based strategies, such as eccentric strengthening, neuromuscular training, and workload management, have demonstrated effectiveness in reducing injury risk and recurrence. However, gaps in the literature, including the role of genetic factors and the long-term impact of interventions, underscore the need for further research. The integration of standardized protocols, individualized approaches, and education can enhance the effectiveness of injury prevention and rehabilitation programs, ultimately improving player health, performance, and career longevity. By prioritizing these strategies, football teams can create a safer and more sustainable environment for their athletes, reducing the burden of hamstring injuries and promoting success at all levels of the sport.

Authors' Contributions

N. G. A. contributed to the conceptualization of the study, review of the literature, and drafting of the manuscript. M. S. conducted data extraction, performed descriptive analysis, and contributed to critical revisions of the manuscript. H. N.

was responsible for synthesizing findings, identifying gaps, and refining the discussion and conclusion sections. All authors reviewed and approved the final manuscript.

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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