# Incidence of athletic hamstring injuries in professional football players from 2016 to 2018

**Poljak, Dino**

**UNIVERSITY OF SPLIT**
**SCHOOL OF MEDICINE**

**Dino Poljak**

# INCIDENCE OF ATHLETIC HAMSTRING INJURIES IN PROFESSIONAL FOOTBALL PLAYERS FROM 2016 TO 2018

**Diploma thesis**

**Academic year: 2018/2019**

**Mentor:**
**Assist. Prof. Fabijan Čukelj, MD, PhD**

**Split, July 2019**

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## ACKNOWLEDGMENT

*Firstly, I would like to express my profound gratitude and indebtedness to my mentor Assis. Prof. Fabijan Čukelj, MD, PhD for the consistent help, guidance and contributions-, throughout this research project.*

*I wish to thank Dr Ante Bandalović for the help in offering me the materials to complete my thesis.*

*I would like to express my immense gratitude to my family for the on-going help and support.*

*Finally, I would like to thank to all my friends, that were there always by me throughout this incredible journey and for their assistance that they provided.*

# 1. INTRODUCTION

Hamstring injuries are one of the most common non-contact injuries in sports, for e.g. rugby, soccer, American football, Australian football, sprinting and cricket (1). They can range from acute hamstring muscle strains and ruptures to chronic proximal hamstring tendinopathy (2). In soccer for example occurrence of hamstring injuries are between 15% and 50 % of all muscle injuries, the highest percentage of hamstring injuries among the sports that have been assessed as a percentage of the players' numbers (3). The trend for hamstring injuries has been increasing for the last decade, representing 12–17 % of total injuries (3). Evidence for that we can find in the observations from UEFA's Champions League soccer that suggests total hamstring injuries per 1000 h of exposure have increased by 2.3% per year over the past 13 years (4) and also it was noticed in the Champions League soccer competition that 70% of hamstring injuries occur during high-speed running, and compared to 2007. players are now exposed to 30% more high-speed running than they were back then (4). Based on this we can see why there is still an increase in occurrence of this kind of injuries. Hamstring injuries require protracted treatment and lengthy rehabilitation periods (of more than a month), even with preventive protocols a high recurrence rate of 12–33 % is observed (3) which then leads to considerable time lost from training and competition and therefore results in financial loss and decreased athletic performance (1). The muscle that is most commonly affected out of hamstring muscles is biceps femoris (BF), while the most common sites of disruption are muscle-tendon junction and adjacent muscle fibre (1).

## 1.1. Anatomy and biomechanism

### 1.1.1. Anatomy

The hamstring is a group of skeletal muscles that consists of the biceps femoris (long and short heads), the semitendinosus, and the semimembranosus and all of them, except for the short head of the biceps femoris, originate from the ischial tuberosity as a common tendon (5). The short head of the biceps femoris originates from the lateral lip of the linea aspera and supracondylar ridge of the femur (6). The long head of the biceps femoris becomes tendinous and merges with a short head in the inferior part of the thigh (6). The tendon of the conjoined biceps femoris muscles attaches to the fibular head (6). The semimembranosus has multiple insertions at the posteromedial corner of the medial condyle of tibia (5). The semitendinosus attaches to the medial aspect of the proximal tibia, together with the sartorius and gracilis tendons with whom it forms the pes anserinus (Figure 1) (6). The distal musculotendinous complex covers approximately two-thirds of the length of the biceps femoris and slightly more than half of the length of the semimembranosus and semitendinosus muscles (5). The semimembranosus, semitendinosus, and long head of the biceps femoris are innervated by the tibial division of the sciatic nerve, and the short head of the biceps is innervated by the common fibular division of the sciatic nerve (5). Due to the different nerve supply of the two heads of biceps femoris a wound in the posterior thigh with nerve injury would paralyze one head and not the other (6).

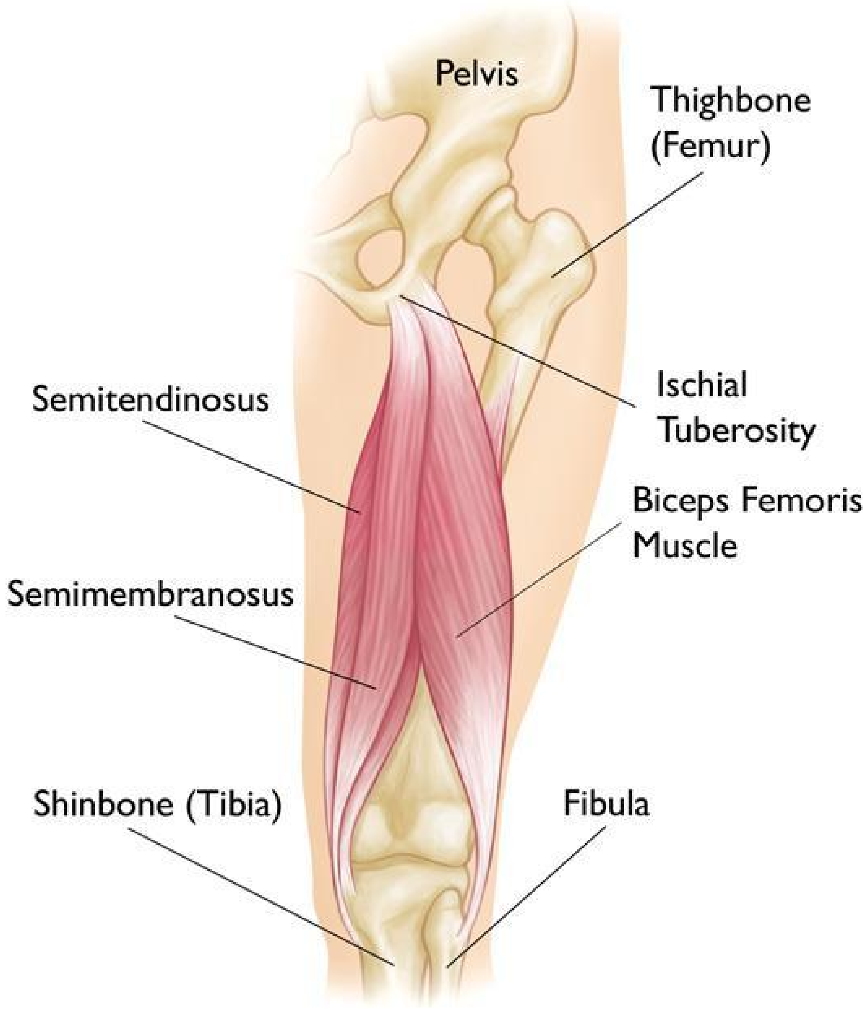


**Figure 1.** Hamstring anatomy. Source: https://orthoinfo.aaos.org/en/diseases--conditions/hamstring-muscle-injuries/

### 1.1.2. Biomechanism

The hamstrings are active in thigh extension under all circumstances except for the full flexion of the knee, including maintenance of the relaxed standing posture (standing at ease) (6). Paralyzed hamstrings cause the patient to fall forward because the gluteus maximus cannot maintain the necessary muscle tone stand straight (6). The hamstrings are activated during hip extension while walking on the flat ground, during which the gluteus maximus demonstrates minimal activity (6). Instead of either hip extension or knee flexion per se during normal walking, the hamstring muscles have the highest level of activity when they are eccentrically contracting, resisting (decelerating) hip flexion and knee extension during the terminal swing (between midswing and heel strike) (Figure 2) (6). The semimembranosus role is to flex and medially rotate the leg at the knee also it has a role in extending, adducting, and medially rotating the thigh at the hip as well as to give more stability to the knee (5). The semitendinosus has a function to flex and internally rotate the tibia at the knee and additionally provides medial stability to the knee (5). The short head of the biceps femoris flexes the knee and extends the thigh together with the long head also the long head gives the posterior stability to the pelvis and extends the femur at the hip (5).

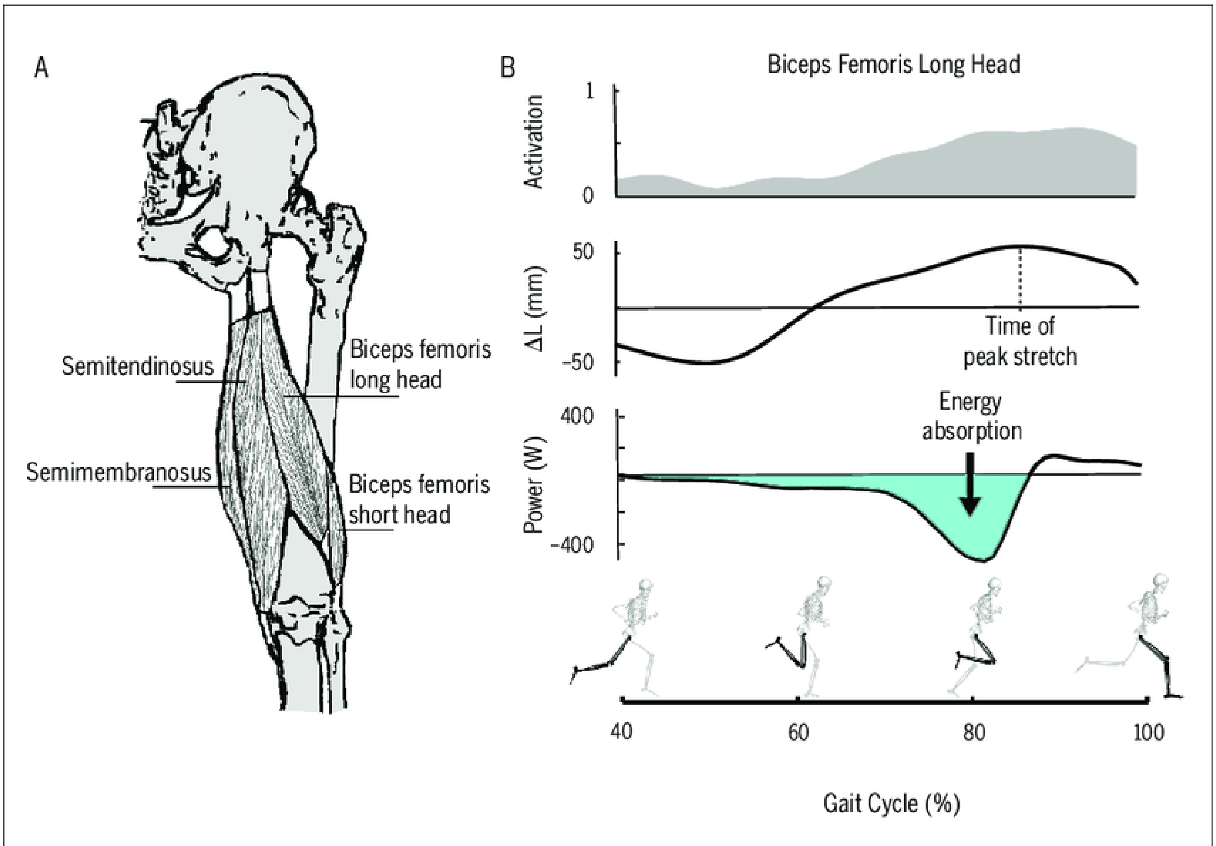


**Figure 2.** (A) Hamstring muscle group. (B) Biomechanism of biceps femoris. (7)

### 1.2. Mechanism of hamstring injuries

The hamstring muscles connect both the hip and knee joints, producing the potential for rapid and extreme muscle lengthening (5). The majority of these injuries occur in the biceps femoris muscle, mainly at the muscle-tendon junction, which typically is the weakest component of the hamstring muscle, most commonly occurring during eccentric muscle contraction (5,8). Although kicking, tackling, cutting and slow speed stretching can cause hamstring injuries running is responsible for the majority of them in soccer and rugby union (1). Analysis of running biomechanics has found that hamstrings are active during the entire gait cycle with pinnacles in activation during the terminal swing and early stance phases (1,5). Whilst the terminal swing phase the hamstrings contract forcefully at the same time lengthening to decelerate the extending knee and flexing hip reaching their maximum length, being the BF long head (BFL) that undergoes the greatest stretch out of them, and undergo eccentric contraction just before heel strike (1,5) In addition, the maximum torques for hip extension and knee flexion are occurring during ground contact in overground sprinting in which they are acting primarily concentrically to extend the hip (1,5). The presence of a high force eccentric contraction that has been described in circumstances like the stance and swing phases (e.g. during the late stance phase of overground sprinting) likely contributes to the high rates of HSIs during maximal speed running (1). The terminal swing phase is contemplated as the most dangerous because hamstring muscle-tendon units achieve their strongest activity and longest length at that point of the gait cycle (1). Another possible period of susceptibility to HSIs is the stance phase as a result of high hip extension and knee flexion torque although it involves much shorter hamstring lengths compared to the terminal swing (1). Additionally, to strain injuries the hamstrings are also afflicted by tendinopathies and back related injuries that referred pain to the posterior thigh (1). Furthermore, this type of injuries is presented with a fluctuating aetiological characteristic and due to that the causes of these injuries vary considerably (1) The mechanism of proximal avulsions is through an eccentric contraction with the hip flexed and the knee extended and occurs with higher energy ballistic activities (5). Observations have suggested that the magnitude of muscle strain with the eccentric force are determining factors in the occurrence of strain injury (1). An argument for muscle strain being a necessary condition it needs to be additionally analysed and researched because the HSIs have been reported for both high (i.e. kicking) and low (i.e. sprinting) strain tasks (1). The same can be implied for the eccentric force e.g. strain injury may be avoided in tasks that involve high levels of strain if the level of is low and the same may be true for high eccentric force/low strain activities (1). Further investigations are needed to be done to see if the HSIs most typically occur as a result of accumulated microscopic muscle damage, or as a result of a single event that exceeds the mechanical limits of the muscle (1).

## 1.3. Classification

Based to the mechanism of trauma, muscle injuries may be categorized as direct and indirect (9,10).

### 1.3.1. Muscle injury after direct trauma

Injuries that are caused after a direct trauma can be additionally divided into contusion injuries and lacerations. A contusion is caused by an insult from a direct trauma against the opponent or a sport related tool and based on the functional disability which was produced it can be classified as mild, moderate, and severe (9,10). Laceration injuries arise from an impact against a sharp surface and are not classified further (9,10). Athletes should be re-evaluated 24 hours after the trauma to better assess the essence of the injury as the pain may be disabling shortly after the trauma, with the risk of overrating the injury (9,10).

### 1.3.2. Muscle injury after indirect trauma

In this type of injury, the muscle has not collided against the opponent or any tool (9,10) They can furtherly subdivide into a non-structural and structural injury (9,10). In non-structural injuries, the muscle fibres do not have any anatomically evident lesion as opposed to the structural injuries which present with an anatomically defined lesion (9,10).

Non-structural injuries are most commonly observed, accounting for 70% of all muscle injuries in soccer players (9). Although the lesion may not be readily recognized, they involved in more than 50% of days of absence away from sports activity and training and if neglected they may become structural injuries (9). Non-structural injuries are further separated into type 1A and 1B, a fatigue muscle disorder, and type 2A and 2B, a neuromuscular disorder. A 1A injury is resulted by fatigue and different modalities in training protocols, running surfaces, and high intensity activities and 1B injury are caused due to excessive and prolonged eccentric contractions (9,10). A 2A injuries are mostly connected to spinal disorders, as in minor inter-vertebral disorders which irritate the spinal nerve, altering the control of the muscle tone of the "targeted" muscle and it was observed that there is a high incidence of misdiagnosis (9,10). In these cases, the main goal is to treat the spinal disorder (9,10). A 2B injury may happen from an unbalanced control of the neuro-musculoskeletal system, usually due to the mechanism of mutual inhibition coming from the muscle spindles (9,10). An imbalance of these neuromuscular mechanisms may put in jeopardy the control of the muscle tone causing the muscle disorders, occurring when the inhibition system of the agonist muscles is altered and weakened, while the agonist muscle is excessively contracted for compensation (9,10).

Structural injuries: have three sub-groups based on the types of lesions within the muscle (9,10). A type 3A injury is produced by a minor partial lesion involving one or more primary fascicles within a secondary bundle, while the type 3B lesion is caused by a moderate partial lesion involving at least a secondary bundle, with less than 50% of breakage surface (9,10). A type 4 injury is characterized by a sub-total tear with more than 50% of breakage surface involved or a total tear of the muscle involving the muscle belly or the musculotendinous junction (9,10).

An additional classification of structural injuries is defined by the site of the lesions in terms of proximal (P), middle (M), and distal (D) (9,10). The proximal lesions of hamstring muscles and rectus femoris have a poorer prognosis than that of the injuries of the same size involving the middle or distal portion of these muscles, although in the triceps surae the worst prognosis is presented in distal injuries (9,10).

## 1.4. Risk factors

A number of non-modifiable and modifiable risk factors have shown to increase the possibility for sustaining hamstring injuries, including, but not limited to, increasing age, previous injury, ethnicity, strength imbalances, extremes of flexibility and fatigue (1).

### 1.4.1. Non-modifiable risk factors

*1.4.1.1. Age*

Increasing age has been identified by a number of investigators as an independent risk factor for hamstring injuries in Australian footballers and soccer players (1). For example, Australian footballers and soccer players over 23 years have an increased risk of HSI, with the odds ratios (ORs) as high as 4.4 (95% CI 1.6, 12.5) for the older athlete, also it was observed that for each year of age the risk of sustaining an HSI is increased by as much as 1.3-fold (OR; 95%CI 1.1, 1.5) in Australian footballers and by 1.8-fold (OR; 95% CI 1.2, 2.7) in soccer players (1). There are several hypotheses that try to explain how and in which way does age lead to an increased risk to hamstring injuries some of those are an increase in body weight and reduced hip flexor flexibility as well as changes to muscle structure and entrapment of L5/S1 nerve root due to hypertrophy of the lumbosacral ligament (1). For example, muscle strength, especially of type II fibres, is known to decrease with age, with age implicated to be a confounder of low muscle strength, or that relative weakness may be a mechanism by which older players are more likely to sustain hamstring and calf muscle injuries (11). Although age as a risk factor was observed there is still a need to further investigate and explain what physiological changes, that are attributed to age, are causing muscle injuries.

*1.4.1.2. Previous Injury*

Several studies have indicated that Australian footballers and in elite professional soccer players with previous HSI are at an elevated risk of sustaining a future HSI and has been reported to increase the risk of future injury as much as 11.6-fold (OR; 95% CI 3.5, 39.0) (1). After a hamstring injury, the main goal must be to identify the predisposing factor responsible for the injury and treat it so that the athlete would not remain at an elevated risk of future HSIs despite sufficient convalescence (1). There are several post-HSI maladaptation's that are thought to contribute to the increased risk of future injury. Some of the maladaptation's include the formation of non-functional scar tissue that is connected with an alteration in lengthening biomechanics of the muscle, decreased flexibility, persistent reductions in eccentric strength, long-term atrophy of the injured muscle, alterations in the angle of peak knee flexor torque and alterations in lower limb biomechanics (1). In one study it was suggested that previous hamstring injury at the muscle-tendon junction results in a proliferation of scar tissue in this region and in the end causes for the adjacent muscle fibres to experience greater strain during eccentric contraction (1,12). In such case, it would cause muscle lengthening biomechanics following the injury to become susceptible to a greater risk of re-injury due to the association between higher levels of muscle fibre strain and being more prone to muscle damage (1). It was also noticed in several studies that not just previous injury of the hamstring muscle but also other muscle injuries, e.g. calf muscles, can be a risk factor for future hamstring injury (13). Even though the previous injury of muscles has been shown to enhance the risk of future injury there is still the need for further investigations to determine what abnormalities are responsible for this increased risk.

##### *1.4.1.3. Ethnicity*

There were studies that have observed that Aboriginal and Black African or Caribbean ethnicity as risk factors for a hamstring injury, some suggestions as to how does the ethnicity affect the hamstring were that these populations have high proportions of type II fibres and excessive anterior pelvic tilt (1,14). Further investigations and more evidence are needed.

### 1.4.2. Modifiable risk factors

#### *1.4.2.1. Strength Imbalances*

Strength imbalances of the hamstring muscle group have long been suggested as a possible cause for injury (1). In this review, it was divided into strength, bilateral asymmetry, hamstrings to quadriceps (H: Q) ratios and angle of peak knee flexion torque.

##### 1.4.2.1.1. Strength

Results gained from animal studies have shown that fully activated muscles are able to tolerate higher levels of stress before stretch induced failure as opposed to partially activated muscles (1). The suggested theory is that with stronger muscles there would be greater protection from strain injury and that muscle weakness may be a risk factor for muscle strain injury, despite that, the evidence linking hamstring weakness to HSIs in humans is inconclusive (1).

##### 1.4.2.1.2. Bilateral Asymmetry

To determine if there is a limb with weaker hamstring muscles, we use unilateral hamstring strength test and in cases when there is a difference in strength it is called a hamstring bilateral asymmetry, which may predispose to an increased risk of hamstring injury (1). The use of a between-leg comparison of strength may be a more useful marker of weakness for individuals than comparing it with a group average or standardized score (1). Studies suggested that between-leg hamstring strength asymmetry greater than 8% - 15% was a predictor of hamstring injury in various sports (1). Although some disagreement does exist in the literature even today, a number of studies have confirmed that bilateral hamstring strength asymmetry predisposes to an increased risk of sustaining an HSI in a number of athletic cohorts (1).

1.4.2.1.3. Hamstrings: Quadriceps Strength Ratio

A lower H: Q ratio suggests a reduced capacity for the hamstrings to decelerate at the flexing hip and extending knee joints during the terminal swing phase of running (1). Forceful contraction of the quadriceps, while in the early swing phase of gait, produces angular momentum at the knee joint that surpasses the mechanical limits of the hamstring (1). Earlier investigations focused on comparisons of concentric strength imbalances across the knee joint, known as the conventional hamstrings to quadriceps ratio (H: Q conv), but has been criticized, as it neglects the forceful eccentric contraction of the hamstring (1). Recently, the comparison of eccentric hamstrings to concentric quadriceps strength, known as a functional strength ratio (H :Q func), has been more popular and suggested (1,15) One of the first studies to investigate the relationship between H:Q conv ratios and future injury risk observed that American footballers with an H: Q conv ratio of less than 0.50 have an increased risk of HIS (1). Because the studies used athletes at different levels of expertise and professionalism and used different methodologies it all caused the comparison of the findings to be difficult (1). The strongest study that investigated the association between H:Q ratios and HSIs (n = 462) found that uncorrected strength imbalances in soccer players, which included an H:Qconv ratio below 0.45–0.47 (exact cut-off depends on dynamometer brand used) and an H:Qfunc ratio below 0.80–0.89 were connected to an increased frequency of HSIs compared with athletes without strength imbalances (1,15). By correcting the strength imbalances, normalizing H: Q ratios, led to a significant decrease in HSI frequency compared with athletes who had uncorrected imbalances (1,15). These results suggested available that sufficient H: Q ratios protect athletes from future HSIs.

1.4.2.1.4. Angle of Peak Knee Flexion Torque

Athletes with a greater knee angle at peak concentric knee flexion torque (those who produce peak knee flexor torque at shorter muscle lengths) are suggested to be at greater risk of HSIs (1,16). Patients with a previous unilateral hamstring injury display peak knee flexion torque at a greater degree of knee flexion on their injured limb compared with the uninjured limb, on the other hand, it is unknown if this is the cause or is it due to the previous injury given the retrospective nature of these observations (1,16). The evidence referring to the usefulness of the angle of peak knee flexor torque to predict previous or future HSIs is too inadequate to conclude firmly, and additional work in this area is required (1).

*1.4.2.2. Flexibility*

Stretching exercises that increase the flexibility of an athlete have been suggested to be a key component of injury prevention in athletes despite insufficient scientific evidence (1). The idea is that increase in flexibility may decrease the risk of strain injury as a result of an enhanced ability of the passive components of the muscle-tendon unit to absorb energy as a result of greater compliance, however, there are still some disputes of this idea in the literature (1). However, different studies have various results about hamstring flexibility increasing the risk of HSIs in athletes (1,17). Using more objective measures and creating a gold standard in testing would be expected to improve the validity of clinical flexibility tests and provide us with more accurate evidence (1).

*1.4.2.3. Fatigue*

Fatigue and its connection with the decline in performance are often believed as a causative factor for injury (1). Truly, studies of injury incidence have proven the increase of hamstring injuries occur in the latter stages of competitive matches and training (1) e.g. injuries happen more often in the end halves of the football match (18). By observing the effect of fatigue on muscle lengthening properties it was noticed that muscles that were pre-fatigued absorbed less energy before failure when compared with unfatigued muscles and although, fatigued and control muscles still failed at the same length, it was suggested that in a fatigued muscle the cause of injury may be due to a reduced capacity to resist over lengthening (1,19). It was observed that there was a perception of normal hamstring muscle lengths during running, although in reality, repeated over-lengthening of the hamstrings is happening and such deficits in proprioception when fatigued may increase the risk of injury

(1). Multiple microscopic muscle damages, that occur due to the over-lengthening, would eventually lead to becoming a macroscopic damage e.g. strain injury (1). It was also observed that those who exhibit greater levels of preferential eccentric hamstring fatigue would be more susceptible to a hamstring injury with prolonged activity given the link between eccentric weakness and hamstring injury risk (1,15). There still some more factors that possibly contribute to the increase of the injury like altered technique, reductions in concentration and other intrinsic physiological changes (1), however, more evidence and investigations about those factors are needed.

*1.4.2.4. Body Weight*

In respectable studies, it was not demonstrated a difference in weight between the injured and non-injured groups, although it was observed that in heavier athletes being the occurrence of a hamstring injury is more common (13). However, some studies did demonstrate an association between weight and hamstring muscle strain-type injuries, although this association was only identified in football players aged ≥25 years. They noticed that for each kilogram increase in body weight, the risk of sustaining a hamstring injury increases by 7% (20).

## 1.5. Imaging and diagnosis

### 1.5.1. Clinical presentations

*1.5.1.1. History*

Most cases of hamstring injuries are presented with a sudden onset of posterior thigh pain resulted from a specific activity, most commonly high-speed running (7). When there is a description of an audible pop together with the onset of pain in athletes it is most likely to be due to a proximal tendon injury and further activity is prevented as a result of the limiting pain (7). Reported pain at the ischial tuberosity when sitting is most commonly connected to the proximal tendon injury (7). Because the recurrence of hamstring injuries is high, patients may report a previous hamstring injury, often adjacent to or close to the current site of injury (7).

*1.5.1.2. Physical examination*

In the case when an injury is suspected the purpose of the physical examination is more to determine the location and severity of the injury than its presence (7). Hamstring injuries are commonly graded based on the amount of pain, weakness, and loss of motion, resulting in grades of I (mild), II (moderate), or III (severe) (7). These injury grades are describing the degree of muscle fibres or tendon damage (e.g., grade I having minimal damage, with grade III being complete tear or rupture), and can be used to assess the time needed for recovery and devise the rehabilitation program (7)  For injuries of the intramuscular tendon and adjacent muscle fibres, a variety of tests that measure strength, range of motion, and pain can help to assess the duration of rehabilitation (7). Although these tests are not useful in predicting recovery time for proximal free tendon injuries, they still should be used to provide a baseline and to follow the progress of recovery (7). Also, these tests should be a part of a more detailed examination to provide the information on the adjacent structures that could contribute to the hamstring injury (e.g., the strength of lumbopelvic muscles, quadriceps tightness) (7).

#### *1.5.1.3. Strength*

Strength test of hamstring muscles should be done by applying manual resistance to the knee and hip (7). To properly test the hamstring muscles multiple tests are utilized to assess isometric strength and pain provocation (7). For instance, while the patient is in a prone position and with the hip stabilized at 0° of extension the knee flexion strength is examined by applying the resistance at the heel in both 15° and 90° of knee flexion (7). Also, because the hamstring muscles are involved in extending the hip it is recommended that hip extension strength should be assessed with the knee positioned at 90° and 0° of flexion whilst the resistance is applied to the distal posterior thigh and heel (7). It also should be emphasized that only pain provocation but also weakness is a relevant finding and for each measure, a bilateral comparison should be done (7).

#### *1.5.1.4. Range of motion*

Range-of-motion tests, like in strength testing, should exam both the hip and knee joints (7). Passive straight leg raises (hip) and active knee extension test (knee) are mostly used in a sequence to evaluate hamstring flexibility and maximum length (7). Normal hamstring length usually allows the hip to flex 80° while the passive straight leg raise and the knee to extend to 20° on the active knee extension test (7). The range of motion that can be achieved by postinjury muscle length should be based on the patient’s onset of discomfort or stiffness (7). In an acute state the test results of musculotendon extensibility may not be exact due to the fact that the tests are limited by pain and also it is recommended always to perform bilateral comparison (7)

*1.5.1.5. Palpation*

Palpation of the posterior thigh allows us to identify the exact region of injury by using the pain provocation, additionally, it can help us to determine if there is or if there is not a palpable defect present in the musculotendon unit (7). While the patient is in a prone position the examiner should do repeated passive knee flexion-extension movements through a small range of motion which could help us to identify the location of the individual hamstring muscles and tendons (7). While the knee is in full extension, palpation and location of the maximal point of pain in regards to the ischial tuberosity can be determined together with the measurement of the painful regions total length (7). Although both measures are used, only the location of the point of maximum pain (relative to the ischial tuberosity) is connected to the recovery period, meaning the more proximal the site of maximum pain is the longer the time to return to pre-injury level is needed (7). The degree of involvement of the proximal tendon of the injured muscle is assumed to be shown by the proximity to the ischial tuberosity (7). The greater the extent of injury of the proximal tendon that is involved the longer the recovery period is (7).

*1.5.1.6. Differential examination*

As part of the differential examination process, additional sources of posterior thigh pain should be considered.

One of the possible causes of the posterior thigh pain can be an adverse neural tension which can be determined by using the active slump test (7). If the test is positive while in the forward-slumped posture the cause of the posterior thigh pain could be due to a more proximal contribution, for example, sciatic nerve, lumbar spine) (7). This can be observed in patients with recurrent hamstring injuries due to the residual inflammation and scarring that is thought to interfere with normal sciatic mobility (7). For example, in patients with a possible hamstring strain injury grade I with no muscle injury present and absence of a specific injury mechanism adverse neural tension should be considered as the only cause of the symptoms (7). Another possible cause can be hip adductor strain injuries that are also common during athletic events and therefore should be differentiated from the hamstring injuries, due to their proximity (7). Adductor strain injuries usually happen during movements that include quick acceleration or change of direction and also those requiring extreme hip abduction and external rotation (7). Combined injury of the hamstrings (semimembranosus) and hip adductor muscles (adductor magnus) can be seen during a sagittal split motion in sports such as tennis and during high kicking connected to dancing (7). Pain is usually felt by palpating the adductor tendons on or near their insertion to the pubic ramus, together with resisted hip adduction, furthermore, imaging procedures should be done to determine more precisely the injury location and to rule out other possible causes of inguinal pain (7).

### 1.5.2. Ultrasound and MRI

#### *1.5.2.1. Ultrasound*

Advances in technology allow us to visualise muscular architecture at in-plane resolution under 200 mm and with a section thickness of 0.5–1.0 mm via the ultrasound (21). US has some advantages compared to the MRI, like for example it can be used for dynamic muscle evaluation, it is faster and easier to perform, it is cheaper, and it is useful for following the progress of recovery of the patient, and it can be used to perform real-time interventions (21). Additionally, with the US it is possible to observe the muscle structure and other relevant anatomy surrounding an injury that can commonly be hidden by oedema on MR images (21).

##### 1.5.2.1.1.US Technique

The initial taking of anamnesis and doing the relevant physical examination allows the subsequent US examination to pinpoint the most relevant areas (21). During the examination, the usage of linear transducers is advised to assess the skeletal muscles that lie superficially within the body (21). With modern multifrequency transducers that have centre frequency greater than 10–17 MHz enable the visualization of most muscle groups, while lower-frequency linear probes with 8–10 MHz could be used in very muscular patients, especially in the gluteal region and proximal thigh (21). The examination starts with longitudinal and transverse scanning of the symptomatic area, that most commonly accurately locates the muscle lesion in injuries, but the examiner must be confident of the anatomy being examined and the exact position of the lesion (21). After observing the appearance of the muscle and any lesion at rest, the abnormal area and surrounding tissues should be evaluated dynamically with active and/or passive contraction and by doing that we can observe the consistency of the abnormality (e.g., solid or cystic), alteration in muscle function, and any movement of disrupted fibres which can help the examiner to differentiate grades of tears, as well as to become more apparent (21). In some other cases further manoeuvres may be needed, e.g. in muscle hernias in which the patients need to stand because the hernias become only apparent in that position (21).

1.5.2.1.2 US Features

Normal muscle fibres align to form parallel hypoechoic bundles, fascicles, that are encircled by echogenic fibroadipose septa in a “pennate” configuration (21). The muscle fibres and fascicles have lower echogenicity in comparison to the adjacent fascia and nervous tissue (21). The perimysium due to its thickness and echogenicity appearance, as result of the fibrous (collagen) content, can be visualized in pennate muscles during the longitudinal scanning as multiple parallel lines forming oblique angles (separated by the hypoechoic fascicles) with the MTJ (21). Perimysium in comparison to the long axis of the muscle has an oblique orientation in uni-/bipennate muscles and parallel in fusiform muscles, furthermore, these linear structures gather together to the MTJ with the tendon observed as a discrete fibrillar echogenic structure as it becomes more defined (21). During the transverse scanning, the muscle fibres have hypoechoic appearance while the intervening septae are seen as smaller linear areas and echogenic spots (21). Lastly, there is another thick layer of fascia, epimysium, that surrounds the whole muscle and that, as well as the perimysium, has echogenic appearance due to its fibrous content (Figure 3) (21). The US features in clinically grade 1 injury, may be either negative or show some focal or diffuse ill-defined areas of increased echogenicity within the muscle at the site of injury (21). In cases when there is a focal fibre disruption of less than 5% of the cross-sectional area of the muscle, the grade 1 injury ,may be observed as a well-defined focal hypoechoic or anechoic area within the muscle, however, there is still no consensus about this definition due to the fact that some authors consider any degree of partial disruption as a grade 2 injury (21). Most commonly in grade 2 injuries a disruption of the echogenic perimysial striae around the MTJ or the myofascial junction would be observed (21). Also, an intramuscular hematoma may be seen in a grade 2 injury and its appearance on the US changes with the post-injury time (21). In the initial 24 to 48 hours the intramuscular hematoma commonly looks like an ill-defined muscle laceration separated by a hypoechoic fluid with more pronounced reflectivity in the surrounding muscle and later on it can solidify with the increase of echogenicity compared to the surrounding muscle (21). In the later stages, 48-72 hours, hematomas will become a well-defined hypoechoic fluid collection with an echogenic margin that may fill the hematoma in a centripetal fashion, while still slowly enlarging (21). A case of the grade 3 injury is when the patient has a complete discontinuity or disruption of the MTJ with different degrees of retraction that is observed in the US (21). In such cases a palpable gap is usually felt by an examiner between the retracted ends of the muscle affected and the examiner may on the US visualize the perifascial fluid that may have an increased echogenicity as a result of the presence of extravascular blood ,however, it is most commonly hypoechoic due to the fact that most examinations happen more than 24 hours after injury (21). The examiners should keep in mind that the perifascial fluid visualization is not a specific sign as it can be seen in any grade of injury (21).

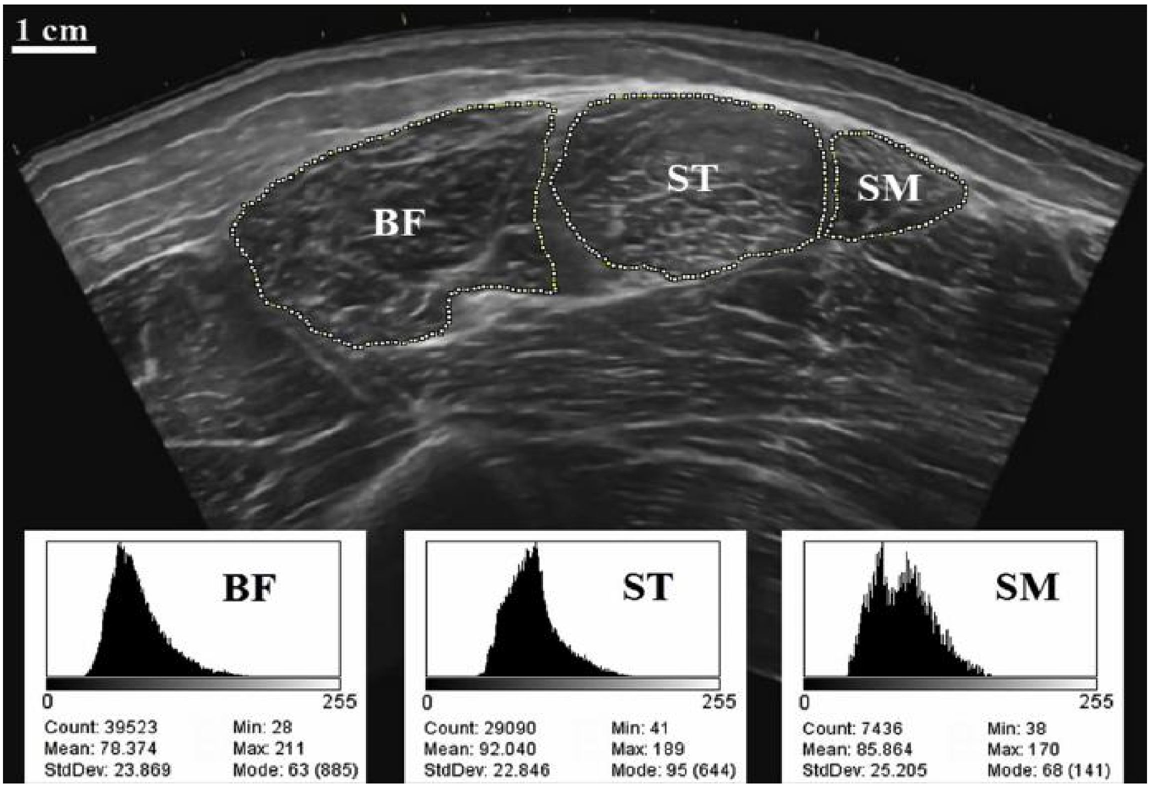


**Figure 3.** Transverse plane panoramic ultrasound image of the long head of the biceps femoris (BF), semitendinosus (ST) and semimembranosus (SM) muscles (22).

1.5.2.1.3. Artefacts and Pitfalls in US Evaluation of Muscle Injury

Because of the linear configuration, the septae are more prone to anisotropy artefact which can cause the decreased echogenicity or absent visibility of septae and therefore careful probe repositioning is needed to exclude the possibility of an artefact (21). Also other possible cause of artefacts can be due to  prominent intramuscular vessels, which can mimic tears, however the errors due to this artefacts can be avoided by using the Doppler and by carefully tracing of the vessels through the septae to their neurovascular bundles, as well as by determining that the surrounding muscle structure is normal right up to the vessel boundary (21). Other causes of artefacts can also be, for example, due to the thickened or scarred septae that can cause acoustic shadowing that makes the underlying muscle look hypoechoic or after exercise when muscle swelling and displacement of the overlying fascial planes happens due to increased blood flow (21).

*1.5.2.2. MRI*

*1.5.2.2.1. MR Imaging Technique*

MRI should be used to visualize and estimate the degree of muscle injuries due to its potential to show the soft tissues with excellent contrast and with high spatial resolution and multiplanar assessment (21). Also, MRI, compared to the US, may be more suitable for estimation of muscle lesions in deep muscle compartments (21). Most commonly the imaging is only performed on the affected limb by using a dedicated surface coil, that provides an image with higher resolution with thinner sections and smaller field of view, however, in some cases, for example suspected bilateral injury, simultaneous imaging of the contralateral limb should be done (21). Before the imaging the right coil should selected based on the field of view that is desired and a skin marker should be placed over the suspected area of injury to help with comparing the results of imaging with clinical features (21).  Pulse sequences must include fat-suppressed fluid-sensitive techniques, for example, fat-suppressed spin-echo T2-weighted or proton density–weighted sequences, that grants the possibility of discovering oedematous changes around the myotendinous and myofascial junctions, together with the delineation of intramuscular or perifascial fluid collections or hematomas (21). Although T1-weighted spin-echo sequences are less precise for oedematous changes within the muscle in acute injury, they could be used to estimate subacute haemorrhages and hematomas, as well as to observe and assess the degree of atrophy and fatty infiltration and scar tissue formation in chronic injuries (21).

1.5.2.2.2. MR Imaging Features of Muscle Injury

On the fluid sensitive coronal or sagittal MR images, interstitial oedema and haemorrhage around MTJ, the most common site of injury, may extend along the adjacent muscle fibres and fascicles and have an ill-defined focal or diffuse high-signal-intensity area with a pennate appearance (Figure 4) (21). In grade 1 injury usually, only oedema without substantial disruption of muscle fibres can be observed without the loss of muscle function (21). Also, in grade 1 injury the tendon at the MTJ can have a normal (low) signal intensity with all pulse sequences or it may be mildly thickened with an abnormal intensity, but without disruption or laxity, and sometimes mild perifascial fluid may be found (21). On MRI grade 2 injuries may be observed with partial disruption of muscle with hematoma formation around MTJ plus the already described grade 1 features (21).

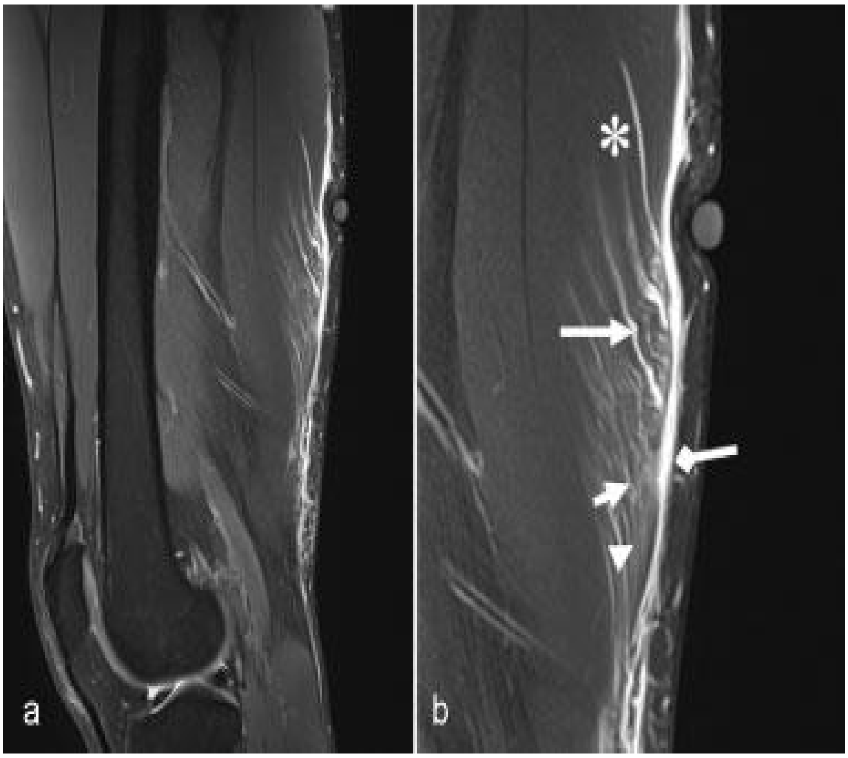


**Figure 4.** A 35-year-old professional soccer player sustained an indirect posterior thigh injury while sprinting. (a) Sagittal fat-suppressed proton density (PD) MR image through the distal thigh and (b) magnified fat suppressed PDMR image demonstrate moderately extensive intramuscular oedema in the distal aspect of the long head biceps femoris, marginating against the investing fascia, with interfascicular (asterisk) and intrafascicular (arrowhead) components, redundant fascicle morphology (long arrow), with small foci of secondary fascicle discontinuity (short arrow), small segment of poor definition of the investing fascia, indicating fascial injury, with overlying thin layer of perifascial fluid (diamond arrowhead) (23).

On the MR image, partial disruption has an appearance of the focal area of well-defined high signal intensity (21). The tendon that is near to the MTJ may be thickened and lax with the possible visualization of partial disruption of it (21). Commonly there can be observed some loss of function in the grade 2 injuries, depending on the degree of the injury, together with moderate to severe perifascial fluid being usually present on MR images (21). Lastly, in grade 3 injuries complete disruption of the MTJ with the hematoma can be seen on the MR images, although, if the complete loss of function, a gap that is palpable and muscle retraction is observed during the clinical examination, then often only clinical examination is enough to diagnose it (21). Furthermore, in cases of complete avulsion of the MTJ or tendons from bony attachment grade 3 injury should be suspected (21). Intramuscular hematomas on MRI, which are not only observed in grade 2 and 3 injuries but also in muscle contusions, usually change their appearance based on the blood degradation pattern, as opposed to the intermuscular (or perifascial) hematomas for which this is not always true (21). Injuries can also happen within the muscle belly and far from the main MTJ, or at the peripheral myofascial junction (around the epimysial interface) with visualization of the oedema pattern at the periphery of muscles (21). However, these injuries may or may not be connected either to the focal fascial disruption or to the focal partial disruption of the adjacent muscle fibres (21).

#### 1.5.2.2.3. Advanced MR Imaging Techniques

The most advanced MR imaging techniques for muscle assessment, like T2 mapping, are still mostly used for scientific purposes and research although they show great potential for usage in sports medicine (21). Due to the increase of T2 values in stressed muscles, it is possible to isolate the activated muscles after specific exercises and even in some cases to assess the degree of activation, muscle activity and muscle strength, due to their possible correlation with the degree of increase in T2 values (21,24). Diffusion tensor imaging allows diffusion quantification of anisotropic tissues, for example muscles, utilizing a series of diffusion weighted images and muscle fibre tracking ,which can help the examiner to see the skeletal muscle fibre direction, to visualize subclinical changes in muscles after strenuous exercise, observe muscle injury on a microscopic level, and demarcate injured muscles from normal control muscles (21,25) Skeletal muscle MR elastography grants the possibility for studying the physiologic response of normal or diseased and damaged muscles, for example it is proven that there is a difference in the stiffness of muscles with and without neuromuscular disease (21,26).

## 1.6. Treatment

### 1.6.1. Non-surgical treatment

*1.6.1.1. PRICE and POLICE*

In the acute stage of hamstring injuries PRICE protocol should be undertaken. PRICE is an acronym that stands for protection, rest, ice, compression and elevation. The reasoning for the use of rest, ice (cold), compression, and elevation is that it is very practical and also by using those 4 means the minimization of bleeding into the injury site is intended (27). Investigations that emphasize shield, unload and/or prevent joint movement are advocating the use of protection and rest after injury (28) due to the fact that if the injured extremity is promptly put to rest and protected after the trauma, there is a higher chance to limit the further retraction of the ruptured muscle and formation of a larger gap within the muscle and therefore decrease in the size of the hematoma and the connective tissue scar (27). However, the prolonged periods of unloading and rest may cause negative changes to tissue biomechanics and morphology, so limited rest and progressive mechanical loading should be advocated to restore strength and morphological characteristics of collagenous tissue (28). Combination of the usage of ice, that causes smaller hematomas, inflammation and faster early regeneration, together with the compression, that reduces the intramuscular blood flow to the injured area, should be applied in shifts of 15 to 20 minutes in duration, repeated at intervals of 30 to 60 minutes, because in this kind of protocol a decrease of 3° to 7° C in the intramuscular temperature and a 50% reduction in the intramuscular blood flow is observed (27). Lastly, the injured limb should be elevated above the level of the heart, which results in a decrease in hydrostatic pressure and causes a reduction in the accumulation of interstitial fluid (27). The new and updated protocol that is suggested is called the „POLICE" (Protection Optimal Load Ice Compression Elevation) protocol with the optimal load as the only major novelty (9,28). A balanced rehabilitation program should steadily be introduced by using controlled mechanical stresses, that differ based on the affected site, while still providing the affected muscle with needed rest (9).

*1.6.1.2. Rehabilitation*

The main goals of rehabilitation are to decrease the time of return to play and restoring the function that it was before the injury, as well as to minimize the risk of reinjury (29). If the rehabilitation that was conducted was inadequate, athletes may still experience altered neuromuscular control, persistent weakness, or reduced extensibility of the musculotendon, as a result of the residual scar tissue and adaptive changes in the biomechanics and motor patterns of sports movements after injury and return to play (29). Not only should the rehabilitation focus on these potential deficits it should also try by using therapeutic exercises and manual techniques, such as joint mobilizations and soft tissue mobilization, to correct modifiable risk factors as the reason of the initial injury (29). The hamstring muscle may reach peak force at shorter lengths after recovery, increasing the chance of further injury during activity in a lengthened position (29). However, by using the eccentric exercises the peak force may be achieved in longer muscle lengths, which could help in restoring the optimal musculotendon length for tension production and reducing the risk of reinjury (29). Together with increasing the strength of the injured hamstring muscle, neuromobilization techniques should be included as part of the treatment program if a positive result of the slump test is seen on examination (29). In cases of grade I injury with mild disruption of muscle fibres, slump stretching has demonstrated a reduction of return to play time, although more evidence is needed for more severe injuries (29). While keeping in mind the above-mentioned considerations, the rehabilitation protocol which is e.g. proposed in the treatment of grade I and II hamstring strain injuries that involve the intramuscular tendon has three phases (29,30). With the aim of phase I being the reduction of pain and oedema, recovery of normal neuromuscular control at slow speed, and prevention of excessive scar formation while protecting the fibres in recovery from overlengthening (29,30). In phase II exercises of higher intensity, neuromuscular training at a faster speed and larger amplitudes, and the introduction of eccentric resistance training, as well as steady increase in range of motion and lengthening of the hamstring, are tolerated in comparison to phase I (29,30). During phase III of rehabilitation, more advanced neuromuscular control and eccentric strengthening exercises, as well as sport-specific exercises with the aim of returning to sport are allowed, with the athlete mainly no longer having the restriction of range of motion in this phase (29,30). The criteria for return-to-play consists of no pain with palpation over the injury site, full concentric and eccentric strength of the hamstrings without pain, no kinesiophobia, full functional capacity in sport-specific movements at near maximum speed, and intensity without pain (30).

### *1.6.1.3. Acetaminophen and NSAIDs*

Conservative medical management can include the use of nonsteroidal anti-inflammatory drugs (NSAIDs), although for example, in cases of acute hamstring strains the early use of NSAIDs is controversial because of their potential to increase bleeding and to increase subsequent muscle fibrosis, due to failure of the previous studies to demonstrate benefit (30,31) so the use of acetaminophen for pain relief as needed is recommended, while avoiding NSAIDs (29).

### *1.6.1.4. Platelet-Rich Plasma (PRP)*

Platelet-Rich Plasma therapy is a cost efficient, minimally invasive procedure that delivers high concentrations of autologous platelets and growth factors directly to the injured tissue (5,9,32,33). Platelets containing dense and alpha granules, promote tissue modulation and regeneration and also are activating the healing process cascade that is divided into three phases: inflammation, proliferation, and remodelling (5,9,32,33). It is suggested that the platelet concentration that is administered should be 3 to 4 times higher compared to the blood levels, based on the belief that lower concentrations would not be able to improve the tissue healing and that higher concentrations may be of no benefit (33). PRP is believed to be safe treatment modality because it is autologous, so there is no concern related to the possibility of acquiring transmissible diseases or rejection-related issues which are mostly seen with allogeneic transplants (33). Possible side effects that are connected to the PRP include bleeding, deep organ puncture and infection, also there is a possibility for an allergic reaction if the bovine thrombin for exogenously activation of PRP is used, however using the calcium chloride or endogenous thrombin for activation eliminates that risk (33). PRP should not be used in patients who are diagnosed with thrombocytopenia or a condition of platelet dysfunction and also most of the complaints from the patient are due to the pain at the site of injection as a result of the acute inflammatory cascade response (33). However, even though it is suggested that PRP has numerous benefits and that it has promising results reported for its therapeutic potential, the clinical outcomes are miscellaneous and sometimes contradictory

(5,32). The reason behind those controversial findings is due to the fact that different clinical protocols are applied, making it difficult to compare results and draw conclusions about its real efficacy, as well as the lack of standardization in PRP preparation procedures (5,32). Therefore, further research is needed to standardize formulations and protocols and to investigate its value in clinical practice (5,9,32).

*1.6.1.5. Corticosteroid injections*

The usage of intramuscular glucocorticoids injections were suggested for their anti-inflammatory role, for example in athletes with prolonged pain a corticosteroid injection may be used to reduce the acute inflammation and reduce pain, (29) however, a connection to atrophy, disruption of normal muscle architecture, and decrease in tendon collagen fascicle strength has been observed (31). Generally, intramuscular glucocorticosteroid injection for muscle strain injuries should be avoided because of the potentially negative long-term consequences on muscle regeneration and function (31). In patients with chronic tendinopathy, therapy with corticosteroid injections is also controversial due to the potential risks, including local irritation, skin depigmentation, suppression of tenocyte activity and collagen synthesis, and tendon avulsion (30). Further research should be conducted to fully determine the benefit of corticosteroid injection.

### 1.6.2. Surgical treatment

A complete lesion of the muscle belly or of the MTJ, and subtotal lesion with persistent pain and loss of strength after conservative management are the main indications for surgical therapy (9). In cases of the muscle laceration repair, which are technically challenging to perform, the likelihood of clinical failure is high (9). It is also hard to successfully to repair muscle belly because of the sutures pull-out (9). Although many suture configurations have been proposed none of them seemed to have a clear advantage of one over another (9). For the suture to be optimal it needs to be able to withstand early rehabilitation by having a low risk of rerupture or stitch pull-out, with the current techniques, that are in trend, are resistant to traction and tensile loading, with a lower risk of pull-out (9). If the epimysium is incorporated the biomechanical properties of sutured muscle bellies are greatly improved (9). The evidence that supports routine surgical management is poor, despite the fact that excellent results have been reported after repair of complete lesions (9).

# 2. OBJECTIVE

The purpose of this study is to investigate the incidence of hamstring muscle injuries in professional football players based on:

1. The number of professional football players that were injured per year
2. The characteristics of injuries over the 3-year period of investigation
3. Seasonal part of the year in which the incidence and severity of injuries are increased
4. The characteristics of injury that occurred during the training or during the football match
5. The years of age of professional football players when the injury happened correlated to the severity of the injury

**Hypotheses:**

**1)** HI occur more common during the competitive part of the year

**2)** Higher incidence and the severity of HI can be observed during the matches, as a result of increased physical exertion and fatigue

**3)** With increasing age in professional football players, muscle injuries occur more commonly and are more severe

# 3. MATERIALS AND METHODS

## 3.1. Study design

The study was conducted as a retrospective study.

## 3.2. Study population

In this study patients from the official clinic of a local football club in Split, that suffered HI, were included from the beginning of January 2016 until the end of December 2018.

*Inclusion criteria:*

1) Male professional football players, with HI, that were members of the senior teams in a local football club in Split
2) Types of HI that were included were DOMS, distension, FIMD, cramps, hematomas, contusion, muscle pain, partial rupture and rupture

*Exclusion criteria:*

1) Patients with HI that were the result of tendinosis, tendinopathies, and friction syndrome

## 3.3. Methods of collecting and analysing data

The study material was retrieved from a local professional football club medical database and archives. The clubs medical staff had documented injuries and provided information about the diagnosis, dates, players age and circumstances (training or match) of injury occurrence.

A muscle injury was described as ‘‘a traumatic distraction or overuse injury to the muscle leading to a player being unable to fully participate in training or match play” (34). The team’s medical staff reports of HI were based on the clinical examination and the US.

The modified Peetrons classification consists four injury severity categories: grade 0 indicates negative MRI without any pathology; grade 1 oedema without architectural distortion; grade 2 architectural distortion indicating a partial tear; grade 3 total muscle or tendon rupture (35).

For this study purposes HI were divided based on the severity into two groups, with the severe muscle injuries group including injuries such as total and partial muscle ruptures, and mild injuries, such as DOMS, distension, FIMD, cramps, hematomas, contusion, and muscle pain, whereas tendinitises and tendinopathies were excluded.

Gathered materials from the computer database and archives about the patients and the medical histories were reviewed and inserted in Microsoft Excel program, version 2016 (Microsoft Excel Software, Redmond, Washington, USA).

### 3.3.1. Primary outcome measures

The primary outcomes were seasonal variations, age, the incidence of HI and the occurrence of HI during training/match.

### 3.3.2. Secondary outcome measures

The secondary outcome measures were the severity of HI that were developed.

## 3.4. Statistical analysis

By using the medical history of the patients, the parameters needed were analysed and are shown in figures and tables. Microsoft Word Processing Software, version 2016 (Microsoft Word Software, Redmond, Washington, USA), Microsoft Excel, version 2016 (Microsoft Excel Software, Redmond, Washington, USA) and the statistical software MedCalc for Windows, version 17.9.4 (MedCalc Software bvba, Ostend, Belgium) were used to make the analysis, tables and figures. In the statistical software MedCalc for Windows Chi-squared and Mann-Whitney test were used. Statistical significance was set at $p<0.05$.

# 4. RESULTS

In the year 2016 the professional club had 50 professional football players out of which 25 had an occurrence of a HI and in the following two years 2017 and 2018 the number of injured professional players were 15 and 13 with the same total number players as it is shown in Table 1. and Figure 5.

**Table 1**. Number of male professional football players with HI per year

| Year | Number of injured players | Total number of players |
|---|---|---|
| **2016** | 25 | 50 |
| **2017** | 15 | 50 |
| **2018** | 13 | 50 |

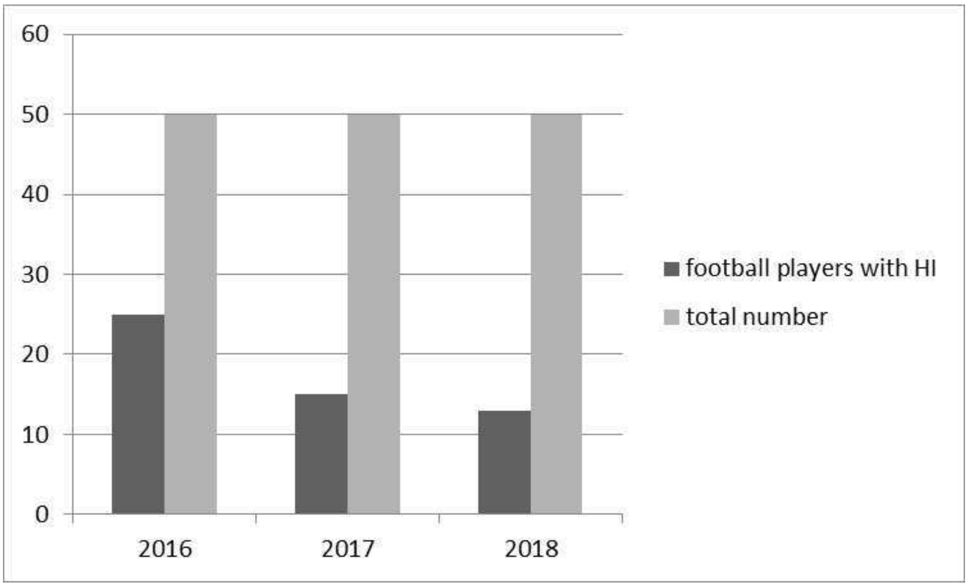


**Figure 5.** Number of male professional football players that suffered a hamstring injury per year

Over the 2016, 2017 and 2018 HI occurred 81 time out which 64 were with mild severity and 17 were severe. There was no statistical significance found by comparing the severity of the injury and the year of incidence (P =0.149) (Table 2).

**Table 2.** Number of injury and their severity per year

| Year | Injury severity (n, %) | | | P* |
|---|---|---|---|---|
| | Mild | Severe | Total | |
| **2016** | 34 (42%) | 5 (6.2%) | 39 | 0.149 |
| **2017** | 19 (23.5%) | 6 (7.4%) | 25 | |
| **2018** | 11 (13.6%) | 6 (7.4%) | 17 | |
| **Total** | 64 | 17 | 81 | |

*Chi squared test.

Over the 3-year period, the youngest professional football player that got injured was 15 years old, while the oldest one reported was 34 years old. The median age for mild injuries was 21 years and 6 months with 95% CI being from 20 to 24 years and for the severe injuries the median was 22 years (95% CI 21 -26 years) (Table 3). No statistical significance between the age and the injury grade was found (P= 0.238).

**Table 3.** Patients age when they suffered from an injury

| | Injury severity | | P* |
|---|---|---|---|
| | Mild | Severe | |
| **Age in years (median, 95%CI)** | 21.5 (20-24) | 22 (21-26) | 0.238 |

*Mann-Whitney test

In Table 4. the seasonal variation of HI incidence and the injury grade on the sample from 2016 to 2018 can be seen. During the summer period highest incidence of mild hamstring injuries was observed (20 out of 64 injuries), however, the highest incidence of severe HI was reported during the spring (8 out of 17 injuries) (Figure 6). No evidence that would prove statistical significance could be found (P=0.238).

**Table 4.** Seasonal variation of HI

| Season | Injury severity (n, %) | | | P* |
|---|---|---|---|---|
| | Mild | Severe | Total | |
| **Spring** | 16 (19.8%) | 8 (9.9%) | 24 | 0.238 |
| **Summer** | 20 (24.7%) | 2 (2.5%) | 22 | |
| **Autumn** | 18 (22.2%) | 5 (6.2%) | 23 | |
| **Winter** | 10 (12.3%) | 2 (2.5%) | 12 | |
| **Total** | 64 | 17 | 81 | |

*Chi squared test.

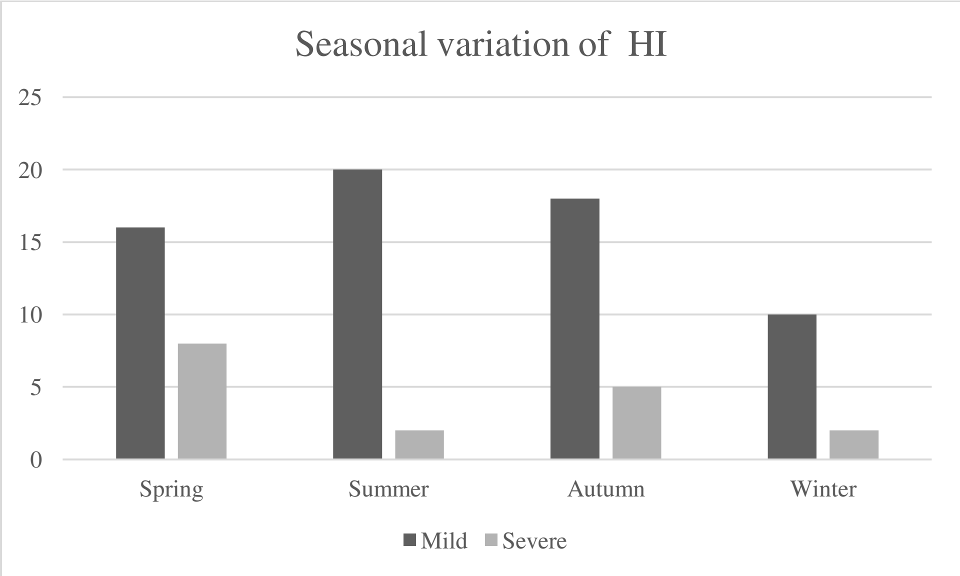


**Figure 6**. Number of HI that occurred per season

Table 5. shows the incidence and the severity of HI that occurred either on the training or on the match. From the total number of 81 injuries, 51 arose during the training practice out of which 42 (51.9%) were mild and 9 (11.1%) were severe. The other 30 HI were observed during the match with 22 (27.2%) of those being mild and 8 (9.9%) severe. However, there was no statistical significance found (P= 0.339) when we analysed this data.

**Table 5.** Patients whose injuries developed during the training or during the match

| **Occurrence of injury** | **Injury severity (n, %)** | | | **P*** |
|---|---|---|---|---|
| | Mild | Severe | Total | |
| **Training** | 42 (51.9%) | 9 (11.1%) | 51 | 0.339 |
| **Match** | 22 (27.2%) | 8 (9.9%) | 30 | |
| **Total** | 64 | 17 | 81 | |

*Chi squared test.

# 5. DISCUSSION

This was a retrospective study that was aiming to compare the incidence and severity of hamstring injuries based on the total number and the grade of injury of the professional football players per year, their age, seasonal variations, as well as if the injury developed during the training or match.

Based on the consensus of sports epidemiologists a hamstring injury was defined as an injury that leads to the inability of a player to fully participate in the match or training session (36). To diagnose such injury the examiner begins with a thorough history of the event that led to the trauma, followed by inspection and palpation of the involved muscles as part of the clinical examination, as well as testing of the function of the injured muscles by applying external resistance and without it and finally, by using imaging modalities such as US and MRI as a mean to confirm the injury (27).

In this study, the data from 50 professional players were used, with 25 players being part of the A senior team and the other 25 part of the B senior team.

The highest incidence of players developing HI occurred during 2016 which was 25, in comparison in the years 2017 and 2018, the number of injured players were 15 and 13. A possible explanation for this could be, for example, change of the coach and the coaching staff that were responsible for the fitness and training regimens or it may be due to the possible change of players that were part of the team during the summer and winter transfer periods. Furthermore, detailed research is needed to support this claim.

Out of a total of 81 HI that were observed over the three-year period, 39 HI occurred in 2016, 25 in 2017 and 17 in 2018. Over the three-year period, 64 injuries were mild and 17 were severe. Although more injuries have occurred in 2016 there was no statistical significance that proves increased risk for HI in a specific year.

In Table 3 we can see that the median age of mildly injured players was 21 years and 6 months and for those who were severely injured the median was 22 years. However, there was no statistical significance that could provide proof of higher age as a risk factor for the development of more severe injuries. Although in this research our primary aim was to prove the existence of a correlation between age and the grade of injury, other studies have hypothesised that there might be an affinity for the increased incidence of HI in older players

(34). However, after analysis of their data, no valid proof has been found that could support such claims (34).

In this study, we hypothesised that the seasonal variation might be a risk factor for a higher-grade injury in football players. Despite the fact that the highest incidence of severe injuries was reported during Spring there is no valid evidence that would prove our hypothesis. However, traumatic injuries were found to be of a higher incidence during the competitive season (September to May), while overuse injuries were more common during the preseason preparation period in July (37). In their study, they also found that, for example, the risk of sustaining a hamstring strain was substantially higher during the competitive season (37).

We speculated that there might be a relation between the incidence of HI during the training or match and the grade of the injury that was sustained, for example, we hypothesised that the injuries that developed during the match would be of a higher grade due to the increased physical exertion, especially towards the end of the halves. Ekstrand J. et al (2016) reported, in a study that had a bigger sample, that 35% HI occurred in training and 65% in match play (38). They also have noticed in their study an annual increase of HI, especially during the training session and as a possible explanation for this, they suggested that the training sessions included more repeated high-intensity actions that are trying to simulate the intensity and movement patterns of matches and thereby increase the risk for HI (38). However, in our study, HI was observed in 63% of cases during training and 37% during the match. Although no statistical significant conclusion from our data could be done for our hypothesis, the difference of results that were describing the incidence of injuries that had occurred during the training or match day in our study when compared to the Ekstrand, J., et al (2016) research shows us that further research on this topic should be conducted.

There are some limitations that we were faced with in our study. One of those limitations is that the participating players, that were part of the club, varied during the study period. The teams were made of 25 players and that number was consistent throughout this study, however, the players that were part of the study changed due to the fact that they would leave the club and hence could not be followed up. Another limitation was the data that was collected, as this was a retrospective study, there was no way to gather the information that was missing. Furthermore, it is advised that further research should be conducted with a bigger sample size, as a way of increasing the power of the study.

# 6. CONCLUSION

1. HI are one of the most common muscle injuries in professional football players
2. The median age of players with mild injuries was 21 years and 6 months and those with severe injuries was 22 years, additionally there was no statistical significance found that would connect the age, as a risk factor, with the severity of the injury that was developed.
3. There was no correlation between seasonal variations and the severity of injuries, however, there is a higher incidence of HI during the competitive season
4. A higher number of HI was observed during the training (63%) than in the matches (37%), but no connection could be found between the grade of the injury and training/match risk factor.

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# 8. SUMMARY

**Background:** Hamstring injuries are one of the most common muscle injuries in sports. The aim of this study was to investigate the incidence of hamstring injuries in professional male football players and the severity of the injuries that they have developed.

**Methods:** From the beginning of January 2016 until the end of December 2018 male professional football players from the official clinic data records of a local football club in Split, that suffered HI, were included. Patients were separated into two groups based on the severity of their injury. The yearly incidence of hamstring injuries, number of players that sustained such injuries, age, seasonal variation and training/match incidence were compared between the groups.

**Results:** There were no statistically significant findings between the groups regarding the yearly incidence of HI ($P$=0.149), seasonal variations ($P$=0.238), age ($P$=0.238) and incidence of HI during training/match ($P$=0.339). Most HI were recorded in 2016 when 25 out of 50 players were injured.

**Conclusion:** In this study, we did not find any statistically significant evidence, based on the data that was collected, that would support our hypothesis. However, further research is suggested and they should be conducted with a bigger sample size and with the effort to try to follow up on players even if they leave the football club.

# 9. SUMMARY IN CROATIAN

**Cilj istraživanja:** Ozljede stražnje lože su jedne od najčešćih mišićnih ozljeda u sportu. Cilj ovog istraživanja je bio istražiti učestalost ozljeda stražnje lože u profesionalaca u muškom nogometu i težinu tih ozljeda koje su razvili.

**Ispitanici i metode:** U razdoblju od početka siječnja 2016. do kraja prosinca 2018., profesionalni nogometaši iz arhive službene klinike lokalnog nogometnog kluba iz Splita, koji su imali ozljedu zadnje lože, su uključeni u ovo istraživanje. Pacijenti su podijeljeni u dvije skupine prema težini njihovih ozljeda. Godišnja učestalost ozljeda zadnje lože, broj igrača koji su zadobili takve ozljede, dob igrača, godišnje doba i učestalost tijekom treninga/utakmice su bili uspoređeni između grupa.

**Rezultati:** U našem istraživanju nismo pronašli statistički značajne razlike između grupa, s obzirom na godišnju učestalost ozljeda zadnje lože ($P$=0.149), godišnje doba ($P$=0.238), dob igrača ($P$=0.238), i učestalost ozljeda tijekom treninga/utakmice ($P$=0.339). Najviše ozljeda je bilo zabilježeno tijekom 2016. kada je 25 od 50 igrača bilo ozljeđeno.

**Zaključci:** U ovom istraživanju nismo pronašli statistički važne dokaze, koje se temelju na prikupljenim podatcima, koji bi potkrijepili našu hipotezu. Međutim, preporučuje se da se provedu daljnja istraživanja sa većim brojem igrača uključenim u studiju i da se nastoji pratiti pacijenta/igrača i u situacijama kad napuste klub.

# 10. CURRICULUM VITAE

**PERSONAL INFORMATION**

NAME AND SURNAME: Dino Poljak

DATE AND PLACE OF BIRTH: November 16th 1994, Split

NATIONALITY: Croatian

CURRENT ADRESS: Put sv. Lovre 41a, 21000 Split, Croatia

E-MAIL: dinopoljak@yahoo.com

**EDUCATION**

2001-2009. Osnovna škola "Visoka"

2009-2013. Nadbiskupijska klasična gimnazija "don Frane Bulić"

2013-2019. Medical Studies in English at the University of Split, School of Medicine

**OTHER**

Languages: Croatian (Mother language), English, German

Category „B “driving licence

Class representative 2017-2019.