2 Epidemiology, Biomechanics, and Classification of Proximal Hamstring Injuries

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Epidemiology

Hamstring injuries are an exceedingly common injury in both athletes and the general population. Estimates of injury prevalence range from 8% to 25% of recorded injuries in athletes [1, 2]. Despite the common nature of these injuries, there is a paucity of epidemiological data to reflect hamstring injuries in the general public. Much of the published epidemiological data arises from professional sporting leagues [3–6]. Their large-scale preexisting datasets and close monitoring of players allows for the collection and analysis of many musculoskeletal injuries in a population at higher risk than the general public. This well-documented sample of professional athletes provides a very specific insight on this demographic but may not be completely transferrable to the general public.

Sports requiring bursts of explosive sprinting patterns are frequently noted to have high incidences of injury. Much of the epidemiological data stems from professional rugby, football, and soccer leagues [4, 5, 7–9]. Other activities with a high incidence of hamstring injuries include waterskiing and dancing, likely due to the compromising positions involved [10, 11].

As much of the data surrounding hamstring injury arises from elite athletes, generalizability to recreational athletes or the general public may be limited. The data does, however, provide some insight into risk factors for injury and pathomechanics involved in injury.

There is significant heterogeneity in the established data in terms of sport and competition level. Similarly, the risks of injury are varied and depend on the nature of a given sport. Injury audits of English professional football players demonstrated that hamstring injuries represented 12% of all reported injuries [6, 12]. The majority

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of these injuries (62%) occurred during match play, and specifically tended toward the end of the half [6]. Injuries tended to occur while running (57%) and were non-contact in nature 91% of the time. Reinjury in the setting of hamstring strain is also common, ranging from 12% to 17% [6, 7, 12]. Of the hamstring strains recorded, only 5% were radiographically investigated with even fewer (1.9%) being treated surgically [12], demonstrating that although hamstring injuries are common, the majority do not require any advanced work-up or surgical intervention. Similarly, a study of National Football League player injuries identified hamstring injuries as the second most frequent injury suffered by players, with a rate of 4.07 per 1000 athlete exposures in game situations [3]. Of the most common injuries they recorded, hamstring strain was one of the leading causes of time spent away from play with an average of 8.3 days lost for hamstring injuries experienced in practices and 9.5 days for those suffered in games [3].

Numerous modifiable and non-modifiable risk factors have been identified for hamstrings injuries. Age has been identified as an independent risk factor for hamstring injury, with some reports suggesting the odds of sustaining hamstring injury increase by 1.78 times with each increasing year in age [9]. Sex differences among athletes also contribute to differences in risk profile. A study of American collegiate soccer players demonstrated that men were 64% more likely to suffer a hamstring strain than women and were nearly twice as likely to experience a recurrence [5]. Modifiable risk factors that have been implicated in hamstrings injury include hip flexibility as well as lower extremity power and muscle imbalance [2]. Commonly, the muscle imbalance is the hamstring to quadriceps strength ratio. It is thought that an imbalanced strength ratio increases the extension moment through the knee. This places the hamstring in eccentric stress beyond its elastic capabilities [13]. Specifically, the risk of injury is increased in athletes with hamstring:quadriceps strength ratio less than 0.6 [2]. With regard to hip flexibility, Henderson et al. [9] demonstrated in Premier League soccer players that for each 1° lack of hip flexion range of motion, injury propensity increased by 1.29 times. Similarly, injury propensity increased by 1.47 times for each centimeter increase in non-countermovement jump performance [9].

Injury recurrence and time away from play is a concern for athletes at any level, and many factors have been identified as contributing to the time to return to play [14]. Anatomic location, type of injury, distance from ischial tuberosity [7] have all been identified as factors effecting time to return to play. For example, Askling et al. [7] evaluated the injury characteristics and time to return to sport in athletes suffering hamstring injuries during ballistic movements (sprinting) as compared to extreme length stretching injuries (dancing). They noted that the athletes who suffered running injuries observed a more rapid decline in performance followed by a faster return to pre-injury function when compared to the stretch type injuries experienced by the dancing group.

Biomechanics

The hamstrings represent a group of muscles in the posterior thigh, whose unique anatomy plays a crucial role in the posterior chain by stabilizing both the hip and knee. Their biarticular insertion and high force generation expose the hamstrings to unique stresses and a high rate of injury [15]. The hamstring complex is made up of three muscles: the semimembranosus, semitendinosus, and the short and long heads of the biceps femoris (Fig. 2.1). All three muscles are innervated by the tibial branch of the sciatic nerve, with the exception of the short head of biceps femoris, which receives its innervation from the common peroneal nerve. The semitendinosus and long head of biceps femoris share a common origin from the lateral ischial tuberosity in the form of the conjoint tendon. The long head of biceps femoris travels laterally to unite with the short head of biceps along the posterior femur and inserts on the posterolateral tibia. Semitendinosus travels medially to insert with the gracilis and sartorius at the pes anserinus.

Many biomechanical and kinematic studies have examined the role of the hamstrings in walking and running gait. The biarticular organization, dual innervation of biceps, muscle fiber type, and pelvic tilt have all been implicated in injury

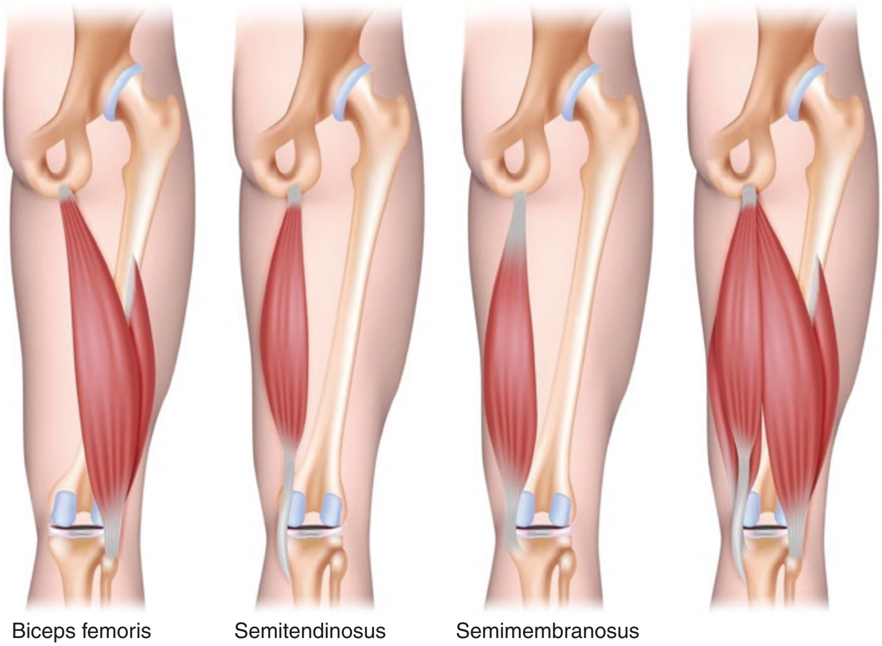

Fig. 2.1 Anatomy of theposterior thigh. Biceps femoris, semitendinosus, and semimembranosus and their relationship as labeled. (From Alila Medical Media. Reproduced with permission)

predisposition [16] Given their biarticular anatomy, the hamstrings act to both extend the hip and flex the knee. During walking gait, the hamstrings assist in flexing the knee as the hip flexes to assist ground clearance of the foot through swing phase [17]. In contrast, kinematic studies of running have demonstrated that the hamstrings remain active throughout nearly the entire cycle of running gait [18–20]. Specifically, eccentric contraction of the hamstring complex is noted in both late swing phase and late stance phase; however, the peak eccentric contraction speeds are far greater in late swing phase [18]. Further it is thought that the application of peak eccentric force, at the moment of maximal fiber length observed in late swing phase create the conditions required for hamstring injury [13, 18, 21]. A schematic representation of the running gait cycle is demonstrated in Fig. 2.2.

A few case reports have been published around studies which coincidentally captured hamstring injuries during kinematic analysis [22, 23]. These injuries were unfortunate for the participants; however, the active data capture during injury has provided excellent insight on the conditions surrounding injury. The first of which captured a hamstring injury in a 31-year-old professional skier who was running at 5.36 m/s on a 15% incline. Kinematic analysis did demonstrate that the moment of injury occurred in late swing phase, resulting in an injury to the long head of biceps while it was in a position 12.2% longer than standing resting length [22]. A similar injury was captured in a sprint trial with an elite Australian Football player [23]. Kinematic data again identified the moment of injury as occurring in late swing phase. Interestingly, both individuals in the case reports had suffered previous hamstring injuries, further supporting the high rate of hamstring injury recurrence.

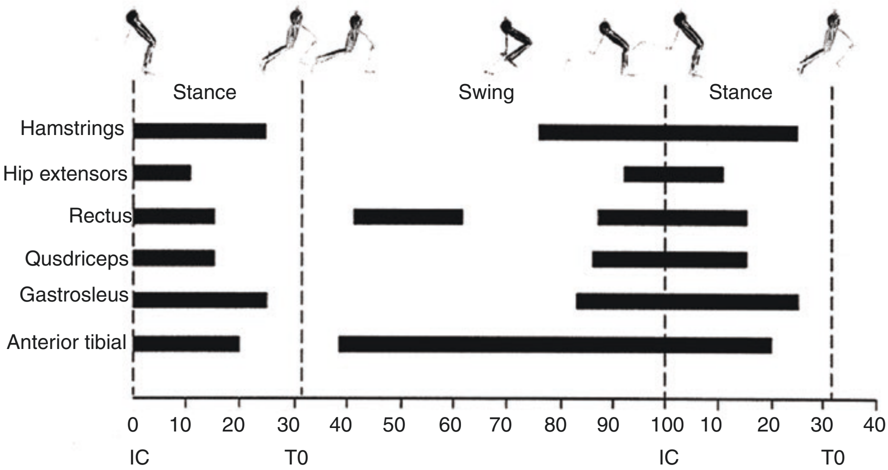

Fig. 2.2 Running gait cycle. Approximately 1.3 gait cycles are depicted in an effort to better visualize the continuous nature of running gait. Muscle activity is represented by the solid bars in relation to the gait cycle. (Reproduced with permission from Novacheck [20])

Classification

Characterization of injury severity represents an important part in the work up of suspected hamstring tear. Ideally classification systems assist in guiding therapeutic interventions and aid in prognostication of injuries. However, classification of hamstring injuries remains a challenge. Many classification systems exist but most only examine certain injury characteristics. Currently no overarching system has been identified to include all facets of injury, and many of the existing classification systems have not yet been validated [24].

Classic descriptions of magnetic resonance findings in muscle strain injuries have been previously described and can be generalized and applied specifically to hamstring injuries [25]. These descriptions are outlined in Table 2.1. First degree strains are described as microscopic injury with adjacent hyperintense T2 signal without identifiable muscle fiber disruption. Second degree strains encompass moderate strains with macroscopic tears at the myotendinous junction, this is represented by high signal intensity on T2 imaging and focal hematoma. Third degree strains present as severe strains with complete disruption of the myotendinous junction, with or without retraction. In this case, imaging demonstrates disruption of fibers and fluid-filled collection in the negative space, should the muscle demonstrated retraction [26].

One hamstring-specific radiographic classification system was proposed by Peetrons [27] which can be applied to ultrasound or magnetic resonance imaging and outlines four grades of muscle injury severity. Grade 0 injuries are described as a lack of ultrasound (or MRI) lesion, contrasted by Grade I injuries which describe minimal elongations with less than 5% of muscle involved. Grades 2 and 3 encompass injuries with muscle fiber tearing. Grade 2 injuries are comprised of partial tears involving 5–50% volume or cross-sectional diameter, whereas Grade III lesions demonstrate complete muscle tears, subcategorized by a lack (3A) or presence (3B) of muscle retraction. An example of a grade 3B tear is demonstrated in Fig. 2.3. Excellent inter and intraobserver reliability was demonstrated with the use of this classification system in MR imaging in acute hamstring injuries in athletes [8]. This classification system was further explored to assess its role in prognostic prediction. A study of 516 hamstring injuries in Union of European Football Association (UEFA) players evaluated the use of Peetrons grading on MRI as a prognostic factor for time out of play following injury. Of those athletes who underwent MRI, 13% were Peetrons grade 0, 57% grade 1, 27% grade 2, 3% grade 3 [4].

Table 2.1 Radiologic grade for strain based on MRI

Grade	Description
I	T2 hyperintense signal surrounding a tendon or muscle with no fiber disruption
II	T2 hyperintense signal surrounding and within a tendon or muscle with fiber disruption equal to less than half of the tendon or muscle width
III	Disruption of muscle or tendon fibers greater than half the muscle or tendon width, with hyperintense T2 signal present in the injured tissue

Adapted from Shelley et al. [25]

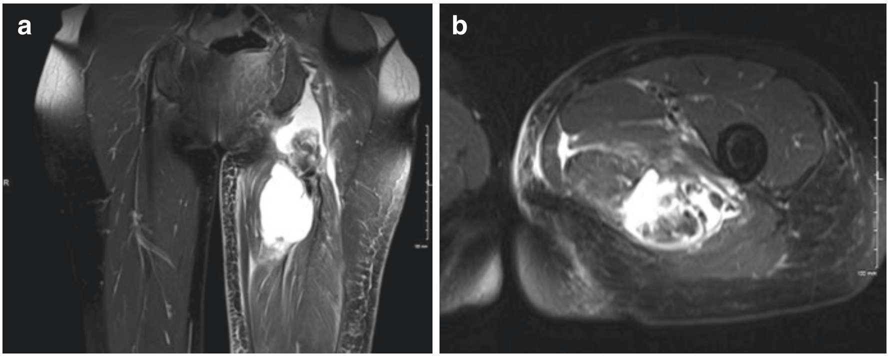

Fig. 2.3 MRI demonstrating complete rupture of the common hamstrings origin with retraction. (**a**) coronal T2-weighted view; (**b**) axial T2-weighted view

Table 2.2 MRI scoring system proposed by Cohen et al. [26]

Points	Age (y)	Muscles involved (n)	Location	Insertion	Muscle injury (%)	Retraction (cm)	Long axis T2 signal length (cm)
0				No	0	None	0
1	≤25	1	Proximal		25	<2	1–5
2	26–31	2	Middle	Yes	50	≥2	6–10
3	≥32	3	Distal		≥ 75		>10

National Football League players with scores >15 were associated with a prolonged recovery, whereas players with scores <10 missed one or fewer games

They further determined that MRI grading of severity did correlate with time off from play, defined as absence from full team practice and match play. Specifically, they demonstrated average time off at 8, 17, 22, 73 days for Grades 0–3, respectively.

An additional predictive scoring system was proposed by Cohen et al. arising from retrospective analysis of hamstring injuries in National Football League players [26]. Their system was developed in efforts to predict time off based on MRI findings. Their scoring system is outlined in Table 2.2. Through their analysis they observed that players with scores less than 10 missed one game or less, whereas scores greater than 15 were associated with prolonged time to return to play (five or more missed games) [26].

Additional classification systems have been developed to provide descriptive categorization. For example, Wood et al. created a surgically focused classification system to describe proximal hamstring avulsion injuries in a case series of 72 successive cases undergoing operative fixation (Table 2.3). Specifically they address proximal hamstring avulsions based on anatomic location, degree of avulsion (complete or incomplete), degree of muscle retraction, and sciatic nerve tethering if present [28]. They divide the injuries into five types: type 1 injuries being osseous avulsions, whereas type 2 avulsions occur at the myotendinous junction. Type 3 injuries are incomplete tendon avulsions from bone. Type 4 represents complete

Table 2.3 Classification of proximal hamstring avulsion injuries as described by Wood et al. [28]

Type	Description
1	Osseous injury in skeletally mature patient
2	Injury at musculotendinous junction
3	Partial tendon avulsion
4	Complete tendon avulsion with no retraction
5A	Complete avulsion with associated retraction but no associated sciatic nerve tethering
5B	Complete avulsion with associated retraction with associated sciatic nerve tethering

avulsions with minimal or no retraction, and type 5 represents complete avulsion with retraction of the junction ends [28]. Interestingly, they identified waterskiing as the most frequent cause of injury (29% of patients) in this operative group.

References

1. Copland ST, Tipton JS, Fields KB. Evidence-based treatment of hamstring tears. Curr Sports Med Rep. 2009;8:308–14.
2. Orchard J, Marsden J, Lord S, Garlick D. Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. Am J Sports Med. 1997;25(1):81–5.
3. Feeley BT, Kennelly S, Barnes RP, et al. Epidemiology of national football league training camp injuries from 1998 to 2007. Am J Sports Med. 2008;36(8):1597–603. https://doi.org/10.1177/0363546508316021.
4. 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. https://doi.org/10.1136/bjsports-2011-090155.
5. Cross KM, Gurka KK, Saliba S, Conaway M, Hertel J. Comparison of hamstring strain injury rates between male and female intercollegiate soccer athletes. Am J Sports Med. 2013;41(4):742–8. https://doi.org/10.1177/0363546513475342.
6. Woods C, Hawkins RD, Maltby S, Hulse M, Thomas A, Hodson A. 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. https://doi.org/10.1136/bjsm.2002.002352.
7. Askling C, Saartok T, Thorstensson A. Type of acute hamstring strain affects flexibility, strength, and time to return to pre-injury level. Br J Sports Med. 2006;40(1):40–4. https://doi.org/10.1136/bjsm.2005.018879.
8. Hamilton B, Whiteley R, Almusa E, Roger B, Geertsema C, Tol JL. Excellent reliability for MRI grading and prognostic parameters in acute hamstring injuries. Br J Sports Med. 2014;48(18):1385–7. https://doi.org/10.1136/bjsports-2013-092564.
9. 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. https://doi.org/10.1016/j.jsams.2009.08.003.
10. Troyer JD, Dunn WR. Epidemiology of hamstring and quadriceps injury. In: Hamstring and quadriceps injuries in athletes: Springer US; 2014. p. 29–43. https://doi.org/10.1007/978-1-4899-7510-2_3.
11. Hostetler SG, Hostetler TL, Smith GA, Xiang H. Characteristics of water skiing-related and wakeboarding-related injuries treated in emergency departments in the United States, 2001–2003. Am J Sports Med. 2005;33(7):1065–70. https://doi.org/10.1177/0363546504271748.
12. Dadebo B, White J, George KP. A survey of flexibility training protocols and hamstring strains in professional football clubs in England. Br J Sports Med. 2004;38:388–94. https://doi.org/10.1135/bjsm.2002.000044.

13. Carlson C. The natural history and management of hamstring injuries. Curr Rev Musculoskelet Med. 2008;1(2):120–3. https://doi.org/10.1007/s12178-007-9018-8.
14. Brukner P. Hamstring injuries: prevention and treatment – an update. Br J Sports Med. 2015;49(19):1241–4. https://doi.org/10.1136/bjsports-2014-094427.
15. Kopydlowski NJ, Weber AE, Sekiya JK. Functional anatomy of the hamstrings and quadriceps. In: Hamstring and quadriceps injuries in athletes: Springer US; 2014. p. 1–14. https://doi.org/10.1007/978-1-4899-7510-2_1.
16. Opar DA, Williams MD, Shield AJ. Hamstring strain injuries factors that lead to injury and re-injury. Sports Med. 2012;42(3):209–26.
17. Mann RA, Hagy J. Biomechanics of walking, running, and sprinting. Am J Sports Med. 1980;8(5):345–50.
18. Yu B, Queen RM, Abbey AN, Liu Y, Moorman CT, Garrett WE. Hamstring muscle kinematics and activation during overground sprinting. J Biomech. 2008;41(15):3121–6. https://doi.org/10.1016/j.jbiomech.2008.09.005.
19. Slocum DB, James SL. Biomechanics of running. J Am Med Assoc. 1968;205(11):721–8. https://jamanetwork.com/.
20. Novacheck TF. The biomechanics of running. Gait Posture. 1998;7:77–95.
21. Chumanov ES, Heiderscheit BC, Thelen DG. Hamstring musculotendon dynamics during stance and swing phases of high-speed running. Med Sci Sports Exerc. 2011;43(3):525–32. https://doi.org/10.1249/MSS.0b013e3181f23fe8.
22. Heiderscheit BC, Hoerth DM, Chumanov ES, Swanson SC, Thelen BJ, Thelen DG. Identifying the time of occurrence of a hamstring strain injury during treadmill running: a case study. Clin Biomech. 2005;20(10):1072–8. https://doi.org/10.1016/j.clinbiomech.2005.07.005.
23. Schache AG, Wrigley TV, Baker R, Pandy MG. Biomechanical response to hamstring muscle strain injury. Gait Posture. 2009;29(2):332–8. https://doi.org/10.1016/j.gaitpost.2008.10.054.
24. Alzahrani MM, Aldebeyan S, Abduljabbar F, Martineau PA. Hamstring injuries in athletes: diagnosis and treatment. JBJS Rev. 2015;3(6):1–11. https://doi.org/10.2106/JBJS.RVW.N.00108.
25. Shelly MJ, Hodnett PA, MacMahon PJ, Moynagh MR, Kavanagh EC, Eustace SJ. MR imaging of muscle injury. Magn Reson Imaging Clin N Am. 2009;17(4):757–73. https://doi.org/10.1016/j.mric.2009.06.012.
26. Cohen SB, Towers JD, Zoga A, et al. Hamstring injuries in professional football players: magnetic resonance imaging correlation with return to play. Sports Health. 2011;3(5):423–30. https://doi.org/10.1177/1941738111403107.
27. Peetrons P. Ultrasound of muscles. Eur Radiol. 2002;12(1):35–43. https://doi.org/10.1007/s00330-001-1164-6.
28. Wood DG, Packham I, Trikha SP, Linklater J. Avulsion of the proximal hamstring origin. J Bone Joint Surg. 2008;90(11):2365–74. https://doi.org/10.2106/JBJS.G.00685.