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Hamstring Strain in Sprinting Athletes: Biomechanics, Risk Factors, and Injury Prevention Strategies

Victoria Zhixu Wang[1,a,*]

[1]University of Toronto, Toronto, M5S 1A1, Canada
a. victoriazx.wang@alumni.utoronto.ca
**corresponding author*

Abstract: Hamstring–related injuries, primarily hamstring strain, frequently affect both recreational and professional athletes, especially in sports that involve running, jumping, kicking, and sudden directional changes. This study presents a comprehensive analysis of HSIs, covering anatomical and biomechanical factors, kinematics, diagnostic methods, and strategies for prevention and treatment. Although the exact mechanism of HSIs during sprinting remains uncertain, no specific phase of the running cycle has been identified as presenting the highest risk. Stretch-induced HSIs, often triggered by excessive hip flexion and knee hyperextension, place significant stress on the proximal tendon and musculotendinous junction, particularly affecting the semimembranosus muscle. Risk factors for HSIs are categorized as non-modifiable (age, previous injuries, playing position) and modifiable (muscle weakness, fatigue, imbalances, limited flexibility, and poor neuromuscular control). Physiotherapy approaches that emphasize eccentric strength training—progressing through flexibility, stabilization, and specific strength phases—reduce injury rates, especially when integrated with concentric training in sprinting related sports.

Keywords: Hamstring strain injuries, anatomy and pathology, prevention and recovery, treatment plans, management protocols.

1. Introduction

Hamstring related injuries, typically the hamstring strain (HSI), frequently occur in both recreational and professional sports, especially in activities that require running, jumping, kicking, and abrupt directional changes [1]. These muscles are vital for high-intensity athletic movements, rendering them indispensable for sports like American football, soccer, rugby, or the track and field, where rapid running is frequently necessary [2]. The estimated incidence rate of HSIs caries from 0.87 to 0.96 per 1,000 hours of exposure in non-contact and contact sports respectively [3]. Injuries rates are notebly elevated, with soccer representing 37% of all muscle injuries, and their recurrence rates varying between 12% to 33% [4,5]. HSIs undermine individual performance and team achievement, with recurrence rates in sports such as the American National Football League reaching as high as 32% [6]. Despite comprehensive research on prevention strategies, the recurrence rate, especially during the first year following the resumption of activity, continues to pose a significant issue, frequently resulting in more severe effects than the first occurrence of injury [7]. Considering the elevated incidence of HSI, it is necessary to understand their anatomy, biomechanics, and risk factors of hamstrings injuries, along with effective methods for assessment, treatment, and prevention. This

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study offers a comprehensive overview of hamstring injuries, addressing anatomical aspects, kinematics, biomechanics, risk factors, diagnostic approaches, and techniques for prevention and intervention.

2. Hamstring anatomy

Kinematic characteristics during sprint running can influence mechanical strain, depending on functional anatomy and the interaction between anatomical segments. The biceps femoris that commonly injured within this group, composed of two heads, with the long head that arching to pelvis and sacro tuberous ligament, the short head that originating from the femur. This dual attachment indicates that the biceps femoris is crucial for supporting both the pelvis and the sacroiliac joint. The semimembranosus and semitendinosus muscles both insert on the medial aspect of the tibia and facilitate internal rotation of the leg. These muscles, with their attachments to the proximal pelvic and distal knee structures, facilitate dynamic motions and enhance both rotational and translational stability of the knee. Consequently, modifications in the mechanics of either the pelvis or knee can affect hamstring function, consequently raising the injury risk. The complex anatomy and biomechanics of hamstring highlight the importance of comprehending the interactions of these muscles with the upper and lower portions of the lower leg to ensure stability and avert damage.

3. Mechanism of injuries

A full running cycle is composed of both stance and swing phase, corresponding to the period during foot contact ground and during foot lift, respectively. Additionally, these phases can be subdivided into four distinct subphases: the initial and terminal stand phase, and the initial and terminal swing phase. These subphases correspond to the braking propulsion, recovery and pre-activation stages of the cycle, respectively [8].

Acute hamstring injuries most commonly involve the long head of the biceps femoris. Nonetheless, the exact mechanism underlying HSIs, particularly during sprinting, remains unclear, and studies have yet to conclusively identify the running cycle phase with the highest risk factors of HSI. Given the impracticality of directly examining hamstring function in vivo during human running motion, research on hamstring strain injury processes depends on modelling, which incorporates assumptions based on anatomical and biomechanical studies [5]. Animal models have been utilized to clarify the mechanisms underlying hamstring related injuries, indicating that the primary cause of excessive muscular strain is either eccentric contractions or stretching, which are typically categorized into the stretch-related and sprint-related injuries [9].

Hamstring injuries related to stretching typically arise from excessive hip flexion in conjunction with the knee hyperextension, resulting in significant stress on the proximal tendon and musculotendinous junction. This mechanism is frequently observed in actions such as kicking and doing splits in dance, primarily impacting the semimembranosus muscle [10]. Injuries related to sprinting are most likely to happen during the terminal swing phase of the running gait cycle, when the hamstrings contract eccentrically just before foot contact. This form of strain predominantly impacts the biceps femoris (long head) and the semitendinosus at the aponeurosis and surrounding muscle-tendon fibers, as the increased eccentric load heightens the hamstrings' vulnerability to injury in this region [10].

The gait's stance phase, which takes place when one foot touch the ground and whole body moves forward, may also contribute to hamstring muscle strain. Research indicates that injuries during the early stance phase may result from significant opposing pressures as the body advances over the landing point, particularly in athletes exhibiting muscle imbalances or inadequacies, which may hinder their muscles' ability to manage mechanical stress during this phase [8]. Simultaneously, the

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swing phase, during the one foot is lifted from the ground, is subdivided into late and terminal phases. The hamstring muscles undergo eccentric extension in anticipation of foot striking, highlighting a critical juncture for injury risk. This phase presents a considerable risk to the long head of biceps femoris, as it absorbs the majority of the eccentric load [10]. And hamstring's simultaneous extension and contraction under significant stress renders it particularly susceptible to damage, especially during high-velocity activities like sprinting.

Additionally, evidence from biomechanical modeling and functional anatomy research support the influence of sprinting mechanics in hamstring related injuries [11]. Schache at al. found the strain, force, and the negative work of peak muscle tendon in long head of biceps femoris, semitendinosus, and semimembranosus in the late swing phase at maximum sprinting speed [12]. Particularly, the biceps femoris (long head) exhibited the greatest strain (a 12.0% length increase from upright stance), the semitendinosus demonstrated the fastest lengthening velocity, while the semimembranosus produced the highest force, absorbed and generated the most power, and contributed the most to both positive and negative feedback.

Currently, no distinct biomechanical feature has been recognized as the only cause of hamstring strain [11]. The evidence remains inconclusive regarding which phase of the sprinting cycle carries the highest risk of hamstring strains. Nevertheless, the muscle may experience considerable strain during both the terminal swing and the initial stance phases to increase their vulnerability of injuries.

4. Risk factors of hamstring related injuries (HSI)

4.1. Non-modifiable HSI risk factors

Age, previous injuries and playing position are unchangeable contributing factors for HSIs. Older athletes are more vulnerable to hamstring strains due to the inherent decline in flexibility and muscular suppleness associated with aging. A comprehensive analysis of 19 studies found that increasing age is linked to an elevated risk of hamstring strains, with standardized mean difference of 1.6 and 95% confidence interval from 0.6 to 2.6 ($p = 0.002$) [1]. Age may influence HSI risk due to its correlation with exposure; as athletes age, they experience increased mechanical loads and a heightened probability of injury mechanisms. Even minor age difference likely reflects significant variations in exposure within high performance sports. Physiological changes associated with aging may increase the possibility of muscle strains in elder athletes by affecting anatomical and neurological properties.

Individuals with a history of hamstring strains have increased possibility of recurrence, especially during the initial weeks of resuming athletic activity. This highlights the susceptibility of previously strained muscles during the early recovery and the challenges of assuming activity. A history of hamstring related injury relative risk of 2.7 ($p < 0.001$), anterior cruciate ligament injury relative risk of 1.7 ($p = 0.002$), and calf related injury relative risk of 1.5 ($p < 0.001$) significantly increases the risk of future hamstring strains. If the hamstring strain injury happened during the same competitive season, the risk was significantly amplified with relative risk of 4.8 ($p < 0.001$) [1].

Additionally, this history aids in identifying the etiology and characteristics of the injury. a meta-analysis involving 71,324 participates indicated that a prior hamstring strain injury increased the subsequent relative risk of 2.7 and 95% confidence interval of 2.4 [2]. In Australian football, among 1932 athletes with a recent hamstring strain injury (less than past 8 weeks) exhibited a significantly elevated risk of reinjury (OR = 13.1; 95% CI: 11.5, 14.9) compared with athletes injured over 8 weeks old (OR = 3.5; 95% CI: 3.2, 3.9) [2]. However, a history of quadriceps injuries or prior chronic groin injuries did not elevate the possibility of hamstring strain injury [1].

Playing position also corresponds to variations in loading demands and physical attributes, especially in terms of the intensity and frequency of kicking, running, workloads, and high-speed sprints, which disproportionately affect the hamstring muscles. The risk of initial hamstring strains caried by playing position in football (strong evidence), American football (moderate evidence), rugby (moderate evidence), Gaelic football (limited evidence) and cricket (limited evidence) [1,13-18]. Positions with higher running demands were linked with an elevated risk of initial hamstring strains in the midfielders, defenders, forwards and goalkeepers of football; the receivers, defensive backs, running backs, and linemen of American football, the fast bowlers and spin bowlers of cricket [14,18]. The effects of reduced recovery time between marches, schedule congestion, and competition level on HSI risk were inconsistent.

4.2. Modifiable HSI risk factors

Adjustable risk factors for HSI generate from the muscle weakness and fatigue, muscles imbalances, insufficient range of motion and flexibility, and poor neuromuscular control. Weakened and fatigued hamstring muscles exhibit increased susceptibility to injury, particularly during high velocity running or abrupt directional shifts, since they may find it challenging to meet the imposed demands. Decreased hamstring muscle strength properties, including the strength endurance (measured by the single-leg hamstring bridges and repeated eccentric leg curls), as well as muscle strength (assessed through eccentric, isometric and repeated isometric tests), were linked with a higher probability of hamstring muscle strain (level of evidence is limited) [1]. In fact, athlete's weight and BMI score, as well as the size of biceps femoris muscle, and the gluteus maximus and medius muscles, were not associated with an increased incidence of muscle injury syndrome. The length of biceps femoris fascicle and muscle tendon unit of hamstring stiffness was strongly correlated with the possibility of an initial hamstring strain injury with strong level of evidence [1].

Weakened and fatigued hamstring muscles demonstrate heightened vulnerability to injury, especially during high velocity running or sudden directional changes, since they may struggle to fulfill the required demands. Reduced muscle strength characteristics of hamstring, including the endurance of muscle strength (as assessed by the hamstring bridges by the single leg and repeated eccentric leg curls), and the muscle strength that measured through both eccentric, isometric and repeated isometric tests, were linked to a higher probability of hamstring strain, even with the limited level of evidence [1].

Moreover, diminished hamstring flexibility, along with tightness in the quadriceps and hip flexors, elevates their risks of injury by constraining proper movement and imposing additional strain on the hamstrings. Green, Bourne, Dyk, and Pizzari (2020) analyzed that none of the variables related the muscle flexibility, joint mobility or range of motion demonstrated a clear link to the probability of an initial hamstring strain, which including common hamstring evaluations such as the passive knee extension test (strong level of evidence), active knee extension test (strong level of evidence), passive straight leg raise test (strong level of evidence) and the slump test (moderate level of evidence) [1]. An increased deficit in active knee extension immediately upon resuming play was linked to an elevated risk of muscle re-injury, but with limited level of evidence. The associations between limited hip extension that adjusted using the Thomas and the ankle dorsiflexion tests concerning the possibility of initial hamstring strain injury were inconclusive.

Poor neuromuscular control, especially inadequate coordination of the muscles around the pelvis and trunk, can result in inefficient movement patterns that lead to injuries. Reduced electromyographic (EMG) engagement of the truck muscles during the backswing phase of running with limited level of evidence and increase EMG activity of the glutes medius muscle during running at speed of 12 and 15 km/h (limited level of evidence) were correlated with the risk of initial muscle strain [19]. Conflicting results were observed regarding EMG activity monitoring of the flutes maximus during sprinting and running at different submaximal speeds. Notably, increased high-speed running exposure was linked to a higher probability of an initial muscle strain. Sprinting mechanics

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were correlated with the probability of initial muscle strain, when heightened thoracic lateral flexion was observed during the front swing phase, increased anterior pelvic tile was noted during the backswing phase, and both with limited level of evidence [20]. Mitigating these controllable factors through focused strength, flexibility, and neuromuscular training is essential for preventing hamstring strains.

Strength and flexibility of hamstring muscle were the most frequently studies changeable risk factors for muscle strain. While several studies found that the baseline of muscle strength deficits were related with the elevated probability of muscle strain, but the flexibility of muscle, joint mobility and range of motion contributed limited significance as independent risk factors. Muscle strength characteristics vary over time and shift in response to factors such as fatigue. But relying on data collected from a single initial measurement to predict future correlation with hamstring strain may therefore be of questionable validity [21, 22]. Exposure to running is another adjustable risk factor for heat-related illness. Athletes exposed to higher volumes of high-speed running face an elevated risk of hamstring strain, particularly following sudden load increases within the past 7 to 14 days [21, 22]. These athletes may be vulnerable to hamstring injury as a result of fatigue and eccentric muscle damage caused by high-speed running practices.

5. Diagnosis and examination

Timely and precise diagnosis based on clinical evaluation of a hamstring strain is crucial for delivering proper and effective treatment, determining return-to-play readiness, and preventing recurrence. Acute hamstring injuries are commonly diagnosed using a combination of patient injury record, clinical assessment, and imaging when required [23].

5.1. Previous injury history

Starting with the previous injury history to know the cause and characteristics of the injury, patients commonly describe a sudden, sharp pain in the back of the thigh, typically liked with a specific movement, such as running or kicking. Green et al. reported that the risk of muscle strain re-injury was greatest within the ongoing season (relative rate of 4.8) [1]. Malliaropoulos et al. explored that greater reduction in range of motion of active knee was linked to a longer delay in returning to activity. Their study also highlighted a clinically based classification system as a useful tool for evaluating recurrence risk and timeline for back to sport, with Grade II muscle strains showing the highest recurrence rate at 24%, followed by Grade I at 9.3% [6].

5.2. Clinical assessment, inspection and palpation

Assessment of injury severity relies heavily on physical examination, visual inspection and palpation. Swelling or extensive hematoma, along with proximal tendon ruptures, are two indicators necessitating attention during examination. Swelling or visible bruising is characteristic of hamstring tears, particularly in severe cases. This may become more apparent after several days as blood accumulates and discoloration occurs. Full proximal hamstring tendon ruptures may exhibit a discernible deformity [24].

Stretch and isometric contraction evaluations are two specific tests employed to diagnose hamstring injuries. Stretch tests employ various movements to evaluate muscle flexibility and discomfort. The passive straight leg-raising assessment entails flexing the hip while maintaining fully extended knee till the maximum tolerable of stretching is achieved. The passive extension test of the knee entails hip flexion at 90° followed by full knee extension [24]. The lower limb stays in fully extended knee while the hip passively flexes until resistance is felt. Care should be taken to observe the opposite limb for compensatory flexed hip or knee intended to enhance flexion on the tested side of the hip joint, with the value between 80° and 140°, and with values below 80° considered insufficient [6].

The active extension test of the knee requires that the client maintain the 90° flexion at hip joint while extending the knee until a tolerable stretch is attained. Localized discomfort during these stretches suggests a favorable outcome [24]. The client is subsequently instructed to actively knee extension to its maximum range. When the knee encounters restriction, this measurement should be obtained at the knee, as it accurately represents hamstring length. The knee must extend to a minimum of 20° [6].

The isometric contraction tests measure the hamstring's ability to contract without moving at various joint angles. The first test evaluates contraction with both knees and hips flexed at 90° (inner range), whereas the second assessment evaluates muscle contraction at 15° of flexed knee and maintained neutral position of the hip. The outer range isometric test comprises maximum knee extension while the hip is extended to 90° [24]. emphasis can be placed on the medial or lateral of the hamstring muscle by rotating the tibia either internally or externally [6].

Single Leg Hamstring Bridge: This exercise involves placing the injured limb on a 60 cm elevated surface, with the knee flexed at 20 degrees, while the uninjured leg remains elevated. The pelvis is lifted into a bridge position, engaging the hamstrings to support the body. And it then lowered to the floor to complete one repetition. This movement has been suggested in the literature as a reliable method for assessing functional hamstring strength and predicting strength deficits that may lead to future hamstring related injuries [6].

The "empty tuber" is a noticeable indicator at the ischial tuberosity resulting from tendon rupture and retraction. Palpating the ischial tuberosity for pain location and intensity can provide useful insights into the anticipated recovery time. A greater distance of pain from the ischial tuberosity correlates with a more favorable prognosis [6]. This constitutes a crucial diagnostic indicator. A distinct, tangible gap is frequently perceived at the site of a ruptured tendon or muscle, signifying more severe injury. The formation of a substantial hematoma often signifies significant structural injury to the muscle or tendon. Moreover, hematomas may become increasingly apparent several days post-injury as blood continues to accumulate in the affected region. During palpation, the practitioner must observe for pain, whether it arises during passive hamstring stretching, resistance testing of the hamstring, or localized tenderness upon palpation. This physical examination is essential for verifying the diagnosis and differentiating the injury from other conditions such as tendon avulsions or sequelae [24].

Even though the literature suggests the use of palpation, mobility assessment, and resistance testing for diagnosing strains, the diagnostic accuracy has yet to be validated [6].

5.3. Imaging

Imaging is important for diagnosing and assessing hamstring injuries, although its effectiveness differs based on the chosen modality. X-rays are often the first imaging test but are not helpful in diagnosing acute muscle injuries, cause of swelling and inflammation. Ultrasound is an affordable and accessible option that allows for dynamic assessment. However, its accuracy is highly dependent on user, and it may struggle to accurately determine the extent and grade of the injury, especially in muscular or obese patients. MRI and ultrasonography are frequently employed to evaluate tissue integrity following hamstring strain injuries, offering moderate to strong diagnostic and prognostic capabilities [1]. As it allows for accurate localization of the injury, identification of associated injuries, and provides valuable information for preoperative grading and surgical planning. Additionally, numerous injury classification systems depend on preoperative MRI results to assess injury severity, facilitating management and treatment planning [25].

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6. Treatments

6.1. Nonoperative management techniques

Nonoperative techniques for management can serve as a useful complement in addressing acute soft tissue damage. Hamstring muscle strain is most commonly seen at the musculotendinous junction of the proximal biceps femoris. Following injury, a person typically feels sharp, intense pain in the posterior thigh. From the well-established approach is the POLICE method, ice is used two to three times daily to alleviate pain and reduce swelling [24]. Optimal loading emphasizes replacing rest with controlled, gradual loading to promote healing while avoiding excessive strain on the tissue. Additionally, a popping sound or feeling often accompanies movements that place excessive load or overstretch the hamstring. The individual need to stop the practice due to pain and limited mobility. Recurrence rate of hamstring strain ranges from 13.9% to 63.3% when monitored during the current and following seasons [2].

From physiotherapy perspective, without the presence of inflammation and pain, often focus on eccentric strength training, which is broken down into three phases: increasing flexibility, combining exercises for strength and truck/pelvis stabilization and advancing to more specific strength training exercises.

Exercises such as side planks, single leg standing windmills, and lunge twists are utilized to augment trunk stabilization and refine pelvic positioning for optimal tendon tension. The side plank entails supporting the body on the elbow and ankle while positioned laterally, the windmill necessitates standing on the injured leg and bending forward, and the lunge twist is executed by rotating the torso toward the bent knee in a conventional lunge stance. These exercises enhance both strength and stabilization during rehabilitation [26].

A typical exercise regimen consists of Nordic hamstring curls, in which the patient kneels while an assistant stabilizes their ankles as they gradually lean forward. Another exercise, the extender, involves bending the injured hip and knee to 90°, followed by a controlled extension of the knee. The third position – the diver, where the patient stands on the affected limb, leans forward to 90° of hip flexion, and stretches the arms forward [26]. In the comprehensive review, researchers emphasized the combined injury data per one thousand hours of exposure demonstrated the statistically significant reduction in the risk ratio of 0.490 ($p = 0.008$) in exercise regimen that included the Nordic hamstring workout [27]. Groups that incorporated injury prevention programs featuring this exercise achieved a long-term over half percentage decreases in injury rates compared to groups that did not adopt any preventive measures.

Another group of researchers investigated the effects of eccentric strength and flexibility training on hamstring strains incidence among soccer players [28]. Teams following the eccentric training program had a 65% reduced incidence of muscle strains compared to those who only performed flexibility workout. Additionally, the impact of the Nordic hamstring workouts on the incidence and severity of muscle strains was studied in 546 professional players in rugby [29]. Athletes that performed the Nordic hamstring workout demonstrated significant reduced incidence and severity of hamstring injuries compared to both the strengthening and stretching workout groups. Similarly, supportive research carried out a randomized controlled trial to evaluate the preventive impact of the Nordic workout on muscle strains in amateur male soccer players. The intervention group had a significantly lower incidence of muscle strains than the control group ($p = 0.005$) [30].

Paton et al. emphasize that running and sprinting are crucial elements of rehabilitation after hamstring strain injury (HSI) (LOA 98.4%) [31]. This finding aligns with existing literature suggesting that insufficient high-speed running exposure and poorly structured running programs are contributing factors for both first-time muscle strains and recurrence. During running exercise, the three hamstring muscles exhibit varying activation patterns at various lengths and speeds, producing distinct force outputs. In sprinting, the ST muscle shows the highest lengthening velocity, the SM muscle generates the most force, and the BF muscle experiences the greatest strain, with the long head potentially reaching 112% of its resting length. Additionally, muscle behavior may vary based on acceleration levels. This suggests that each muscle might require a tailored rehabilitation approach for return-to-running.

6.2. Operative rehab progression perspective

Meanwhile, there are also operative options available in certain treatments for HSIs. From the perspective of operative rehabilitation progression, there are numerous detailed exercises within each specific phase. Phase I (0–4 weeks) emphasizes protection and soft-tissue healing, both crucial at this period of rehab. Hamstring contraction at around 30–45 degrees can be performed to prevent unnecessary inhibition. Standing balance exercises with the knee bent, as well as aquatic exercises, can be introduced in weeks 2–3 to promote activation and improve functional mobility [6].

In Phase II (5 – 8 weeks), when the patient attains over 70 degrees of knee motion, cycling with low resistance and a high seat position may be employed to initiate mobility and endurance training. Exercises for lumbopelvic stabilization, single leg stand balance, and neuromuscular control can be advanced by introducing bridging movements and transitioning from double-leg to single-leg variations. Progression to Phase III requires normalized stage, no more than a 20% discrepancy in muscle flexibility evaluated by the active extended knee assessment, and adequate isometric hamstring muscle strength [6].

Phase III (8–12 weeks) focuses on eccentric hamstring strengthening at an extended muscle length and further development of lumbo-pelvic stability. Lengthening exercises are beneficial for rebuilding the hamstring's loading capacity in the elongated positions common in athletic activities [6].

7. Prevention and intervention

Majority research on hamstring related injury prevention emphasizes ball related sports over running related athletes [32]. This research demonstrates the value of including eccentric workouts of hamstring strengthening into prevention strategies, showing a decrease in injury rates, especially when speed, eccentric muscle training, and flexibility session are added to existing concentric strength programs.

Strategies for preventing hamstring injuries underscore a multifaceted approach comprising several essential elements. Commencing with eccentric strength workout, which encompasses exercises such as the Nordic practice to strengthen eccentric muscles and prevent injury. Eccentric overload exercises utilizing flywheel apparatus have demonstrated a preventative effect. Moreover, effective warm-up techniques that incorporate running drills or specific exercises can mitigate the risk of hamstring injuries. Furthermore, the FIFA 11+ program comprises a systematic warm-up regimen that integrates running, strength training, plyometrics, and balance exercises to mitigate lower limb injuries. Enhancing neuromuscular control strategies involves fortifying and synchronizing the musculature surrounding the pelvis and core to augment lumbopelvic stability, thereby offering substantial protection against hamstring injuries. Plyometric exercises, including jumps, lateral shuffles, and bounding, enhance agility and muscle strength, thereby aiding in injury prevention. Ultimately, the progressive strength training approach incorporates exercises that incrementally challenge the hamstring muscles at various lengths, including Romanian deadlifts and stiff leg deadlifts. All these strategies integrated scientific based methodologies to provide an idea of muscle strain prevention [24].

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Conversely, intervention techniques for hamstring injuries encompass a blend of stretching, strengthening, and neuromuscular control exercises designed for both recovery and preventive phases. Static stretching interventions are crucial during rehabilitation to restore muscle flexibility. Progressive running programs systematically rehabilitate the capacity to accelerate, sustain velocity, and decelerate, which is essential for reinstating pre-injury performance levels. Eccentric strengthening exercises, emphasizing prolonged eccentric contractions, are fundamental for injury prevention and rehabilitation, improving strength and flexibility. Furthermore, neuromuscular control and agility exercises within the PATS protocol aim to enhance agility and trunk stability, thereby mitigating the risk of reinjury. Exercises targeting core and lumbopelvic control, such as bridging, improve stability, facilitate efficient workout routine and prevent injuries. Finally, strength training should focus on contraction mode, especially high-intensity strength, to prevent future injuries. Collectively, these interventions constitute a holistic rehabilitation strategy to guarantee optimal recovery and a secure return to athletic performance [24].

To assess the efficacy of hamstring strain prevention and intervention programs, all personnels includes coach, physiotherapists, and trainers periodically assessed the program's outcomes. Muscle strengthening was objectively measured by improvements in resistance training performance. A decrease in the time demanded for each athlete to clear fifteen low set miniature hurdles at predetermined distances verified the enhancement of neuromuscular function. Dynamic flexibility, which is the opposition to active movement across one or multiple joints, was assessed by the smoothness and speed of sprinting movements involving all lower limb joints [32].

8. Conclusion

Hamstring related injuries (HSIs) are prevalent, particularly in sport requiring explosive movements. Effective prevention and rehabilitation of HSIs benefit from a multifaceted approach that includes understanding the biomechanics and risk factors and incorporating eccentric strength training into prevention programs. From a physiotherapy standpoint, focusing sequentially on flexibility, stabilization, and specific strength exercises, aids in recovery. Emphasizing eccentric training in prevention programs, especially in sprinting related sports, has been shown to reduce injury rates significantly when combined with concentric strength protocols. Based on all relevant research that provide in this paper, the exact mechanism underlying hamstring strain during sprinting and the most effective management protocols for HSIs are still not well defined. This limited clarity largely stems from weaknesses in existing evidence, particularly the frequent use of uncontrolled studies, retrospective design, and less new updated database. Such limitations restrict the ability to reach clear conclusions about both the risk factors and best practice for managing hamstring related injuries.

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