

Prevention and Treatment of Hamstring Injuries

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Abstract. Hamstring injuries in baseball players and soccer players have become progressively more severe due to active lengthening and high-speed running. This paper analyzes the anatomy, mechanisms, prevention, and rehabilitation of hamstring injuries to optimize training methods and reduce the recurrence of hamstring injuries. The results of the study indicated that several training methods, such as Nordic hamstring exercises, eccentric single-leg deadlift and maximal double-leg eccentric hamstring slider exercises, are effective in strengthening the hamstrings. These measures can effectively enhance hamstring strength and reduce the incidence of re-injury. Rehabilitation should follow a phased approach, beginning with submaximal bilateral eccentric exercises in the subacute phase, progressing to high-intensity eccentric training, and culminating in sport-specific neuromuscular retraining. Advanced biomechanical analysis and individualized programs further minimize reinjury risk by restoring strength and functional control. These evidence-based strategies not only accelerate safe return to sport but also emphasize the importance of structured rehabilitation in improving long-term athletic performance.

Keywords: Hamstring injury, eccentric loading, rehabilitation and prevention, biceps femoris, nordic hamstring exercise

1. Introduction

Hamstring injury refers to damage (overstretching, tearing, or chronic strain) to the muscles or tendons of the hamstring group located on the back of the thigh, which is very common among athletes, particularly those who actively participate in explosive or high-speed movements such as sprinting, soccer and rugby. In Australian football, there are 81% of hamstring injuries occur during the process of sprinting [1]. As a result, several preventive strategies have been driven by this theory. This theory has driven preventive strategies such as eccentric strengthening exercises, which are associated with significantly reduced injury rates. Another theory suggests that injuries occur in the early stages of gait support, as there is a greater re/resistance when the body advances forward above the landing point. These mechanical explanations align with clinical observations; an increasing number of studies have reported that hamstring injuries not only occupy around one-third of all athletic injuries, across all sports, especially among many elite athletes who suffer from this pain, but also have a high rate of re-injury. Typically, a lot of athletes will have negative emotions when they suffer hamstring injuries due to a lack of training and competition. As a result, affected athletes will have anxiety and even depression, and treatment outcomes are often suboptimal. In turn,

professional practitioners should fully understand the reasons and mechanisms of hamstring injury, develop a thorough understanding of the causative factors and pathological processes involved in hamstring strain injuries, acquire the skills to perform complete clinical assessments, and master the principles of progressive tissue loading to ensure safe and effective rehabilitation. Hamstring injuries typically require 24 days of recovery, leading to considerable economic and competitive losses for elite athletes and teams. Particularly, dancers experience a heightened susceptibility to such muscle injuries. These factors underscore the significance of hamstring injuries in sports and physical performance fields. In this essay, the main purpose of a rehabilitation program after hamstring injury is to provide multiple prevention and treatments, facilitating the athlete's return to sport at the highest possible performance level as fast as possible, but with a minimal risk of re-injury.

2. Anatomy of the hamstring

The hamstring muscle has both hip extension and knee flexion functions and is composed of three different muscles, namely the biceps femoris (BF), semitendinosus (ST), and semimembranosus (SM). These three muscles all originate from the ischial tuberosity of the pelvis, which is sometimes referred to as the ischium. In terms of their insertions, all three muscles insert into different places, starting with the muscle belly of semimembranosus, which is situated on the most medial side of the posterior thigh, and its muscle belly insertion is located at the more posterior aspect of the medial tibial condyle. In contrast, the semitendinosus actually crosses over the semimembranosus distally, ultimately inserting at the medial tibial condyle within the pes anserinus region. Finally, the biceps femoris is located on the most lateral side of the posterior thigh. This muscle has two heads: one is the long head that originates from the ischial tuberosity, and the head is the short head, which originates from the linea aspera of the femur.

In terms of their insertion, they join almost together at the head of the fibula and muscles join the branch together before inserting on the fibula on the lateral side. Functionally, the hamstrings are essential for movements such as running, jumping, and climbing. They act as antagonists to the quadriceps, helping decelerate knee extension during gait. Due to their biarticular nature (crossing both the hip and knee joints), they are particularly prone to strains, especially in athletes. Therefore, understanding their precise anatomy is critical for effective rehabilitation and injury prevention strategies.

3. Mechanism of hamstring injury

It is important to emphasize that the hamstrings are among the most frequently injured muscles in soccer. According to statistics, 37% of sports-related muscle injuries appear in the hamstring region [2]. The most common mechanism is when the hamstring undergoes sudden contraction while in a stretched or lengthened state, a phenomenon known as eccentric loading. For instance, during high-speed running, especially in the late swing phase, sprinters may experience elongation of muscle tendon units beyond the normal range. American football players, while kicking, as their movements require extreme ranges of motion, this eccentric to concentric transition greatly increases the risk of hamstring injuries, particularly, the muscle is fatigued or insufficiently warmed up. Football players, such as Robert Lewandowski have a kicking motion when reaching for the ball with an extended leg. Moreover, both American football and soccer players perform dynamic movements that involve active lengthening of their muscle-tendon units. Repetitive high-intensity training constitutes one of the significant pathogenic factors contributing to chronic hamstring injuries; thus, establishing

systematic prevention protocols is of substantial clinical significance. A study suggests that the most frequently injured hamstring muscle is the biceps femoris long head, followed likely by the semimembranosus. Notably, proximal hamstring injuries near the hip are significantly more common than distal injuries near the knee. This pattern aligns with the mechanism of injury during eccentric contraction in a lengthened position, as observed in activities requiring extreme hip flexion, such as NFL kicking motions. In movements involving extreme hip flexion, such as kicking in American football, the hamstring muscles are elongated near the hip joint, which explains why proximal hamstring injuries are more common than distal injuries. Importantly, the location of the injury has a significant impact on rehabilitation and prognosis. Another study conducted a systematic review and identified previous hamstring injuries as the most significant predictor of re-injury, with a re-injury rate of up to 60% within two years after the initial injury [3]. This alarming statistic underscores the critical importance of structured rehabilitation protocols. The data suggest that insufficient rehabilitation significantly enhances re-injury risk, potentially due to incomplete tissue remodeling or persistent neuromuscular defects.

4. Prevention of hamstring injury

The goal of the prevention of hamstring injury is to always decrease the rate of hamstring injury. 60%-70% of hamstring injuries can be reduced by eccentric exercises, which have been shown by statistics during a competitive season [4]. To maximize hamstring injury prevention, eccentric exercises should involve such following characteristics as high forces, maximal muscle elongation, high velocities, multi-joint movements, closed-chain actions, unilateral loading, and cost-effective, easily implemented techniques. Since other lower-body muscle groups, such as the hip flexors, plantar flexors, and hip adductors, are also prone to strain, exercises should address these areas as well.

Although Nordic exercises have solved many of these problems, they still have some limitations. Firstly, as an open-chain unilateral exercise, Nordic exercises may lead to uneven load between the legs, with stronger limbs bearing more tension. After just four weeks of Nordic training, many participants showed increased asymmetry in optimal muscle length between legs [5]. This is because the dominant leg absorbed more tension. Such imbalances are known to elevate injury risk. Secondly, the Nordic hamstring exercise is a single-joint exercise, which focuses on knee flexion and hip extension [6]. As a result, it fails to fully engage the hamstrings' natural biarticular function involving both hip extension and knee flexion. Sport-specific movements would better benefit from multi-joint eccentric exercises that coordinate multiple muscle groups. Finally, some trainees may adapt Nordic hamstring exercises after experiencing a period of training time; they will have a desire to pursue this exercise with bigger weights or higher velocities, which may increase the risk of injury. Although the Nordic hamstring exercise has these inherent drawbacks, it is still a great way to develop hamstring strength.

4.1. Eccentric single dead lift

The main benefit of the eccentric deadlift is balancing the hamstring muscle between legs during the training process. Based on its unilateral benefits, eccentric deadlift promotes lower limb balance through isolating and loading each hamstring independently, reducing strength imbalance between legs [7]. Another upside of the eccentric single deadlift is actively elongates the hamstring muscle tendon. This situation is similar to the late phase of swing during high velocity running. Imitating the functional lengthening patterns of the hamstring muscle can significantly enhance our hamstring

muscle adaptation for sprint competition while mitigating the risks of hamstring injury that is associated with asymmetry.

4.2. Sub Maximal Bilateral (SMB) eccentric hamstring slider exercise

SMB eccentric hamstring slider exercise is an excellent training mode, because this training method not only serves as a prevention method for hamstring injury in the early rehabilitation stage, but also a great training for hamstring muscle strength. Similarly, this training mode is as same as the eccentric deadlift. When you use your leg to push forward a piece of towel or a dumbbell tablet, your hamstring muscle is actively elongated, which closely mimics the biomechanical demand of the late phase of swing during high-speed running. Moreover, this positive method of eccentric loading has been indicated to enhance hamstring strength and the long head of the biceps femoris muscle fascicle length. Hamstring muscle strain can be recovered within a period of short period after acute injury. For clinical implementation, practitioners should emphasize controlled eccentric phases (3-5s duration) with submaximal effort (60-80% perceived exertion) to optimize tissue remodeling while minimizing excessive mechanical stress—a strategy shown to reduce re-injury rates by 52% in college athletes [8].

5. Treatment of hamstring injury

Tears in the hamstrings are divided into three grades; the first is the most slight, with a small number of muscle fibers on the back of the thigh, reduced exercise ability, but not affecting light activities, such as jogging, cycling, etc., and the recovery time is 1-2 weeks. The second is a moderate partial tear, with an increased number of muscle fiber tears, accompanied by fascial damage and tingling in the long head of the biceps femoris muscle, swelling and bruising on the back of the thigh within 48 hours, and the recovery time is 3-6 weeks. The third situation is the most serious one; the tendon from the ischial tubercle junction is completely broken. Athletes can often hear a popping sound in the back of the thigh during exercise; in this situation, the athlete can no longer walk normally. Therefore, they need to rely on a wheelchair to walk; at the same time, this situation may require clinical surgical intervention, and the recovery time is long, which takes 3-6 months [9].

During the subacute phase of hamstring strain (3 days to 2 weeks after injury), tissue repair is in the proliferative phase, when collagen fibers begin to deposit but have not yet formed good mechanical properties. This phase of rehabilitation focuses on promoting the orderly alignment of collagen fibers through controlled submaximal load training while avoiding re-injury caused by premature high-stress stimuli. Studies have shown that direct high-intensity eccentric training may cause microdamage to immature scar tissue and induce delayed muscle soreness (DOMS), thereby delaying the recovery process. Therefore, the Submaximal Bilateral Eccentric Hamstring Slider Exercise is recommended as a transitional intervention. This training provides progressive mechanical stimulation while reducing knee moment by reducing the load intensity (30-50% 1RM) and bilateral symmetrical force pattern, thereby maintaining muscle activation and preventing force loss. In addition, combined with isometric contraction exercises, it can further optimize neuromuscular control, reducing muscle inhibition, and lay the foundation for subsequent higher-intensity rehabilitation phases. It is recommended to gradually adjust the training parameters under the supervision of a professional rehabilitation or physical therapist based on individual pain tolerance and functional recovery to ensure a safe and effective rehabilitation process. Moreover, in the third stage of hamstring injury rehabilitation (usually 2-6 weeks after injury), as tissue repair enters the mature stage, the mechanical properties of collagen fibers are significantly improved, and

progressive eccentric training and functional exercise integration should be introduced. According to the research, Nordic Hamstring Exercise can serve as a eccentric training program that can be systematically implemented in this stage, and its mechanism of action is mainly reflected in three aspects: first, eccentric training can induce sarcomerogenesis through mechanical stress stimulation, thereby optimizing the length-tension relationship of muscles. Secondly, the controllable elongation load can promote the directional arrangement of collagen fibers along the stress line and enhance the mechanical adaptability of the tissue structure. Finally, this training method can significantly improve the eccentric strength of the hamstrings, which plays a key role in the prevention of sports injuries. Finally, a systematic high-level rehabilitation training program should be implemented after the athlete completes the recovery of basic functions and meets the standard for returning to sports. Furthermore, it is recommended to use a 3D motion capture system for sports biomechanical analysis when possible, focusing on evaluating the load characteristics and compensation mode of the hamstring muscles in running and special technical movements, and optimizing the exercise technique in a targeted manner. This comprehensive training regimen not only significantly improves eccentric strength. For example, isokinetic strength testing has confirmed that it can restore muscle strength to more than 95% of the healthy side. More importantly, reduces the risk of reinjury by 40-60% by establishing an optimized neuromuscular control model. During the training implementation, it is necessary to strictly follow the principle of individualization and evaluate the muscle activation mode in real time through surface electromyography monitoring to ensure that the special exercise ability is gradually rebuilt under the premise of painlessness.

6. Conclusion

Hamstring injuries remain a prevalent and challenging issue in sports, particularly among athletes engaged in high-speed running and explosive movements. This essay analyzes the anatomical basis of hamstring injuries, highlighting the vulnerability of the biceps femoris during eccentric loading, and explores mechanisms such as sprinting and kicking that predispose athletes to strains. Preventive measures, including Nordic Hamstring Exercises, eccentric single-leg deadlifts, and submaximal bilateral slider exercises, were shown to enhance muscle strength and fascicle length while addressing biomechanical imbalances. Rehabilitation protocols emphasized a phased approach, beginning with submaximal eccentric loading in the subacute phase, progressing to high-intensity eccentric training, and culminating in sport-specific neuromuscular retraining to restore functional control and reduce reinjury risk by up to 60%. These findings highlight the importance of incorporating eccentric reinforcement into routine training protocols and adopting personalized rehabilitation programs to address muscle asymmetry and biomechanical deficits. However, there are limitations, including variations in the severity of the injury and personal responses to recovery, which may affect the outcome. Future studies should examine the long-term efficacy of combined prevention strategies, such as fusing eccentric training with neuromuscular control exercises, and exploring the role of emerging technologies such as wearable sensors and AI-driven biomechanical analysis in personalized rehabilitation. By advancing these methods, the risk of hamstring injury can be greatly reduced by clinicians and coaches and increase exercise lifespan.

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