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 injuries¹. Even more problematic, they have a high tendency (up to 16%) to re-occur². 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 HAMSTINGS

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,
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. 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.

The hamstrings are innervated by the sciatic nerve and its subdivisions, the tibial branch (BFih,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 BFih and ST and more distally for the SM, BFsh and the distal part of the ST (past the raphe).

Currently, hamstring injuries involving the intramuscular tendon (sometimes referred to as the central tendon) are receiving much attention in the literature. 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). 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. However, there was no difference in re-injury rates as compared to non-intramuscular tendinous injuries. 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.

**Biceps Femoris long head**

The BFih has received much research interest as it is the most commonly injured muscle of the hamstring group (more than 80%). 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). The BFih shares its proximal origin with the ST muscle at the posteromedial aspect of the ischial tuberosity. 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 when it is disrupted.
The conjoint tendon is shaped like an oval at the origin and as it travels into the muscle belly of the BFhl 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). 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.

**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). 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. 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. The distal insertion of the SM is varied and complex, but at least three major insertion points have been recognised in the literature:

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 BFhl. 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.
2. the anterior expansion, that runs to
the anteromedial part of the knee and
inserts in the medial meniscus and the
medial collateral ligament, and
3. the direct expansion, that inserts into
the distal tendon contact and the fascia
of the popliteous muscle. These distal
insertions contribute to the stability
of the posteromedial knee complex.
Similar to the BFlh, the proximal and
distal tendon overlap3,12.

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 all the hamstring
muscles, might be protective against
injury4. 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
surgeries40. 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 tibia41.

Biceps Femoris Short Head

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 tissue34. These projections
maximise surface area and thus provide
better mechanical force transmission be-
tween the muscle and the extracellular
matrix35. Whenever an injury occurs at
the MTJ several distinguishable phases of
healing happen33–35. 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 hematoxylin rich in monocytes. These
monocytes remove necrotic tissue through
phagocytosis. Subsequently, myoblasts (for-
med 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 dura-
tion of myofiber regeneration whilst ne-
crotic tissue is removed by macrophages36.
With subsequent maturation of these
myotubes into new myofibers they form
their own basement membrane and the old
one is shed37. Fibroblasts deposit scar tissue
in the gap and as this scar tissue matures,
it forms new MTJs with the stumps of the
damaged fibers38. 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 Scott26 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 myotubes26.

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 rehabilitation27. Most likely, relative rest is not ideal as confirmed by recent studies suggesting that an early start with rehabilitation expedites return to sport28.

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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WHAT IS A HAMSTRING INJURY?