FIFA MEDICAL CENTRE OF EXCELLENCE

# Muscle Injuries Clinical Guide 3.0

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# CHAPTER 1. INTRODUCTION

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The aim of the following chapters is to outline the importance of muscle injuries in sports medicine, especially in football.

Everybody is aware that muscle injuries, and particularly hamstring injuries are one of the most frequent injuries and due to these, a player will have long periods of time lost.

For this reason, our medical staff decided to create the first muscle guide in 2009, to provide tools and explain our particular experience in managing muscle injuries.

During the following years, we applied the guidelines in our guide, but day by day it made us learn new experiences that became the basis for the new guide which focuses on the hamstring injuries, but has a common framework which could be applied when managing other types of muscle injuries.

Collecting data, we realised that in young football players, particularly in teenagers, the most common injury was a tear of the rectus femoris, whereas in professional football players it was the hamstring. This is the main reason why we decided to focus this second guide on describing hamstring injuries in depth.

The second guide was written in collaboration with Aspetar Medical Staff and from now on we want to start the third guide taking into account our mutual knowledge based on clinical experiences and supported by scientific evidence.

Going through the key changes in the second guide the most important are:

-Epidemiologically muscle injuries have been increasing over the last 12 years despite assessing risk factors and applying prevention protocols

-Proposal for a new classification considering connective tissue the main structure involved in muscle injuries

-In managing muscle injuries both MRI and US are useful in making decisions

-Several injuries, specially those located in the free tendon close to the ischial tuberosity, have to be treated surgically.

-Rehabilitation process must be performed within a strict framework

-Return to play has to be understood as a personalized criteria.

-Prevention: the real concept behind primary prevention nowadays is good training and strength in performance.

# CHAPTER 2. EPIDEMIOLOGY

*Coordinators: Daniel Medina, Cristiano Eirale, Hans Tol, Adam Weir*

The ultimate goal of all sports injury research is injury prevention and reduction. Research has proven that muscle injuries have a high prevalence in football[1], representing between 20% and 46% of all time loss injuries at men's professional level[1; 2] and 18% to 23% at men's amateur level. A club with a 25-player squad can expect 15 muscle injuries each season, and these muscle injuries will account for more than one-fourth of all layoff time through injuries. A footballer will typically suffer 0.6 muscle injuries per season[3] with approximately two weeks missed for each muscle injury[4]. Due to the magnitude of the problem, a need for better understanding of muscle injuries and their prevention has become an emerging challenge for football clubs.

As proposed by van Mechelen[5], the first step in injury prevention is to evaluate the epidemiology of injuries and establish injury risk and injury circumstances. The epidemiology and characteristics of football muscle injuries is well documented, in matches and training in top level international tournaments such as the English, Swedish and Norwegian leagues, European Champions League and World Cup[2].

The main objective of this chapter is to summarise the published epidemiology of muscle injuries in football as the first steps towards muscle injury understanding and prevention.

## 2.1. Injury Definition and Severity

The UEFA Champions League study has defined very strict criteria on injury definition: an injury that occurred during a scheduled training session or match that caused absence from the next training session or match[6]. Obviously, using a 'time loss' injury definition, it is important to take injury severity into consideration, and this is usually described according to the number of days of absence from participation. According to the UEFA consensus discussions, injury severity must be categorized as minimal (1-3 days absence), mild (4-7 days), moderate (8-28 days) and severe (> 28 days.)

A reinjury is defined as an injury of the same type and location as a previous injury that occurred within two months of the final rehabilitation day of the previous injury.

## 2.2. Epidemiology of Muscle Injuries in Football

Muscle injuries account for 31-46% of all injuries in football, in comparison with sprain/ligament injuries and hematoma/contusion/bruise injuries, which constituted 18% and 16% of all injuries respectively[1; 4]. Each season, 37% of players will miss training or matches due to muscle injuries[4].

### 2.2.1. Incidence and Prevalence

Overall injury incidence (injuries/1000 hours) was 2.8 for all muscle injuries. On average, a male elite-level football team with a squad of 25 players can expect around 18 muscle injuries per season. Of these, seven will affect hamstrings and three quadriceps, five or six will be groin injuries, and two or three will affect calves[1].
During preseason, a lower rate of adductor, hamstring and calf injury has been recorded compared with the competitive season. Injury rates for quadriceps injuries, however, are higher during preseason[3].

The incidence of muscle injuries increases with players aged over 30. However, there are no significant differences for intermediate age groups (22-30 years), while younger players had a lower incidence (1.19/1000 h) during trainings compared to older players (1.63/1000h.) During matches, there were no inter-group differences for hamstring and quadriceps; however, the highest for groin were intermediate age groups, and calf increased with age[4].

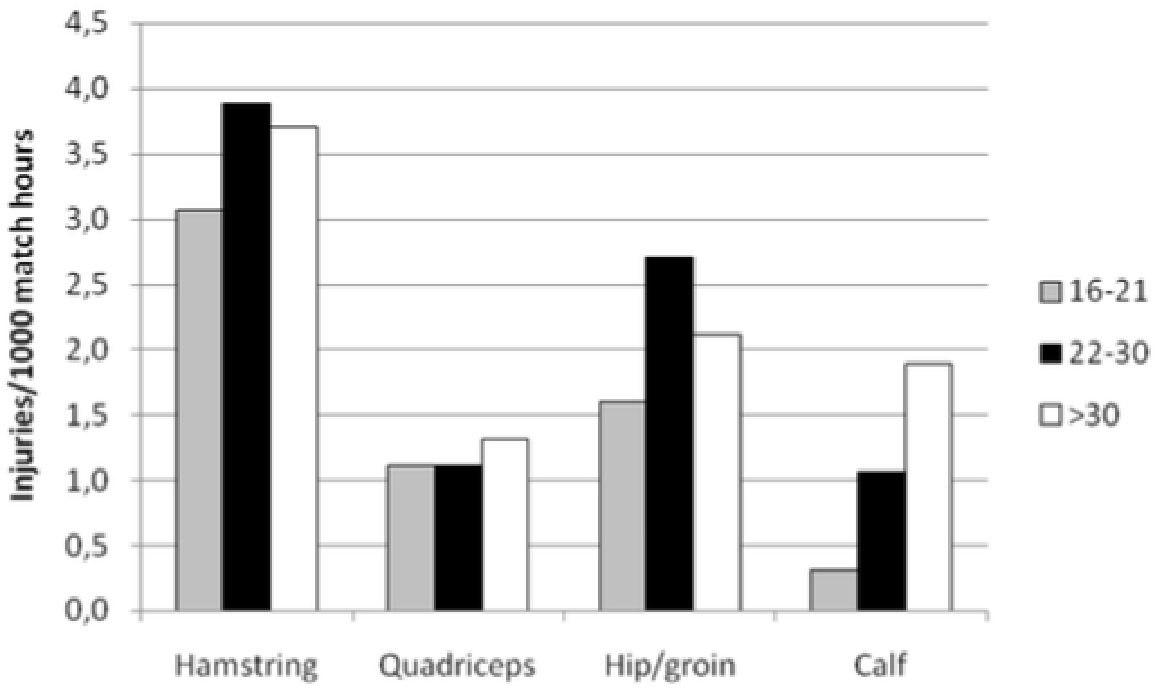


***Table 1.*** *From Ekstrand, J. et al (2011) – match incidence of the four most common muscle strain injuries in age groups.*

*Regarding surface of play, Ekstrand (2011) found that the incidence of muscle injuries was significantly lower when playing on new generation artificial turf.*

## 2.2.2. Localisation and Severity

The majority of muscle injuries (92%) affect the lower extremity involving the four major muscle groups: hamstrings, adductors, quadriceps and calves[4]. The most common localisation of muscle injuries are thighs (55%), followed by the hip/groin area (30%.)

Hamstring injuries are the most common single type of injury representing 12-37% of all injuries; adductors represent 23%, quadriceps 19% and calf 12-13%[1; 4]. There is no significant relationship between dominant leg (preferred kicking leg) and muscle injuries except for quadriceps (60 %.)[4]

Hip/groin injuries are the most common location for overuse injuries with gradual onset. However, the majority of these injuries (66%) are traumatic with acute onset.

Most muscle injuries, between 39-62%, are moderate (8-28 days.) In general, thigh and calf injuries cause more moderate to severe injuries in comparison with hip/groin injuries[1].

### 2.2.3. Match vs Training Incidence

More than half of muscle injuries (53%) occur during matches and 47% during training[4]. The risk of muscle incidence is six times higher during match play (8.70 vs 1.37/1000 hours) compared to training[1; 4]. In fact, 66% of all hamstring injuries occur during matches[1].

In matches, the distribution of the risk of thigh muscle injuries increases over time in both the first and second halves of matches. A similar tendency is seen for hip/groin injuries in the first half, while the risk of calf injuries is fairly constant until the last 15 minutes of the match when it increases substantially[1; 4] (Table 2.)

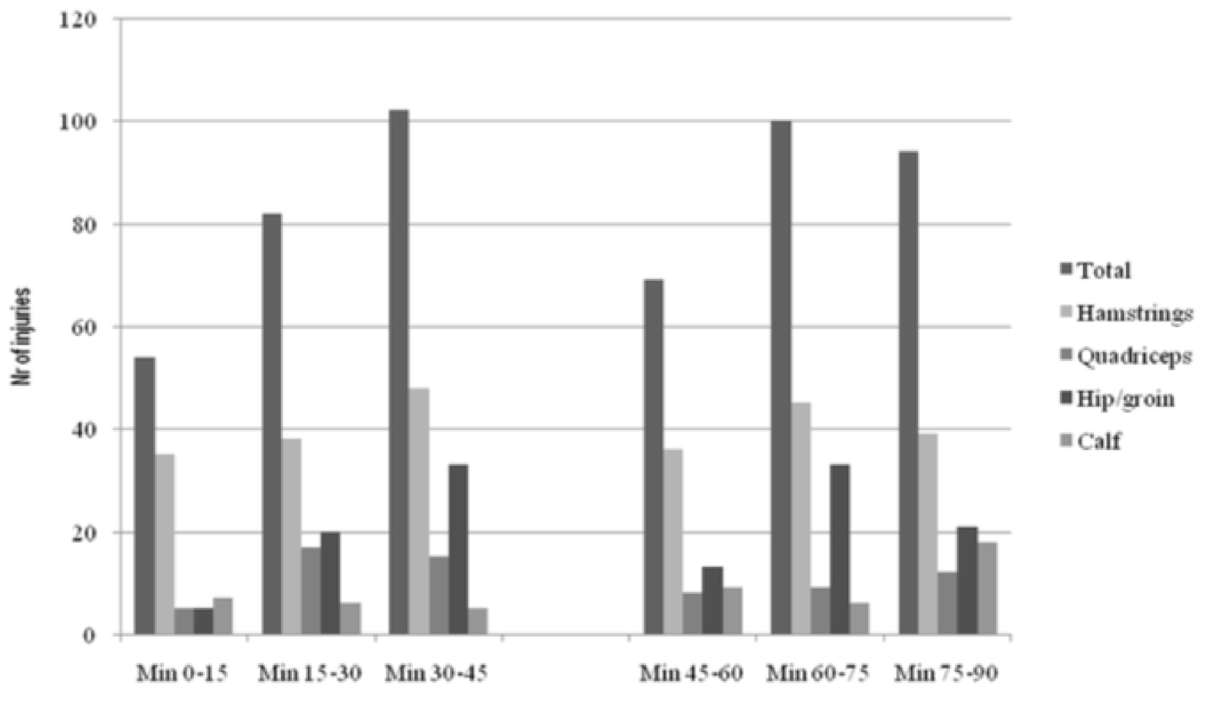


***Table 2.*** *From Ekstrand, J. et al (2011) – distribution of traumatic injuries during a match.*

In match play, players under 22 had a significantly lower incidence than players ranging 22-30 years and those over 30 years[4].

Interestingly, the rate of muscle injuries during matches and training has been proven to remain steady during 11 consecutive years with no significant difference in between seasons[7].

### 2.2.4. Recurrent Injuries

About 16% of muscle injuries in elite soccer are recurrent injuries. The risk of recurrence is higher for hip/groin injuries in comparison with thigh and calf injuries[1]. No differences in the recurrence rate between the four most common injury locations (adductors, 18%; hamstrings, 16%; quadriceps, 17%; and calves, 13%) have been observed[4].

On average, repeat injuries caused a 30% longer period of absence than the initial injury[1].

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# Chapter 3. MUSCLE INJURY CLASSIFICATION

*Coordinators: Xavier Valle, Hans Tol, Bruce Hamilton*

The muscle extracellular matrix (ECM) is a complex and interconnected structure[1-3] where the muscle fibres are embedded. This structure is mechanically interconnected[4] so the forces generated by actin-myosin interaction will be transmitted to the net of connective tissue. This connective tissue net structure and its role in force generation and transmission is a key factor in muscle injury signs, symptoms and prognosis[5].

Magnetic Resonance Imaging[6-15] (MRI) and Ultrasound[16-18] (US) are needed to describe with accuracy muscle injuries, especially the location, size and tendon involvement. Several parameters regarding the size of muscle injury and the tendon involvement could be associated with the severity of the injury.

When there are no findings on MRI and US another condition must be considered, but recently the concept of grade 0 muscle injury has been developed[15,19]. It represents a muscle injury which is undetectable with current imaging modalities[20,21]. This injury grade has been associated with a quicker return to sport and, therefore, it is of relevance in a grading system.

## 3.1. Previous Classifications

Several grading and classification systems for muscle injuries[22-28], for specific muscles[29-30], or group of muscles[31-33], have been published during the last century. New proposals have recently been published, one imaging-based which introduced injury anatomical description (US and MRI) [34]; another that is focused on the location of the injury and its relation to the tendon and fascia[35]; and lastly the third which combines clinical signs and imaging[19] (Table 3.) In recent years, functional assessment[32] and clinical evaluation[19] have also been considered as prognostic factors[36].

The best classification should be reproducible, capable of distinguishing between different categories, easy to remember and related to the prognosis.

*Table 3: Summary of previous classifications*

| Based on | | G 0 | G I | G II | G III | G IV |
|---|---|---|---|---|---|---|
| Clinical Signs | O'Donoghue | - | No appreciable tissue tear. | Tissue damage and reduced strength of the MTU. | Complete tear of MTU and complete loss of function. | - |
| | Ryan | - | Tear of a very small number of fibres with fascia remaining intact. | Tear of a higher number of fibres, fascia still remains intact. | Greater number of muscle fibres involved, the muscular fascia is a least partially torn. | Complete tear of the muscle belly and fascia rupture. |
| Imaging | Takebayashi | - | No abnormalities or diffuse bleeding with or without focal fibre rupture (less than 5% of the muscle involved. | Focal fibre rupture more than 5% of the muscle involved, with or without fascial injury. | Complete muscle rupture with retraction, fascial injury is present. | - |
| | Peetrons | Lack of US lesion. | Minimal elongations with less than 5% of muscle involved. | Lesions involving from 5 to 50% of the muscle volume or cross-sectional diameter. | Complete muscle tears with complete retraction. | - |
| | Stoller | | Hyperintense edema ±hemorrhage with preservation of muscle morphology.<br>Edema pattern = interstitial hyperintensity + feathery distribution on FS PD or T2 FSE + STIR images.<br>Hyperintense subcutaneous tissue edema + intermuscular fluid. | Hyperintense hemorrhage with tearing of up to 50% of muscle fibers<br>Interstitial hyperintensity with focal hyperintensity representing hemorrhage in muscle belly ± intramuscular fluid<br>Hyperintense focal defect + partial retraction of muscle fibers<br>Associated myotendinous + tendinous injuries<br>Hyperintensity + interruption ± widening of muscle-tendon-unit | Complete tearing ± muscle retraction<br>Hyperintense fluid filled gap = hyperintense on FS PD FSE + STIR<br>Associated adjacent hyperintense interstitial muscle changes | - |
| | Chang | Use US and MRI criteria to establish injury's grade, and describes injury's anatomical location and MTJ relations. | | | | |
| Mixed | Munich | Indirect | Functional muscle disorder. | | | |
| | | | Structural muscle injury: Grading on US/MRI classification system. | | | |
| | | Direct Muscle injury | | | | |
| | Pollock | Myofascial tear (four grades), incorporating cranio-caudal length and cross sectional area for grading. | | | | |
| | | Muscle Tendon Junction Tear (four grades), incorporating cranio-caudal length and cross sectional area for grading. | | | | |
| | | Intra-Tendinous Tear. (four grades), incorporating cranio-caudal length and cross sectional area for grading. | | | | |

### 3.2. New Proposal "MLG-R"

Our proposal describes the injury based on mechanism "M", location "L" and its relation with the muscle tendon junction (MTJ) and connective tissue evaluation, grading by imaging description "G" and, finally, re-injury "R". This classification system is summarised in table 4. Imaging diagnosis techniques, both MRI and US, are essential in correctly describing the injury. US is capable of providing a description of the location[38,39], but the best description will be based on the MRI features of the muscle injury[40-42]. This classification has been designed for hamstrings because it is the most frequently injured muscle group in almost all sports worldwide. In the future, another muscles and special situations must be considered.

- 1st type is a capital letter regarding the **Mechanism.** It describes the mechanism of injury, which could be a direct blow or an indirect strain. Direct injuries are named '**D**' and indirect injuries '**I**'.
- 2nd type for direct injuries is a lowercase letter regarding the **Location.** '**p**' is used for direct injuries which affects the proximal third, '**m**' is used the direct injuries which affect the middle third; and '**d**' is used for direct injuries which affect the distal third.
- 2nd type for indirect injuries is a capital letter followed or not followed by a lowercase letter regarding the **Location.** It describes the type of connective tissue damaged, which could be the tendon or the muscle tendon junction (MTJ). '**T**' is used for the injury which extends into the tendon, and they are the most severe injuries[43]. '**J**' is used for the injuries at the MTJ. After the **T** and **J**, as a sub-index, the proximal and distal location must be specified with **p** for the proximal ones and **d** for the distal ones.

  '**F**' is used for the injuries that can't be assigned to any concrete MTJ. These injuries have been named myofascial, aponeurotic or epimysial by several authors, and would correspond to peripheral injures, that which have the lowest grade of severity.

  When more than one zone of the muscle belly is affected the most severe location should be used.

The distance from the muscle origin nowadays has some lack of consistency, but will be relevant in the near future and could be included in further versions of muscle injury classification.

- 3rd type is a number from 0 to 4 regarding the **Grade**, through MRI. The affected area is considered where there is related to the amount of pixels where there is a hyper-signal change on fat suppressed/STIR images. The grade refers to the percentage of the cross sectional area (CSA) of the affected muscle to total muscle belly, in the axial plane where the injury is greater. If more than one muscle is injured, the muscle with the greater area of signal abnormality or architectural distortion will be considered the primary site of injury and the grading criteria will be taken for that particular muscle.
    - '**0**' Grade 0: clinical suspicion of muscle injury without MRI findings
    - '**1**' Grade 1: ≤10% of CSA.
    - '**2**' Grade 2: 11-25% of CSA.
    - '**3**' Grade 3: 26-49% of CSA.
    - '**4**' Grade 4: ≥50% of CSA.

  In the future, the architectural distortion, more than the oedema, should be the key in the imaging evaluation to grade the muscle injuries.
- 4th type is a number following the letter 'R' regarding the **Reinjury**: It describes whether or not this is the first episode.
    - '**R0**': first episode
    - '**R1**': first reinjury;
    - '**R2**': second reinjury,
    - And so on.

The specific muscle that has been injured should also be named.

The main goal would be to group the injuries by severity and further try to link with different management protocols and therapies. An easy, useful and reliable classification would allow monitoring of each injury with any therapy protocol and its progression[43]. With an acronym, we offer the possibility of describing the injury, the mechanism, the location and chronological evolution.

*Table 4. Summary of MLG-R classification system*

| Mechanism | Location | | Grade | Reinjury |
|---|---|---|---|---|
| **D** direct | **Dp** | proximal third direct muscle injury | **0** negative MRI<br>**1** < 10 % CSA<br>**2** 11 – 25 % CSA<br>**3** 26 – 49 % CSA<br>**4** >50 % CSA | **R0** 1st episode<br>**R1** 2nd episode<br>**R2** 3rd episode<br>**R…** … episode |
| | **Dm** | medial third direct muscle injury | | |
| | **Dd** | distal third direct muscle injury | | |
| **I** indirect | **ITp** | proximal tendon tear | | |
| | **ITd** | distal tendon tear | | |
| | **IJp** | proximal MTJ tear | | |
| | **IJd** | distal MTJ tear | | |
| | **IF** | peripheral tear | | |

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# Chapter 4. DIAGNOSIS AND MANAGEMENT OF MUSCULAR INJURIES

*Coordinators: Lluis Til, Hans Tol, Bruce Hamilton, Erik Witvrouw*

As a result of the frequency of muscle injuries, many are treated clinically in the absence of confirmatory imaging. However, the clinical appearance is not always clear, and determining the optimal treatment for an injury can be difficult. Imaging can help confirm both the presence and extent of muscle injury, and the typical modalities utilised include Magnetic Resonance Imaging (MRI) and ultrasound (US.)[1]

The clinical appearance of a skeletal muscle injury depends on the severity of the injury and, in part, on the nature of the resulting hematoma[2]. Detailed history of the injury mechanism and preceding history in combination with careful examination is essential in making a correct diagnosis. A critical goal of the history and examination is to differentiate between those patients with injuries possibly requiring surgical treatment and those patients with non-surgical injuries.

**An appropriate history** should incorporate the following elements:-

| **Regarding the general history of the athlete:** |
|---|
| • *Has the player suffered similar injuries before?*<br>*(Some muscle injuries have a high rate of recurrence, patients may report a previous injury, often adjacent to or near the current site of injury [3].)* |
| • *Is he/she susceptible to injuries?* |
| • *Is the patient using any medications?* |
| **Regarding the mechanism of injury:** |
| • *What was the trauma mechanism?*<br>*(A direct blow to the muscle or an indirect mechanism.)* |
| • *During work, leisure, training or competition?* |
| • *When did it start?*<br>*Date and relationship with the sports session (beginning, middle or the end of the session)* |

| |
|---|
| • *How did it start? (Suddenly, gradually, progressively)* |
| • *Any audible pop or snapping sensation with the onset of pain* [4] |
| **Regarding the initial progress:** |
| • *Was the player able to continue or was he/she forced to stop?* |
| • *How was the patient treated following the immediate injury?* |
| • *How is the pain has progressed over time?* |

Physical examination involves the inspection and palpation of the injured area, as well as testing the function of the potentially injured muscles both with and without external resistance. A bilateral comparison should always be performed. The physical examination is performed to determine the location (region, tissue, muscle, tendon or fascia) and severity of the injury.

For injuries involving the intramuscular tendon and adjacent muscle fibres, a 'battery' of tests which incorporate measures of function, strength and range of motion may provide an acceptable estimate of rehabilitation duration[5]. Specifically, a past history of hamstring strain and being unable to walk at a normal pace pain-free within 24 hours of injury were independent predictors of being unable to return to play in less than four weeks from the time of injury in Australian football rules following a confirmed hamstring strain[6].

By comparison, for injuries to the proximal free tendon, the amount of impairment identified from these tests is not predictive of the recovery time needed to return to pre-injury level[7]. We recommend that specific measures be used during the examination of all acute muscle injuries, at the very least to serve as a baseline from which progress can be assessed.

**Muscle examination** should include:

| | |
|---|---|
| ***Inspection*** | *Looking for ecchymosis or deformities on the muscle belly profile* |
| ***Palpation*** | *Useful for identifying the specific region/muscle injured through pain provocation, as well as the presence or absence of a palpable defect in the musculotendinous junction* |
| ***Strength assessment*** | *Through manual resistance applied distally to the injury site. Due to the changes in musculotendon length that occur with joint positions, multiple* |

| | |
|---|---|
| | *test positions are utilized to assess isometric strength and pain provocation. It is important to note that pain provocation with this assessment is as relevant as noting weakness* |
| ***Range-of motion*** | *Tests should consider joints at either end of the injury site. For hamstring injuries, passive straight leg raise (hip), and active and passive knee extension test (knee) (AKET, PKET) are commonly used to estimate hamstring flexibility and maximum length [8]. Pain and discomfort during testing are key considerations when performing and evaluating these tests.* |
| ***Muscle length*** | *The extent of joint motion available should be based on the onset of discomfort or stiffness reported by the patient. In the acutely injured athlete, tests are often limited by pain and may not provide a valid assessment of musclotendon extensibility.* |
| ***Pain provocation manoeuvres*** | *It has been suggested that players with a biceps injury would feel more pain during stretching than contraction (on VAS), while those injured in SM or ST will have more pain during contraction than stretching.* |

## 4.1. Imaging of Muscle Injury

Unless an avulsion fracture with bony fragment or apophyseal fracture in a skeletally immature individual is suspected, the value of plain radiographs is limited[9]. By contrast, MRI and US are able to describe the location (which muscle and tissue), the lesion size and the lesion nature (oedema, haemorrhage) as depicted by echotexture and signal intensity respectively[10].

Both imaging modalities are useful in identifying muscle injuries when edema and haemorrhage are present[11]. As a result of its cost effectiveness, US has traditionally been the imaging system of choice for clinical diagnosis of muscle injuries. However, it has the disadvantage of being radiologist experience dependent.

US is a dynamic and interactive process, allowing ‘echopalpation’ of painful areas which complements the clinical examination. US also enables the monitoring of progress and can guide the evacuation of fluid collections; as such it is of great help in topographic diagnosis. However, MRI is considered superior for evaluating injuries to deep portions of muscles[12], or when a previous injury is present as residual scarring can be misinterpreted on an US image as an acute injury.

Due to its increased sensitivity in highlighting subtle edema, measuring the size of injury (length and cross-sectional area) is probably more accurate with MRI. MRI has also been shown to be useful in prognosticating return to play (RTP) with MRI grading associated with lay-off times after injury[13.]

Hamstring muscles are the most well documented in the literature, and MRI provides very specific anatomical and pathological information. MRI can sensitively evaluate the relative involvement of tendons, fascia and muscle contractile tissue[14]. MRI has been shown to be more accurate than US in the evaluation of proximal hamstring injuries, and it can assess the degree of tendon retraction, which has been shown to be an important element of preoperative planning in proximal hamstring ruptures or avulsions[15]. Whereas MRI correctly identified all avulsion cases, US identified only 58% of hamstring avulsions despite the examination being performed by experienced musculoskeletal operators[16].

In distal hamstring injuries, US is better able to detect injuries as a result of the more superficial anatomy of the distal hamstring tendons[10]. With injuries near and/or at the groin area or close to the myotendinous junction, MRI has also shown its superiority over US[11].

The limited availability and high costs of MRI may restrict the use of this modality for routine assessment of injuries among junior, amateur and self-funding athletes. Schneider-Kolsky et al showed that MRI was not required for estimating the duration of rehabilitation for an acute minor hamstring injury in professional football players. However, a positive MRI result appeared useful as a predictor of duration of rehabilitation in severe hamstring injuries, and also that MRI was helpful in the planning of surgical interventions[5].

However, a recent review independently screened the searched results and assessed risk of bias on the value of MRI for muscle injury prognosis. The results suggest that of the 12 studies included, 11 have a high risk of bias. There is moderate evidence that injuries without any hyperintense signal on fluid sensitive sequences are associated with a shorter time to RTP, and that injuries involving the proximal free tendon have a longer time to RTP. Limited evidence supports an association between central tendon disruption, injuries not affecting the musculotendinous junction and a total muscle rupture with a longer time to RTP. Other MRI features studied show either no association or conflicting evidence of impact on prognosis. It can be concluded that there is currently no strong evidence for any MRI variable to predict the time to RTP after an acute hamstring injury due to considerable risks of bias in the studies[22].

**Routine MRI protocol:** As an absolute minimum, each MRI examination should generally include at least two orthogonal planes and pulse sequences. In addition to the requisite axial plane, the long-axis plane is generally sagittal (when evaluating abnormalities at the anterior or posterior aspect of an extremity) or coronal (when evaluating abnormalities at the medial or lateral aspect of an extremity.) At least one of these pulse sequences should use a fat-suppression technique[21].

## 4.2. Initial Management of a Suspected Muscle Injury

In Table 3, the most appropriate timing for carrying out complementary investigations is highlighted. Real utilisation will depend on the physician and athlete preference, funding and the availability of resources.

### Management of a muscle injury

| Timing | | Clinical history | Physical exam | US | MRI | Treatment |
|---|---|---|---|---|---|---|
| Initial acute phase | Immediate | X | X | | Could be made anytime | Rest<br>Ice<br>Compression<br>Elevation<br>Analgesia |
| | 12 hours | | X | X | | |
| | 24 hours | | X | X | | |
| | 48 hours | | X | X | | |
| | | | | | Functional tests (*) | |
| Subacute & functional phase | 1st week | Monitoring players feelings | X | x | To evaluate how the progression of loads are assumed | Rehabilitation<br>Progressive protocol |
| | weekly | | X | X | | |
| | Return to play | | X | X | | |

**(*) For follow-up the functional recovery and sometimes to help to decide return to play:**

- *At muscle:* tensiomyography, electromyography and strength tests.
- *At player:* GPS, HR and self-administered scales during and after the rehabilitation sessions on field

• **Immediately.** Once injury is suspected through observation of the injury occurring, questioning of the player about their general history regarding the mechanism of injury, and the initial progress (see above.) A structured physical examination based on inspection, palpation, strength assessment, range of motion and post-injury muscle length without pain or stiffness (see above.) When the injury is not an obvious or significant 'strain' early detailed diagnosis may not be easy. It is important and necessary to observe the injury for several hours to note its progression as well as carrying out the appropriate complementary tests.

• **Twelve hours.** An ultrasound study at this early stage does not allow for an accurate diagnosis of minor muscular injuries, but may detect the more severe grade II injuries.

• **Twenty-four hours.** Most specialists in MRI agree that this is the most appropriate time to establish a clear diagnosis and prognosis. It is important that the personnel who interpret the MRI have experience in this type of injury. It has been suggested that in an injury of the proximal musclotendinous junction of the biceps femoris muscle, the following parameters are prognostic for the return to competition and the risk of re-injury[18]:-

- total length of the injury
- distance between the ischiatic tuberosity and the proxima ending of the injury
- cross sectional area of affected muscle[19].

• **Forty-eight hours.** This has been determined to be the optimum time to establish an accurate diagnosis and prognosis when using US alone.

Tensiomyography evaluates the involuntary contractibility of the muscle belly, and it is influenced by the viscoelastic properties of the muscle. While there is little scientific evidence for this methodology, further research should support a role for it in monitoring the functional recovery with US and strength test[20].

## 4.3. Summary

When a typical history of muscle contusion or muscle strain is followed by local pain, swelling and/or distal ecchymosis, the diagnosis of a muscle injury may be apparent. The grade of injury and what muscle is injured, particularly if the athlete is unable to walk at a normal pace pain-free within 24 hours of injury, may all be relatively straight forward. On the other hand, hematomas that are small in size and those injuries deep within the muscle belly can be more difficult to diagnose clinically, but the imaging modalities (ultrasonography and MRI) provide useful means to delineate injury details.
MRI can accurately confirm or exclude a muscle injury, and is able to provide a very detailed characterisation of the lesion, even with the risk of being considered somewhat oversensitive at times. The clinical diagnosis of muscle injury is sufficient in most cases, but US can be considered a valid first line tool if a more exact characterization of the injury is desired. MRI might be of value when there is a clear discrepancy between the clinical symptoms, the physician's findings, and/or the US finding.

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# Chapter 5. SURGICAL TREATMENT OF MUSCLE INJURIES

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Operative treatment is seldom considered in the treatment of muscle injuries, including hamstring strains, and the phrase "muscle injuries heal without intervention" could be used as a guiding principle."[1; 2] However, there are certain highly specific indications in which surgical intervention might actually be beneficial for severe muscle injuries, even in the absence of an evidence-based treatment protocol. These indications include an athlete with a complete (grade III) rupture of a muscle with few or no agonist muscles, a tear (grade II) if more than half of the muscle is torn, or a large intramuscular hematoma(s)[3; 4]. Many authors claim that surgery has no place due to the lack of firm evidence, while some surgeons believe surgical treatments with postoperative rehabilitation protocols should be considered if a patient complains of chronic pain (duration > 4-6 months) in a previously injured muscle, especially if the pain is accompanied by a clear extension deficit[5]. In these chronic cases, scar tissue formation and adhesions restricting the movement should be suspected and surgical release of adhesions can be considered.

## 5.1. Proximal Hamstring Injuries

Most authors advocate that only in the presence of a complete rupture of the proximal attachment of the musculotendinous complex should surgical repair be considered[6]. More assertive recommendations have recently been made[7] suggesting that a pure isolated biceps femoris and semitendinosus conjoint tendon avulsion should be repaired in active patients. Nowadays with elite athletes, it is often advised to repair cases when BFLH and ST are ruptured. In cases where only one of them is torn, the controversy persists. Cohen and Bradley[8] suggested surgical treatment when two out of three hamstring tendons are ruptured at the ischial tuberosity.

Due to the low incidence of proximal hamstring avulsions, most published reports are retrospective case studies with limited numbers of patients. Technical notes on endoscopical repair have recently been published[9] . These less invasive techniques could have some advantages with minimal disruption of normal anatomy and improved visualisation with possible decreased neurovascular complications and decreased bleeding, but it involves some technical challenges of passing and shuttling the suture for repair and increased operative time. This arthroscopic repair would be done to avoid scarring and ishio-femoral impingement on the nerve.

### 5.2. Distal Hamstring Injuries

Distal hamstring injuries are usually associated with severe traumas to the knee joint or with other traumatic musculotendinous injuries around the knee (LaPrade and Terry 1997, Clanton and Coupe 1998, Bencardino et al 2000.) However, isolated distal hamstring tendon avulsions have also been described, and operative treatment for these has been recommended (Sebastianelli et al. 1990, David et al 1994, Alioto et al 1997, Clanton and Coupe 1998, Werlich 2001, Mann et al 2007.) Bruce Hamilton has some data on good results in track and field athletes who were treated without intervention.

### 5.3. Proximal Avulsion Fracture

In adolescents, apophyseal avulsions at sites of proximal hamstring muscle insertions are occasionally seen (Rossi and Dragoni 2001.) Operative treatment has been recommended if the displacement of the avulsed fragment is 2 cm or more (Kujala and Orava 1993, Servant and Jones 1998.) Gidwani and Bircher (2007) suggested even more active operative treatment and recommended early surgical fixation if the fracture displacement is more than 1 cm.

## 5.4. Chronic Hamstrings Ruptures

It has been shown that an athlete is unlikely to return to the previous level of sporting activity after complete proximal hamstring rupture unless treated surgically (Kurosawa et al 1996, Sallay et al 1996, Gidwani and Bircher 2007.) On the other hand, no

differences between early and late repairs have been identified with regard to functional outcome or return to sport (Klingele and Sallay 2002.) Based on the authors' own experiences and assumptions, in elite athletes early surgical refixation of complete proximal hamstring ruptures is recommended (Orava and Kujala 1995, Brucker and Imhoff 2005, Chakravarthy et al 2005, Cohen and Bradley 2007, McGrecor et al 2008, Stradley et al 2008.)

## 5.5. Postoperative Rehabilitation

Postoperative rehabilitation is guided by the diagnosis, the surgical procedure and the patient's progress. We recommend an elastic bandage for one to two weeks post-operatively without immobilization, casts, or orthoses.

Postoperatively for two to four weeks, light touch weight-bearing is allowed with gradual progression to full weight-bearing at the end of six weeks. After three to four weeks, light pool training including swimming is allowed, and after four to six weeks cycling is allowed. Range of motion exercises start during this phase, but stretching exercises of the hamstrings should be avoided during the first four weeks. Progressing to running and more active muscle training is advised two to four months after the operation depending on the patient's progress.

| Type of Injury | Muscle | Part of Muscle | Tendon | Treatment |
|---|---|---|---|---|
| Tendon bone detachment desinserctions | Quadriceps | Rectus Femoris Proximal | Direct head | Surgical reattachment |
| | | | Indirect head | Small gap conservative<br>Large gap surgical |
| | | | Direct + Indirect | Surgical |
| | Hamstrings | Proximal | Biceps Femoris Long Head and/or Semitendinosus (Common tendon) | Surgical |
| | | | Semimembranosus | Conservative,<br>if there are persisting symptoms after 4 m: surgical reattachment must be considered |
| | | Distal | All (rare) | Surgical reattachment must be considered |
| | Adductors | Not included in this project by different approaches between FCB group (this injury is a progression of groin pain could be treated with tenotomy) and Turku group ( the acute injuries could be treated with surgical reattachment) | | |
| Bone avulsions | Quadriceps | Proximal | ASIS or AIIS | Conservative ; unless > 2cm |
| | | Distal | Patellar avulsion | Surgical ; (except non displaced) |
| | Hamstrings | Proximal | Ischial tuberosity | Gap < 2cm conservative<br>Larger gaps : surgical |
| | | Distal | All (rare) | Surgical reattachment must be considered |
| Muscle injuries at the myotendinous junction, when the main tendon is evolved at less than 7cm from bone origin, with loss of tension of the rest of the tendon | | Quadriceps & Hamstrings | < 2 cm from bone insertion | Reattachment to the bone and liberate tension at MTJ |
| | | | 2 – 7 cm from bone insertion | Surgical treatment: Anatomical Repair with minimally invasive approach |

## 5.6. Chronic Injuries

Surgery should be considered if the symptoms (pain, weakness and loss of function) persist longer than six months, which is the time expected for healing. The surgical procedure may include excision of adhesions, fasciectomies and tendon bone reattachments. Occasionally retracted muscles can be reattached to the bone by using an autograft augmentation. In chronic hamstring injuries, the ischial nerve should be freed from adhesions. Rectus femoris distal gastrocnemius and soleus can be affected by symptomatic chronic myofascial injuries which could be treated by excision of scar tissue.

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# Chapter 6. REHABILITATION PROGRAMS

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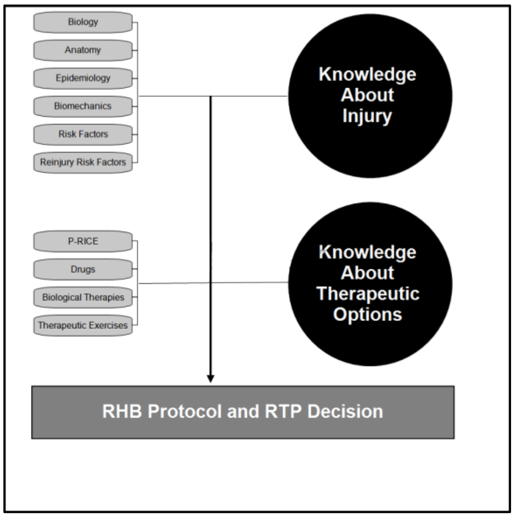
## 6.1. Introduction

To design a particular rehabilitation protocol for each muscular injury based on its grade and/or muscle location is an impossible task; in our opinion, therefore, rehabilitation protocols designed for muscle injuries should be built on the scientific knowledge about the injury and the therapeutic options we have to treat them.

The knowledge about muscle injuries would include: muscle injuries biology, muscle group anatomy, structure, histology and function, types and mechanisms of injury, injury risk factors and reinjury risk factors, etc. The biology of healing a muscle injury is a reparative process[1] with the formation of a scar[2]. The healing process of a skeletal muscle injury is divided into three phases[3]: destruction, repair and remodelling; ending with a new myotendinous junction (MTJ) between the repaired myofibers[3-5]. The optimal healing process is characterised by stimulating regeneration and minimizing reparation, so the smallest scar possible.

The main body of knowledge about muscle injuries comes from studies about hamstrings or rectus femoris, so we will describe the design process for a rehabilitation protocol for hamstring injuries, for example, based on the previous described thought process.

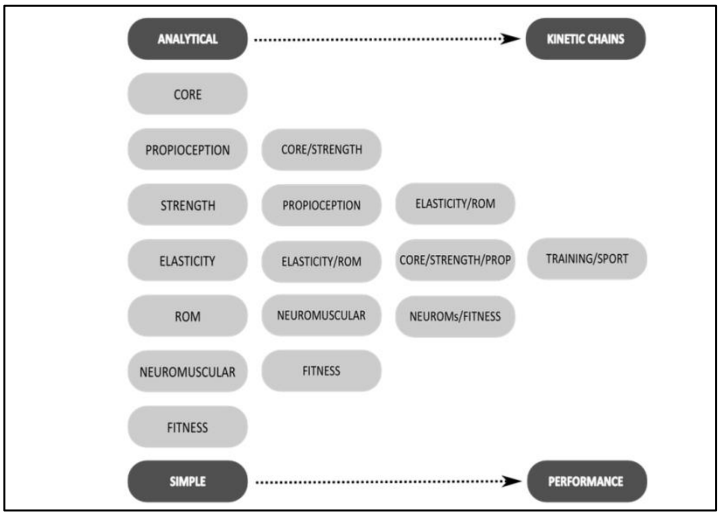


## 6.2. Knowledge about the Therapeutic Options, Clinical Considerations in Rehabilitation

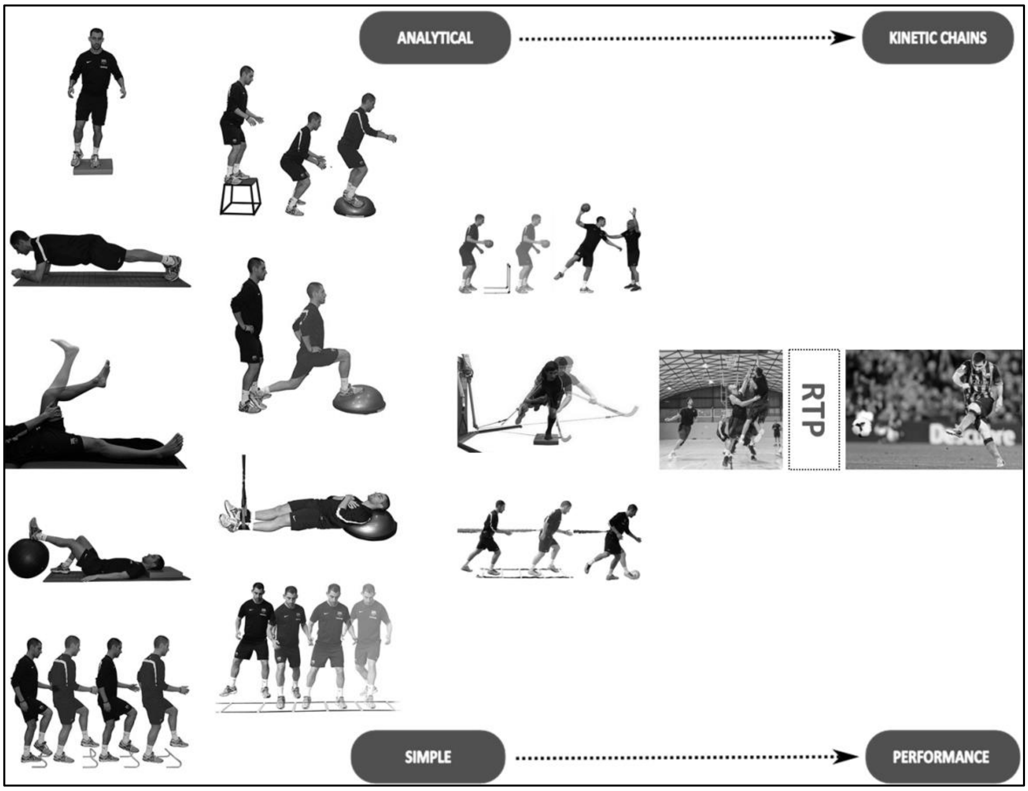
There is no clear evidence regarding the use of medications[6], cooling[7] or Platelet Rich Plasma[8] with limited impact on RTP or reinjury statistics. Several protocols have been published to treat HMIs using stretching exercises[9], balance[10], eccentrics exercises[11; 12] and different combinations[13-16]. Although the aetiology of hamstrings muscle injuries (HMIs) is multifactorial[17-20], most rehabilitation programs focus on just one or two factors. Our purpose is to design and develop a criteria-based rehabilitation program with clear objectives progression criterion for each phase and RTP.

We also describe the standard in designing a battery of exercises to achieve a global approach to the injury, with the aim of correcting and reducing the biomechanical disorders which influence the progression of injury [19; 21; 22]. We will include all exercises or programs showing effectiveness as treatments for HMIs, or reducing the risk of injury to lower extremities such as proprioception or neuromuscular exercises[10; 23].

To design an exercise standard offers the option of adapting the protocol to the patient's physical condition, sport or the available equipment. Exercises will progress from single, basic, low demanding to more complex and combined, until accomplished exercises reproduce sport movements.



The design of exercises will be completed keeping in mind hamstring anatomy and function, injury mechanism, etc in order to target the muscle and location we need to treat[24-26]. It is also important to design the exercises focusing not only on contraction type and load; ROM, uni-bilateral exercises in open-closed kinetic chain, hip or knee dominant and multi-joint movements exercise, length of the movement, etc[27-29] need to be taken into account.




Regardless of the severity of the injury, progression between phases is based on achieving clear criterion[30], as previously illustrated[16] (Table 5.)

| EXERCISE DESIGN CRITERIA | | Acute Phase | Sub-acute phase | Functional Phase |
|---|---|---|---|---|
| | **Proprioception** | On a stable surface and progress to light instability (soft mat, dynadisk or similar.)<br>Knee flexion, start 0° and progress until 30°.<br>Static movement and progress to low unstable dynamic. | Increase instability (bosu, balance board, rocker board or similar)<br>Knee flexion, progress to 45°<br>Moderate reactive/strength movement.<br>Active and wide movements. | Unstable surface.<br>Knee flexion progress to 90°.<br>Intense strength and reactive movements. |
| | **Core** | Static exercises on stable surface in frontal, sagittal and transverse planes. | Dynamic exercises in frontal, sagittal and transverse planes from stable surface and progress to one unstable point; unstable elements progressing in instability (soft mat to fitball.) | Dynamic exercises on two unstable points.<br>Exercises in standing position reproducing functional movements (acceleration, deceleration, and dynamic stabilization.) |
| | **Flexibility and ROM** | Stretch with ESH ≤ 45, avoiding pain. | Stretch with ESH ≤ 70, avoiding pain. | No limit. |
| | **Strength and Power** | ESH ≤ 45, avoiding pain.<br>Isolated knee flexion or hip extension exercises, progress to combine both actions.<br>When starting CKC | ESH ≤ 70 avoiding pain.<br>In the corresponding ESH, progress in analytic movements length, velocity and load to the maximum effort; and | No limit.<br>Progress in length, joint velocity, load and complexity.<br>Horizontal strength |

| | | | | |
|---|---|---|---|---|
| | | exercises, first unipodal and progress to bipodal. In the corresponding ESH star with ISOM, progress to CONC and ECC and progress in muscle length avoiding pain or discomfort. | increase combine movement demands. OKC and CKCuni and bipodal exercises. | application exercises. |
| | **Neuromuscular and fitness** | ESH ≤ 45, avoiding pain. Start on a soft surface and progress to hard (to reduce eccentric contraction.) Start walking on treadmill and progress until V max ≤ 8 km/h, 5% slope to decrease ESH. | ESH ≤ 70 avoiding pain. Start on a soft surface and progress to hard. Run on treadmill, progress until 70% of athletes maximal speed, 3 % slope to decrease ESH. | No limit. On hard surface. Progress until maximal speed, start on flat and progress to negative slope. |

*Table 5: CKC: Close Kinetic Chain, OKC: Open Kinetic Chain, ISOM: Isometric, CONC: Concentric, ECC: Eccentric, ROM: Range of Motion; ESH (Elongation Stress on Hamstrings.)*

### 6.3. P-Rice

Immediately after the injury, compression[31], ice[7] and non-painful movements are encouraged[3; 15]. As soon as a normal gait (pain free) and a normal posture are achieved[32], the rehabilitation protocol has to be started.

### 6.4. Elongation Stress on Hamstrings

The concept of Elongation Stress on Hamstrings (ESH) has recently been introduced and aims to assess hamstring elongation. This is achieved by subtracting the knee flexion angle from the hip flexion angle[33]. The more positive the ESH is, the more

stress on hamstrings, and the opposite[27]. Therefore, we can use the ESH as a criterion to objectively monitor hamstring stretch progression during

## 6.5. Strength

The load for an exercise is a key point in a training program, and as muscle injury rehabilitation is a training program, if loads are not appropriated correctly, we will not be able to achieve our goals.

Hamstrings part torque (PT) angle shifts to longer muscle length after eccentric training, and as more elongate is the muscle during eccentric work higher is the shift in the PT angle[34]. This shift in hamstrings PT angle has been also reported after concentric exercises[35], but only when performed at long lengths[34]. Eccentric lengthening exercises has shown good results,[12] in HMIs rehabilitation; we purpose to perform all strength exercises at longer length possible in order to correct PT angle during the whole rehabilitation process.

Only general recommendations about the quantification and progression of strength exercises are found[1; 3]. Isometric, concentric and eccentric exercises will overlap during the protocol; with part of the strength work performed at long lengths[36; 37].

## 6.6. Health and Performance Evaluation

As described[30], RTP decisions should be taken based on specific criteria including assessment tests to confirm recovery; we applied this concept to the whole rehabilitation protocol.

When all functional phase criteria are achieved, strength, flexibility, fitness, etc will be normalised, but this does not mean that the athlete's performance is also recovered. Based on our experience with elite athletes, we recommend that the athlete has to accomplish a normal week training of at least four sessions without pain, discomfort or 'fear'[38]. During this week performance can be monitored for normality by GPS[39] and heart rate data; this performance control should be extended to competitions after RTP. Obviously, before starting normal training, there will be a

progression in exercise demands, physically and technically, to go from individual to team training.

| | Acute Phase | Subacute Phase | Functional Phase |
|---|---|---|---|
| GOALS AND TEST | No pain or discomfort during exercises.<br>To find and maintain a neutral spine in static position.<br>(laying, standing or siting) and during exercises. | No pain or discomfort during exercises.<br>Not tilting the pelvis or flattening the spine during exercises. | No pain or discomfort during exercises.<br>Correct spine control and strength transfer during exercises.<br>Integrate strength, neuromuscular and proprioceptive work. |
| | Isometric knee flexion strength, decubitoprono knee flexion 45° and hip 0° > 50% of previous data or uninjured leg (dynamometer or similar.)<br><br>Isometric hip extension strength, decubitosupino hip flexion 45° and knee 0° > 0% of previous data or uninjured leg (dynamometer or similar.) | Isometric knee flexion strength in decubitosupino knee flexion 25° and hip flexion 45°, less than 10% asymmetry from previous data<br><br>or uninjured leg (dynamometer or similar.)<br><br>Isometric hip extension strength in decubitosupino knee 0° and hip flexion 70°, less than 10% asymmetry from previous data<br><br>or uninjured leg (dynamometer or similar.) | Hip strength test in bipedestation knee 0° hip at maximum hip flexion achieved in contralateral leg, no asymmetry (dynamometer or similar.)<br><br>Isokinetic criteria:<br><br>We should avoid differences higher than 20% in absolute values.<br><br>Normal isokinetic ratios |
| | Full knee and hip isolated tested ROM | Less than 10° asymmetry in in AKET.<br>Less than 10° asymmetry in the Active Hip Flexion Test.<br>Modified Thomas test > 5 and symmetry below | No asymmetry in the Active Hip Flexion Test.<br><br>No asymmetry in AKET |

| | | | |
|---|---|---|---|
| | | horizontal. | |
| | | Deep squat test [21].<br>Single leg squat [22].<br>Runner pose test [22].<br>In-line lunge test [21]. | |

*Table 6: ROM: Range of Motion; AKET (Active Knee Extension Test)*

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# Chapter 7. CRITERIA RETURN TO PLAY AND SEQUENTIAL MANAGEMENT MODEL FOR MUSCULAR INJURY

*Coordinators: Ricard Pruna, Rodney Whiteley, Hans Tol, Erik Witvrouw*

## 7.1. Criteria In Order to Give the All-Clear to Play

When the injured player has completed the process of rehabilitation and regained his fitness, he will start training with the team. We aim to make a decision on when he can return to play with a low chance of reinjury. However, the risk of a reinjury in the same place is very high in muscular injuries, 14 -16% over the two months after being given the all-clear[1]. Unfortunately, we are unaware of evidence for the efficacy of the outlined strategies, although we recommend continuing with the best clinical experience in the absence of evidence, but we have some criteria we find very useful in making the best decision.

**Regarding objective criteria to allow return to sport**, we propose the following points:-

1. Clinical criteria: clinical and physical examination
2. Imaging criteria: ultrasound
3. Functional criteria:-
    - Test of strength (isokinetic study, lab muscle etc.)
    - General physical test
    - Specific physical test

Return to play is defined as "the decision–making process of returning an injured or ill athlete to competition" (modified from Ekstrand and Hallen 2014.)[2] Nowadays, we consider the training phase after an injury as the last part in the recovery and adaptation process towards complete healing. We believe that with such an approach we can reduce the probability of reinjury in muscle injuries.

**Factors to be considered when making decisions regarding to return to play:-**

1. Hamstrings are a heterogeneous group of muscles and for this reason it is necessary to create injured muscle sub-groups, resulting in different 'lay-off' and recovery times.

2. To ensure accurate diagnosis, primarily, we consider ultrasound and clinical diagnosis and, secondly, MRI information. Such an approach allows us to make the right decision in return to play.

3. Return to play in the near future will be individualised based not only on type and location of injury, but also on player position in the field and individual anatomical features.

4. Athletes have to be seen as 'healthy' individuals after they have had an injury. This point of view includes the fact that they have to be able to perform high workloads and compete at the highest level. Moreover, they have to present minimum probabilities of re-injury.

**According to these considerations, we postulate the following criteria which allow the player an appropriate return to play regarding muscle injuries:-**

1. Regarding the type and site of injury, it is mandatory to follow the biological time of progression.

2. Lack of clinical symptoms, and ultrasound static and dynamic test demonstrating good quality tissue healing.

3. High explosive eccentric strength must be demonstrated in a sport-specific and injury-relevant manner. It is suggested, for example, that the Askling H-Test would be

appropriate in a case of a stretch-type injury, whereas symptom-free high speed running could be appropriate for a sprint-type injury.

4. Work with core[3] and proprioception[4; 5] during recovery until relevant objective abilities are achieved. Typically this is at least 70% of the rehabilitation time.

5. GPS[6] assessment: normality in step balance; normalized, symptom-free sport-specific parameters and individualized speed peaks, ideally derived from existing pre-injury match data. For example, in football, running > 21km/h without symptomatology; accelerations, most of them into 3-4 $m/s^2$ and total tolerance to braking/deceleration.

6. The player should ideally participate in at least six normal training sessions with the team (typically three days comprising two training cycles) and GPS parameters must be recorded and compared favourably with pre-injury data.

7. Where the primary aim is to prevent re-injury, the most important criteria we have to consider are the five initial matches as part of the recovery process, where players progressively acquire and demonstrate the performance needed to return to play. For example, in football we suggest, depending on the match calendar and times, and staff, when a player returns to play will be decided like this: 20', 35', 45', 65' and 90' respectively, between the first and fifth match. In practice, this decision will be modified through appropriate weighing up of the risks of early return with the benefit of delayed gradual resumption of sport.

## 7.2. <u>Sequential Management Model of the Treatment of Muscular Injuries</u>

In this section we present our model of the sequential treatment of muscular injuries. This model is very important in understanding how different professionals are progressively included in the recovery of each muscular injury.

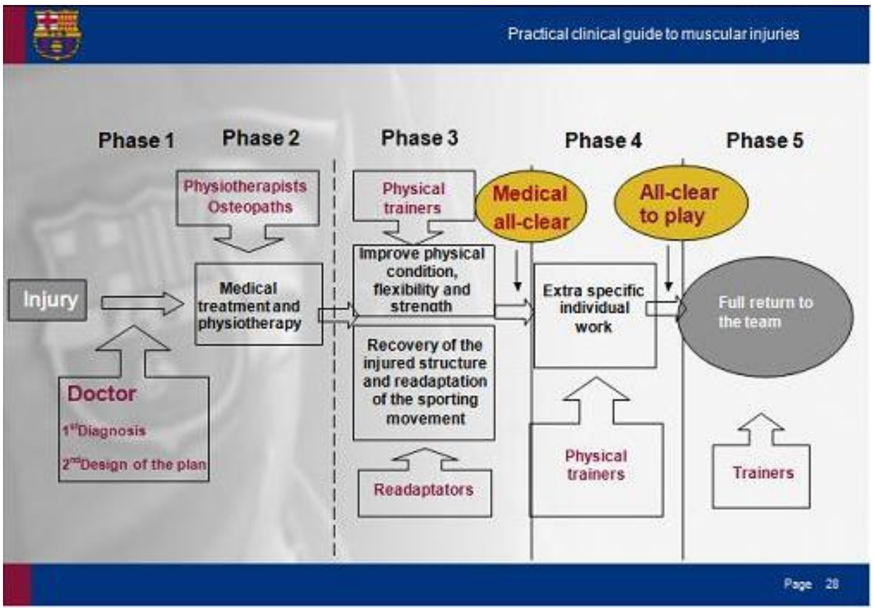
To optimise management, it is important that several members of the multidisciplinary team are involved in the acute examination and subsequent care planning. Equally important is that these members are equipped with the appropriate tools to perform these tasks. Ensuring this allows clear communication of roles and expected milestones for all those involved in the athlete's care.

Normally, the team doctor will be the principal manager and coordinate the other professionals such as physiotherapists, physical fitness trainers and rehabilitation trainers. These rehabilitation professionals are very common in professional football teams which have specialised in optimising the transfer of players "from the stretcher to the pitch", so the physical fitness trainers are able to re-establish the athlete's physical conditioning and sports skills with maximum safety.

Initially, the multidisciplinary team agrees to carry out a recovery program taking into account the basic protocols described previously, usually with a series of assessment checks and a possible date for the medical all-clear and the all-clear to play (see below.)

The protocol must always be personalised, and during rehabilitation care must be taken to ensure that the objectives of each phase have been achieved. An important ancillary benefit of this approach is that this well-coordinated athlete-centred approach maximises the player's perception of their care.

We understand that the concepts of medical all-clear and all-clear to play are readily perceptible, but in reality they are often confused. Normally, when we give the medical all-clear we also give the all-clear to play, in which the player is now working with the group performing all duties. He, therefore, trains for a few days, and if all goes well, he is fit again to play in matches.



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# Chapter 8. PREVENTION OF MUSCLE INJURIES

*Coordinators: Gil Rodas, Xavier Yanguas, Erik Witvrouw, Adam Weir*

## 8.1. Introduction

Recent years have seen a qualitative step forward in the field of sports injury prevention by incorporating scientific methods, with the objective of evaluating if the different strategies being used to reduce the incidence of injury are effective or not.
31% of injuries involved muscles in professional football players[1], and trying to reduce their incidence is an important goal in sports medicine. To establish prevention programs, it is important to identify risk factors associated with the occurrence of injury[2]. According to Hägglund et al[3], some intrinsic risk factors identified for lower limb muscle injury in professional footballers include previous injury, older age, poor flexibility and decreased muscle strength or strength imbalances; therefore, extrinsic factors like fatigue and match play factors (type of match, match location – home or away – and match result) may influence general injury rates.
It is possible to imagine infinite numbers of scenarios based on the combination of intrinsic and extrinsic risk factors. However, in order to prevent injuries, we must identify, target and attempt to ameliorate the effects of modifiable risk factors through the introduction of appropriate and timely injury prevention strategies[4].
Prevention plans in sports injury have been proposed using different kinds of stretching activities, eccentric strength training, proprioception exercises, core stability and combinations of these, and most studies have focused only on one particular intervention[5]:

### 8.1.1. Stretching

Improved flexibility has been proposed as a strategy to reduce the number of muscle injuries, but the results of these studies are still contradictory[6-8].

### 8.1.2. Eccentric Training

Many studies show that eccentric strength training reduces hamstring injury incidence in heterogeneous populations of football players[9-14]. Similar kinds of eccentric protocols have also been proposed for preventing quadriceps injuries, and a gradual increase in the volume of kicking actions in footballers in critical periods to help to reduce the rate of injury[3]. Hip adduction training with elastic bands increases the eccentric strength of adductor muscles among footballers, and may be a promising approach towards prevention[15]. The optimal intensity of eccentric training programs is not yet clear[16]. Whereas some authors claim that intensity should be high to provide the stimulus necessary to produce further adaptations, others have found that the protective effect of eccentric training may be observed even using low intensity. For us, it is a major challenge to know what the optimum stimulus in eccentric training is to prevent muscle injuries.

### 8.1.3. Proprioception

Proprioception training to prevent injuries has been used as a part of a plan to reduce all kind of injuries[17; 18]. In the Kraemer study[19] on balance training and hamstring injuries, we observed that football-specific balance training (protective balancing) reduced non-contact hamstring injuries and also patellar and Achilles tendinopathy. A dose-effect relationship between duration of balance training and incidence of injury is evident. At the same time, the difficulty and execution speed have to be higher each time for completing and defining the ability of neuromuscular control, and optimizing the specific movement during the proprioceptive training.

### 8.1.4. Core Stability

In a study of Australian football players[20], it was found that many of the hamstring injuries occurred in trunk flexion during running, in the typical position assumed during shooting and accelerating. Motor control of the lumbar spine and pelvis is essential in the preparation and execution of the different sports movements. Including core exercises in training sessions may also decrease the load in rectus femoris (quadriceps) and reduce the risk of injury[16]. Core stability is useful to prevent groin injuries and adductor-related injuries[21; 22].

### 8.1.5. Multi-Intervention

Stretching seems to have no beneficial effect, whereas multiple exposure programs with proprioception and strength training showed a trend towards increasing effect[5]. Multi-component injury prevention training programs have been effective for reducing the number of muscle injuries[23], and these kinds of preventive strategies (combination of stretching, strength, proprioception and core stability) has been developed to reduce muscle injury incidence. Concerning the effects of multi-intervention training programs, it remains unclear whether and to what extent the various training components may have contributed to the observed reduction in injury risk[24].

### 8.1.6. Other Interventions

Other interventions such as **Agility and Coordination Training** are beneficial for injury prevention as categories for training during the season with our athletes and can give us more dynamic components and specific movements of the sport we are focused on. A successful example of a combination of preventive strategies is the FIFA 11+ program. It includes core stability, balance, dynamic stabilisation and eccentric hamstring strength to try to prevent ankle and knee sprains, hamstrings and groin strains. It can be completed in 10-15 minutes and requires no equipment other than a ball. Four years after the launch of the program, teams that includes "The 11" as a part of their warm-up had 11.5% fewer match injuries and 25.3% fewer training injuries than teams that warmed up as usual[25]. This program, developed initially for football, has been used successfully in other sports[26].

## 8.2. Primary and secondary prevention programs

The aim of primary prevention is to avoid muscle injury before it happens, and it is understood as a part of general football training included for all players. In case of identification of an intrinsic risk factor in one particular player, he has to follow a specific preventative program. Secondary prevention consists of avoiding muscle injury when the player has suffered a previous injury. This is a common risk factor in hamstring, quadriceps, adductor and calf, and the most important risk factor for a new injury[3]. Players who have been injured need to develop an individual, personalised program. Based on the studies published to date and taking into account our experience at the club, we propose a protocol for the prevention of the most common muscle injuries in football.

### 8.2.1. FC Barcelona Primary Prevention Program

With the Primary Prevention Program at FC Barcelona, we have developed different levels of specificity based on the section above.

In the First Level, we have **Indoor Prevention** done in the gym for all players where they train with a *quad prevention program* (specific exercises depending of the training period and type of week) and also a *player individual strength program* (from the personal power input data and positional requirements of the game.)

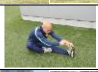
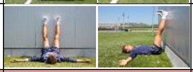
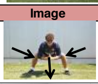
The Second Level is the **Daily Prevention Warm Up** on the field for all players where they start every training session with different activities and exercises that help us to achieve the prevention objectives. We have established four different categories for days before the game.

The Third Level is **Multi-Station Prevention Circuits** on the pitch where we mix football and prevention content for all players during the session to provide variability and specificity during training. To organise and with the objective of changing training structures and parameters every week, we have some examples (see below.)

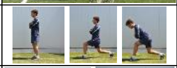
The Fourth Level in the prevention program are the on pitch **Football Circuit Drills** where all players use patterns of play drills for training with different elements of prevention content.

| LEVEL | PROGRAM | FREQUENCY | CATEGORIES | EXERCISES |
|---|---|---|---|---|
| 1. Indoor Prevention | Squad Prevention Program | 1 p week | **St**retching<br>**ST**rength | St 1<br>STq1, STq2 |
| | Player Individual Strength Program | 2 p week | | |
| 2. Daily Prevention Warm Up | Eccentric Training | 1 p week | **St**retching<br>**ST**rength<br>**PR**oprioception<br>**C**ore**S**tability<br>**AG**ility | St2, St3, St4<br>STh1, STh3<br>PR2<br>CS1, CS2, CS3<br>AG 2 |
| | Proprioception | 1 p week | | |
| | Agility & Coordination | 1 p week | | |
| | Speed Reaction | 1 p week | | |
| 3. Multi-Station Prevention Circuits | Multi-Station Circuit Not Ball | 1-2 week | **St**retching<br>**ST**rength<br>**PR**oprioception<br>**C**ore**S**tability<br>**A**gility<br>**M**ulti-<br>**I**ntervention | St2,<br>STh1, STh2,STq3<br>PR2, PR3<br>CS1,CS2,CS3<br>AG 1<br>MI 1, MI 2, MI 3 |
| | Multi-Station Circuit with Boxes | | | |
| | Multi-Station Circuit with Passing Drills | | | |
| | Multi-Station Circuit with Possession Games | | | |
| 4. Football Circuit D rills | Football Specific Strength Circuits | 1-2 week | **ST**rength<br>**PR**oprioception<br>**AG**ility | STh1, STq3<br>PR 3<br>AG 1 |

## Stretching — Primary Prevention

| Hamstrings | Image | Code | Description | minimum stimulus series | minimum stimulus repet./time | maximum stimulus series | maximum stimulus repet./time | frequency | When |
|---|---|---|---|---|---|---|---|---|---|
| Knee hiperextension with pelvic anterversion |  | St1 | Standing with flexion of the trunk and pelvis in anteversion perform knee extension | 1 | 3 | 1 | 5 | every day | Pre-trainning |
| Passive Stretching |  | St2 | Sitting with legs stretched forward trunk tilt | 1 | 15"-20" | 2 | 15"-20" | Minimum 3 times a week | Post-training |
| Active hamstring stretch with musculador belt. |  | St3 | Standing with belt over knees; We drop to flexion and perceive posterior stretching | 3 | 4 to 8 | 3 | 4-8 (with 3kg) | 1x7 (1 competition)/10 days( 2 competitions) | All: half cycle or after match |
| Stretching back chain (SGA). |  | St4 | Chain stretching; Supine with legs straight in abduction on the wall. | 1 | 3'-4' | | | 1x 7/10 days | All: half cycle or after match |
| **Quadriceps** | **Image** | **Code** | **Description** | **series** | **repet./time** | **series** | **repet./time** | **frequency** | **When** |
| Passive Stretching |  | St5 | Standing on one leg to perform a forced flexion of the knee | 1 | 15"-20" | 2 | 15"-20" | Minimum 3 times a week | Pre/Post-training |
| **Adductors** | **Image** | **Code** | **Description** | **series** | **repet./time** | **series** | **repet./time** | **frequency** | **When** |
| Active tension stretch's add's |  | St6 | Standing with trunk flexion and hips at Abd, to do tension with elbows. | 1 | 4" | | | every day | Pre-trainning |
| Passive Stretching |  | St7 | kneeling, knees apart and moving the weight back / On one knee separating the opposite leg | 1 | 15"-20" | 2 | 15"-20" | Minimum 3 times a week | Pre/Post-training |
| Stretching back chain (SGA). |  | St8 | Chain stretching; Supine with legs straight in abduction on the wall. | 1 | 3'-4' | | | 1x7 (1 competition)/10 days( 2 competitions) | All: half cycle or after match |
| **Calf** | **Image** | **Code** | **Description** | **series** | **repet./time** | **series** | **repet./time** | **frequency** | **When** |
| Passive Stretching |  | St9 | Position your body against a wall as showw with one food behind / the same with knee flexion | 1 | 15"-20" | 2 | 15"-20" | Minimum 3 times a week | Pre/Post-training |

## Strength Training — Primary Prevention

| strength training of the hamstrings | Image | Code | Description | minimum stimulus weight | minimum stimulus Ser/Repet | maximum stimulus weight | maximum stimulus Ser/Repet | frequency | When |
|---|---|---|---|---|---|---|---|---|---|
| Musculador belt |  | STh1 | Eccentric working with variants in dop: drop with rotation, different angles of flexion.. | body weight or body weight with 3kg | 3x4 | body weight or body weight with 3kg | 3x8 | 1x7 (1 competition)/10 days( 2 competitions) | Before or afther 48 hours to match |
| Splits with body flexion |  | STh2 | Work hamstring | body weight | 4 repetitions | body weight | 8 repetitions | once or twice a week | Alternate days , never before or afther to match |
| Angel |  | STh3 | Work hamstring | body weight | 4 repetitions | body weight | 8 repetitions | once or twice a week | Alternate days , never before or afther to match |

## Strength Training — Primary Prevention

| strength training of the quadriceps | Image | Code | Description | minimum stimulus weight | minimum stimulus Ser/Repet | maximum stimulus weight | maximum stimulus Ser/Repet | frequency | When |
|---|---|---|---|---|---|---|---|---|---|
| Squat Multifunction |  | STq1 | Squat technique working | according to the results of the test power | 3x8 | according to the results of the test power | 3x10 | once or twice a week | Alternate days , never before or afther to match |
| Musculador belt |  | STq2 | Eccentric working with variants in dop: drop with rotation, different angles of flexion.. | body weight or body weight with 3kg | 3x4 | body weight | 3x8 | 1x7 (1 competition)/10 days( 2 competitions) | Before or afther 48 hours to match |

## Primary Prevention

**Multi intervention**

| | | | | minimum stimulus | | maximum stimulus | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Multi intervention** | **Image** | **Code** | **Description** | **series** | **repeticions/temps** | **series** | **repetitions/time** | **frequency** | **When** |
| Superman |  | MI1 | Make extension of arms and legs on quadrupeds. Try to enhance antagonist muscles and improve coordination. | 1 | for 30" dynamically | | | once a week | At the end of the week, usually 3 days before match. |
| Hip Abduction on side |  | MI2 | Make leg abducction with extension knee on side.Try to enhance antagonist muscles and inhibit adductors. | 1 | for 30" dynamically | | | once a week | At the end of the week, usually 3 days before match. |
| Dog |  | MI3 | Make leg abducction with flexion knee on quadrupeds. Try to enhance antagonist muscles and inhibit adductors. | 1 | for 30" dynamically | | | once a week | At the end of the week, usually 3 days before match. |

## Primary Prevention

**Core stability**

| | | | | minimum stimulus | | maximum stimulus | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Core stability** | **Image** | **Code** | **Description** | **series** | **repeticions/temps** | **series** | **repetitions/time** | **frequency** | **When** |
| Frontal plank |  | CS1 | Making front bridge maintaining isometric CORE contraction; Add variants like instabilities, associated actions, reduction supports .. | 1 | 30" | | | once a week | At the end of the week, usually 3 days before match. |
| Side plank |  | CS2 | Making side bridge maintaining isometric CORE contraction; Add variants like instabilities, associated actions, reduction supports .. | 1 | 30" | | | once a week | At the end of the week, usually 3 days before match. |
| Back bridge |  | CS3 | Activate CORE on supine. Adding muscle synergies like activation muscles glúteo raising pelvic or adductors contraction. | 1 | for 30" dynamically | | | once a week | At the end of the week, usually 3 days before match. |

## Primary Prevention

**Proprioception**

| | | | | minimum stimulus | | maximum stimulus | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Proprioception** | **Image** | **Code** | **Description** | **series** | **repeticions/temps** | **series** | **repetitions/time** | **frequency** | **When** |
| Leg stance on instability |  | Pr1 | Standing with support monopodal on Bossu. Add variants like playing sports gesture .. Proprioceptive reeducation joints of lower limbs. | 1 | during 30", alternating leg each 5" | same | same | once a week | At the end of the week, usually 3 days before match. |
| Support knee on instability |  | Pr2 | Sitting on Bossu. Proprioceptive reeducation of lumbar-pelvic region. | 1 | 30" | | | once every 15 days | At the end of the week, usually 3 days before match. |
| Lateral skipping on instability |  | Pr3 | Perform lateral skipping on Bossu . Proprioceptive reeducation through dynamic specific gesture. | 1 | 30" | | | once every 15 days | At the end of the week, usually 3 days before match. |

## Primary Prevention

**Agility**

| | | | | minimum stimulus | | maximum stimulus | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Neuromuscular** | **Image** | **Code** | **Description** | **series** | **repeticions/temps** | **series** | **repetitions/time** | **frequency** | **When** |
| Coordination on scale + ball pass |  | AG1 | Skipping inside scale; Add complementary movements. | 1 | 30" | | | twice a week | At the end of the week, usually 3 days and one day before match. |
| Agility Circuit |  | AG2 | Circuits with different tasks of agility | 1 | as fast as possible | | | twice a week | warm up |

### 8.2.2. Secondary Prevention Hamstring

Seated Eccentric Knee Flexor Stretch (Seated Straight-Leg Raise)

The athlete sits on a treatment table with knees bent at a 90° angle and pelvis tilted forward. Grasping the athlete's heel with one hand and placing his other hand on the distal part of the athlete's thigh as a counter-hold, the exercise partner progressively extends the athlete's knee towards full extension whilst the athlete resists. After completing with one leg, repeat with the other leg.

In a second series, the trunk can be flexed further so as to stretch the posterior muscle chain to a greater degree. It is important for the pelvic forward tilt to be maintained at all times.

Eccentric Knee Flexor Extension with Inertial Technology (Yo-Yo Knee Extension)

Starting from the prone position, the athlete is assisted while bending both knees at the same time to then offer resistance to the inertial knee extension movement with one leg only. After doing the repetitions with one leg, repeat the exercise with the other leg.




Eccentric knee flexor stretch, final swing phase

The individual positions himself kneeling on one leg, leaving his other foot resting on a skateboard and positioned forward with the knee slightly bent. The assistant places his hands on the upper part of the athlete's heel to pull on the heel, bringing the knee progressively into extension whilst the athlete resists this movement. After doing the repetitions with one leg, repeat the exercise with the other leg.


Eccentric Hip Extensor Stretch with Inertial Technology

From supine position with one leg at maximum pelvic tilt, the athlete makes a hip extension movement, subsequently stopping the inertial movement toward the hip flexion with the extensor muscles.

This exercise can be done with assistance keeping the supporting leg in a fixed position preventing compensatory motion.

### 8.2.3. Secondary Prevention: Rectus Femoris Quadriceps

Seated Eccentric Knee Extensor Stretch

The athlete lies down on a treatment table with his knees off the table. He leaves one of his knees fully extended. With one hand resting on the athlete's lower shin, the exercise partner progressively bends the athlete's leg towards 90° flexion whilst the athlete offers resistance. After doing this exercise with one leg, repeat with the other leg.

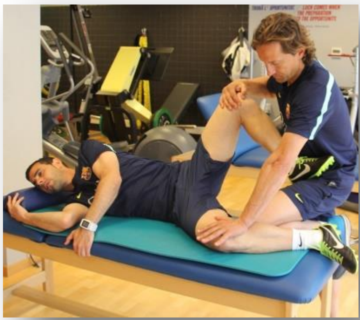
Eccentric Hip flexor and Knee Extensor Stretch (Anterior Chain Stretch)

The individual positions himself on his knees with trunk upright, and legs and ankles together. The anterior side of his feet remains in contact with the floor. Occipital, scapular and sacral areas are aligned using a stick. The athlete bends backward as far as possible without arching his spine, maintaining the occipital, scapular and sacral alignment. Once this position is reached, it is held in isometric tension.

### 8.2.4. Secondary Prevention: Adductors

Eccentric Table Exercises for the Adductors

*a)* The athlete lies down on his side with hips and knees slightly bent. Placing his hands on the insides of knees, the exercise partner makes an abduction movement by pulling on the knee closest to him whilst the individual resists the movement. After completing with one leg, repeat with the other leg. *(For ease of movement, the athlete's foot can be located in the area of the anterosuperior iliac spine to facilitate the hinge movement of the leg being exercised.)*



*b)* The individual lying on his back with hip and knees flexed at approximately a 45° angle, legs together, the exercise partner places his hands on the inside of the knees making an abduction movement whilst the athlete resists the movement.

Eccentric Side Lunge Stretch

The individual, standing with a towel under one foot, lunges sideways by sliding the leg that has the towel under it over the floor as far as possible. At this point, the individual brings his static leg up to the towel leg, then starts this same movement again. After completing this exercise with one leg, repeat with the other leg.

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