WHAT IS A HAMSTRING INJURY?

AN OVERVIEW OF ANATOMY, MUSCLE HEALING AND OPTIMAL LOADING

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INTRODUCTION

One only needs to look back to the 2018 FIFA World Cup™ in Russia to see that hamstring injuries are still a major problem in football. In the opening match of the biggest sports event in the world, Russian midfielder Alan Dzagoev sustained a hamstring injury in the 22nd minute. He was set to miss the rest of the World Cup but luckily he recovered, and was able to play a major role in the quarterfinals.

This is just one example of the many hamstring injuries that affect football players and athletes every year. In fact, hamstring injuries remain the most frequent muscle injury in elite football, accounting for 34% of all muscle injuries[1]. Even more problematic, they have a high tendency (up to 16%) to re-occur[1,2].

Hamstring injuries receive considerable attention in both clinical practice and research studies. Risk factors are investigated, rehabilitation trials are conducted, and prevention efforts are studied to better manage this common football injury. However, to support these efforts in managing this very common but complex injury, we must first revisit the basics.

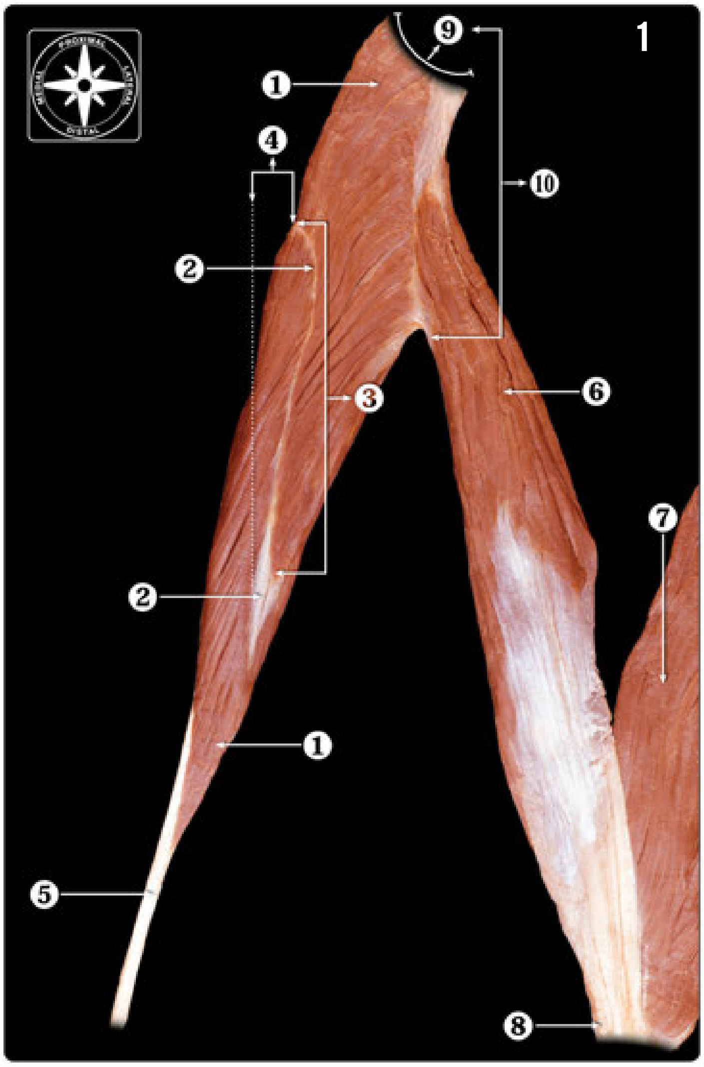
THE ANATOMY OF THE HAMSTRINGS

The hamstring muscle group (Figure 1) consists of four muscles divided into two groups:

1. semitendinosus (ST) and semimembranosus (SM) form the medial group,
2. biceps femoris long head (BFlh) and biceps femoris short head (BFsh) form the lateral group.

The hamstrings are a major knee flexor and hip extensor. Furthermore, they act as the antagonist to the quadriceps muscle and also prevent excessive anterior translation of the tibia. Separately, the medial group assists with internal rotation and the lateral group with external rotation of the tibia (and they act as antagonists in this regard)[3].

Although the hamstrings function as a group, the individual muscles all vary significantly in morphology, architecture,



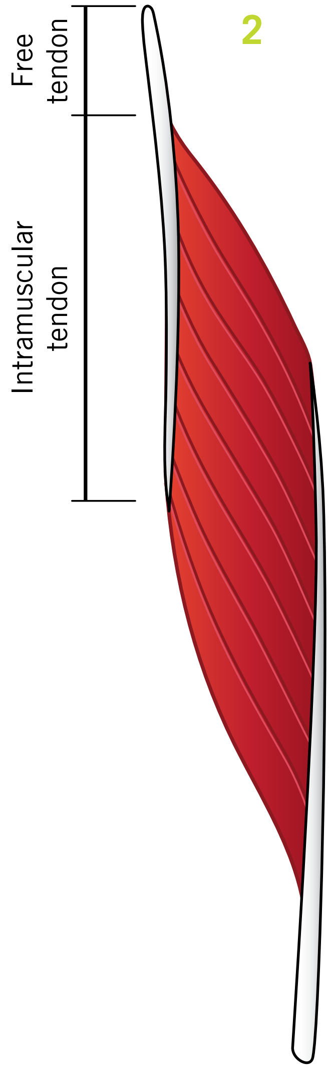


Figure 1: Anatomy of the hamstring muscles. 1 Semitendinosus muscle. 2 Raphe. 3+4 Length and width of raphe. 5 Semitendinosus tendon. 6 Biceps Femoris Long Head. 7 Biceps Femoris Short Head. 8 Distal tendon of Biceps Femoris. 9 Ischial tuberosity. 10 Conjoint tendon. Reproduced from van der Made et al Knee Surg Sports Traumatol Arthrosc. 2015 Jul;23(7):2115–22 with permission of copyright owner.

Figure 2: Schematic overview of free tendon, intramuscular tendon and the relationship of proximal (combined free and intramuscular tendon) versus distal tendon. Reproduced from van der Made et al Br J Sports Med. 2018 Jan;52(2):83–8 with permission of copyright owner.

and injury mechanisms. Many have hypothesised correlations between hamstring anatomy and injury patterns, but to date no strong clinical evidence exists for any of these hypotheses[4]. However, we do have a growing understanding of the type of injury and their overall rehabilitation period.

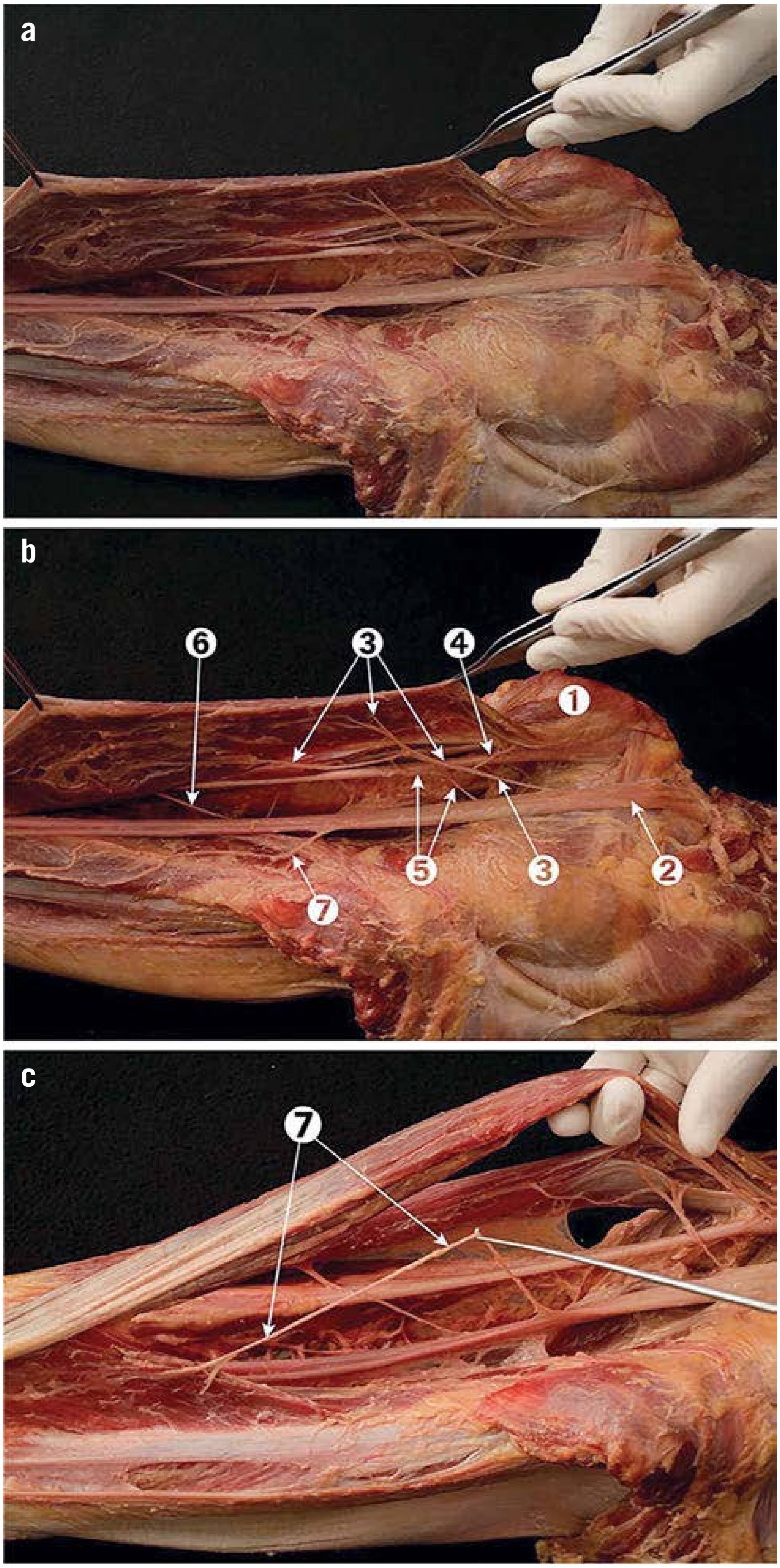
The proximal myotendinous junction is the most injured location in acute hamstring injuries and these injuries generally have a shorter return to play time than injuries affecting the free tendon (Figure 2). Likewise, complete avulsions occur predominantly in the proximal tendons but fortunately, avulsions are rare. This rarity, however, can make it a blind spot for clinicians[5].

The hamstrings are innervated by the sciatic nerve and its subdivisions, the tibial branch (BFlh,SM,ST) and the fibular branch (BFsh) (Figure 3). All muscles are innervated by one motor branch, except for the ST which is innervated by two branches due to its raphe (discussed in following section). These motor branches split proximally for the BFlh and ST and more distally for the SM, BFsh and the distal part of the ST (past the raphe)[3].

Currently, hamstring injuries involving the intramuscular tendon (sometimes referred to as the central tendon) are receiving much attention in the literature[6–9]. The intramuscular tendon is defined by van der Made et al as ''the part of the tendon to which the muscle fibres attach'' (Figure 2)[6]. In a study compromised of primarily football players, a full thickness injury accompanied by a wavy appearance of the tendon increased return to play by ten days[6]. However, there was no difference in re-injury rates as compared to non-intramuscular tendinous injuries[6]. At the same time, it is important to recognise that due to the different biomechanical demands, these (re-) injury rates might be higher in other sports such as (elite) athletics, Australian football league (AFL) and rugby; but high quality evidence is still lacking[7,8].

Biceps Femoris long head

The BFlh has received much research interest as it is the most commonly injured muscle of the hamstring group (more than 80%)[1]. It is most frequently injured during sport involving high speed running such as football, AFL, rugby and athletics; injuries occur predominantly in the proximal musculotendinous junction (MTJ)[10,11]. The BFlh shares its proximal origin with the ST muscle at the posteromedial aspect of the ischial tuberosity[12]. At the posterior margin of this origin, the sacrotuberous ligament commonly inserts into (and is continuous with) the conjoint tendon and ischial tuberosity. The sacrotuberous ligament might play an important role in complete tendinous avulsions; if it stays intact the muscle tends to retract less than when it is disrupted (Figure 4)[13].



The conjoint tendon is shaped like an oval at the origin and as it travels into the muscle belly of the BFlh it becomes more sheet-like in appearance. The (common) distal tendon overlaps with the proximal tendon and has a bifurcated insertion into the posterolateral edge of the head of the fibula (direct arm) and the lateral edge of the head of the fibula (anterior arm)[14]. The distal biceps tendinous insertions have an important function as dynamic stabilisers of the posterolateral knee complex and run close to the common peroneal nerve, which can cause an entrapment neuropathy[15].

Semimembranosus

In professional football, the SM muscle is the second or third most injured muscle of the hamstring group, depending on the study (interchanging with the ST)[11,16]. Injuries occur predominantly in the proximal MTJ. In other sports such as ballet the proximal free tendon is the most injured location and this injury is recognised as being of the slow-speed stretching type[17]. The SM originates anterolaterally from the common BF-ST origin at the ischial tuberosity, where it has a crescent-shaped footprint. Its proximal tendon is the longest of all the muscles in the hamstring group and starts out as an asymmetrical, aponeurotic sheath before any fascicles attach to it at around 10 cm from the ischial tuberosity[18]. The distal insertion of the SM is varied and complex, but at least three major insertion points have been recognised in the literature[19]:

1. The oblique popliteal expansion, that runs across the popliteal fossa from its proximal superomedial aspect to its distal inferolateral aspect and inserts into the posterior capsule,

Figure 3: Hamstring innervation (lateral view) a-c. 1 Ischial tuberosity. 2 sciatic nerve. 3 motor branch to BFlh. 4 recurrent branch to the proximal attachment of conjoint tendon. 5 motor branch to the ST. 6 motor branch to the SM. 7 motor branch to the BFsh. Reproduced from Stepien et al Knee Surg Sports Traumatol Arthrosc (2018) with permission of copyright owner.

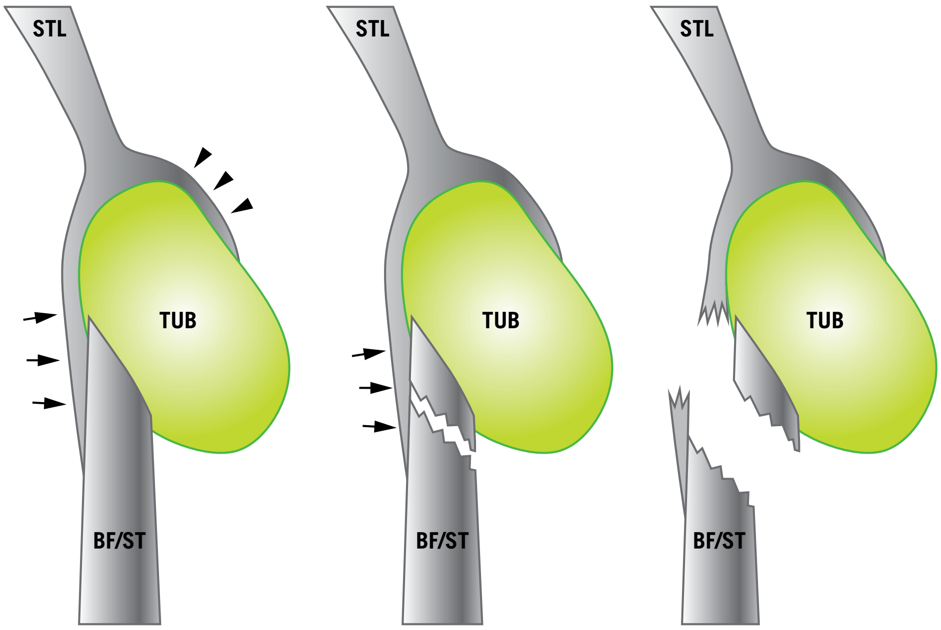


Figure 4: Schematic drawing of relationship of Sacrotuberous Ligament (STL) to the ischial tuberosity (TUB) and the conjoint tendon (BF/ST). BF/ST retraction might be less with an intact STL. Reproduced from Bierry G, Simeone FJ, Borg-Stein JP, Clavert P, Palmer WE. Sacrotuberous ligament: relationship to normal, torn, and retracted hamstring tendons on MR images. Radiology. 2013;271(1):162–171 with permission of copyright owner.

2. the anterior expansion, that runs to the anteriomedial part of the knee and inserts in the medial meniscus and the medial collateral ligament, and
3. the direct expansion, that inserts into the medial tibial condyle and the fascia of the popliteus muscle. These distal insertions contribute to the stability of the posteromedial knee complex. Similar to the BFlh, the proximal and distal tendon overlap[3,12].

Semitendinosus

As described previously, the ST is the second or third most injured muscle in the hamstring group, depending on which literature you consult. It shares most of its tendinous origin with the BFlh but a small amount of muscle fibers arise directly from the ischial tuberosity. This common tendon is mostly occupied by the muscle fibers of the ST. More distally, the fibers of the BFlh arise (around 10 cm from the ischium). Unlike the BFlh and SM, the proximal and distal tendon of the ST do not overlap. Going from proximal to distal in the ST, you encounter a reverse V-shaped tendinous inscription called the raphe. Currently it is still unclear what the function of this raphe is, though it might function as a sort of 'strut' that divides the ST into two regions. It is thought that this raphe, together with the ST having the smallest physiological cross-sectional area of the all the hamstring muscles, might be protective against injury[18]. The distal tendon of the ST is the longest free tendon of the hamstrings. For this reason, it is commonly harvested for use in ACL and other ligament reconstruction surgeries[20]. It inserts into the anteromedial side of the tibia. Just proximal to this insertion it fuses together with the Gracilis, and this combined tendon, together with the insertion from the Sartorius muscle, form the Pes Anserinus. Along the way, the ST tendon can give off aponeurotic bands to various structures such as the medial gastrocnemius, popliteal fascia and various parts of the tibia[21].

Biceps Femoris Short Head

The BFsh is an often underappreciated part of the hamstring group due to the low injury rates in this muscle, which may be related to its uni-articular nature. In isolation it accounts for 7% of the injuries to the distal MTJ of the lateral hamstring complex[22]. Unsurprisingly, an injury to the BFsh occurs more frequently in conjunction with an injury to the BFlh[22]. This might be explained due to the fact that they share a distal MTJ.

The BFsh muscle is the only muscle in the hamstring group that does not have a proximal tendon but its fibers originate directly from the linea aspera, the lateral intermuscular septum and the lateral supracondylar line.

MUSCLE HEALING – A SIMPLIFIED OVERVIEW

As clinicians dealing with hamstring muscle injuries, it is pivotal to understand the basics of muscle healing to optimise our rehabilitation of these injuries. Simultaneously, this knowledge is useful to manage stakeholder expectations and most importantly, the athlete's risks of (early) return to sport. Most muscle injuries happen at the MTJ. This area is frequently thought of as the weakest link in the chain, because the MTJ is where the projections of the myofibers interface with the connective tissue[23]. These projections maximise surface area and thus provide better mechanical force transmission between the muscle and the extracellular matrix[23]. Whenever an injury occurs at the MTJ several distinguishable phases of healing happen[23–25]. For example, during a hamstring injury, the myofibers are disrupted, and their associated basal lamina and blood vessels rupture and retract. This leaves a gap in the junction which is filled in with hematoma rich in monocytes. These monocytes remove necrotic tissue through phagocytosis. Subsequently, myoblasts (formed from satellite cells) appear around the damaged fibers and fibroblasts appear in the gap. To replace damaged muscle fibers, myoblasts merge together to form myotubes in the old basement membrane which functions as a scaffold for the duration of myofiber regeneration whilst necrotic tissue is removed by macrophages[25]. With subsequent maturation of these myotubes into new myofibers they form their own basement membrane and the old one is shed[25]. Fibroblasts deposit scar tissue in the gap and as this scar tissue matures, it forms new MTJs with the stumps of the damaged fibers[24]. This maturation is driven by mechanical loading. This is exactly the process where the clinician can provide the most benefit through mechanotherapy.

OPTIMAL LOADING – HOW TO OPTIMISE MECHANOTHERAPY

In elite sports it is of paramount importance to get an athlete ready to return to sport as soon as possible after an acute hamstring injury. It is a blend of art and science to balance the exposure to sufficient load in a safe and efficient manner, and minimising the risk of worsening the injury, thus delaying the return to sport process. It requires a lot of decision making concerning the micro-environment (e.g. tissue healing), the macro-environment (e.g. re-injury risk management, retaining fitness, external pressures) and their interaction. In this section we will focus on the micro-environment, i.e. tissue healing, as it is modifiable through mechanotherapy.

The underlying mechanism for mechanotherapy is mechanotransduction, which is defined by Khan and Scott[26] as 'the processes whereby cells convert physiological mechanical stimuli into biochemical responses'. Muscle is already a highly adaptive tissue and this is reflected in the process of mechanotransduction as well: loading the newly formed scar tissue facilitates maturation through better alignment and faster regeneration of myotubes, resulting in less disorganised scar tissue and normotrophic uninjured myotubes[26].

Traditionally, management of acute hamstring injuries (or other acute muscle injuries) included a set amount of days of treatment with (P)RICE, usually combined with passive/active stretching before active loading is commenced. However, there is no strong evidence supporting this approach when managing acute hamstring injuries in the early period. Bleakley et al already suggested a revision of this model called POLICE, adding in Optimal Loading (OL) as a replacement for Rest (R)[27]. The aim is to encourage clinicians to think about the optimal progression of rehabilitation and apply an appropriate loading strategy during the first crucial days of rehabilitation[27]. Most likely, relative rest is not ideal as confirmed by recent studies suggesting that an early start with rehabilitation expedites return to sport.[28].

CONCLUSION

The hamstrings are a heterogeneous and complex group of muscles that require an in depth knowledge of the anatomy to accurately diagnose and treat our football players. The MTJ is the most injured location and requires a balanced but active approach in treatment. Considering the anatomy, physiology and mechanotherapy presented here, we might suggest a basic clinical guideline:

Respect the healing tissue, but start loading early!

References available at www.aspetar.com/journal

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