

Tears of biceps femoris, semimembranosus, and semitendinosus are not equal—a new individual muscle-tendon concept in athletes

Lasse Lempainen, Jussi Kosola , Ricard Pruna, Juha-Jaakko Sinikumpu, Xavier Valle, Olli Heinonen, Sakari Orava and Nicola Maffulli

Abstract

Objectives: Hamstring injuries are common and can now be accurately diagnosed. In addition, novel surgical indications have been introduced. However, evidence-based guidelines on the hamstring injuries in management of top-level athletes are missing.

Methods: The management methods and outcomes of treatment are classically based on relatively small case series. We discuss a novel concept based on the fact that each tendon of the hamstrings muscle should be managed in an individual fashion. Furthermore, suitable indications for hamstring surgery in athletes are introduced.

Results: The present study introduces modern treatment principles for hamstring injury management. Typical clinical and imaging findings as well as surgical treatment are presented based on a critical review of the available literature and personal experience.

Conclusions: Hamstring injuries should not be considered to be all equal given the complexity of this anatomical region: The three separate tendons are different, and this impacts greatly on the decision-making process and outcomes in athletes.

Keywords

Hamstring injury, surgical treatment, athlete, tendon, biceps femoris, semitendinosus, semimembranosus

Date received: 13 April 2020, accepted: 8 December 2020

Introduction

The three major muscles forming the hamstring muscle group are biceps femoris (BF), semimembranosus (SM), and semitendinosus (ST).¹ These individual muscles—BF, SM, ST—serve different functions and exert a specific role and a specific contact times while walking, running, or turning, although their anatomy partially overlaps proximally.²

Typically, hamstring injuries are classified according to the location of the injury (i.e. proximal, middle, or distal), and the muscles are often

considered as part of the hamstring complex.^{3,4} Injuries of the proximal hamstrings can range from partial to complete tears, and one, two, or all three tendons may avulse from the ischial tuberosity.⁵⁻⁸ The higher the grade of injury, the more likely it is for an athlete to undergo operative treatment.^{5,6}

Hamstring injuries are common in running, sprinting, and jumping events and especially common in soccer⁹: up to five hamstring strains per club per season have been reported.¹⁰ Most of these injuries can be managed conservatively, and surgery is generally not necessary.^{3,11,12}

Scandinavian Journal of Surgery
2021, Vol. 110(4) 483–491
© The Finnish Surgical Society 2021



Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/1457496920984274
journals.sagepub.com/home/sjs



Corresponding author:

Lasse Lempainen
Sports Trauma Research Unit,
Hospital Mehiläinen NEO,
Joukahaisenkatu 6, Turku,
FI 20520, Finland
Department of Physical Activity
and Health, Paavo Nurmi Centre,
University of Turku, Turku, Finland
Email: lasse.lempainen@utu.fi

Jussi Kosola
Department of Physical Activity
and Health, Paavo Nurmi Centre,
University of Turku, Turku, Finland
Department of Surgery,
Kanta-Häme Central Hospital,
Hämeenlinna, Finland

Ricard Pruna
Xavier Valle
FC Barcelona, Medical Services,
FIFA Center of Excellence,
Barcelona, Spain

Juha-Jaakko Sinikumpu
Department of Children and
Adolescents, PEDEGO unit and
MRC Oulu, Oulu University
Hospital and University of Oulu,
Oulu, Finland

Olli Heinonen
Department of Physical Activity
and Health, Paavo Nurmi Centre,
University of Turku, Turku, Finland

Sakari Orava
Sports Trauma Research Unit,
Hospital Mehiläinen NEO, Turku,
Finland
Department of Physical Activity
and Health, Paavo Nurmi Centre,
University of Turku, Turku, Finland

Nicola Maffulli
Department of Musculoskeletal
Disorders, University of Salerno
School of Medicine, Surgery and
Dentistry, Salerno, Italy
Centre for Sports and Exercise
Medicine, Queen Mary University
of London, London, UK
Institute of Science and
Technology in Medicine, Keele
University School of Medicine,
Stoke on Trent, UK

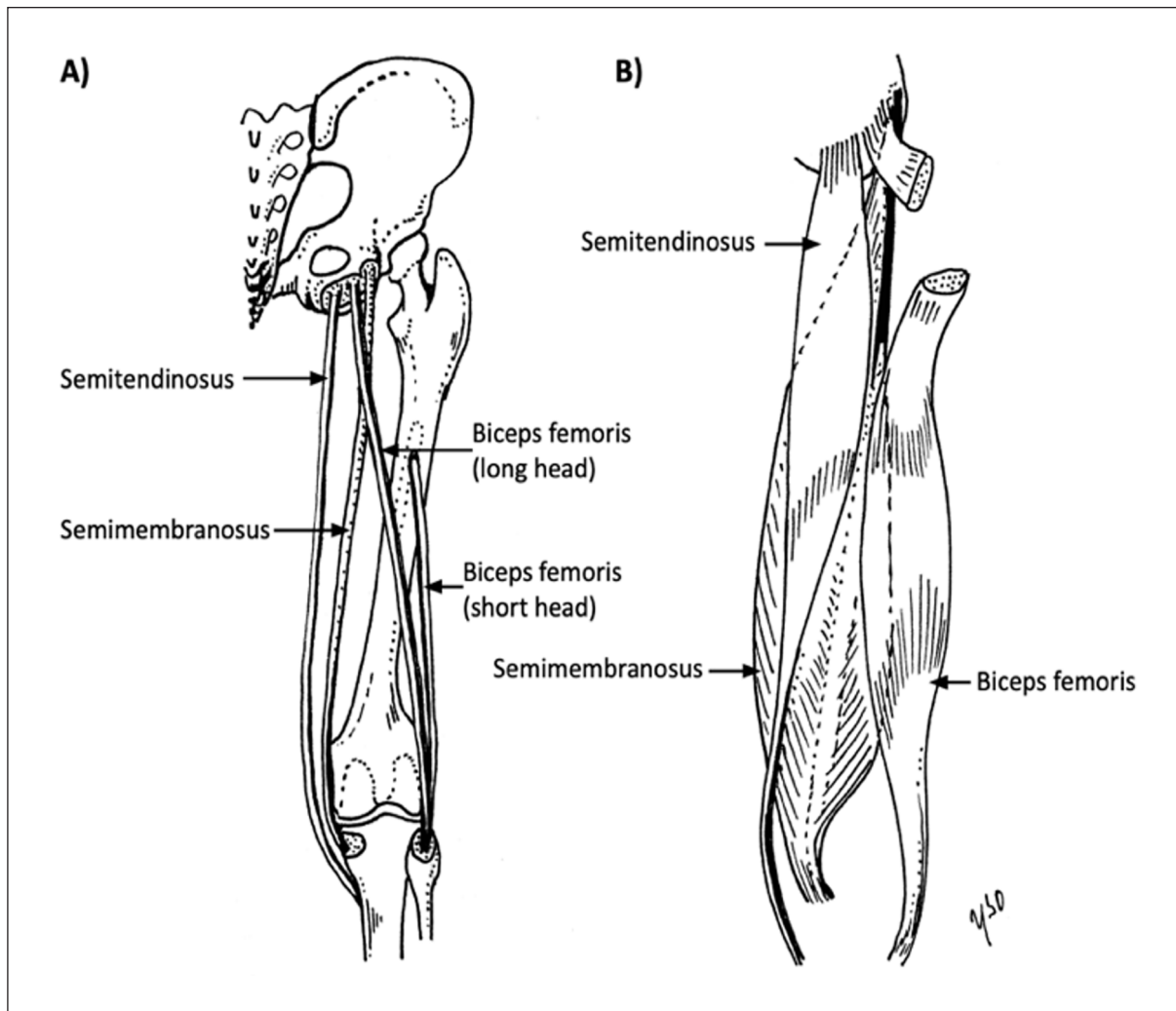


Fig. 1. The illustrative drawing of each individual hamstring structure: A) tendons, B) muscles.

However, the optimal treatment of these injuries is still largely unknown, and recurrent hamstring injuries occur far too often.¹³

The aim of this study is to highlight the importance of the individuality of every single hamstring muscle-tendon unit to allow to make a treatment decision in hamstring injuries in athletes. Hamstring tears are not all equal: this concept simplifies making the treatment decision, highlights the importance of each single muscle-tendon unit, and should optimize the treatment results in athletes. We demonstrate the relevance of this concept by showing different individual tendon injuries and giving perspective for their subsequent treatment.

Different functional anatomy of each hamstrings

The hamstring muscle complex cross the hip and the knee (Fig. 1). With the exception of the short head of BF, the

muscles of the posterior aspect of the thigh are mainly hip extensors and knee flexors with subtle rotational features. Distally, these muscles act as horse reins for rotational stabilization and reinforce the capsule while stabilizing the posterior structures such as menisci.¹⁴

The short head of BF originates at the linea aspera of the posterior aspect of the femur, and the ischial tuberosity is the origin of all the other hamstring muscles.¹ The SM originates at the anterolateral portion of the ischial tuberosity, and the ST and the long head of the BF originate at the posteromedial parts with a partly conjoined tendon.¹⁵ Recently, more interest has focused on the central tendon of the hamstring muscles.^{16,17} The central tendons originate at their relevant muscle belly and extend along the entire length of the muscle.^{1,18}

The ST has the shortest proximal tendon and the smallest physiological cross-sectional area (8.08 cm²) of the hamstring muscle group.¹ It attaches distally at the superior aspect of the medial tibiae becoming part of the pes anserinus.

The SM is the largest muscle of the posterior thigh, with the longest proximal tendon. Its proximal insertion is connected to the ischial tuberosity with a broad aponeurosis. The distal portion consists of tendinous branches joined to the popliteal fascia and the oblique popliteal ligament and attached to the posterior portion of the medial tibial condyle.¹⁴

The BF exerts more force compared with ST or SM.¹⁹ Distally, the BF tendon inserts at the anterior and posterior border of the proximal portion of the fibular head.²⁰

Injury patterns

The typical mechanism of hamstring injuries is an eccentric muscle contraction accompanied by forced hyperflexion of the hip and extension of the knee.^{21,22} Patients often report a “popping” sensation when sustaining this injury.²³ A common mechanism for the most severe hamstring injury is a rapid flexion of the hip during an ipsilateral eccentric knee extension, often from a fall while, for example, water skiing resulting in a front split, with a (complete) proximal hamstring rupture. A proximal isolated SM rupture can occur in extreme positions during the extended hip flexion movements performed by ballet dancers.²⁴ Isolated SM strain can also occur in slow, apparently well-controlled, stretching exercises performed to the limit of the range of motion when isolated proximal BF injury occurs often, for example, while sprinting.

While these injury patterns are fairly typical in proximal hamstring tears, the distal parts of hamstrings may suffer an injury in a different way. The distal ST has been reported to tear during eccentric hamstring load during high-speed running, when the hamstrings are maximally activated.²⁵ At this time, a switch from an eccentric to a concentric muscle contraction mode, with the individual muscles approaching their peak length, makes them most vulnerable to injury.

Treatment decision when hamstring injury occurs—individual muscle concept

Clear evidence-based guidelines concerning proximal isolated injuries of ST, SM, and BF are not available in the current literature. Studies have introduced injury types which could correlate to poorer prognosis, and therefore treatment algorithms point toward to operative or nonoperative treatments have been made.^{26,27} However, the current literature does not consider these hamstring muscles or tendons individually.

The first step in decision making is to formulate an exact diagnosis (Fig. 2). Clinical findings, mechanism of injury, and patient's history lead to the suspicion of a hamstring injury^{28,29} which is typically verified by magnetic resonance imaging (MRI). MRI allows to detect the location and extent of the injury, the presence of fluid collection, and which muscle and tendon structures are involved.^{30,31} At times, a

repeat MRI is needed 2 weeks after injury to obtain more detailed information.¹⁷ Injuries with a good prognosis after appropriate conservative treatment include injuries at myotendinous junction and low-grade muscle tears.²⁸ A hamstring injury is a risk factor for chronic and recurrent hamstring injuries²⁸; thus, treatment should be well planned, and patients closely followed.³² Other possible risk factors include age, untreated muscle strength imbalance, and reduced flexibility.³³⁻³⁸

Proximal tendon

Recently, surgical treatment has become more popular for the management of hamstring injuries.²⁷ If a tendon avulses from the ischial tuberosity, the degree of retraction seems to be associated with a poorer outcome³⁹: a retraction greater than 2 cm is a classical indication for operative treatment in athletes. Retrospective data show that, in 25 patients, conservative and surgical management eventually resulted in a similar acceptable outcome, but initial nonoperative treatment led to conversion to surgery in 40% of the patients.⁴⁰ Current literature regarding the management of one- or two-tendon avulsions is largely lacking, but most of these patients with symptomatic incomplete hamstring avulsions who are unresponsive to conservative management improved after surgical reinsertion.⁴¹ Early surgical treatment is recommended in complete proximal three-tendon hamstring avulsions (Fig. 3) and two-tendon (BF + ST / BF + SM, Fig. 4) hamstring avulsions^{6,16,42-44}, with a highly predictable rate of return to pre-injury level of sports. In proximal non-retracted partial avulsions that remain symptomatic, MRI can show fluid between the ischial tuberosity and the injured tendon attachment, indicating an incomplete healing process. For these patients, surgery is equally also indicated, with a high rate of successful outcomes.^{5,45}

In a proximal single-tendon avulsion with retraction from the ischial tuberosity, surgery is also recommended in high-level athletes regardless of which of the hamstring tendons is involved: BF (Fig. 5A), ST or SM (Fig. 5B).⁶ Without optimal treatment, permanent weakness and pain produce a sub-optimal hamstring function.

Distal tendon

Severe distal tendon injuries are rare compared with proximal hamstring tendon injuries. In athletes, in a complete distal tendon rupture surgery is usually indicated, and nonoperative management carries a high risk of failure.^{21,46-48} A complete distal rupture of BF or ST should be repaired anatomically as soon as possible after acute or acute-on-chronic injury^{23,25,48,49} (Figs. 2 and 6). Distal SM avulsion injuries are rare, with a marked negative impact on competitive sports participation. They are typically managed operatively.^{23,50}

Central tendon

Central or free (paramuscular) tendon injuries of the BF tend to become chronic and to recur despite appropriate conservative

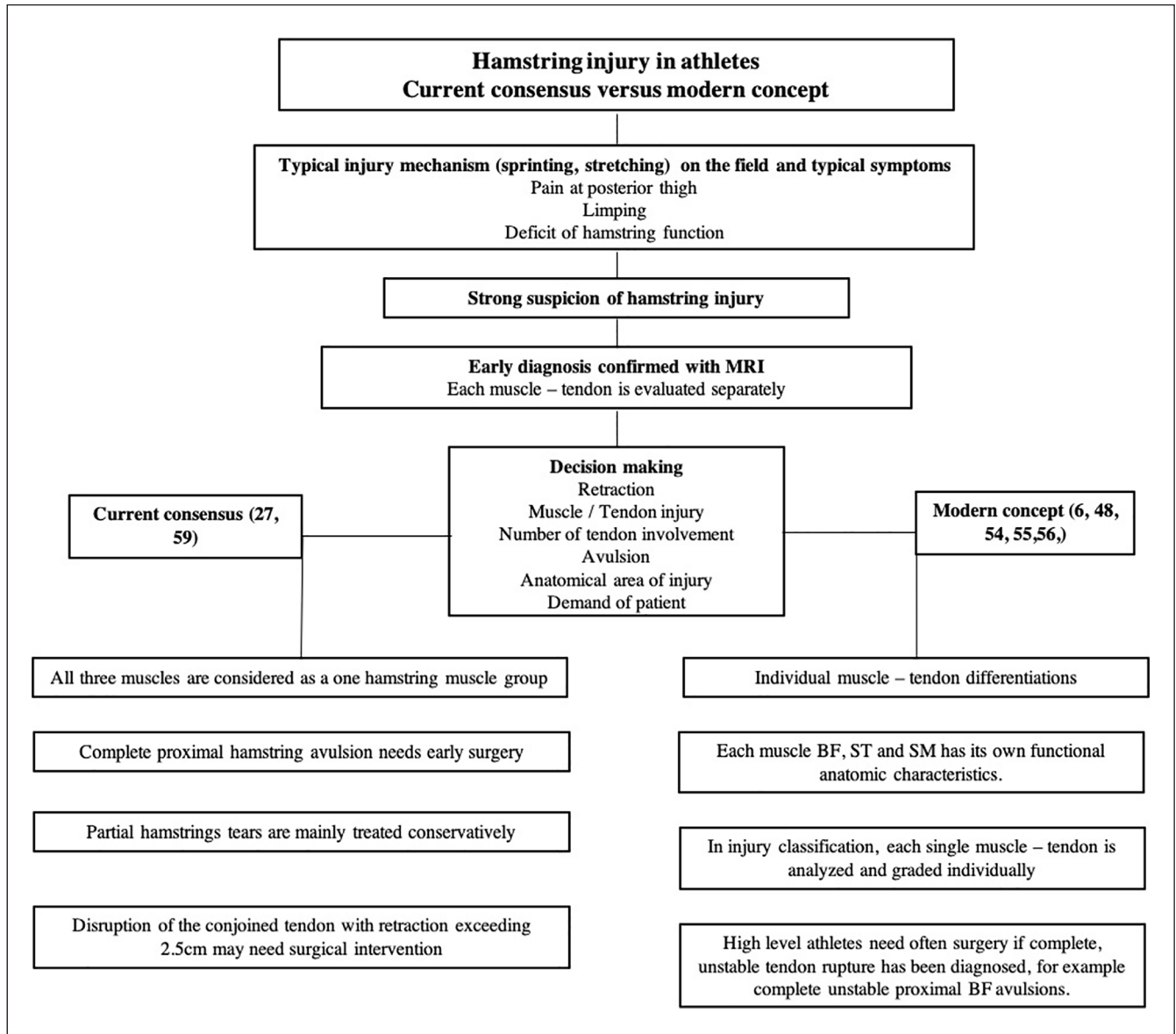


Fig. 2. Comparison between current and modern treatment algorithms based on the present literature.

management¹⁷ (Fig. 7). In addition, recurrent central tendon injuries produce longer absence from play compared with other hamstring injuries. These central tendon injuries have a high risk of poor healing with nonoperative measures.¹⁶ If adequate nonoperative management following an acute injury has failed, and recurrent injuries ensue, surgery should be considered.

Nonoperative treatment of proximal hamstring tendon avulsions

Complete proximal hamstring avulsions have a poor prognosis to heal without adequate treatment, especially in athletes.

Many studies have been conducted to compare whether operative or nonoperative treatments are superior.^{40,50-52} However, it seems that these complete three-tendon avulsion injuries do not heal properly without anatomical repair, especially if there is a clear retraction from the ischial tuberosity.^{39,53} Only some case series have been published on individual proximal hamstring tendon injuries⁵⁴⁻⁵⁶ showing superior result of surgery in athletes. Nonoperative treatment of isolated proximal tendon ruptures in athletes has not been fully discussed in the literature. However, most of the hamstring injuries are muscle tissue strains or partial tears with good prognosis when treated by conservative means (modified rest, ice, and progressive rehabilitation).

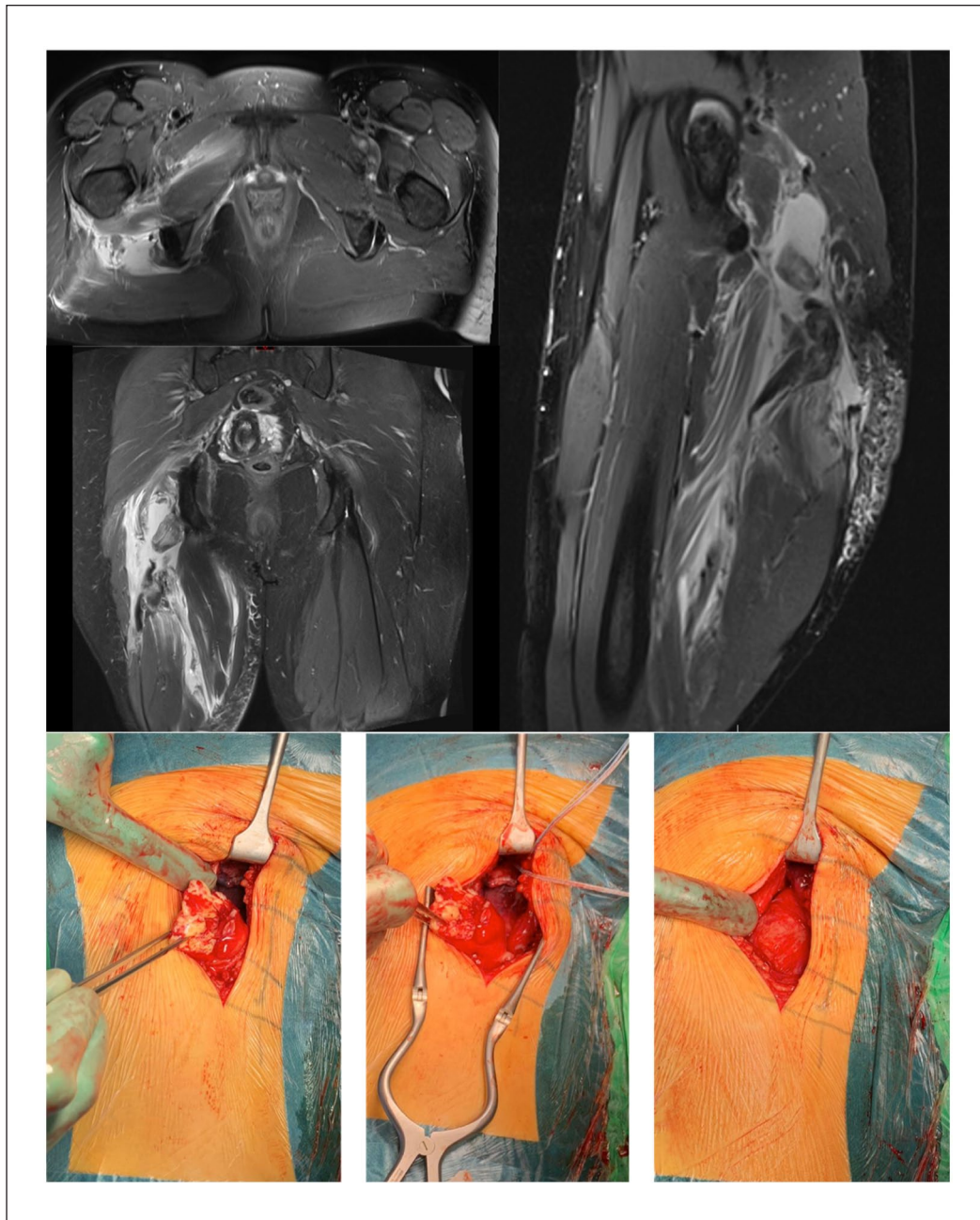


Fig. 3. Complete three-tendon proximal hamstring rupture with a clear retraction at the right side.

Discussion

The present article introduces the individual muscle-tendon concept in athletes. These injuries are prone to become disabling and chronic if misdiagnosed.³² Each hamstring muscle—BF, ST, and SM—has its own function and anatomy, and therefore should be considered individually. When BF, ST, and SM are considered separately and appropriate treatment administered, the risk of recurrent injury might be lower.

Hamstring injuries are typically related to soccer⁹, and recurrent injuries are common, often leading to substantial loss of play.¹⁰ Hamstring injuries can eventually jeopardize players' careers. Based on our clinical observations, hamstring injuries should be managed according to which individual muscles and tendons are involved. Each hamstring muscle—BF, ST, and SM—has its own function, purpose, and injury pattern. If one of these three tendons is completely ruptured, it may permanently impair athlete's performance and often also cause significant pain. These injuries should be

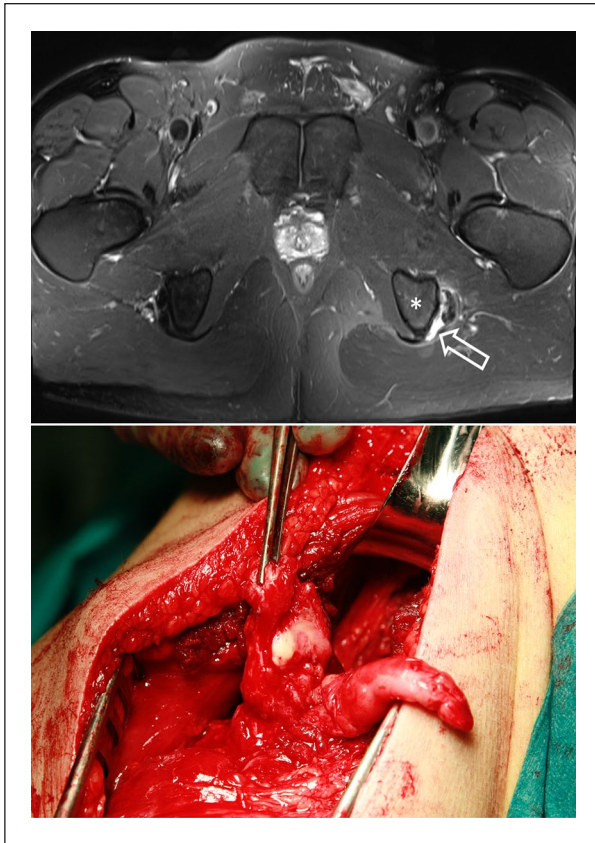


Fig. 4. Perioperative image of the complete proximal two-tendon (BF and ST)—rupture. Arrow showing the ruptured area.

probably managed surgically in top-level athletes. In practice, we should deal and manage each muscle and tendon of the hamstring complex individually, similar to what already happens in the gastrocnemius / soleus / Achilles muscle-tendon complex, and consider BF, ST, and SM and each of their tendons separately.

Different classifications of hamstring injuries are available.^{4,57} However, clinical and MRI data can contrast with each other.⁵⁸ The MLG-R classification takes into consideration the mechanism of injury (M), location of injury (L), level of severity (G), and number of muscle re-injuries (R) and is based on an MRI. Although the return to play seems to somewhat correlate to the higher grade of injury, the choice of treatment should be considered individually.

Typically, avulsion of the three attachment tendons from the ischial tuberosity is considered an indication for surgery,⁵⁹ but the treatment strategy with partial or single proximal tendon avulsion can be debated.^{40,50} In athletes, the loss of time to return to play and the rate of recurrence should be minimized. High-quality studies regarding individual hamstring tendon avulsion are scarce. Recently, Ayuob et al have published case series of operative treatment to avulsions of single tendon.⁵⁵

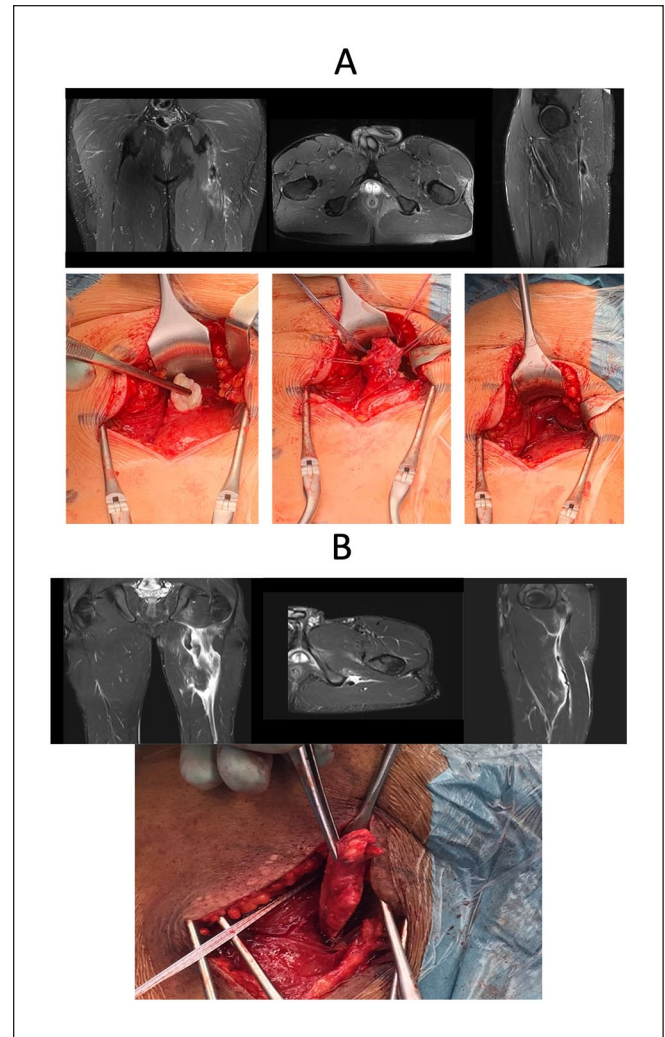


Fig. 5. Isolated complete proximal single-tendon rupture: A) BF (MRI and perioperative images), B) SM (MRI and perioperative images).

These results are in line with other earlier studies.^{6,54} However, level 1 evidence is lacking as comparative studies do not exist in the current literature.

In conclusion, based on the present knowledge of anatomy and the different functions of each of the muscles of the posterior aspect of the thigh, and the capability of MRI to allow to formulate an accurate diagnosis, the term “hamstring injury” seems somewhat inaccurate. To improve the standard level of the treatment, especially in athletes, we should precisely identify which individual muscle(s) is(are) affected. Formulating a precise diagnosis would prompt to talk about BF, SM, or ST injury, or a combination of them. Complete single-tendon avulsions—BF, ST, SM, or their combined injury—in high-performance athletes could lead to a marked loss of function and chronic disability, and therefore operative treatment should often be considered.

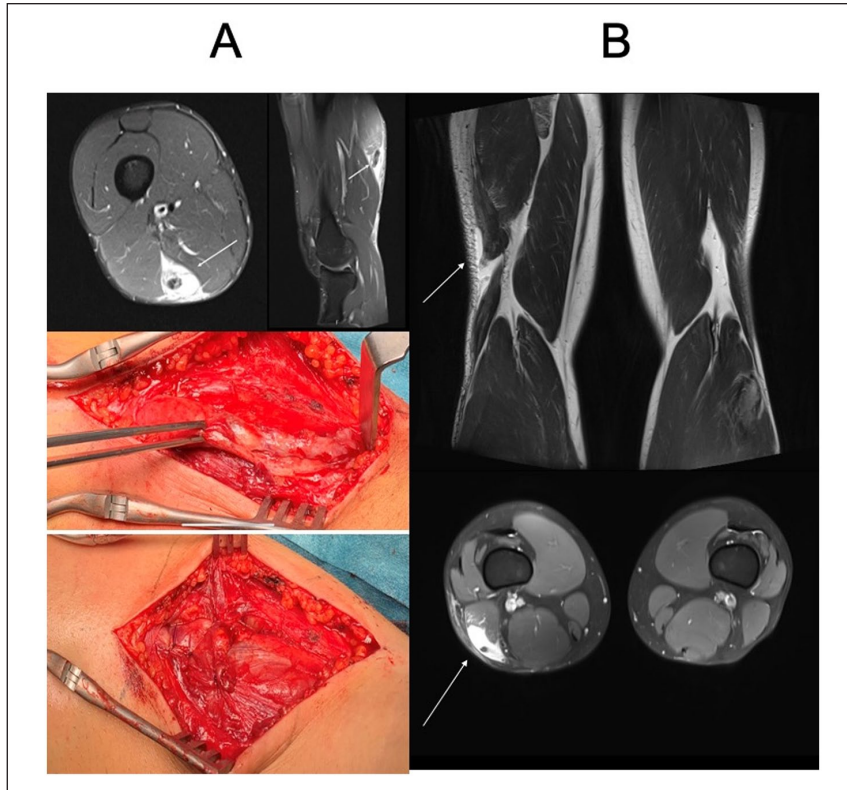


Fig. 6. A) Distal tendon rupture of the ST (MRI and perioperative images before and after repair) and B) distal MTJ area rupture of the BF (MRI images, arrows indicate the retracted muscle belly and tendon stump).

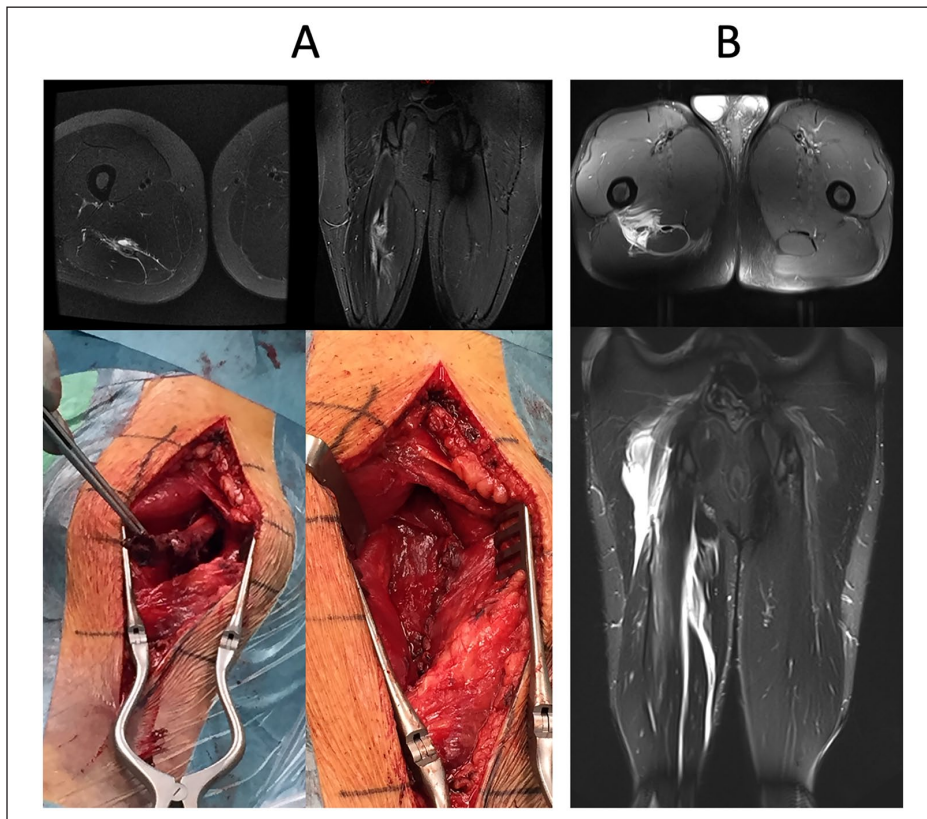


Fig. 7. A) Central tendon rupture of the SM (recurrent injury, MRI and perioperative images before and after repair) and B) BF (acute injury, MRI).


Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Jussi Kosola  <https://orcid.org/0000-0003-4428-7472>

References

- Woodley SJ, Mercer SR: Hamstring muscles: Architecture and innervation. *Cells Tissues Organs* 2005; 179(3): 125–141.
- Thelen DG, Chumanov ES, Hoerth DM et al: Hamstring muscle kinematics during treadmill sprinting. *Med Sci Sports Exerc* 2005; 37(1): 108–114.
- Maffulli N, Oliva F, Frizziero A et al: ISMuLT guidelines for muscle injuries. *Muscles Ligaments Tendons J* 2014; 3(4): 241–249.
- Chan O, Del Buono A, Best TM et al: Acute muscle strain injuries: A proposed new classification system. *Knee Surg Sports Traumatol Arthrosc* 2012; 20(11): 2356–2362.
- Lempainen L, Johansson K, Banke IJ et al: Expert opinion: Diagnosis and treatment of proximal hamstring tendinopathy. *Muscles Ligaments Tendons J* 2015; 5(1): 23–28.
- Lempainen L, Banke IJ, Johansson K et al: Clinical principles in the management of hamstring injuries. *Knee Surg Sports Traumatol Arthrosc* 2015; 23(8): 2449–2456.
- Pollock N, James SL, Lee JC et al: British athletics muscle injury classification: A new grading system. *Br J Sports Med* 2014; 48(18): 1347–1351.
- Valle X, Tol H, Hamilton B: Muscle injury classification. From muscle injuries clinical guide 3.0, <https://muscletechnetwork.org/wp-content/uploads/2015/04/MUSCLE-INJURIES-CLINICAL-GUIDE-3.0-LAST-VERSION.pdf> (accessed January 2015).
- Ekstrand J, Hagglund M, Walden M: Epidemiology of muscle injuries in professional football (soccer). *Am J Sports Med* 2011; 39(6): 1226–1232.
- Woods C, Hawkins RD, Maltby S et al: The football association medical research programme: An audit of injuries in professional football—Analysis of hamstring injuries. *Br J Sports Med* 2004; 38(1): 36–41.
- Järvinen TAH, Järvinen M, Kalimo H: Regeneration of injured skeletal muscle after the injury. *Muscles Ligaments Tendons J* 2013; 3(4): 337–345.
- Ahmad CS, Redler LH, Ciccotti MG et al: Evaluation and management of hamstring injuries. *Am J Sports Med* 2013; 41(12): 2933–2947.
- Ekstrand J, Hagglund M, Walden M: Injury incidence and injury patterns in professional football: The UEFA injury study. *Br J Sports Med* 2011; 45(7): 553–558.
- Beltran J, Matityahu A, Hwang K et al: The distal semimembranosus complex: Normal MR anatomy, variants, biomechanics and pathology. *Skeletal Radiol* 2003; 32(8): 435–445.
- Sato K, Nimura A, Yamaguchi K et al: Anatomical study of the proximal origin of hamstring muscles. *J Orthop Sci* 2012; 17(5): 614–618.
- Brukner P, Connell D: “Serious thigh muscle strains”: Beware the intramuscular tendon which plays an important role in difficult hamstring and quadriceps muscle strains. *Br J Sports Med* 2016; 50(4): 205–208.
- Lempainen L, Kosola J, Pruna R et al: Central tendon injuries of hamstring muscles: Case series of operative treatment. *Orthop J Sports Med* 2018; 6(2): 2325967118755992.
- Garrett WE Jr, Califf JC, Bassett FH 3rd: Histochemical correlates of hamstring injuries. *Am J Sports Med* 1984; 12(2): 98–103.
- Dolman B, Verrall G, Reid I: Physical principles demonstrate that the biceps femoris muscle relative to the other hamstring muscles exerts the most force: Implications for hamstring muscle strain injuries. *Muscles Ligaments Tendons J* 2014; 4(3): 371–377.
- Branch EA, Anz AW: Distal insertions of the biceps femoris—A quantitative analysis. *Orthop J Sports Med* 2015; 3(9): 2325967115602255.
- Blakeney WG, Zilko SR, Edmonston SJ et al: A prospective evaluation of proximal hamstring tendon avulsions: Improved functional outcomes following surgical repair. *Knee Surg Sports Traumatol Arthrosc* 2017; 25(6): 1943–1950.
- Stevens MA, El-Khoury GY, Kathol MH et al: Imaging features of avulsion injuries. *Radiographics* 1999; 19(3): 655–672.
- Sivasundaram L, Matcuk GR Jr, White EA et al: Partial semitendinosus tendon tear in a young athlete: A case report and review of the distal semitendinosus anatomy. *Skeletal Radiol* 2015; 44(7): 1051–1056.
- Askling C, Tengvar M, Saartok T et al: Sports related hamstring strains—two cases with different etiologies and injury sites. *Scand J Med Sci Sports* 2000; 10(5): 304–307.
- Lempainen L, Sarimo J, Mattila K et al: Distal tears of the hamstring muscles: Review of the literature and our results of surgical treatment. *Br J Sports Med* 2007; 41(2): 80–83; discussion 83.
- Fournier-Farley C, Lamontagne M, Gendron P et al: Determinants of return to play after the nonoperative management of hamstring injuries in athletes: A systematic review. *Am J Sports Med* 2016; 44(8): 2166–2172.
- Arner JW, McClincy MP, Bradley JP: Hamstring injuries in athletes: Evidence-based treatment. *J Am Acad Orthop Surg* 2019; 27(23): 868–877.
- Malliaropoulos N, Papacostas E, Kiritsi O et al: Posterior thigh muscle injuries in elite track and field athletes. *Am J Sports Med* 2010; 38(9): 1813–1819.
- Valle X, Malliaropoulos N, Parraga Botero JD et al: Hamstring and other thigh injuries in children and young athletes. *Scand J Med Sci Sports* 2018; 28(12): 2630–2637.
- Entwistle T, Ling Y, Splatt A et al: Distal musculotendinous T junction injuries of the biceps femoris: An MRI case review. *Orthop J Sports Med* 2017; 5(7): 2325967117714998.
- Greenky M, Cohen SB: Magnetic resonance imaging for assessing hamstring injuries: Clinical benefits and pitfalls—A review of the current literature. *Open Access J Sports Med* 2017; 8: 167–170.
- Brukner P, Nealon A, Morgan C et al: Recurrent hamstring muscle injury: Applying the limited evidence in the professional football setting with a seven-point programme. *Br J Sports Med* 2014; 48(11): 929–938.

33. Henderson G, Barnes CA, Portas MD: Factors associated with increased propensity for hamstring injury in English Premier League soccer players. *J Sci Med Sport* 2010; 13(4): 397–402.
34. van Beijsterveldt AM, van de Port IG, Vereijken AJ et al: Risk factors for hamstring injuries in male soccer players: A systematic review of prospective studies. *Scand J Med Sci Sports* 2013; 23(3): 253–262.
35. Engebretsen AH, Myklebust G, Holme I et al: Intrinsic risk factors for hamstring injuries among male soccer players: A prospective cohort study. *Am J Sports Med* 2010; 38(6): 1147–1153.
36. Hagglund M, Walden M, Ekstrand J: Previous injury as a risk factor for injury in elite football: A prospective study over two consecutive seasons. *Br J Sports Med* 2006; 40(9): 767–772.
37. Fousekis K, Tsepis E, Poulmedis P et al: Intrinsic risk factors of non-contact quadriceps and hamstring strains in soccer: A prospective study of 100 professional players. *Br J Sports Med* 2011; 45(9): 709–714.
38. Tokutake G, Kuramochi R, Murata Y et al: The risk factors of hamstring strain injury induced by high-speed running. *J Sports Sci Med* 2018; 17(4): 650–655.
39. Wood DG, Packham I, Trikha SP et al: Avulsion of the proximal hamstring origin. *J Bone Joint Surg Am* 2008; 90: 2365–2374.
40. Piposar JR, Vinod AV, Olsen JR et al: High-grade partial and retracted (<2 cm) proximal hamstring ruptures nonsurgical treatment revisited. *Orthop J Sports Med* 2017; 5(2): 2325967117692507.
41. Aldridge SE, Heilpern GN, Carmichael JR et al: Incomplete avulsion of the proximal insertion of the hamstring: Outcome two years following surgical repair. *J Bone Joint Surg Br* 2012; 94(5): 660–662.
42. Orava S, Kujala UM: Rupture of the ischial origin of the hamstring muscles. *Am J Sports Med* 1995; 23(6): 702–705.
43. Sandmann GH, Hahn D, Amereller M et al: Mid-term functional outcome and return to sports after proximal hamstring tendon repair. *Int J Sports Med* 2016; 37(7): 570–576.
44. Sarimo J, Lempainen L, Mattila K et al: Complete proximal hamstring avulsions: A series of 41 patients with operative treatment. *Am J Sports Med* 2008; 36(6): 1110–1115.
45. McGregor C, Ghosh S, Young DA et al: Traumatic and overuse injuries of the ischial origin of the hamstrings. *Disabil Rehabil* 2008; 30(20-22): 1597–1601.
46. Cooper DE, Conway JE: Distal semitendinosus ruptures in elite-level athletes: Low success rates of nonoperative treatment. *Am J Sports Med* 2010; 38(6): 1174–1178.
47. Hallen A, Ekstrand J: Return to play following muscle injuries in professional footballers. *J Sports Sci* 2014; 32(13): 1229–1236.
48. Kayani B, Ayuob A, Begum F et al: Surgical repair of distal musculotendinous T junction injuries of the biceps femoris. *Am J Sports Med* 2020; 48(10): 2456–2464.
49. Knapik DM, Metcalf KB, Voos JE: Isolated tearing and avulsion of the distal biceps femoris tendon during sporting activities: A systematic review. *Orthop J Sports Med* 2018; 6(7): 2325967118781828.
50. Bodendorfer BM, Curley AJ, Kotler JA et al: Outcomes after operative and nonoperative treatment of proximal hamstring avulsions: A systematic review and meta-analysis. *Am J Sports Med* 2018; 46(11): 2798–2808.
51. Shambaugh BC, Olsen JR, Lacerte E et al: A comparison of nonoperative and operative treatment of complete proximal hamstring ruptures. *Orthop J Sports Med* 2017; 5(11): 2325967117738551.
52. Harris JD, Griesser MJ, Best TM et al: Treatment of proximal hamstring ruptures—A systematic review. *Int J Sports Med* 2011; 32(7): 490–495.
53. Cohen S, Bradley J: Acute proximal hamstring rupture. *J Am Acad Orthop Surg* 2007; 15(6): 350–355.
54. Lempainen L, Sarimo J, Heikkila J et al: Surgical treatment of partial tears of the proximal origin of the hamstring muscles. *Br J Sports Med* 2006; 40(8): 688–691.
55. Ayuob A, Kayani B, Haddad FS: Acute surgical repair of complete, nonavulsion proximal semimembranosus injuries in professional athletes. *Am J Sports Med* 2020; 48(9): 2170–2177.
56. Ayuob A, Kayani B, Haddad FS: Musculotendinous junction injuries of the proximal biceps femoris: A prospective study of 64 patients treated surgically. *Am J Sports Med* 2020; 48(8): 1974–1982.
57. Hamilton B, Valle X, Rodas G et al: Classification and grading of muscle injuries: A narrative review. *Br J Sports Med* 2015; 49(5): 306.
58. Ekstrand J, Healy JC, Walden M et al: Hamstring muscle injuries in professional football: The correlation of MRI findings with return to play. *Br J Sports Med* 2012; 46(2): 112–117.
59. Heer ST, Callander JW, Kraeutler MJ et al: Hamstring injuries: Risk factors, treatment, and rehabilitation. *J Bone Joint Surg Am* 2019; 1101(9): 843–853.