DON'T BE HAMSTRUNG BY HAMSTRINGS

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INTRODUCTION

Hamstring muscle strain injuries are one of the most common injuries in football. While they don't necessarily result in the prolonged absence from playing that injuries such as anterior cruciate ligament ruptures may carry, the high rate of recurrence and the tendency to occur in even the most well-conditioned athlete make them a serious issue for all footballers. In recent years there has been increased attention paid to the non-contact hamstring muscle injury, particularly in understanding of risk factors for sustaining an injury, the extent of its impact and the management of the hamstring injury. Despite this, the reality is that many of our management practices have changed little in either principle or application over the last 50 years and both injury incidence and recurrence rates remain high. This article will briefly review the non-contact hamstring muscle strain injury.

HAMSTRING ANATOMY

The hamstring muscle consists of three distinct muscles: the semi-membranosis (SM), semi-tendinosis (ST) and biceps femoris (BF), all arising from distinct elements of the ishial tuberosity. Of academic interest but of unknown clinical significance, superficial elements of the biceps origin are also continuous with the sacrotuberous ligament. Additionally, the biceps femoris also has a 'short head', typically arising from the femoral shaft and the lateral intermuscular septum. Distally, the semi-membranosis and semi-tendinosis are closely related and insert into the medial upper tibia. The ST is part of the pesanserinus complex while the biceps femoris inserts laterally into the head of the fibula. Hence, while the SM and ST are two joint muscles, the biceps femoris may be considered either a three or four joint muscle (i.e. including the proximal tibiofibular joint and the sacroiliac joint). Innervation is typically described as being from the sciatic nerve, although it is likely that there is more complexity and variability in this than previously recognised. Each component muscle of the hamstring group has a distinctive (and between individuals, variable) architecture, with unique proximal and distal tendon

	INTRINSIC	EXTRINSIC
POTENTIALLY MODIFIABLE	*Quadriceps flexibility* *HS flexibility* *Isokinetic strength* *Fatigue* *Anthropometrics/biomechanics*	*Training load* *Recovery* *Sports participation*
NON-MODIFIABLE	*Age* *Previous HS injury* *Previous knee, groin or calf injury* *Race* *Anthropometrics / biomechanics*	

Table 1: Intrinsic and extrinsic risk factors for non-contact hamstring muscle injury. HS=hamstring.

lengths, complex aponeurotic attachments and variable fascicle lengths. For example, the SM proximal tendon is continuous for up to 72% of the entire length of the muscle, compared to just 29% in the ST. The BF musculotendinous junction covers 46% of the entire muscle, compared to just 26% in the ST but, by contrast, the distal tendons are similar lengths between each component muscle, around 60% of the length of the muscle. This complexity in the overlapping tendon/aponeurosis structure in the hamstring muscle group combined with variable length and directed muscle fascicles results in a complex muscle architecture – which has almost certainly been oversimplified in classic anatomical texts[1].

It remains unknown which, if any, of these anatomical factors are relevant in determining risk for a hamstring muscle injury. For example, differential innervation of the long and short heads of biceps have been proposed to potentially result in distinct activity patterns and explain the predominance of BF over biceps femoris short head injury. Similarly, the continuity of the BF origin with the sacrotuberous ligament may implicate the sacroiliac joint in BF injuries. Kinematic studies have shown that due to its anatomical structure, the BF undergoes a greater lengthening during sprinting in comparison with the SM and ST and this too has been considered a potential risk factor. However, to date, the relative impact of these factors remains to be determined.

KNOWN RISK FACTORS FOR NON-CONTACT HAMSTRING MUSCLE INJURIES

Risk factors for hamstring muscle injuries may be classified as intrinsic or extrinsic (Table 1). As with the discussion above regarding anatomical risk factors, the relative merits of each of these in any given hamstring injury remains to be determined. Subsequently, with a patient in front of you, it is vital to remember that in any given injury the causal factors are most likely multi-factorial in origin and the reduction of risk factors to single causative factors are unlikely to explain the entire story. The role of the medical team then, is to evaluate which factors are clinically relevant in any given injury and to address these in the rehabilitation period.

PREVENTION

The incidence of hamstring injuries is quite high (0.5 to 1.5 injuries per 1000 hours of football) and there is a high risk of recurrence. A recent elite football study has shown that 25% of players with a hamstring injury sustain a recurrent injury in the following season. In a further study, a recurrence rate of 22% was observed within the first 2 months after the index injury[2-5].

Biomechanical models have shown that peak hamstring stretch and force occurs during the late swing phase of the running gait cycle and that force increases significantly with speed. Hamstring injuries often occur in the late swing phase, where the hamstrings are required to work eccentrically to decelerate knee extension. Similarly, hamstring muscle injury is suspected to occur during the late stance phase in sprinting when the hamstring muscles are contracting forcefully at a long muscle-tendon length.

One could therefore speculate that being strong eccentrically in the hamstring muscles could be an advantage in order to prevent muscle injuries.

Eccentric hamstring muscle strengthening is a strengthening exercise performed by lengthening the hamstring muscle complex while it is loaded and activated.

Recent studies have indicated that prevention, or at least a reduction in incidence, could be possible using eccentric exercises for the hamstring muscles[6-8]. A large cluster randomised controlled study including nearly 1000 elite and sub-elite players showed a 10-week pre-season training programme including the so called Nordic hamstring exercise (Figure 1). This exercise focuses on increasing hamstring muscle eccentric strength and it was shown to reduce the incidence of new injuries significantly. Importantly, the programme was even more effective in reducing the rate of recurrent injuries[9].

From a practical perspective, players, coaches and clubs might question the relative cost-benefit of yet another prevention programme, which may potentially take time from playing football. The number of players needed to treat (in this case needed to do the programme) to save one player from a hamstring injury is a clinically relevant number that can be used when considering this programme. In the case of preventing hamstring injuries, if 13 players perform the programme (Nordic hamstring exercise over a 10-week pre-season period), one injury can be prevented. Furthermore, in players with a previous hamstring injury, three players performing the programme will prevent one hamstring injury[9].

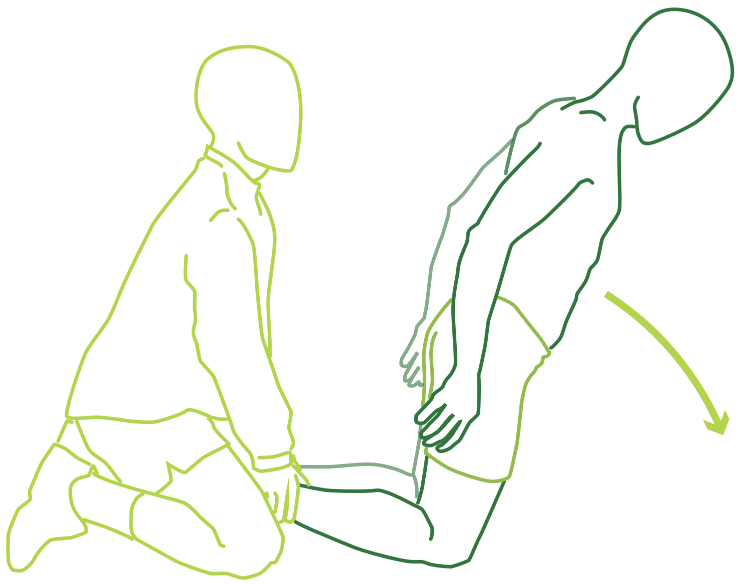

Figure 1: Illustration of the Nordic hamstring exercise. The Nordic hamstring exercise is easy to perform with a partner. It can be done in field with no specific extra equipment and is time effective. Given the very convincing preventive effect, it is highly recommended that it is implemented in football training.

DIAGNOSIS OF HAMSTRING MUSCLE INJURIES

As with most of medicine, diagnosis of hamstring muscle injuries should begin with a clear history of the player (previous hamstring or other lower limb injury, low back symptoms, recent 'spasm', hip joint symptoms, associated medical conditions) and the specific injury mechanism. Classic mechanisms include sprinting or sprinting with pelvic flexion (as when lunging for the line in a sprint, picking up a ball) with resultant lengthening of the hamstrings. Sudden eccentric contraction, as associated with sports such as water skiing, is often associated with rupture of the hamstring origin (in adolescents, avulsion of the apophysis must be considered). Training fatigue, recovery status and other factors preceding the injury, as well as the initial management, should be clarified.

Examination should include careful assessment of hamstring range of motion in both a straight leg raise and hip flexed position. Pain on contraction from a resting and extended position should be assessed, and the extent of tenderness on palpation carefully noted. Skilled palpation is an under-rated tool and one which requires constant practice in order to be able to establish a good 'feel' for the underlying tissue. Comparison with the contra-lateral limb should be made for all elements of the assessment. The hip joint, lumbar spine, knee joint and the proximal tibiofibular joint should be assessed for either limitations or excessive range of motion and underlying pathology and gluteal trigger points which may elevate underlying muscle tone should be identified.

A classic history of the sudden onset of central posterior thigh pain while sprinting, pain on stretch and contraction and tenderness on palpation of the mid belly are typical of a hamstring muscle strain injury. However, it is surprising how frequently the results of this assessment conflicts with magnetic resonance imaging (MRI) finding, which is considered highly sensitive for muscle injury. In fact, up to 20% of clinically diagnosed hamstring muscle injuries may subsequently be negative on MRI. This is important as an MRI negative posterior thigh injury has a significantly better prognosis than those that are MRI positive[3]. Subsequently, in the presence of a classic history and examination but a negative MRI, the treating physician may face a challenging (although perhaps academic) diagnostic dilemma. Specifically, a) is there a muscle injury, but below the sensitivity of MRI to detect it? or b) is this referred pain from sources such as gluteal trigger points, hip joint, other sources or another diagnosis such as 'muscle spasm'. This complex issue, which has recently been highlighted in a novel classification system for muscle injuries which has suggested the presence of 'functional' or non-structural muscle injuries[10]. As with all previous classification or grading systems for muscle injuries, there is a paucity of scientific evidence upon which to formulate robust theories and to date there is no data relating this proposed classification system to clinical outcomes. However, this remains a fascinating area of controversy requiring further academic and clinical consideration.

Despite the conundrum presented above, imaging can play an important role in delineating the exact nature of an injury that is clinically suspected, particularly in the elite athlete. Both ultrasound and MRI have been shown to be sensitive for hamstring muscle injury, which is optimised when imaging is performed 48 hours post injury. Imaging too soon after an injury runs the risk of evaluating an evolving injury, and potentially under-diagnosing. However, imaging in conjunction with a careful clinical evaluation provides enhanced diagnostic detail, allowing a

WEEK	SESIONS/WEEK	SETS	REPS	LOAD
1	1	2	5	↑ load when athlete can control fall forward. When 12 reps can be achieved, ↑ load by: a) Adding speed to the starting phase of the motion. b) Having partner push back of the shoulders.
2	2	2	6	
3	3	3	8 - 6	
4	3	3	10 - 8	
10 - 5	3	3	8 - 10 - 12	

Table 2: Training protocol for the Nordic Hamstring Exercise (includes sessions and reps data).

clearer prognosis to be provided, in addition to accurately directing treatment.

MANAGEMENT

As with all acute muscle injuries, the initial management of a hamstring injury is critical, and can have a significant impact on the long-term outcome. Following an acute non-contact muscle injury, there is a period of tissue degeneration and inflammation. Optimising progress through this phase is thought to be critical, and should involve relative rest, compression, protection from aggravating activities and regular ice. The rationale for cooling is to minimise ongoing bleeding and inflammation, by cooling the area of injury and surrounds. Hence, in comparison with superficial injuries, deep muscle injuries will theoretically require a longer period of cooling to have the same degree of cooling. However, pragmatically we recommend icing for 20 minutes, with protection to avoid ice burns, repeated up to 2-hourly for 48 hours, and 4-hourly for a further 2 to 3 days. Early mobilising in a pain free manner, and progressive pain free mobilising through walking, jogging, running and sprinting should progress sequentially. As pain allows, passive and active gains in range of motion should be sought, and strength training should be initiated progressively from inner range to outer range, and through the classic isometric, concentric and eccentric progressions as pain allows.

Recovery is an important factor to consider in a regenerating muscle, and ensuring that there is adequate regenerative time between loading is important. In the initial phases of regeneration, we recommend loading no more than once daily, but further into the progressions and later in the supposed regeneration phase when endurance training becomes a goal, loading may be increased. Later in the rehabilitation, when loading is reaching the muscle's physiological limits (i.e. when the athlete is being asked to perform repeated maximum effort contractions to fatigue), it is likely that more recovery time will be required – a minimum of 24 hours, but likely closer to 48 hours. In this regard we have found routine daily monitoring of strength using hand-held dynamometry to be of use in determining the appropriate level of exercise to perform that day (when compared with previous measures, and the contralateral side). This relation is range-dependent, with our experience suggesting outer-range strength measures to be the most sensitive to change and clinically predictive. Core stability and progressive functional loading should begin with careful physiotherapist supervision, but systematically can be passed to specialised conditioning coaches to monitor. A graduated return to individual training and then selective elements of team training is one of the most critical elements of the entire process. It is known that injury recurrence is greatest in the first 6 weeks following return to play, but exactly why some players may

have recurrence and others do not is unclear. We believe that careful graduated return to full training, monitoring of fatigue with manipulation of training load as required, and the progressive return to game play should minimise the risk of reinjury.

Anti-inflammatory drugs

Non-steroidal anti-inflammatory drugs (NSAID) are one of the most frequently prescribed medications in sports medicine. While intuitively, the use of anti-inflammatories in the acute phase of injury to assist in minimising inflammation (as per ice and rest) may appear appropriate, in vivo studies have shown that NSAID will impede muscle and collagen regeneration and increase levels of fibrosis (which may increase the risk of re-injury). For this reason, we avoid NSAID and if pain relief is required, we recommend simple analgesia. Given the ease of access to NSAID 'over the counter', it is important that this is highlighted to injured athletes. Similarly, the use of the intramuscular anti-inflammatory cortisone has been in use since the 1950s and has been shown to be beneficial in two small and technically limited case series of muscle injuries. However, there is overwhelming evidence that the histopathological impact of intra-muscular cortisone on muscle regeneration is negative, and we recommend its avoidance.

Platelet rich plasma

To this point, we have described the typical approach to the management of hamstring muscle injuries. This approach was described in detail in the 1950s and while there have been enhancements in some of the details, most of the principles remain unchanged[11]. Any enhancements in our management have been predominantly clinical in origin, with only a limited number of attempts made to scientifically substantiate techniques[12]. Over the past 50 years there have been numerous novel interventions posed for the management of muscle injuries, but unfortunately most interventions have never had their efficacy established. The most recent treatment to be popularised for the management of muscle injuries is the use of platelet rich plasma (PRP). PRP is a concentrate of one's own platelets, typically prepared by centrifugation of 30 to 60 ml of blood. It supposedly works through the application of increased concentrations of 'growth factors' derived from the elevated numbers of platelets. In support of this technique, numerous growth factors, including insulin-like growth factors, fibroblast growth factors, hepatocyte growth factors and platelet-derived growth factors applied individually to damaged muscle tissue have been shown to enhance muscle healing[13]. With its combination of growth factors, PRP has been shown to enhance indicators of muscle regeneration in rats and no adverse effects have been recorded when utilised in muscle. Unfortunately, despite anecdotal evidence from its use around the world, there remains no substantial evidence that PRP will enhance recovery or reduce reinjury in non-contact hamstring muscle injuries. Furthermore, individual growth factors found within PRP such as TGF-ß have been shown to increase fibrosis and scar tissue formation. While in the absence of any treatment scarring is a natural consequence of muscle injury, it is considered an undesirable outcome due to its lack of contractility which is felt to predispose to further injury.

Therefore, while PRP has in vitro and animal model support for its use in muscle injuries, it remains to be determined if this will translate into a significant clinical advantage. Any real advantage will be determined by a more rapid return to play, and at the very least no increase in the re-injury rate. Given the invasive nature of this intervention, long-term careful monitoring for side-effects will also be required.

> *anti-inflammatories will impede muscle and collagen regeneration and increase levels of fibrosis which may increase the risk of re-injury*

SUMMARY

Non-contact hamstring muscle injuries are common and create significant problems for footballers and football clubs around the world. While numerous risk factors are known, the exact risk for any given player at any given time remains difficult to quantify. As a result, preventative techniques, aimed at addressing modifiable variables should be broadly instigated. In the event of a hamstring injury, careful clinical evaluation in combination with appropriate imaging can assist in the formulation of an accurate diagnosis, management plan and prognosis. Management strategies based on clinical refinement of underlying basic science principles remain the most reliable approach, and more novel techniques such as PRP remain to be clinically evaluated.

APPENDUM: A NOTE ON TERMINOLOGY

The terminology used in non-contact muscle injuries continues to evolve and provoke emotive responses from physicians and therapists alike. Since before the 1930s it is clear that the terms muscle "strain", "pull", "rupture" and "tear" have been used interchangeably to describe a muscle injury such as that observed in the hamstring muscle group. In the late 1980s and 1990s, the term "strain" was commonly used in animal models of muscle injury, and implied both the nature of the force transmission and the type of injury. Each of these terms has a specific history of usage in the English language sports medicine literature and appears to imply a degree of mechanistic intent – a mechanism which remains to be fully elucidated. Hence, pending further scientific clarity, the authors' preference is to use the term "non-contact muscle injury", which is felt to be more neutral in tone.

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