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Update Article

Hamstring injuries: update article☆

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ABSTRACT

Hamstring (HS) muscle injuries are the most common injury in sports. They are correlated to long rehabilitations and have a great tendency to recur. The HS consist of the long head of the biceps femoris, semitendinosus, and semimembranosus. The patient's clinical presentation depends on the characteristics of the lesion, which may vary from strain to avulsions of the proximal insertion. The most recognized risk factor is a previous injury. Magnetic resonance imaging is the method of choice for the injury diagnosis and classification. Many classification systems have been proposed; the current classifications aim to describe the injury and correlate it to the prognosis. The treatment is conservative, with the use of anti-inflammatory drugs in the acute phase followed by a muscle rehabilitation program. Proximal avulsions have shown better results with surgical repair. When the patient is pain free, shows recovery of strength and muscle flexibility, and can perform the sport's movements, he/she is able to return to play. Prevention programs based on eccentric strengthening of the muscles have been indicated both to prevent the initial injury as well as preventing recurrence.

Lesões dos isquiotibiais: artigo de atualização

Palavras-chave:
Musculoesquelético/lesões
Traumatismo em atletas
Retorno ao esporte

RESUMO

As lesões dos músculos isquiotibiais (IT) são as mais comuns do esporte e estão correlacionadas com um longo tempo de reabilitação e apresentam uma grande tendência de recidiva. Os IT são compostos pela cabeça longa do bíceps femoral, semitendíneo e semimembranoso. A apresentação clínica do paciente depende das características da lesão, que podem variar desde um estiramento até avulsões da inserção proximal. O fator de risco mais reconhecido é a lesão prévia. A ressonância magnética é o exame de escolha para

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o diagnóstico e classificação da lesão. Muitos sistemas de classificação têm sido propostos; os mais atuais objetivam descrever a lesão e correlacioná-la com o seu prognóstico. O tratamento das lesões é conservador, com o uso de medicações anti-inflamatórias na fase aguda, seguido do programa de reabilitação. As lesões por avulsão proximal têm apresentado melhores resultados com o reparo cirúrgico. Quando o paciente está sem dor, apresenta recuperação da força e do alongamento muscular e consegue fazer os movimentos do esporte, está apto para retornar à atividade física. Programas de prevenção, baseados no fortalecimento excêntrico da musculatura, têm sido indicados tanto para evitar a lesão inicial como a recidiva.

Introduction

Historically, hamstring (HS) injuries are described as frustrating for athletes as they are correlated with a long rehabilitation time; they have a tendency to recur and return to sport is unpredictable.[1,2]

Not all injuries are similar. They range from mild muscle damage to complete tear of muscle fibers. Furthermore, as with the characteristics of the lesions, rehabilitation time is also variable.[3,4]

HS injuries are the most common in sports. They are the most frequently reported injuries in soccer, accounting for 37% of the muscular injuries observed in that sport, which is the most popular in the world, with over 275 million practitioners.[5,6]

Injury incidence is estimated at 3–4.1/1000 h of competition and 0.4–0.5/1000 h of training. A mean increase of 4% per year has been reported; the rate of injuries occurring in training sessions has increased more than that of those occurring during competitive activities.[7,8]

After the injury, runners need 16 weeks, on average, to return to sport without restrictions, while dancers can take up to 50 weeks. In professional soccer, the athlete remains, on average, 14 days away from competitive activities. HS injury is the main cause of injury absence.[2,7,9,10]

In addition to soccer, injuries are common in sports such as football, Australian football, track and field, and water skiing. The most common trauma mechanism is indirect trauma; injuries tend to occur during non-contact activities, and running is the primary activity. Sports that require ballistic movements of the lower limb, such as skiing, dancing, and skating, are associated with proximal avulsion of the HS tendons.[3,11]

The myotendinous junction (MTJ) is the most vulnerable part of the muscle, tendon, and bone junction; the more proximal the injury, the longer the return to sport activity.[11,12]

Of all muscle injuries, those of HS have one of the highest recurrence rates, which is estimated to range between 12% and 33%. Recurrence is the most common complication of HS lesions.[2,6,7]

Anatomy

The HS muscle group consists of the semitendinosus (ST), semimembranosus (SM), and the long head of the biceps femoris (LHBF). These three muscles originate in the ischial tuberosity (IT) as a common tendon, passing through the hip and knee joints; they are biarticular muscles and are innervated by the tibial portion of the sciatic nerve. In the posterior region of the thigh, the short head of the biceps femoris (SHBF), which originates in the posterolateral region of the femur in the linea aspera and in the supracondylar ridge, is added to the HS group. Thus, the SHBF is a monoarticular muscle innervated by the common fibular nerve (Fig. 1).[2,3,5]

In an anatomical study of the HS, Van der Made et al.[11] described that the HS is divided into two portions, upper and lower. The upper portion is subdivided into two facets. The lateral facet is the origin of SM, whereas the medial facet is the origin of the ST and LHBF, which also has origins in the sacrotuberal ligament.[2]

The ST and SM extend to the posteromedial region of the thigh, with insertions in the pes anserinus and the posteromedial corner of the knee and tibia, respectively. In an agonistic pattern, these muscles act in knee flexion and medial rotation, as well as in hip extension; laterally, the LHBF acts in an isolated manner proximally, extending the hip and posterior stabilizing the pelvis. The distal tendon that is inserted in the head of the fibula is formed distally, after the addition of the SHBF fibers, which flex the knee with the thigh in extension.[1–3,5]

To date, no hypothesis has been able to correlate injury patterns with the anatomical structure based solely on the length of the muscle, tendon, or MTJ. It is thought that the muscular architecture, due to the proximal and distal orientations of the tendons, leads to a resulting force that is misaligned with the muscular fibers, predisposing to injury. A tendinous structure in the ST divides it into two parts. This raphe may play a role in protecting against gross injuries of this muscle.[11]

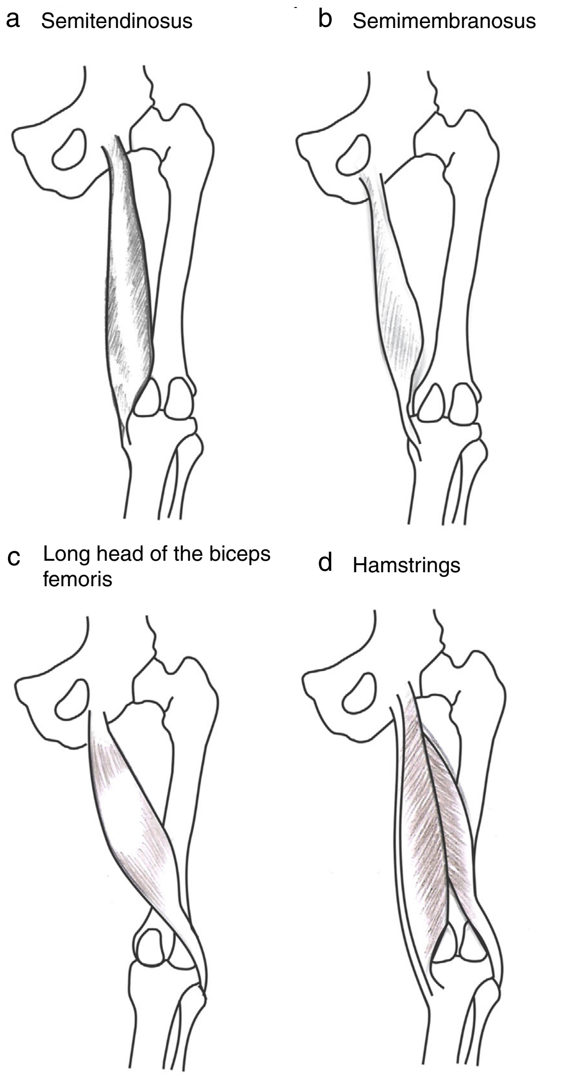

Fig. 1 – Schematic drawing of the hamstrings.

Clinical picture

Clinical presentation of the patient depends on the characteristics of the lesion, which can range from stretching of the muscle fibers to tendon rupture. Nonetheless, regardless of strains or ruptures, proximal lesions are much more common than distal lesions. The LHBF is the most frequently injured muscle and, despite the lack of consensus, the SM is considered to be the second most affected muscle.[2,5,11]

Askling et al.[13] proposed two types of acute injuries. First type occurs during sprinting, and affects the LHBF. The second type is associated with excessive HS stretching in movements such as kicking in soccer or tackling in football, and most often affects the SM.

Eccentric contraction is the muscular action in which the fibers are elongated as a result of an external force, and at the same time contract to decelerate the movement. In indirect trauma, the maximum eccentric contraction period appears to present the greatest risk for muscle injury; the most common injury site is the MTJ, since it bears the greatest eccentric loads. Direct trauma is another mechanism of injury, especially in sports with body contact. It is less frequent and is mainly associated with lesions of the muscular bellies. In the HS, delayed onset muscle soreness is induced by eccentric contraction, representing another common sports-related condition.[2,3,7]

Proximal avulsion of the HS origin corresponds to 12% of these lesions. It is estimated that 9% of these are complete avulsions, which is considered to be the most serious. The typical mechanism of proximal avulsion is eccentric contraction of the HS, as a result of sudden hip hyperflexion, with the knee in extension. This movement is most commonly observed in water skiing.[2,3,7,14]

Clinically, patient presents with a sudden pain in the posterior region of the thigh. The report of an audible click and the inability to continue with physical activity is common. Antalgic gait develops to minimize mobilization of the involved muscle mass and decrease hip extension and knee flexion. In the acute phase, the most common clinical signs are hematoma or ecchymosis in the posterior region of the thigh, painful palpation of the IT region, and muscle weakness. Usually, hematoma volume is correlated with lesion severity, but its absence cannot be confused with a minor lesion, since this sign may be late even in the most severe lesions.[5,7]

HS strength can be tested through knee flexion and hip extension against resistance. A bilateral comparison is indicated to identify the alterations. The “taking off the shoe” clinical test is also described as a means of assessing the HS. The patient is asked to remove the shoe ipsilateral to the injury in the standing position, with the help of the contralateral foot. By leveraging the back of the foot on the contralateral limb, the patient will flex the knee and trigger pain or demonstrate the weakness of the affected muscles.[2,9]

In proximal avulsion, a local gap may be palpable, but sometimes it can be masked by the hematoma. Discomfort in sitting may be reported; palpation helps to identify the location and which muscles are injured. Complete rupture is defined as the rupture of the three HS tendons (BF, ST, and SM). The rope sign has been proposed to differentiate between partial and complete tendon avulsion. A positive test is characterized by the absence of palpable tension in the distal part of the HS with the patient in the prone position, with the knee flexed to 90°. Avulsion can also be evaluated in cases of knee flexion against resistance, when the avulsed muscle mass retracts distally.[2,5,9,15,16]

Neurological clinical examination should always be performed in case of HS injury. Due to local proximity, muscle injuries may be correlated with neurological lesions, which may manifest with paresthesia or motor alterations. In the chronic phases of the lesions, sciatica symptoms may arise.[5,7]

In the acute phase, the pain picture greatly impacts the clinical evaluation of the patient. After 48 h, the acute limitation of pain is expected to have decreased, and the result of the physical examination may be more relevant both for diagnosis and for prognosis. Therefore, specific evaluation is indicated within two days after the injury.[9]

Differential diagnoses range from HS apophysitis, piriformis syndrome, tendinopathies, and bursitis to radiculopathies. Therefore, clinical history, patient’s complaint, and physical examination are crucial for the correct diagnosis.[3]

Risk factors

Many studies have sought to identify the risk factors for HS injury. The ability to recognize the athletes with predisposition and the situations that can lead to injury is paramount for prevention, in order to avoid long periods of rehabilitation and injury leave.[17]

Among the risk factors, the specific characteristics of the muscles play an important role. HS muscle imbalance is defined by the difference in muscle strength when compared with the contralateral side, or an alteration in the ratio of HS strength to ipsilateral quadriceps strength. The risk of injury is higher when the strength deficit between the HS is >10–15%, or when the strength ratio between the HS and the quadriceps is <0.6. However, these values may vary according to each athlete and sport.[3]

The sporting motion is also a predisposing factor of injury. Athletes who anteriorly tilt the pelvis at the moment of acceleration during the stride increase the tension on the HS. Furthermore, iliopsoas shortening and imbalance of the abdominal and lumbar musculature may also promote pelvic anteversion, placing the HS at a mechanical disadvantage by increasing muscle tension at the end of the swing phase of the gait cycle.[2]

Extrinsic factors can also influence the probability of injury. Injuries are more common during competitions than training; short pre-seasons are also correlated with a greater chance of injury. Athletes who have to run due to their positions are at greater risk of injury. In soccer, injuries on the dominant side are more serious, as they are correlated with the kicking movement.[2,7,10,18]

Previous HS injury is the risk factor most commonly correlated with new lesions. Injury recurrence after returning to sport remains the main complication of this pathology. Recurrence is more common when the lesion involves the LHBF. Van Beijsterveldt et al.[17] conducted a systematic review of 11 prospective studies involving 1775 male soccer players with 334 HS injuries. These authors observed that prior HS lesion was significantly correlated with risk for a new lesion. HS injury recurrence rates are reported to range from 14% to 63% within two years after the initial injury.[3,4,7,19]

Pruna et al.[20] hypothesized that the genetic profile could explain why some elite soccer players are more predisposed to injuries than others, as well as the reason for the marked time variation in the rehabilitation of injuries.

Regarding proximal HS avulsions, complete ruptures tend to occur in patients with previous local tendinopathy.[3]

Imaging tests

Imaging tests confirm the diagnosis and provide information for therapeutic decision-making.

As a first modality, the radiographic study is indicated for ruling out HS avulsion fractures, especially in skeletally immature patients.[3]

Ultrasonography (US) has the advantage of being affordable and inexpensive; however, it is operator-dependent. The examination should be performed between the second and seventh days after the trauma; that injury can be detected through visualization of the hematoma and the discontinuity of the fibers. It is also possible to measure the length, width, depth, and cross-sectional area of the muscle injury. In proximal cases, this method has greater limitations to measure this lesion.[3,5,18]

Magnetic resonance imaging (MRI) is the modality of choice for identifying and describing lesions, especially those of proximal location. It precisely defines the site of injury, its severity and extension, the involved tendons, and the retraction of muscle mass.[3,5,21,22]

There is still no consensus on the optimal moment for MRI assessment. Some authors advocate that the test should be performed between 24 h and 48 h after trauma, while others advocate that this interval should be between 48 h and 72 h. The signs of the lesion are mainly recognized in T2-weighted images with fat suppression or in short-tau inversion recovery (STIR); they are more apparent from 24 h up to five days after trauma.[9]

Although MRI is the gold standard exam, 13% of HS lesions in professional soccer players may not be identified by MRI. The reason for this is still unknown. One hypothesis is that these are small lesions that are not detectable, another is that the symptoms may be caused by other pathologies, such as low back pain or neurological changes.[23]

For follow-up of the injuries, MRI is more sensitive than US. The images would be useful in more severe cases and in the assessment of progression and rehabilitation, aiding in the decision of return to sport in elite athletes. In 34–94% of cases, signs of HS injury are still visible after six weeks.[9]

Classification

Classification systems are useful for physicians, athletes, and their coaches, as they guide treatment and prognosis. A wide variety of classifications based on clinical signs and alterations in US and MRI imaging tests has been proposed. However, due to the complexity and heterogeneity of muscle injuries, there is still no widely accepted classification system.[9,24,25]

In clinical practice, a three-degree system is the most commonly used, classifying the injury as minor, moderate, or complete muscle tear. Variations correlated with imaging tests have also been described.[25,26]

Peetrons[27] grouped lesions into grades, according to the alterations observed in the US. Grade I includes lesions that do not present alteration in the muscular architecture, but have signs of edema around the muscle. Grade II includes partial ruptures, and Grade III injuries present complete muscle or tendon tear.

Recently, new classification systems have been developed; these systems aim to be more comprehensive and to standardize the terminology of muscle injury, as well as to provide each degree of injury with a prognosis, which does not occur in the three-degree classification.[24–28]

Table 1 proposes a classification system for muscle injury[26] based on MRI images. Injuries are graded from 0 to 4; in grades 1 to 4, an additional suffix describes the location of the lesion (a, for myofascial lesions; b, for musculotendinous lesions; and c, for intra-tendinous lesions).

Table 1 – British athletics muscle injury classification.

Grade	Description	MRI
Grade 0		
0a	Focal neuromuscular pain	Normal.
0b	Generalized muscle soreness after exercise	Normal or increased signal in one or more muscles.
Grade 1		
1a	Minor myofascial injury	Increased signal from the fascia involving <10% of the muscle belly, and craniocaudal length <5 cm.
1b	Minor myotendinous injury	Signal increase <10% of the transverse section of muscle in the myotendinous area and craniocaudal length <5 cm.
Grade 2		
2a	Moderate myofascial injury	Increased signal from the fascia extending to the muscle, lesion cross-sectional area of 10% and 50%, craniocaudal length >5 and <15 cm, structural fiber disruption <5 cm.
2b	Moderate myotendinous injury	Increased signal in the myotendinous region, lesion cross-sectional area ranging from 10% and 50%, craniocaudal length >5 and <15 cm, structural fiber disruption <5 cm.
2c	Moderate intratendinous injury	Increased signal in the tendon, with longitudinal length <5 cm and <50% of the cross-sectional area of the tendon is involved. No loss of tendon tension or discontinuity are observed.
Grade 3		
3a	Extensive myofascial injury	Increased signal from the fascia extending to the muscle, lesion cross-sectional area >50%, craniocaudal length >15 cm, structural fiber disruption > 5 cm.
3b	Extensive myotendinous injury	Increased signal with lesion cross-sectional area >50%, craniocaudal length >15 cm, and structural fiber disruption > 5 cm.
3c	Extensive intratendinous injury	Increased signal in the tendon, with longitudinal length >5 cm and >50% of the cross-sectional area of the tendon is involved. Loss of tendon tension may be observed, but there is no apparent discontinuity.
Grade 4		
4	Complete muscle injury	Complete muscle discontinuity with retraction.
4c	Complete tendon injury	Complete discontinuation of tendon with retraction.

Grade 0 injuries present no alteration on MRI. This grade represents focal neuromuscular pain and generalized muscle pain caused by exercise. Grade 1 injuries are minor muscle injuries in which the athlete experiences pain during or after the activity. Range of motion (ROM) is normal and the strength is preserved. In Grade 2 injuries, moderate muscle damage is observed. The athlete presents pain during the activity and must interrupt it. The ROM of the affected limb is limited due to pain, and muscle weakness is usually detected upon clinical examination. In Grade 3, muscle injuries are extensive. The athlete usually suffers an abrupt pain, and may fall. Even after 24 h, ROM is usually reduced and the pain picture persists. There is an obvious muscle contractility weakness. Finally, Grade 4 represents complete muscle or tendon tear. The athlete presents sudden pain and activity limitation. A palpable gap can be perceived. Normally, the contraction is less painful than that observed in Grade 3 injuries.[26]

The clinical application of the British Athletics Muscle Injury Classification was demonstrated by Pollock et al.[22] in a study that assessed 65 HS lesions in 44 track and field athletes. The higher the grade of the lesion, the longer the time of rehabilitation and the higher the rate of relapse. Cases with tendon involvement (type C) were more susceptible to relapse and had a longer rehabilitation time.

Table 2 distinguishes between two main groups of muscle injuries[28]: injury by direct or indirect trauma. Within the group of injuries due to indirect trauma, the classification brings the concept of functional and structural lesions. Functional muscle injuries present alterations without macroscopic evidence of fiber tear. These lesions have multifactorial causes and are grouped into subgroups that reflect their clinical origin, such as overload or neuromuscular disorders. Structural muscle injuries are those whose MRI study presents macroscopic evidence of fiber tear, *i.e.*, structural damage. They are usually located in the MTJ, as these areas have biomechanical weak points.

Ekstrand et al.[24] prospectively analyzed 31 professional men's soccer teams during the 2011/2012 season, in accordance with the Munich classification. A total of 393 thigh muscle injures were recorded; two-thirds of them were classified as structural and had a rehabilitation time (in which the athlete was unable to complete) that was significantly higher

Table 2 – Munich classification.

Type of injury		Definition	Symptoms	MRI
Direct		Contusion: blunt trauma from external factor, with intact muscle tissue		Hematoma
		Laceration: blunt trauma from an external factor with muscular rupture		Hematoma
Indirect	Functional	*Type 1: overload-related muscle disorder*		
		1A: fatigue-induced muscle disorder	Muscle stiffness	Negative
		1B: delayed onset muscle soreness	Acute inflammatory pain	Negative or isolated edema
		Type 2: muscle disorder of neuromuscular origin		
		2A: spine-related neuromuscular muscle disorder	Increased muscle tone due to neurological disorder	Negative or isolated edema
		2B: muscle-related neuromuscular muscle disorder	Increased muscle tone due to altered neuromuscular control	Negative or isolated edema
	Structural	*Type 3: Partial muscle tear*		
		3A: minor partial muscle tear: tear involving a small area of the maximal muscle diameter		Fiber rupture
		3B: moderate partial muscle tear: tear involving moderate area of maximum muscle diameter		Retraction and hematoma
		Type 4: (sub)total muscle tear with avulsion:		
		Involvement of the entire muscle diameter, muscle defect		Complete discontinuation of fibers

than that observed in functional injuries. Within structural lesions, significant differences were also observed in the subgroups (minor, moderate, and complete injury); the greater the severity, the longer the time to return to sport. In the present study, no significant differences were observed outcomes of anterior or posterior thigh muscle injuries.

Treatment

Most HS lesions are muscle strains or partial lesions at the MTJ level that can be conservatively managed and generally result in full recovery.[14]

In the initial phase, treatment aims to minimize intramuscular bleeding and control inflammatory response. Analgesia, rest, ice packs, muscle compression, and limb elevation are used. However, clinical evidence to support the use of these treatment modalities is still limited. The best treatment for HS injuries is yet to be identified.[2,3,7,29]

A greater emphasis on pain reduction in the first days after injury is necessary, because it reduces the neuromuscular inhibition associated with pain. Moreover, unnecessary immobilization should be avoided, as it leads to muscle atrophy. With early mobilization through stretching and strengthening exercises, a stable and functional healing is expected.[4,7]

The inflammatory reaction, triggered in response to injury, is responsible for the onset of tissue repair. However, as a result of the enzymes released after cell lesion, the process also causes tissue degradation, which, together with local ischemia resulting from trauma to the blood supply, increases the muscle injury by involving the adjacent tissue and increasing inflammatory symptoms, such as pain and edema. Anti-inflammatory medication is indicated to modulate the inflammatory response and to control pain, allowing early initiation of rehabilitation. Non-steroidal anti-inflammatory drugs are the most used, and are indicated until the first 48–72 h of the lesion, to avoid interfering with tissue repair. After this phase, analgesics are used for antalgic management.[2,3,7]

Corticosteroids can also be used for inflammation control, both orally and intramuscularly. Intralesion administration, which may be guided by US, is indicated when the acute condition does not present pain improvement and the patient has difficulty to perform the rehabilitation program. However, local use of corticosteroids may have deleterious effects on muscle tissue, because they act on collagen bonds and decrease tissue healing.[2,3,7]

Treatment of proximal avulsions

HS lesions due to proximal tendon avulsion may lead to significant sequelae, such as strength deficit and inability to return to sports practice at the pre-injury level. Surgical repair of the local anatomy is indicated to avoid such complications, especially in athletes or physically active patients. In most surgical techniques described, the repair is performed using anchors and non-absorbable suture.[5,11,14,30]

Hofmann et al.[15] assessed the outcome of conservative treatment for complete proximal avulsions of the HS. A total of 30% of the patients were unable to return to the pre-injury level of sports activity, and almost half of them regretted not having undergone surgical treatment.

Barnett et al.[14] reported that good-to-excellent results can be expected in most patients after surgical reinsertion of proximal avulsion of the HS. These authors also reported a high percentage of patients who returned to their pre-injury level; the vast majority of patients was satisfied with surgery and would opt for the same treatment again.

In general, conservative therapy is indicated for single-tendon acute proximal tendon avulsions or multiple tendon lesions with less than 2 cm of retraction. Asymptomatic chronic lesions, despite dislocation, are also treated conservatively.[3,5,16,21]

Surgical treatment is the best option for ischial apophysis avulsions in skeletally immature patients, avulsions with the HS bone fragment, and proximal avulsions of the entire HS complex.[16,21]

The surgery is also indicated for patients with active avulsions in one or two tendons and retraction greater than 2 cm. In recreational athletes or inactive patients, surgery is indicated only when the avulsion is symptomatic.[2,7,11]

Surgery may also be indicated in tendon injuries when avulsion is symptomatic, particularly in athletes or highly active patients. Theoretically, an LHBF avulsion may require surgical repair, since no other muscle acts as an agonist, unlike the ST and MS, which act synergistically.[5,7]

When the diagnosis of proximal avulsion is confirmed, the possibility of surgical treatment should be addressed as early as possible, in order to repair the lesion during the acute phase. The consensus indicates that reinsertion should ideally be performed within two weeks of injury. Early repair minimizes muscle atrophy and shortening, facilitates rehabilitation (by making it more predictable), and avoids surgical difficulties and complications, such as adhesions between the avulsed tissue and the sciatic nerve, which form around the end of the second week. In addition to sciatic nerve involvement, the posterior femoral cutaneous nerve and lower gluteal nerve can also be involved, causing dysesthesia and weakness of the hip extensors.[2,3,5,7,15,16,21]

Injuries that are not surgically treated may evolve with neuralgia and sciatica. Surgical repair is also indicated in these chronic cases and in lesions that, despite conservative treatment, persist with debilitating pain and weakness. However, it is worth emphasizing that the neurological symptoms may persist after the surgical procedure.[7,16,21]

Platelet-rich plasma

Myogeny is not restricted to prenatal development; it also occurs in muscle regeneration after injury. Several growth factors have been suggested as regulators of this process. Platelets are known for their role in hemostasis, but they also mediate tissue injury repair, due to their ability to release growth factors, which lead to the stimulation of angiogenesis (responsible for neovascularization) and increased metabolic activity, with tendon and muscle tissue proliferation.[31]

The indication for the use of platelet-rich plasma (PRP) is based on the concept that the growth factors released by platelets would increase the natural healing process, especially in tissues with low potential for cure; this claim is supported by many *in vitro* studies. Because of the potential to enhance the tissue repair process, PRP has been investigated as part of the therapeutic arsenal for many lesions, including those of the HS.[3,29,32]

Hamid et al.[29] studied 28 patients with acute HS injuries classified as partial ruptures. They were randomly allocated for treatment with autologous PRP combined with a rehabilitation program, or for rehabilitation program alone. The primary outcome of the study was the time to return to sports. The authors also assessed level of pain and interference of pain over time. That study demonstrated that a single injection of 3 mL of autologous PRP combined with a rehabilitation program was significantly more effective in reducing pain severity, allowing a shorter time to return to sport after an acute HS injury.

Rossi et al.[33] also described a study in which a single application of autologous PRP associated with a rehabilitation program was compared with rehabilitation program alone in partial HS lesions; these authors observed a significantly decrease in time to return to sport in the combined treatment. At two years of follow-up, no differences were observed between groups regarding recurrence rate.

In a study of 25 HS injuries in professional soccer players, Zanon et al.[32] demonstrated that the use of PRP was safe; the authors did not report a decrease in recovery time, but did show a smaller scar and improved tissue repair in the MRI control images.

Reurink et al., [34] in a randomized, multicenter, double-blinded study with 80 recreational athletes with HS lesions, did not observe statistically or clinically significant results to justify the use of PRP.

In addition to the isolated use of PRP, its associations have also been studied. In an animal model, Terada et al.[35] demonstrated that PRP combined with the use of losartan promoted an improvement in skeletal muscle healing after contusion by increasing revascularization rate and muscle regeneration, as well as by inhibiting the development of fibrosis. Losartan has an antifibrotic action, and it is also a widely used antihypertensive. Its association with PRP would stimulate angiogenesis and inhibit the development of fibrosis.

Despite the various studies, there is still insufficient evidence to indicate the use of PRP in acute muscle injury. Due to the increase in popularity, its real effectiveness has been increasingly debated, especially regarding the process of muscle injury rehabilitation in physically active patients and in athletes, thus it represents an important area of research.[3,4,29,33]

Current literature shows promising pre-clinical outcomes, but clinical findings are contradictory. A detailed analysis is hampered by the lack of standardization of study protocols, PRP preparation techniques, and outcome measures.[31,36]

High quality studies are critical to confirm these preliminary results and provide scientific evidence to indicate the use of PRP. Further research is needed to standardize PRP preparation, administration regimens (including the volume to be applied), treatment duration and frequency, and application method (blind or guided by US).[3,31]

Rehabilitation

The rehabilitation process is based on muscle stretching and strengthening programs, since tissue healing involves muscle regeneration and fibrosis formation. Early mobility minimizes disorganized healing of the fibers and, therefore, lesion recurrence.[3]

Prognostic factors related to a long rehabilitation period include muscle injury observed on MRI, extensive lesion demonstrated on MRI, recurrent HS lesions, and indirect injury as the trauma mechanism.[9]

The functional rehabilitation of HS lesions should be individualized to the needs of each patient; the overall goals are to restore pre-injury muscle strength and flexibility, as well as to relieve pain. Muscle strengthening is both a rehabilitation and prevention factor.[2,10]

The process begins with concentric strengthening, which leads to clinical improvement; open kinetic chain exercises are used progressively to initiate eccentric strengthening. Eccentric strengthening exercises are more effective than concentric exercises, and should be performed with the muscle in a stretched, as they help to restore muscle length after injury.[2,4]

Return to sports practice

Return to sports is the desired outcome after HS injuries. Isolated lesions of the LHBF involving <50% of the cross-sectional area and minimum perimuscular edema are correlated with a rapid return to sport, usually within seven days. Delayed return, after over two or three weeks, is correlated with lesions in multiple muscles, MTJ lesions, lesions involving the SHBF, lesions with a cross-sectional area greater than 75%, presence of retraction, and lesions with circumferential muscle edema. A delay in the recovery process is also associated with primary injury and indirect injury as the trauma mechanism.[3,37]

The criteria for sports return are: absence of pain, ability to make the respective sporting movements without hesitation, recovery of strength and stretching of the involved muscle group, and the athlete's own confidence for returning to physical activity. The assessment of muscle strength can be determined by the isokinetic test. Restoration of limb strength compared to contralateral side (between 90% and 95%) and HS to quadriceps strength ratio between 50% and 60% are desirable.[2,7]

Most HS relapses occur at the same site as the primary lesions, early after the return to sport; these new lesions are radiologically more severe. Specific exercise programs focused on preventing new injuries are highly recommended after returning to sports.[19]

Prevention

Given the major complications of HS injuries, especially in athletes, prevention is still better than treatment and rehabilitation process, especially considering the threat of recurrence. Several studies have aimed to identify patterns that predict injury, in order to avoid or correct these situations.

Duhig et al.,[38] who assessed soccer players and their sprints using GPS devices, observed that athletes who developed HS injury traveled a greater distance than their two-year average for high-speed sprinting (>24 km/h) in the four weeks prior to the injury.

Van Dyk et al.[10] do not recommend the isokinetic test to determine the association between strength differences and HS injury, as they were unable to determine the factors that would identify soccer players at risk for injury in a study on the relationship between the eccentric HS strength and concentric quadriceps strength in the isokinetic evaluation of 614 players over four seasons.

However, Dauty et al.[39] studied all soccer players in the major French league between the 2001/02 and 2011/12 seasons by isokinetic testing. According to those authors, it is possible to predict the occurrence of HS injury based on the results of the test conducted at the beginning of the season.

Schache et al.[40] reported that the asymmetric measures on isokinetic tests of maximal voluntary contractions of the HS muscles may be a useful clinical test to identify susceptibility to injury. In the case report of an elite Australian football player, the HS isokinetic test demonstrated that, over four weeks, the asymmetry between the maximum voluntary contraction was minimal (<1.2%); however, five days prior to the injury, the side that would be affected presented a reduction in the maximum voluntary contraction force of 10.9%.

Despite the discrepancy between the different results of the studies, with variant methodologies, muscle strengthening is considered to be the main prevention factor. Regarding muscle stretching, little has been shown about its prophylactic function. However, the most enduring clinical sign after HS injury is the reduction of muscle elongation; therefore, stretching is especially useful for rehabilitating the primary lesion and preventing relapse. HS stretching with the pelvis in anterior inclination has been shown to be more effective than the standard stretches.[2,7]

Regarding muscle strengthening, Mendiguchia et al.[41] reported that seven weeks of neuromuscular training focusing on the HS, combined with soccer training, was more effective than isolated training effective in improving concentric contraction force, specifically HS eccentric strength. This result ensures that the program maintains the athlete's performance and helps prevent HS injuries.

Porter and Rushton[42] conducted a systematic review of the effectiveness of eccentric strengthening exercises in the prevention of HS injuries in male professional soccer athletes. Those authors concluded that, although sufficient evidence is still lacking, there is scientific support in the literature for the indication of this prevention modality.

In summary, many authors agree that an exercise program for eccentric HS strengthening may reduce the incidence of injury. The effectiveness of those programs can be explained by the fact that the injury typically occurs when the HS muscles act on the deceleration of knee extension through an eccentric contraction in the final swing phase during the stride, when they are elongated by hip flexion and knee extension. The force required for the deceleration is proportional to the speed and force applied in the sprint.[2,4,6]

Nordic flexion is considered to be one of the most effective exercises in eccentric HS strengthening; it has been used with good results in professional soccer teams and amateur athletes. The exercise begins with the athlete kneeling with the thighs and trunk aligned, at a right angle to the legs. A training partner helps hold the feet and legs on the ground. The athlete initiates the activity by tilting the trunk toward the floor as slowly as possible, in order to increase the muscular load during the eccentric phase. When the trunk approaches the ground, the upper limbs are used to prevent the fall and push the athlete's back, minimizing the loading during the concentric phase (Fig. 2).[2,6]

Bourne et al.[43] assessed the Nordic flexion through functional MR images and found that the HS that had suffered injury muscle were less activated than the contralateral side.

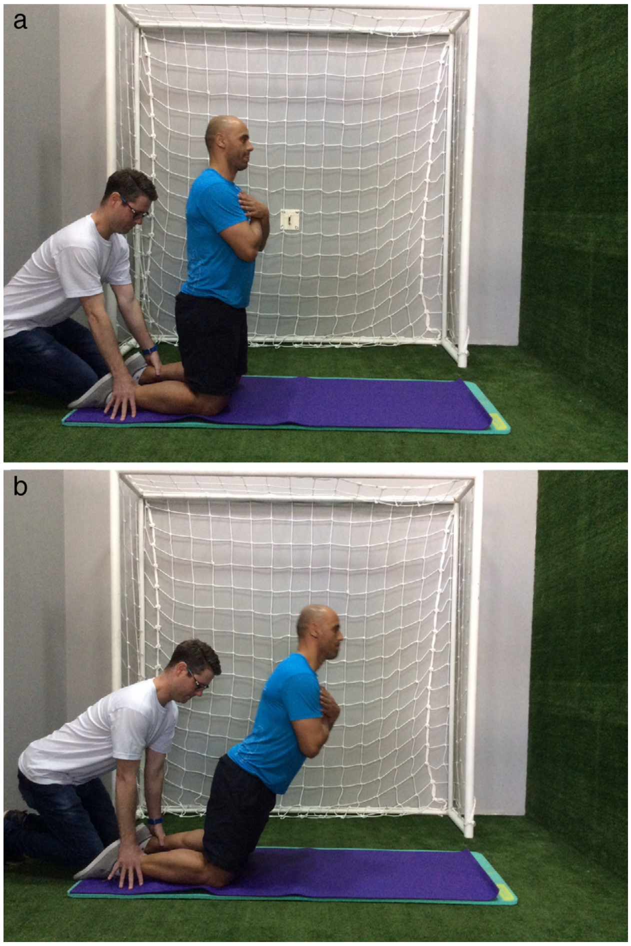

Fig. 2 – Nordic flexion: (a) athlete in initial kneeling position, (b) athlete makes the trunk inclination movement toward the ground as slowly as possible, with eccentric contraction of the hamstrings.

They also showed that the ST is the most significantly activated muscle. Regarding the analysis by electromyography, the same group, in a different study,[44] observed that, although not selective for LHBF, Nordic flexion presented the highest levels of activation in the eccentric contraction of this muscle when compared with the other exercises assessed in their study. Those authors concluded that the HS muscles are activated differently during hip or knee-based exercises. Thus, exercises based on hip extension are more selective in lateral activation, whereas those with knee flexion preferentially engage the medial musculature.

Laboratory parameters can also be used to prevent injury. Classically, creatine phosphokinase and lactate dehydrogenase are used as biochemical markers. Serum levels depend on age, gender, ethnicity, muscle mass, physical activity, and even weather conditions. These parameters should not be used for the diagnosis or prognosis of lesions, due to their low sensitivity and specificity. However, an increase in these parameters indicates an incomplete recovery from the muscular overload when compared with the athlete's baseline measurements. Special attention should be given to correcting factors that may predispose to injury.[9,45,46]

Conflicts of interest

The authors declare no conflicts of interest.

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REFERENCES

1. Agre JC. Hamstring injuries. Proposed aetiological factors, prevention, and treatment. Sports Med. 1985;2(1):21–33.
2. Carlson C. The natural history and management of hamstring injuries. Curr Rev Musculoskelet Med. 2008;1(2):120–3.
3. Ahmad CS, Redler LH, Ciccotti MG, Maffulli N, Longo UG, Bradley J. Evaluation and management of hamstring injuries. Am J Sports Med. 2013;41(12):2933–47.
4. Brukner P. Hamstring injuries: prevention and treatment – an update. Br J Sports Med. 2015;49(19):1241–4.
5. Askling CM, Koulouris G, Saartok T, Werner S, Best TM. Total proximal hamstring ruptures: clinical and MRI aspects including guidelines for postoperative rehabilitation. Knee Surg Sports Traumatol Arthrosc. 2013;21(3):515–33.
6. van der Horst N, Smits DW, Petersen J, Goedhart EA, Backx FJ. The preventive effect of the nordic hamstring exercise on hamstring injuries in amateur soccer players: a randomized controlled trial. Am J Sports Med. 2015;43(6):1316–23.
7. Lempainen L, Banke IJ, Johansson K, Brucker PU, Sarimo J, Orava S, et al. Clinical principles in the management of hamstring injuries. Knee Surg Sports Traumatol Arthrosc. 2015;23(8):2449–56.
8. Ekstrand J, Waldén M, Hägglund M. Hamstring injuries have increased by 4% annually in men's professional football, since 2001: a 13-year longitudinal analysis of the UEFA Elite Club injury study. Br J Sports Med. 2016;50(12):731–7.
9. Kerkhoffs GM, van Es N, Wieldraaijer T, Sierevelt IN, Ekstrand J, van Dikk CN. Diagnosis and prognosis of acute hamstring injuries in athletes. Knee Surg Sports Traumatol Arthrosc. 2013;21(2):500–9.
10. van Dyk N, Bahr R, Whiteley R, Tol JL, Kumar BD, Hamilton B, et al. Hamstring and quadriceps isokinetic strength deficits are weak risk factors for hamstring strain injuries: a 4-year cohort study. Am J Sports Med. 2016;44(7):95–1789.
11. van der Made AD, Wieldraaijer T, Kerkhoffs GM, Kleipool RP, Engebretsen L, van Dijk CN, et al. The hamstring muscle complex. Knee Surg Sports Traumatol Arthrosc. 2015;23(7):2115–22.
12. Askling CM, Tengvar M, Saartok T, Thorstensson A. Acute first-time hamstring strains during high-speed running: a longitudinal study including clinical and magnetic resonance imaging findings. Am J Sports Med. 2007;35(2):197–206.
13. Askling CM, Malliaropoulos N, Karlsson J. High-speed running type or stretching-type of hamstring injuries makes a difference to treatment and prognosis. Br J Sports Med. 2012;46(2):86–7.
14. Barnett AJ, Negus JJ, Barton T, Wood DG. Reattachment of the proximal hamstring origin: outcome in patients with partial and complete tears. Knee Surg Sports Traumatol Arthrosc. 2015;(7):2130–5.
15. Hofmann KJ, Paggi A, Connors D, Miller SL. Complete avulsion of the proximal hamstring insertion: functional outcomes

after nonsurgical treatment. J Bone Joint Surg Am. 2014;96(12):1022–5.
16. Birmingham P, Muller M, Wickiewicz T, Cavanaugh J, Rodeo S, Warren R. Functional outcome after repair of proximal hamstring avulsions. J Bone Joint Surg Am. 2011;93(19):1819–26.
17. van Beijsterveldt AM, van de Port IG, Vereijken AJ, Backx FJ. Risk factors for hamstring injuries in male soccer players: a systematic review of prospective studies. Scand J Med Sci Sports. 2013;23(3):253–62.
18. Svensson K, Eckerman M, Alricsson M, Magounakis T, Werner S. Muscle injuries of the dominant or non-dominant leg in male football players at elite level. Knee Surg Sports Traumatol Arthrosc. 2016;(June).
19. Wangensteen A, Tol JL, Witvrouw E, Van Linschoten R, Almusa E, Hamilton B, et al. Hamstring reinjuries occur at the same location and early after return to sport: a descriptive study of MRI-confirmed reinjuries. Am J Sports Med. 2016;44(8):2112–21.
20. Pruna R, Artells R, Lundblad M, Maffulli N. Genetic biomarkers in non-contact muscle injuries in elite soccer players. Knee Surg Sports Traumatol Arthrosc. 2016;(April), http://dx.doi.org/10.1007/s00167-016-4081-6 [Epub ahead of print].
21. Carmichael J, Packham I, Trikha SP, Wood DG. Avulsion of the proximal hamstring origin. Surgical technique. J Bone Joint Surg Am. 2009;91 Suppl 2:249–56.
22. Pollock N, Patel A, Chakraverty J, Suokas A, James SL, Chakraverty R. Time to return to full training is delayed and recurrence rate is higher in intratendinous ('c') acute hamstring injury in elite track and field athletes: clinical application of the British Athletics Muscle Injury Classification. Br J Sports Med. 2016;50(5):305–10.
23. Ekstrand J, Healy JC, Waldén M, Lee JC, English B, Hägglund M. Hamstring muscle injuries in professional football: the correlation of MRI findings with return to play. Br J Sports Med. 2012;46(2):112–7.
24. Ekstrand J, Askling C, Magnusson H, Mithoefer K. Return to play after thigh muscle injury in elite football players: implementation and validation of the Munich muscle injury classification. Br J Sports Med. 2013;47(12):769–74.
25. Grassi A, Quaglia A, Canata GL, Zaffagnini S. An update on the grading of muscle injuries: a narrative review from clinical to comprehensive systems. Joints. 2016;4(1): 39–46.
26. Pollock N, James SL, Lee JC, Chakraverty R. British athletics muscle injury classification: a new grading system. Br J Sports Med. 2014;48(18):1347–51.
27. Peetrons P. Ultrasound of muscles. Eur Radiol. 2002;12(1):35–43.
28. Mueller-Wohlfahrt HW, Haensel L, Mithoefer K, Ekstrand J, English B, McNally S, et al. Terminology and classification of muscle injuries in sport: the Munich consensus statement. Br J Sports Med. 2013;47(6):342–50.
29. A Hamid MS, Mohamed Ali MR, Yusof A, George J, Lee LP. Platelet-rich plasma injections for the treatment of hamstring injuries: a randomized controlled trial. Am J Sports Med. 2014;42(10):2410–8.
30. Tanksley JA, Werner BC, Ma R, Hogan MV, Miller MD. What's new in sports medicine. J Bone Joint Surg Am. 2015;97(8):682–90.
31. Kon E, Filardo G, Di Martino A, Marcacci M. Platelet-rich plasma (PRP) to treat sports injuries: evidence to support its use. Knee Surg Sports Traumatol Arthrosc. 2011;19(4): 516–27.
32. Zanon G, Combi F, Combi A, Perticarini L, Sammarchi L, Benazzo F. Platelet-rich plasma in the treatment of acute hamstring injuries in professional football players. Joints. 2016;4(1):17–23.
33. Rossi LA, Molina Rómoli AR, Bertona Altieri BA, Burgos Flor JA, Scordo WE. Does platelet-rich plasma decrease time to return to sports in acute muscle tear? A randomized controlled trial. Knee Surg Sports Traumatol Arthrosc. 2016;(April), http://dx.doi.org/10.1007/s00167-016-4129-7 [Epub ahead of print].
34. Reurink G, Goudswaard GJ, Moen MH, Weir A, Verhaar JA, Bierma-Zeinstra SM, et al. Dutch Hamstring Injection Therapy (HIT) study investigators platelet-rich plasma injections in acute muscle injury. N Engl J Med. 2014;370(26):7–2546.
35. Terada S, Ota S, Kobayashi M, Kobayashi T, Mifune Y, Takayama K, et al. Use of an antifibrotic agent improves the effect of platelet-rich plasma on muscle healing after injury. J Bone Joint Surg Am. 2013;95(11):980–8.
36. Sheth U, Simunovic N, Klein G, Fu F, Einhorn TA, Schemitsch E, et al. Efficacy of autologous platelet-rich plasma use for orthopaedic indications: a meta-analysis. J Bone Joint Surg Am. 2012;94(4):298–307.
37. Cloke D, Moore O, Shah T, Rushton S, Shirley MD, Deehan DJ. Thigh muscle injuries in youth soccer: predictors of recovery. Am J Sports Med. 2012;40(2):433–9.
38. Duhig S, Shield AJ, Opar D, Gabbett TJ, Ferguson C, Williams M. Effect of high-speed running on hamstring strain injury risk. Br J Sports Med. 2016;50(24):1536–40.
39. Dauty M, Menu P, Fouasson-Chailloux A, Ferréol S, Dubois C. Prediction of hamstring injury in professional soccer players by isokinetic measurements. Muscles Ligaments Tendons J. 2016;6(1):116–23.
40. Schache AG, Crossley KM, Macindoe IG, Fahrner BB, Pandy MG. Can a clinical test of hamstring strength identify football players at risk of hamstring strain? Knee Surg Sports Traumatol Arthrosc. 2011;19(1):38–41.
41. Mendiguchia J, Martinez-Ruiz E, Morin JB, Samozino P, Edouard P, Alcaraz PE, et al. Effects of hamstring-emphasized neuromuscular training on strength and sprinting mechanics in football players. Scand J Med Sci Sports. 2015;25(6): e621–9.
42. Porter T, Rushton A. The efficacy of exercise in preventing injury in adult male football: a systematic review of randomised controlled trials. Sports Med Open. 2015;1(1):4.
43. Bourne MN, Opar DA, Williams MD, Al Najjar A, Shield AJ. Muscle activation patterns in the Nordic hamstring exercise: impact of prior strain injury. Scand J Med Sci Sports. 2016;26(6):666–74.
44. Bourne MN, Williams MD, Opar DA, Al Najjar A, Kerr GK, Shield AJ. Impact of exercise selection on hamstring muscle activation. Br J Sports Med. 2017;51(13):1021–8.
45. Brancaccio P, Maffulli N, Buonauro R, Limongelli FM. Serum enzyme monitoring in sports medicine. Clin Sports Med. 2008;27(1):1–18.
46. Banfi G, Colombini A, Lombardi G, Lubkowska A. Metabolic markers in sports medicine. Adv Clin Chem. 2012;56:1–54.