Knee Surg Sports Traumatol Arthrosc (2015) 23:2449–2456
DOI 10.1007/s00167-014-2912-x

SPORTS MEDICINE

Clinical principles in the management of hamstring injuries

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Received: 13 June 2013 / Accepted: 9 February 2014 / Published online: 21 February 2014

Abstract
Purpose Hamstring injuries are among the most common muscle injuries seen in sports clinical practice. This narrative review covers essential knowledge of hamstring injuries, ranging from strains to total proximal three-tendon ruptures. The primary aim is to provide basic information for clinicians and sports medicine therapists dealing with hamstring problems.
Methods In this review, existing literature of hamstring injuries was taken together. Emphasis was given to subjects less well covered in previous reviews, such as preventive measures, as well as the most relevant information needed in the treatment of these injuries.
Results Occasionally, symptoms remain after hamstring injuries which can be successfully treated with surgery. Knowledge of the effectiveness of preventive measures and nonsurgical and surgical treatment is limited by small studies of low evidence level.
Conclusions Evidence-based treatment algorithms are not available. Larger studies of better quality with more concrete grading of hamstring tears are needed to improve knowledge in prevention and treatment of hamstring injuries.
Level of evidence IV.

Keywords Hamstring · Injury · Treatment · Review

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Introduction

Hamstring injuries are among the most common muscle injuries seen in sports clinical practice. To prevent hamstring injuries, more information is required about the extent of the injury problem, the risk factors contributing to the injury and the effectiveness of strategies designed to reduce the risks. Secondary prevention is also important and is needed to better treat these injuries so that long-term symptoms can be avoided and complications and risks of re-injuries can be reduced.

Hamstring injuries vary from strains that heal well to severe ruptures. Previous reviews have mostly addressed the treatment of total proximal hamstring tears, and less attention has been given to the treatment of hamstring injuries of other degrees as well. This narrative review mostly focuses on important clinical phases of treating and preventing hamstring injuries.

Epidemiology of injury

Hamstring injuries are common in athletes, and they represent a major cause of time lost from sports [28]. They have been reported in various sports, such as sprinting and running, track and field, soccer, rugby, gymnastics and waterskiing [11, 13, 68]. However, they have also been reported in the general population as people increase their level of activity.

In Australian Football, hamstring muscle injuries are the most common and most prevalent injury, constituting 15 % of all injuries, with the average professional Australian Football League club having six injuries per club (40 players) and 21 missed matches per club per season [52]. Similarly, in British soccer, hamstring muscle injuries account for 12 % of the total injuries with an average of five per club per season, resulting in 15 missed matches and 90 missed training days [70]. The incidence of hamstring muscle injuries has been estimated to be 3.0–4.1 hamstring strains per 1,000 h of match play and 0.4–0.5 per 1,000 h of training [3]. The most severe hamstring injury, a complete proximal rupture, is a quite rare injury [25]. The prevalence of complete proximal hamstring ruptures has been estimated to be 9 % of all by MRI-evaluated hamstring injuries [10, 36].

Factors predisposing to injury and re-injury

New conceptual models based on the strengthening of interrelationship between the different risk factors are favoured [48, 71]. Interaction between the varying evidence-based risk factors such as previous injury and/or inadequate rehabilitation of predominantly hamstrings but also calf muscle, knee or groin, age, hamstring flexibility, warm-up and stretching, hamstring strength, core stability, fatigue and low fitness level, anatomical and architectural reasons and race may be much more important in prediction of hamstring injury than their respective isolated impact [19, 48, 71].

Previous hamstring injury displays the greatest risk factor with 2–6 times elevated re-injury rates [48]. In the very few prospective studies with at least 200 subjects, Arnason et al. [4], Gabbe et al. [26] and Engebretsen et al. [24] demonstrated previous strain and age as independent predictors of hamstring injury over a complete season. Whether inadequate rehabilitation or intrinsic residues from initial injury are responsible remains still open.

Also extrinsic factors have an important role in hamstring injuries. Elliott et al. [21] concluded from a 10-year study period with 1,716 hamstring injuries in the National Football League that the majority of injuries occur in the short preseason period with elevated risk especially for the speed position players as well as players on the special team units.

Incidence of recurrent hamstring injuries is 13.9–63.3 % in the same playing season up to 2 years after initial injury [18]. In a prospective cohort study of Verrall et al. [67] with 30 hamstring-injured athletes from professional Australian Rules football teams, a larger size of the initial injury was associated with a 2.2–2.3 times increased risk for re-injury in the same combined with the subsequent playing season [66]. In the studies by Gibbs et al. [29] and Malliaropoulos et al. [46], re-injuries were more often associated with hamstring injury at initial injury grade I (24.1–35 %) compared to grade 0 (absence of any lesion in magnetic resonance imaging (MRI) or sonography (US) despite clinical diagnosis of posterior thigh muscle injury; 0–9.3 %) and grade II (6.3 %) according to the grading system of Peetrons [53], modified for MRI by Davis [15]. In an MRI-study by Rettig et al. [57], an initial injury around cross-sectional area of more than 50 % of the muscle circumference and an initial length of the injury greater than 60 mm were at increased risk of re-injury. Also previous reconstruction of the ipsilateral anterior cruciate ligament has been shown to be associated with an increased risk of hamstring re-injury (66.6 vs. 17.1 %) [38].

Mechanism of injury

Injuries causing proximal hamstring ruptures are often sports-related non-contact injuries and have been previously well described in the literature [12, 59, 70]. The injury mechanism is usually similar involving a rapid forceful hip flexion with the ipsilateral knee in extension. This is the main cause of severe two- and three-tendon avulsions.

Proximal hamstring tendon avulsions after unconventional mechanisms of injury are less well reported. Tendon avulsions can be caused by seemingly less dramatic mechanisms resembling those seen in hamstring strains [60]. Occasionally, these one-tendon avulsions can occur in sprinting or in rapid changes in direction while running. Sometimes, an athlete loses balance while running or skating and possibly due to a corrective movement of the body, a rapid tensioning of the hamstrings occurs and in an awkward position leads to a proximal hamstring tendon avulsion.

Injury classification

Hamstring muscle injuries are typically strains, but also contusions occur in contact sports [40]. Delayed onset muscle soreness induced by eccentric exercise is also a common hamstring problem in sports [35, 40]. The injury spectrum ranges from minor hamstring strain to complete avulsion with retraction [13]. These injuries are often classified into one of the three groups according to their severity: mild (grade I), moderate (grade II) and severe (grade III) [35, 40]. No validated classification system exists.

Grade I injuries represent a small disruption of the structural integrity of the musculotendinous unit with minor swelling and discomfort and with no or only minimal loss of strength and function. However, these injuries may often be distressing to the athlete.

Grade II injuries represent partial tears with at least some intact fibres left but also with a clear loss of strength and function. In the literature, for example, isolated SM or isolated BF rupture is usually considered as a partial grade II hamstring tear due to the fact that the whole hamstring muscle complex (the BF, the ST and the SM) is not ruptured [42, 48].

Grade III injuries are characterized by complete disruption of the musculotendinous unit, resulting in a total lack of muscle function. A complete hamstring rupture usually occurs as an avulsion injury from the ischial tuberosity [20]. Avulsion fractures of the ischial tuberosity are also included in this group, but they are almost exclusively seen among the skeletally immature [41].

Typically, hamstring injuries occur at the musculotendinous junction (MTJ). Because the long proximal and distal tendons of the hamstrings extend far into the muscle bellies forming elongated MTJs, almost any area along the course of the muscle can be injured [40, 69]. According to this, hamstring injuries could also be categorized into proximal, central and distal tears [47]. Proximally, hamstring injuries affect the tendon origin sites of the ischial tuberosity and proximal MTJs, and injuries from partial tears to complete ruptures have been reported [12, 42, 59]. Centrally, hamstring injuries affect the MTJs and muscle bellies, causing intramuscular tears [17, 40, 47]. Distal hamstring injuries affect the distal MTJs, distal tendons or tendon insertion sites [2, 43, 61, 62]. Absence of a haematoma during the first day after injury should not be wrongly deduced to a minor injury, since this sign may appear days later even in severe ruptures.

MRI and US are the imaging modalities of choice in diagnosing hamstring injuries [37]. If a more serious proximal hamstring injury is suspected, an MRI should be done to confirm the diagnosis and to assess the amount of tendon retraction, which may be an important feature for planning the optimal treatment [9, 16]. Radiology in proximal hamstring injuries has been extensively addressed in previous studies and reviewed just recently by Askling et al. [6].

Clinical picture and typical symptoms

The clinical presentation of a hamstring muscle injury depends on the severity of the injury. The main goal is to differentiate those patients with severe injuries requiring surgery from patients with mild injuries suitable for conservative treatment.

Patients with grade I hamstring injuries will probably seldom seek medical evaluation acutely after injury. Typical symptoms are tenderness, pain and stiffness of the hamstrings. Normally, these symptoms alleviate already within a few days.

When a more severe hamstring tear (grades II–III) occurs, the patient often feels that the injury is something more serious than just a strain [58]. There is a sudden onset of pain, and patients often describe a tearing sensation in the area of the ischial tuberosity in cases of proximal injuries. Running is often impossible, and even walking can be difficult in the early phase [59]. Sitting is troublesome due to pain and tenderness in the gluteal region. The patient may complain of discomfort and weakness in the thigh, poor leg control and feelings of instability. Cramping can also be present especially when the patient attempts to run or does hamstring strengthening exercises. Sciatica-type symptoms have also been described in the more chronic phase of the injury [40, 59].

Visible signs of bleeding may vary from nothing at all to massive haematoma covering the thigh and extending down to the calf. A large haematoma formation seems to be suggestive of more extensive damage, i.e. a three-tendon avulsion. Even in cases of three-tendon avulsions, it may take a few days before the large haematoma becomes visible, and therefore, the lack of haematoma during the first couple of days after the injury should not be interpreted as a sign of a less severe injury. However, the persistent lack of ecchymosis does not rule out a proximal avulsion.

In the early phase, a palpable gap may be present just distal to the ischial tuberosity; however, this may sometimes be masked by a haematoma [58, 59]. A decrease in the knee flexion and hip extension strength is often noted. In complete proximal avulsions when the patient is asked to flex the knee against resistance, it may become visible how the avulsed muscle retracts distally forming a bulge.

Injury-related complications

Recurrence is the most common complication of hamstring injuries, which makes it one of the most frustrating injuries for athletes, coaches, treating doctors and physiotherapists [48]. This is reflected by increase in re-injury risk of two to six times or recurrence incidence in athletes of 13.9–63.3 % [18, 48].

Higher grades of injuries naturally result in longer rehabilitation and later return to sports [46]. Without dividing into subgroups according to injury severity, Australian footballers had the highest recurrence rates in the first (12.6 %) and the second weeks (8.1 %) of return to sports, while a persistent significantly increased risk of recurrence remained for a couple of months after return to play [51].

Post-injury remodelling of the hamstrings may involve scar tissue formation, evident in MRI for up to 1 year after return to sports [63]. Adhesions, scar tissue as well as altered muscle transmission pathways, decreased compliance of tendon/aponeurosis and modified muscle deformation patterns can result, all contributing to impaired mechanical properties of the hamstrings [40, 48, 50].

In particular, in three-tendon avulsions, it can be that the retracted muscles cause stretching of the nerves [59]. This may occur acutely at the time of injury but also chronically if the retraction is not repaired. In study by Sarimo et al. [59], diffuse denervation of the hamstring muscles in ENMG studies and in MRI fatty degeneration of the musculature in cases with delayed diagnosis of a proximal three-tendon avulsion have been seen. In these cases, even after successful repair of the avulsion, results may be poor assumable due to the nerve injury, and therefore, persistent neuralgia and weakness of the hamstring muscles may be the result.

In chronic cases of proximal hamstring, avulsions without repair neuralgia and sciatica type of symptoms have been reported [15, 59]. Even a complete foot drop due to sciatic nerve irritation is possible, appearing weeks or even months after the proximal hamstring tear [1, 33, 65].

Non-surgical treatment

Non-surgical treatment is based on limited evidence. Initially, treatment measures limiting the extent of injury accordingly to the RICE-principle is recommended [34]. Unnecessary immobilization with concomitant muscle atrophy has to be avoided with the aim of generating a stable scar without re-tear. The use of non-steroidal anti-inflammatory drugs might be beneficial primarily but can also have detrimental effects [56]. Intramuscular corticosteroid injections are known to have detrimental effects on initial tissue damage and healing [8], though clinical use is reported here as well [45]. Comparable stretching of both legs and painless use of the injured muscles during basic movements reveals capability for gradual return to sports. Reduced active flexibility, in particular, has been shown to remain longer than other clinical signs following strain injuries [7]. Readiness to return to competition can also be determined by isokinetic testing. Correction of muscle strength imbalances, hamstring–quadriceps ratio of 50–60 % and sufficiently restored strength of the injured compared to the unaffected leg is desirable [13].

Surgical treatment

Despite little high-level supporting evidence, proximal hamstring ruptures are increasingly treated surgically. According to the common guidelines, acute complete proximal hamstring avulsions/ruptures with loss of function (grade III) should be operated on as soon as possible, as should chronic cases with impairing pain (>4–6 months), extension deficit and/or muscle weakness after sufficient non-surgical therapy in which, in the late stage of repair, the scar and adhesions prevent the normal function of the hamstring muscle [34, 40]. This is supported by a recent systematic review of Harris et al. [31] who stated after inclusion of 18 studies with 300 proximal hamstring injuries that surgical repair leads to significantly better subjective outcomes, greater strength/endurance and greater rate of return to pre-injury sports level than non-surgical management. Importantly acute (<4 weeks) repair had significantly better overall outcomes with reduced risk of complications and re-rupture compared to chronic (>4 weeks) repair. This review was, however, limited to studies on complete ruptures. Above the age of 50 with awareness of the lower healing potential, primary surgical intervention is favoured in cases with greater job/sports demands or chronic daily compromising pain/muscle weakness. For athletes, more aggressive recommendations with reattachment of isolated tendon avulsions (BF/ST/SM) can be found [25]. Askling et al. [6] proposed recently a well-illustrated post-operative rehabilitation program, following surgery for total proximal hamstring rupture.

Surgical technique

The authors perform and recommend the following surgical technique. Some perioperative photographs give further information. After incision (in acute phase mostly a transverse incision within the gluteal crease cantered above the ischial tuberosity, in chronic case with retracted tendons mostly a vertical incision) and vertical fasciotomy, the lower edge of the gluteus maximus muscle is exposed, retracted proximally, and the posterior cutaneous femoral nerve identified and spared. The proximally ruptured hamstrings are approached distal of the greater gluteus muscle and the tendon stumps, mostly evident after drainage of a haematoma (in acute cases) or seroma (in chronic cases) as a leading sign, identified (Figs. 1, 2). After capturing of the retracted stumps with EthiBond No. 6 sutures (Ethicon) (retracted), muscles are released as far distally as possible with dull digital palpation with the aim of mobilization of the stumps to their respective areas of origin on the ischium. After debridement, two to three grooves are cut into the ischial tuberosity at the site of

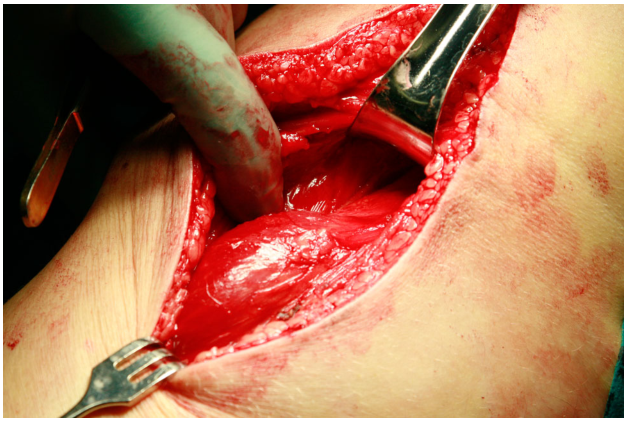

Fig. 1 Common perioperative sight of loose and retracted hamstrings

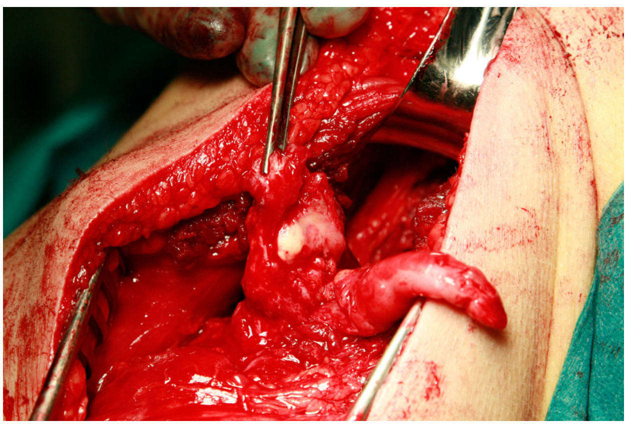

Fig. 2 Retracted hamstring tendons have been discovered. This is a typical example of two-tendon avulsion: biceps femoris and semitendinosus have completely avulsed from the ischial tuberosity

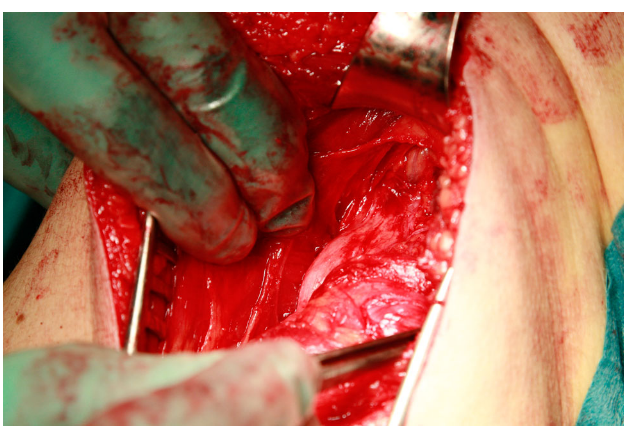

Fig. 3 The sciatic nerve has been identified just laterally from the ischial tuberosity

detachment. An anchor (e.g. Arthrex Titanium Corkscrew FT2) double armed each with size 2 fibre wire sutures is placed into each groove. The stumps are secured with Krakow locking whip stitches and tied down as a pulley

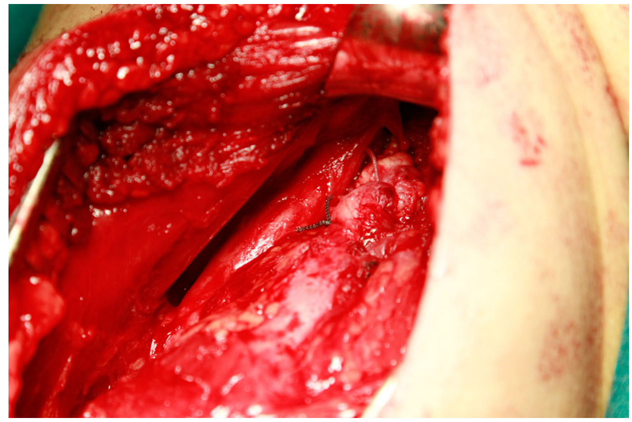

Fig. 4 The ruptured tendons have been reattached by suture anchors

tackle to the suture anchors. In cases of delayed surgery, extensive mobilization of the retracted muscles and debridement of the tendon stumps as well as neurolysis of the sciatic nerve should be performed before reattachment (Figs. 3, 4). In chronic repairs with increased retraction of muscles and/or large defect area hindering anatomic reinsertion of the stump to its bony origin, tension-free reattachment of the stump can be achieved with fascia lata autograft [44] or Achilles allograft [49].

Primary and secondary prevention

The prevention of hamstring (re-)injuries, especially at high-risk sports such as football, is an ongoing process required as long as participants are exposed to risky physical activities. Reductions in the incidence exhibit the potential to reduce suffering, medical costs and lost time from work or leisure. Despite wide use of a variety of interventions by participants, therapists, trainers and coaches with respect to the relatively high incidence of hamstring injuries in sport, evidence of the efficacy of primary and secondary preventive interventions is yet not well established [14, 30, 54].

Regarding primary prevention in the systematic review of Goldman and Jones, seven randomized controlled trials involving 1,919 participants (young adults, participating in regular sporting activities) were included [30]. The authors conclude insufficient evidence on the effectiveness of interventions for prevention of hamstring injuries in people participating in football or other high-risk activities for these injuries requiring further research.

Strengthening protocol for hamstring muscle group. In a recent randomized controlled study by Petersen et al. [55], significantly preventive effect of eccentric strengthening of the hamstring muscles using the Nordic hamstring exercise compared with no additional hamstring exercise on the rate of overall, new and recurrent acute hamstring injuries could be shown. Askling et al. [5] found a significant benefit for strengthening with 30 elite soccer players. However, in the control group not receiving additional specific hamstring training, the rate of mainly minor hamstring injury was unusually high (67 %). Gabbe et al. [27] found no evidence of strengthening benefit in 220 community-level Australian footballers. Overall compliance was low (only 46.8 % of all players completed at least two program sessions) with poorest compliance in strengthening group. No evidence of benefit for hamstring strengthening beside low overall compliance was also found by Engebretsen et al. [23].

Proprioceptive neuromuscular training (balance training) protocol. Kraemer et al. [39] reported in a cohort study with 24 elite female soccer players after 3-year proprioceptive balance training intervention significant reduction in non-contact hamstring injury rates with a dose–effect relationship between duration of balance training and injury incidence. In the two cluster randomized trials by Emery et al. [22] and Söderman et al. [64], neither intention-to-treat analysis nor the uncorrected data for hamstring injuries showed a statistically significant difference between the intervention and control groups in hamstring injury for either trial. Intention-to-treat analysis corrected for clustering had no effect on statistical significance for either trial.

Warm-up, cool-down and stretching protocol: Hartig et al. [32] showed that increasing hamstring flexibility significantly decreases hamstring muscle strains in 298 military basic trainees. Van Mechelen et al. [66] evaluated the effectiveness of stretching interventions alongside warm-up/cool-down protocols on the prevention of running injuries at the end of the 16-week treatment period. With a loss to follow-up of 23 %, there was no significant benefit in reduction in lower limb injuries including hamstring strains.

Discussion

Surgical treatment seems to be best clinical practice in the treatment of severe hamstring tears. However, as can be concluded from the available literature, there is no definite evidence to guide non-surgical versus surgical treatment in incomplete proximal hamstring tears. Based on author's experiences, the following treatment algorithm for proximal hamstring injuries is proposed, also shown in the Fig. 5.

A one-tendon avulsion is predominantly the domain of non-surgical treatment, especially in recreational athletes and inactive patients. Surgery, early when performed, has to be considered in professional athletes or other high-demand patients when the avulsion is symptomatic.

In two-tendon avulsion, the grade of activity leads to the appropriate therapy. Professional athletes or other high-demand patients receive early surgery, recreational athletes and inactive patients only when the avulsion is symptomatic.

In three-tendon avulsion, early surgery is the treatment of choice in professional and recreational athletes as well as inactive patients. Only if critical contraindications in recreational athletes and inactive patients exist, non-surgical treatment has to be considered case based. Furthermore, one should be aware that whenever non-surgical treatment is unsuccessful, delayed surgery has to be considered.

The rationale behind this algorithm is a proposed uniform classification system that addresses the magnitude of injury in an objectively and orderly fashion. As a treatment proposition, it obviously needs validation since it is based merely on personal experience. The problem seems to be that variations in the current definition of injury classification occur in the literature with the influence of subjective interpretation, especially in non-total grade I–II

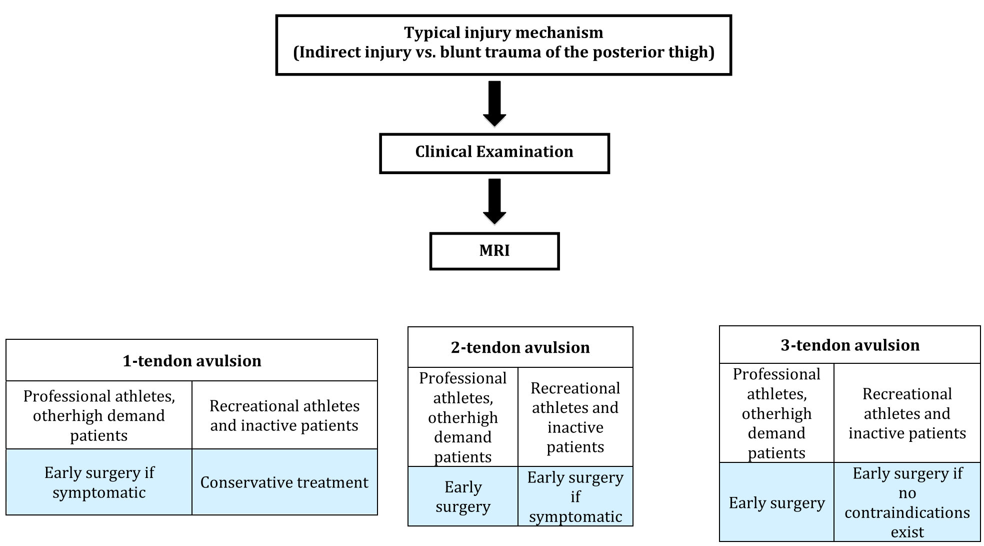

Fig. 5 Authors' recommended treatment algorithm for proximal hamstring avulsions

tendon tears. A division of hamstring tendon tears into partial or subtotal versus total is somewhat confusing and indistinctive in contrast to an MRI-based one-, two- or three-tendon approach that is anatomically more accurate. This more accurate diagnostic approach is a proposition to guide future trials comparing non-surgical and surgical treatments with an objective and measurable classification system.

Gazing into the horizon, we would also want to see ways of predicting those at risk for hamstring tendon tears and ultimately preventing it from happening. More concretely, making an analogue to Achilles tendon tears, it would be most interesting to know whether similar degeneration and underlying tendinopathy is preceded in ruptured hamstring tendons as well. While means to heal tendinopathy are intensively pursued, they could one day be implemented in the primary prevention of hamstring tears.

Conclusion

The research on musculoskeletal disorders is encouragingly active and growing. Surgical treatment is certainly needed in the treatment of severe hamstring tears; however, previous reports have included only a few patients and modest follow-up. It is only through vigorous and quality, evidence level I, research that we can elucidate the remaining questions regarding best clinical practice in hamstring tears. National and international clinical collaboration is desired for attaining sufficiently powered future studies in hamstring disorders. While sports activities are expected to increase, so are the sports-related hamstring injuries too. It is most important to provide efficient treatment, minimizing the time of return to activity.

Conflict of interest The authors report no conflict of interest relevant to this article.

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