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Hamstring Injuries: A Comprehensive Review of Current Treatment Options

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Abstract

Background: Hamstring muscle injuries (HMI) remain the most prevalent non-contact injury in high-speed sports, particularly football and athletics. Despite sports medicine advancements, HMI is characterised by high recurrence rates (12–33%), causing significant time loss and performance decrements.

Aim: This paper provides a comprehensive literature review regarding the functional anatomy, risk factors, diagnostic classification, and evidence-based treatment strategies for HMI.

Material and methods: A narrative literature review was conducted using PubMed and MEDLINE. We focused on high-quality studies (systematic reviews, randomised controlled trials, clinical guidelines) published between 2010 and 2025, covering conservative and surgical management.

Results: The biceps femoris long head's bi-articular architecture and dual innervation predispose it to eccentric strain during sprinting. Diagnosis has evolved with the British Athletics Muscle Injury Classification (BAMIC), which identifies intratendinous involvement as predicting prolonged recovery. Conservative management remains the gold standard for mid-substance injuries; L-protocol (lengthening) and eccentric strengthening show superior outcomes over concentric training. Surgery is indicated for complete proximal avulsions or high-grade partial tears with retraction (>2 cm); acute repair yields better outcomes than chronic reconstruction.

Conclusions: Effective HMI management requires a multimodal approach. While conservative care resolves most injuries, precise MRI diagnosis is crucial to identify surgical candidates early. Return to play must be criteria-based, prioritising restored eccentric strength, fascicle length, and sprint mechanics over time-based protocols or imaging clearance.

Key words: Hamstring injury, eccentric strengthening, proximal avulsion, return to play, sports medicine.

1. Introduction

Hamstring muscle injuries (HMI) represent one of the most prevalent and challenging musculoskeletal disorders in modern sports medicine and traumatology [1, 2, 3]. Due to their specific bi-articular architecture and biomechanics, this muscle group is particularly susceptible to strain, especially in disciplines requiring sudden acceleration, sprinting, and kicking, such as football, track and field, and rugby. Epidemiological data indicate that HMIs account for approximately 12–24% of all injuries in professional football, making them the most frequent non-contact diagnosis in the sport [1, 2].

The core clinical challenge, however, lies not only in the high incidence of these injuries but primarily in the alarmingly high recurrence rate. It is estimated that reinjury occurs in 12–33% of athletes within the first year of returning to activity. These recurrent injuries often present with a more severe clinical profile and necessitate significantly longer recovery periods than the primary event [2]. This situation generates not only long-term health consequences for the athletes but also substantial financial and performance losses for clubs and federations.

The etiology of HMI is multifactorial and closely linked to the mechanism of injury—typically occurring during the eccentric contraction phase of the terminal swing in sprinting or during excessive muscle lengthening [3]. Despite a growing understanding of injury biomechanics, a consensus regarding optimal management remains a subject of ongoing debate. While the "gold standard" for the majority of mid-substance injuries remains conservative management based on progressive rehabilitation protocols [4], the approach to proximal hamstring avulsions and the utility of biological adjuncts, such as Platelet-Rich Plasma (PRP) injections, continue to be controversial within the medical community [5].

The aim of this paper is to review the current scientific literature regarding available treatment options for hamstring injuries. This review discusses the evolution of conservative protocols, indications for surgical intervention, the efficacy of biological therapies, and criteria for a safe Return to Play (RTP), based on the latest clinical guidelines and comparative studies.

2. Functional Anatomy and Biomechanics

The hamstring muscle complex comprises three distinct muscles located in the posterior compartment of the thigh: the semitendinosus (ST), the semimembranosus (SM), and the biceps femoris (BF). With the exception of the short head of the biceps femoris (BFsh), all hamstring muscles are bi-articular, spanning both the hip and knee joints [6]. They share a common origin at the ischial tuberosity of the pelvis, a site of particular clinical significance as it is the anatomical location for proximal hamstring tendon avulsions [7]. While the ST and SM run medially to insert onto the tibia, the BF runs laterally, inserting primarily onto the fibular head [6].

2.1. Neuromuscular Characteristics

A critical anatomical feature relevant to injury etiology is the unique innervation of the biceps femoris. The long head (BFlh) is innervated by the tibial division of the sciatic nerve, whereas the BFsh receives innervation from the common peroneal division [7]. It has been hypothesised that this dual innervation may lead to asynchronous neuromuscular firing patterns between the two heads, potentially causing uncoordinated force generation and increasing the risk of strain [8, 9]. Furthermore, the hamstrings possess a high proportion of Type II (fast-twitch) muscle fibres compared to other muscle groups. While this composition is essential for explosive power, it renders the muscle group highly susceptible to fatigue, which is a well-documented risk factor for structural failure [10].

2.2. Musculotendinous Architecture

The internal architecture of the hamstring muscles significantly influences their injury susceptibility. BFlh possesses a complex pennate architecture with relatively short muscle fascicles and a large pennation angle relative to the force-generating axis [11]. This architectural design, combined with a long, narrow proximal aponeurosis, creates a distinct myotendinous junction (MTJ) that extends deep into the muscle belly. Studies utilising CT analysis have consistently identified this proximal MTJ of the BFlh as the most common site of strain in sprinting athletes [12]. Additionally, shorter fascicle lengths in the BFlh have been prospectively associated with a significantly higher risk of future injury [11, 13].

2.3. Biomechanics of Injury

Functionally, the hamstrings act as hip extensors and knee flexors, but their mechanics vary depending on the activity type.

1. High-Speed Running (Sprint-Type): Biomechanical analyses demonstrate that the hamstrings undergo peak musculotendinous stretch and force generation during the terminal swing phase of the gait cycle [14]. In this phase, the muscles must contract eccentrically to decelerate the extending knee and flexing hip. The combination of peak negative work and maximal length makes the terminal

swing the primary moment of vulnerability for "sprint-type" injuries [14, 15].

2. Over-lengthening (Stretch-Type): A secondary mechanism involves excessive lengthening of the muscle at extreme joint ranges, such as simultaneous hip flexion and knee extension (e.g., high kicking or sliding tackle) [16]. Unlike sprint-type injuries, which typically affect the BFlh, these "stretch-type" injuries more frequently involve the proximal free tendon of the semimembranosus and require prolonged rehabilitation periods [4, 16].

3. Risk Factors for Hamstring Strain Injury

Given the complex nature of these injuries described in the previous section, the risk profile is considered multifactorial, consisting of both non-modifiable and modifiable determinants.

3.1. Non-Modifiable Risk Factors

1. Previous Injury - The single most robust predictor of future HMI is a history of previous hamstring injury. A comprehensive meta-analysis indicated that athletes with a prior HMI are significantly more likely to sustain a recurrence, particularly within the first season following recovery [17]. This elevated risk is attributed to maladaptive structural changes, including the formation of non-contractile scar tissue (fibrosis) at the site of the previous tear. This scar tissue alters the mechanical properties of the adjacent muscle fibres and shifts the point of failure, making the muscle less compliant during high-velocity eccentric contractions [18].

2. Age - Advancing age is consistently identified as a primary non-modifiable risk factor. Studies involving elite soccer players have demonstrated a linear correlation between age and injury susceptibility [1]. This is likely underpinned by age-related sarcopenia and a specific reduction in the cross-sectional area of Type II fast-twitch fibres, which are crucial for handling the rapid force demands of sprinting [19].

3.2. Modifiable Risk Factors

1. Eccentric Strength Deficits - Low levels of eccentric knee flexor strength have been prospectively identified as a critical risk factor. Athletes producing lower eccentric force outputs (often measured via isokinetic dynamometry or the NordBord device) are unable to

effectively dampen the high forces generated during the terminal swing phase of gait [20]. Furthermore, significant between-limb strength asymmetries (>15-20%) have been associated with a markedly increased risk of primary and secondary injury, highlighting the importance of unilateral strength assessment [21].

2. Fascicle Architecture - As discussed in the anatomical section, the internal architecture of the biceps femoris long head (BFlh) plays a pivotal role in injury resilience. Recent prospective studies using ultrasound imaging have shown that short fascicle lengths (<10.5 cm) significantly increase the probability of strain injury [11]. Shorter fascicles are forced to operate on the descending limb of the length-tension curve earlier in the range of motion, making them more susceptible to over-lengthening damage. Crucially, unlike age or history, this factor is highly trainable; eccentric training has been shown to lengthen fascicles, thereby serving as a protective mechanism [11].

3. Lumbo-Pelvic Control - The position of the pelvis directly influences the operating length of the hamstrings. An excessive anterior pelvic tilt places the hamstring origin (ischial tuberosity) in a more superior/posterior position, effectively pre-loading and lengthening the muscle group before movement occurs. Deficits in core stability or gluteal activation can exacerbate this tilt during running, increasing the passive tension on the hamstrings and predisposing them to failure under load [22].

4. Diagnosis and Classification

Accurate diagnosis and appropriate classification of hamstring strain injuries are critical not only for confirming the injury but for establishing a valid prognosis. A comprehensive diagnostic process must bridge the gap between structural damage and functional deficits, utilising a multimodal approach that correlates clinical assessment with imaging and functional testing [17, 23].

4.1. Clinical Assessment

The diagnostic process begins with a detailed patient history. In acute cases, athletes typically report a sudden onset of sharp pain in the posterior thigh, often accompanied by an audible "pop," occurring during high-velocity running or excessive lengthening of the muscle [19]. The mechanism of injury—sprinting versus stretching—provides early prognostic value, as stretching-type injuries often involve the semimembranosus and require longer recovery periods [24].

The physical examination focuses on:

- Palpation - Identifying the point of maximal tenderness is crucial. Injuries located proximally near the ischial tuberosity are generally associated with prolonged rehabilitation compared to mid-belly strains [18, 24].

- Range of Motion and Strength - Pain is reproduced during active knee extension or passive straight leg raise (SLR). Isometric contraction against resistance assesses pain and strength deficits, which correlate with the extent of tissue damage [21].

- Specific Clinical Tests - The Askling H-test (active ballistic straight leg raise) is highly recommended. It places high eccentric demand on the hamstrings and is considered one of the most sensitive tests for both diagnosing the injury and clearing an athlete for return to play [24].

4.2. Diagnostic Imaging

While clinical examination is fundamental, Magnetic Resonance Imaging (MRI) is considered the gold standard for visualising soft tissue injuries and is essential for modern classification systems [23, 25]. MRI allows for the precise differentiation between myofascial, musculotendinous, and intratendinous injuries [18, 23].

However, the correlation between MRI findings and clinical recovery is complex. Silder et al. [18] highlighted that MRI findings, such as signal hyperintensity and scarring, often persist long after the athlete has clinically recovered. Furthermore, Wangensteen et al. [25] demonstrated in a large cohort study that while MRI is excellent for diagnosis, the size of the oedema does not always perfectly correlate with the time to return to play (RTP). This suggests that imaging should guide the *classification* but not dictate the *timeline* in isolation [18, 25].

4.3. Classification Systems

Historically, hamstring strain injuries classification relied on a simple Grade I-III system based on macroscopic disruption. However, this system lacks prognostic precision. The current "bible" of muscle injury grading is the British Athletics Muscle Injury Classification (BAMIC) proposed by Pollock et al. [23].

The BAMIC system improves upon older models by categorising injuries based on their anatomical site within the muscle-tendon unit:

- Type A (Myofascial) - Injuries to the peripheral aspect of the muscle.
- Type B (Musculotendinous) - Injuries at the muscle-tendon junction (most common).
- Type C (Intratendinous) - Injuries extending into the tendon.

This distinction is vital because Pollock et al. [23] and Green et al. [17] note that injuries involving the tendon (Type c) have significantly higher recurrence rates and require longer rehabilitation than myofascial injuries.

4.4. Functional Diagnosis and Risk Profiling

Modern diagnosis extends beyond tissue pathology to functional capability. Identifying neuromuscular deficits is essential to prevent the "risk of recurrence" highlighted in recent epidemiological updates [17, 19].

- Eccentric Strength - Opar et al. [20] established that low eccentric hamstring strength is a primary risk factor. Screening with isokinetic dynamometry or the NordBord is standard practice to quantify these deficits [20].
- Muscular Imbalance - Croisier et al. [21] provided prospective evidence that normalising the hamstring-to-quadriceps (H:Q) ratio significantly reduces injury risk. Athletes with untreated imbalances had a fourfold higher injury risk compared to those who underwent corrective intervention [21].
- Neuromuscular Control - Strength metrics alone are insufficient. Schuermans et al. [22] used electromyography (EMG) to show that previously injured players exhibit altered muscle recruitment patterns (neuromuscular inhibition) in the proximal segments, even after strength recovery. This highlights the need to diagnose deficits in "proximal neuromuscular control" alongside pure strength [22].

In conclusion, a robust diagnosis requires identifying the specific anatomical location via MRI (using the BAMIC system) [23], assessing functional capacity via the Askling H-test [24], and quantifying strength deficits [20]. This multi-layered diagnosis is the prerequisite for the rehabilitation strategies discussed in the following chapter.

5. Conservative Treatment

Conservative management remains the primary therapeutic strategy for the vast majority of hamstring strain injuries, including Grade I and II injuries, and many Grade III injuries involving the muscle belly [26]. The contemporary approach has shifted significantly from passive modalities and immobilisation toward early mobilisation and progressive mechanical loading. The overarching goal is to restore the structural integrity of the injured tissue while addressing modifiable risk factors, such as eccentric strength deficits and neuromuscular control [27].

5.1. Acute Phase: From RICE to PEACE & LOVE

Historically, the immediate management of soft tissue injuries relied on the RICE protocol (Rest, Ice, Compression, Elevation). However, recent evidence suggests that complete rest and cryotherapy may inhibit the necessary inflammatory response required for optimal tissue regeneration. Consequently, Dubois and Esculier [26] proposed the acronym PEACE & LOVE to guide the acute phase.

- P - Protection: Avoid activities that increase pain during the first 1-3 days to minimise bleeding and prevent distension of the injured fibres.

- E - Elevation & C - Compression: Utilised to manage interstitial edema.

- A - Avoid Anti-inflammatories: NSAIDs may negatively affect long-term tissue healing.

- Load - The "LOVE" component emphasises that mechanical stress should be introduced early. As soon as symptoms allow, optimal loading promotes collagen realignment.

5.2. Sub-acute Phase: Restoration of Muscle Function

Once the acute inflammatory signs have subsided, the rehabilitation focus shifts to restoring muscle activation and range of motion without exceeding the pain threshold.

- Isometric Loading - Isometric exercises are introduced early to maintain motor unit recruitment and reduce tendon inhibition. Hickey et al. [27] demonstrated that performing exercises within a pain threshold of ≤4/10 on the VAS scale does not impede healing and may facilitate better strength outcomes than pain-free rehabilitation.

- Neuromuscular Control - Core stability and lumbopelvic control exercises are integrated to address the "proximal control" deficits highlighted in the diagnostic chapter.

5.3. Remodelling Phase: The "L-Protocol" and Eccentric Strengthening

This phase is the cornerstone of successful rehabilitation. The objective is to increase the load-bearing capacity of the hamstrings, particularly at long muscle lengths.

Lengthening Exercises (The L-Protocol) - The work of Askling et al. [4] has revolutionised HMI rehabilitation. In a landmark randomised controlled trial, they compared a conventional protocol (C-protocol) focusing on concentric strength and stretching against a lengthening protocol (L-protocol) emphasising eccentric loading at end-range motion. The L-protocol consisted of three key exercises:

The Extender - Focused on flexibility and eccentric control.

The Diver - A hip-dominant exercise stimulating the proximal hamstring.

The Glider - A high-load eccentric exercise at long muscle lengths.

The study found that the L-protocol significantly reduced the time to return to play (28 days vs. 51 days) compared to conventional training [4].

Eccentric Strengthening: In addition to the L-protocol, isolated eccentric strengthening is mandatory. The Nordic Hamstring Exercise (NHE) has been extensively validated for its ability to increase fascicle length and eccentric strength. Mendiguchia et al. [28] emphasise that while the NHE is crucial, a multifactorial approach that also targets horizontal force production (e.g., hip extension exercises like the 45° hyper-extension) is necessary for complete recovery.

5.4. Functional Phase and Return to Sport (RTS)

The final stage involves bridging the gap between clinical rehabilitation and the specific demands of the sport.

- High-Speed Running - Running is the most specific functional test. A progressive running program, culminating in maximal sprinting, is essential. Mendiguchia et al. [29] argue that "sprinting is the best vaccine against sprinting injuries." The rehabilitation must expose the athlete to high-velocity mechanics to prepare the tissue for the demands of competition.

- RTS Criteria - The decision to clear an athlete for sport should not be time-based but criteria-based. This includes:
    1. Full range of motion (comparable to the uninjured limb).
    2. Use of the Askling H-Test without pain or apprehension [4].
    3. Restoration of eccentric strength (e.g., <10% asymmetry on dynamometry).
    4. Completion of a full training session without symptoms.

In conclusion, conservative treatment is a dynamic continuum. It progresses from acute protection (PEACE & LOVE) to lengthening-biased strengthening (Askling’s L-protocol) and culminates in sport-specific sprinting exposure. This active approach yields superior outcomes compared to passive therapies.

6. Surgical Treatment

While conservative management yields excellent results for the vast majority of hamstring injuries, particularly those involving the muscle belly and myotendinous junction, specific injury patterns necessitate surgical intervention to restore optimal function. The paradigm of surgical treatment has evolved significantly, shifting from a measure of last resort to a primary indication for specific high-grade avulsions [16, 30].

6.1. Indications for Surgery

The primary indication for surgical repair is a complete proximal hamstring tendon avulsion (PHTA). Unlike mid-substance strains, these injuries involve the detachment of the tendon from the ischial tuberosity and rarely heal with sufficient tension or structural integrity without fixation [30]. Current consensus guidelines recommend surgical repair for:

- Complete avulsions - Rupture of all three tendons (semitendinosus, semimembranosus, and biceps femoris long head) [31].
- Significant retraction - Partial or complete tears with tendon retraction greater than 2 cm.
- Functional failure - Persistent pain, weakness, or cramping despite prolonged conservative management (often seen in chronic partial tears).

Askling et al. [16] emphasise that accurate diagnosis via MRI is critical here, as "stretch-type" injuries involving the free tendon of the semimembranosus can mimic avulsions clinically but often respond to conservative care unless significant retraction is present.

6.2. Timing of Intervention: Acute vs. Chronic

The timing of surgery is a critical determinant of postoperative outcomes. The literature draws a distinct line between acute repairs (performed within 4 weeks of injury) and chronic repairs (performed after 4 weeks). A systematic review by Bodendorfer et al. [31] demonstrated that acute repairs are associated with significantly better subjective outcomes, higher strength scores, and a lower rate of complications compared to chronic repairs. In chronic cases, the retraction of the tendon often leads to scarring of the sciatic nerve (sciaticolysis) and muscle atrophy/fatty infiltration, making the surgery technically more demanding and increasing the risk of iatrogenic nerve injury [31, 32]. Therefore, early surgical consultation is mandatory when an avulsion is suspected.

6.3. Surgical Techniques

The gold standard technique involves open reduction and internal fixation (ORIF). The patient is typically positioned prone, and a transverse or longitudinal incision is made in the gluteal fold. The retracted tendon stump is mobilised, the ischial tuberosity is prepared (decorticated) to stimulate a healing response, and the tendons are reattached using non-absorbable suture anchors [32]. Recently, endoscopic techniques have emerged as a minimally invasive alternative for partial tears or less retracted avulsions. While technically challenging, endoscopic repair offers the potential for reduced scar tissue formation and quicker cosmetic recovery, though long-term functional outcomes appear comparable to open repair [33].

6.4. Outcomes and Return to Play (RTP)

Postoperative outcomes for surgically repaired PHTA are generally favourable. Studies report high patient satisfaction rates and a high likelihood of returning to pre-injury levels of sport. However, the rehabilitation timeline is significantly longer than for conservative management. Van der Made et al. [32] reported that the median time to RTP following surgical repair is approximately 5 to 6 months. It is important to note that while the reinjury rate after surgery is relatively low (approx. 7–8%), residual deficits in end-range eccentric strength and sprinting speed can persist [32, 33]. The most common complication is distinct from recurrence: postoperative irritation of the sciatic nerve (neuralgia), which occurs in roughly 10-20% of cases due to the proximity of the repair site to the nerve sheath [31].

Table 1. Comparison of Conservative and Surgical Treatment for Hamstring Injuries

Feature	**Conservative treatment**	**Surgical treatment**
Primary Indications	Grade I, II, and many Grade III injuries (muscle belly / myotendinous junction); stretch-type injuries without significant retraction.	Complete proximal avulsions (all 3 tendons); retraction > 2 cm; functional failure after prolonged conservative care.
Core Philosophy	Early mobilization and progressive mechanical loading to restore structural integrity and address modifiable risk factors.	Structural reattachment of the avulsed tendon to the ischial tuberosity to restore tension and anatomy.

Feature	Conservative treatment	Surgical treatment
Key Interventions	PEACE & LOVE protocol (acute); isometric loading; L-protocol (lengthening exercises); Nordic Hamstring Exercise; high-speed running.	Open Reduction and Internal Fixation (ORIF) with suture anchors; minimally invasive endoscopic repair.
Return to Play (RTP)	Shorter rehabilitation timeline (e.g., ~28 days with L-protocol for specific strains); clearance is criteria-based.	Significantly longer timeline; median RTP is approximately 5 to 6 months.
Key Risks & Limitations	Potential for functional failure or recurrent injury if eccentric deficits and sprint mechanics are not fully restored.	Postoperative sciatic nerve irritation (neuralgia, 10-20%); surgical complications; residual deficits in end-range strength.

7. Discussion

The management of hamstring muscle injuries has undergone a paradigm shift over the last decade. The transition from passive treatment modalities to active, lengthening-based protocols represents a significant advancement in sports medicine. However, despite these improved rehabilitation strategies, the epidemiological burden of HMI remains high, with recurrence rates showing no sign of decline in elite football [1, 17]. This paradox - better understanding but stagnant injury rates - suggests that current management models may still be overlooking critical factors.

7.1. The "Gray Zone": Management of High-Grade Partial Tears

One of the most debated topics in current literature is the management of the so-called "Grey Zone" injuries. These are typically high-grade partial tears (BAMIC Type 2c or 3c) involving the intramuscular tendon or the proximal free tendon, but without complete retraction [23, 30]. Clinically, these injuries present a dilemma. They do not meet the classic criteria for surgical repair (retraction >2 cm) discussed in the previous chapter, yet they often fail to heal adequately with standard conservative care due to the poor vascularity of the tendon tissue. Lempainen et al. [30] argue that in these "Grey Zone" cases, a prolonged conservative period is often attempted first. However, if symptoms such as pain during sprinting or functional weakness persist after 3–4 months, surgical tenodesis or reconstruction becomes a viable option to restore tension in the posterior chain. This highlights the need for a personalised approach: while the "gold standard" is conservative, the threshold for surgical consultation should be lower for injuries involving significant tendon disruption [32].

7.2. Biological Healing vs. Functional Recovery

A major challenge discussed in this review is the discrepancy between biological healing (observed on MRI) and functional recovery. As noted by Wangensteen et al. [25], athletes often achieve clinical milestones (pain-free range of motion, strength symmetry) while MRI still shows significant oedema and tissue immaturity. This creates a conflict in Return to Play (RTP) decision-making. Relying solely on the resolution of MRI findings would keep athletes sidelined for months unnecessarily. Conversely, ignoring the biological state of the tissue may explain the high rate of early recurrences (within 2 months of RTP) [2]. The literature suggests that the solution lies in "functional hardening"—using the chaotic/high-speed running drills described by Mendiguchia et al. [29] to stress-test the healing tissue before full clearance. The Askling H-test [24] serves as a crucial bridge here, ensuring that the athlete is not just strong, but confident and capable of handling high eccentric velocity.

7.3. The Prevention Paradox

The review of risk factors confirmed that eccentric strength deficits and short fascicle lengths are modifiable determinants of injury [11, 20]. The Nordic Hamstring Exercise (NHE) has been proven to mitigate both. However, implementation remains poor. Buckthorpe et al. [34] suggest that the issue is not a lack of knowledge, but a lack of compliance and integration. The NHE is often viewed as a standalone “vaccine", whereas true prevention requires a holistic approach addressing lumbopelvic control [22], running mechanics [14], and load management. Furthermore, the focus on eccentric strength alone may be reductionist. Recent evidence points towards the importance of horizontal force production and sprint mechanics. As argued by Mendiguchia et al. [29], "sprinting is the best vaccine against sprinting injuries," implying that graded exposure to maximum velocity is a non-negotiable component of both prevention and rehabilitation.

7.4. Limitations of Current Evidence

It is important to acknowledge that much of the high-quality evidence (e.g., Askling et al. [4]) is derived from male cohorts in elite football or track and field. There is a paucity of data regarding HMI in female athletes, despite distinct biomechanical differences in pelvic anatomy and landing mechanics. Additionally, while surgical outcomes are promising [32, 33], there are very few randomised controlled trials directly comparing operative vs. non-operative management for "Grey Zone" injuries, forcing clinicians to rely on lower-level retrospective evidence.

In summary, the optimal management of HMI requires a departure from "protocol-based" medicine toward "criteria-based" progression. Whether treated surgically or conservatively, the ultimate goal is not just tissue healing, but the restoration of the athlete's capacity to withstand the supraphysiological loads of modern sport.

8. Conclusion

Hamstring muscle injuries remain a persistent challenge in high-performance sports, characterised by their high incidence and frustratingly high rates of recurrence. This review demonstrates that the management of these injuries has evolved from a generic, passive approach to a specific, active, and criteria-based model.

The critical findings of this comprehensive review are threefold. First, accurate diagnosis is the cornerstone of effective treatment. The use of the BAMIC classification system via MRI allows clinicians to distinguish between myofascial injuries, which have a favourable prognosis, and intratendinous or proximal avulsion injuries, which require prolonged rehabilitation or surgical intervention [23, 32]. Second, conservative management focusing on eccentric lengthening (L-protocol) and progressive high-speed running is superior to conventional concentric training. This active approach directly addresses the modifiable risk factors of short fascicle length and eccentric weakness [4, 11]. Third, surgical treatment is a highly effective option for proximal avulsions, particularly when performed acutely. However, for the "grey zone" of high-grade partial tears, the decision-making process remains complex and requires a personalised assessment of the athlete's functional deficits [30, 32, 34].

In conclusion, there is no single "magic bullet" for preventing or treating hamstring injuries. Success depends on a multimodal approach that integrates precise anatomical diagnosis, biological healing time, and functional restoration of sprint mechanics. Future research should prioritise high-quality randomised trials comparing operative and non-operative management for partial tendon tears to further refine clinical guidelines.

Disclosure

Author's contribution

Conceptualization: P. Górka; methodology: K. Swoboda; software: K. Borówka; check: P. Górka, W. Kądziołka; formal analysis: J. Frączek, Z. Wiater; investigation: A. Włodarczyk, M. Jakubowska; resources: P. Górka, K. Brankowska; data curation: S. Domagała; writing-rough preparation: K. Swoboda; writing –review and editing: J. Frączek, K. Borówka; visualization: A. Włodarczyk, M. Jakubowska, W. Kądziołka; supervision: P. Górka, K. Swoboda; project administration: P. Górka

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Conflict of interest

The authors deny any conflict of interest.

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