HAMSTRING INJURY PART 1: ANATOMY, FUNCTION AND INJURY

Hamstring injuries are common and may represent up to 12% of sports injuries. So you are likely to see many patients with these injuries. After reading this article you will have refreshed your knowledge of the anatomy and function of the hamstring muscles, as well as the common mechanisms and grades of injury. This will allow you to get the maximum benefit from Part 2, which discusses the rehabilitation of hamstring injury and will be published in the October journal. Read this article online https://bit.ly/2XMH5Og

By Dr Chris Norris PhD, MCSP

HAMSTRING
| 20-07-COKINETIC
FORMATS ▶ WEB
▶ MOBILE ▶ PRINT

All references marked with an asterisk are open access and links are provided in the reference list

●● HAMSTRING INJURY IS COMMON IN SPORT AND THESE INJURIES FREQUENTLY RECUR ●●

Incidence

Hamstring injury is common in sport and these injuries frequently recur. Up to 12% of sports injuries may be to the hamstrings (1*), and it is the most common muscle injury in male footballers (2*). Recurrence rates vary between 12% and 63% depending on the site of injury and severity, and the first month after return to sport sees the greatest risk of reinjury (3*). High-quality rehabilitation is a key factor for recovery from hamstring injury and can affect both recurrence and return to play (RTP).

The hamstrings consist of three muscles, the biceps femoris (BF) laterally, and the semimembranosus (SM) and semitendinosus (ST) medially. The BF is more commonly injured than the ST and SM with rates of 80% compared to 10% respectively (1*). The ischial portion (vertical fibres) of adductor magnus is sometimes considered within the hamstring group, and involvement of this muscle is sometimes seen alongside hamstring injury (4). The anatomy of this region is an important factor in the varying injury incidence between the various hamstring components.

Anatomy

The three hamstring muscles attach to the ischial tuberosity – the SM from the superior-lateral aspect, the ST and BF from the infero-medial portion below the sacrotuberous ligament (Fig. 1). The ST and long head of BF have a combined attachment on the lower medial facet of the ischial tuberosity, the two muscles travelling together for a short distance until they form fusiform muscle bellies. The ST almost instantly forms into a long slender tendon, and travels around the medial condyle of the tibia to attach to the medial surface of the tibia below gracilis. The BF has two proximal attachments; the long head, as described above, and the short head from the lower linea aspera of the femur. The muscle swings downwards and laterally across the posterior aspect of the thigh and around the lateral ligament to insert into the head of the fibula. From this point it has a strong fascial attachment to the peroneus (fibularis) longus and the iliotibial band as part of the lateral and spiral fascial lines (5).

The hamstrings as a group are innervated by the sciatic nerve (tibial branch), but the BF has a dual innervation (tibial and peroneal branch), and asynchronous stimulation of the two heads has been described as a factor in injury (6). The SM comes from the lateral facet of the ischial tuberosity and travels down and medially, becoming flattened and broader as it does so. The SM is deep to both the ST and BF, and divides into five components when it reaches the knee. The principal insertion is to the posterior aspect of the medial tibial tubercle, with attachment into the oblique popliteal ligament and medial meniscus.

The proximal tendon of the BF extends into the muscle by 60% of its length, and the distal tendon by 66%, while for the SM the tendon extension is 78% and 52% (7). The continuity between the two tendons into the centre of the muscle constitutes the central tendon (intramuscular myotendon), which is often a region of disruption in persistent injuries (8*).

Function

The hamstrings have functions over the pelvis, hip and knee. They are two-joint (biarticular) muscles, and (as with all muscles) contribute force through active (contraction) and passive (recoil) means. In open chain motion the muscles will flex the knee and extend the hip, but the short head of BF has an action (flexion) over the knee alone. When the knee is flexed, SM and ST medially rotate the tibia and the BF laterally rotates. In closed chain action the hamstrings will assist in knee extension by drawing the femur into extension over the fixed foot.

Two-Joint Muscles

As biarticular muscles, the hamstrings are unable to permit full movement simultaneously at both joints they span. Full movement may be limited during stretch (passive insufficiency) for example knee extension combined with hip extension, or contraction (active insufficiency) such as knee flexion and hip extension.

Biarticular muscles are arranged as agonist and antagonist: in the case of the thigh, the hamstrings being grouped opposite the rectus femoris. Because both biarticular muscle-sets are not long enough to permit movement at both joints simultaneously, the tension in one muscle is transferred to the other. Using the hip as an example, as the hamstrings contract to extend the hip, passive tension is transmitted to the rectus femoris creating a knee extension force. This type of action, involving either extension or flexion at both joints at the same time, is called concurrent movement. The muscle shortens at one end but lengthens at the other, and so maintains its length with a range of 100% to 130% resting length to conserve tension (9*). When the hip is flexed but the knee extended, the rectus femoris is shortened and rapidly loses tension, while the hamstrings are lengthened and rapidly gain tension, an example of countercurrent movement (10).

Two-joint muscles provide a number of mechanical advantages over monoarticular equivalents. Firstly, they couple movement at both joints. For example, in the upper limb shoulder and elbow flexion occur together in a feeding pattern, and both actions have a contribution from biceps brachii (11). Biarticular muscles also allow the transfer of power from proximal to distal segments (8*), allowing bulky musculature to be kept closer to the trunk, reducing the mass

THE FIRST MONTH AFTER RETURN TO SPORT SEES THE GREATEST RISK OF REINJURY

of the extremity and facilitating limb acceleration.

Secondly, the shortening velocity of a two-joint muscle is less than that of a single-joint muscle (12), contributing to more rapid limb movement. By shortening less than two equivalent monoarticular muscles, a biarticular muscle demonstrates lower contraction velocities and higher force development. For instance, the contraction velocity of the hamstrings during vertical jumping is said to be one quarter of that required by a monoarticular muscle. As force and velocity are linked during muscle performance (force velocity relationship) biarticular muscles can generate approximately three times the force of their monoarticular counterparts (13).

Thirdly, two-joint muscles are said to redistribute muscle force throughout the limb (14). For example, if hip flexion is performed by rectus femoris, recoil of the lengthening hamstrings will tend to flex the knee. Equally recoil of the lengthening rectus femoris in hip extension will tend to extend the knee. A biarticular muscle will also enhance joint stability by allowing co-contraction of the agonist and antagonist muscles without reducing tension, as would occur with monoarticular muscles at both joints.

The hamstrings, as biarticular muscles, have an important function during both running- and lifting-type actions.

Bending

Forward bending is a coupled movement combining lumbar flexion and pelvic rotation (lumbar-pelvic rhythm), which results from a coordinated action between the back-extensor muscles (erector spinae) and the hip extensors (gluteals and hamstrings). Towards end-range forward bending, both the back-extensor muscles and the hip extensors show reduced electrical activity, a phenomenon called the flexion–relaxation response (FRR). As the body

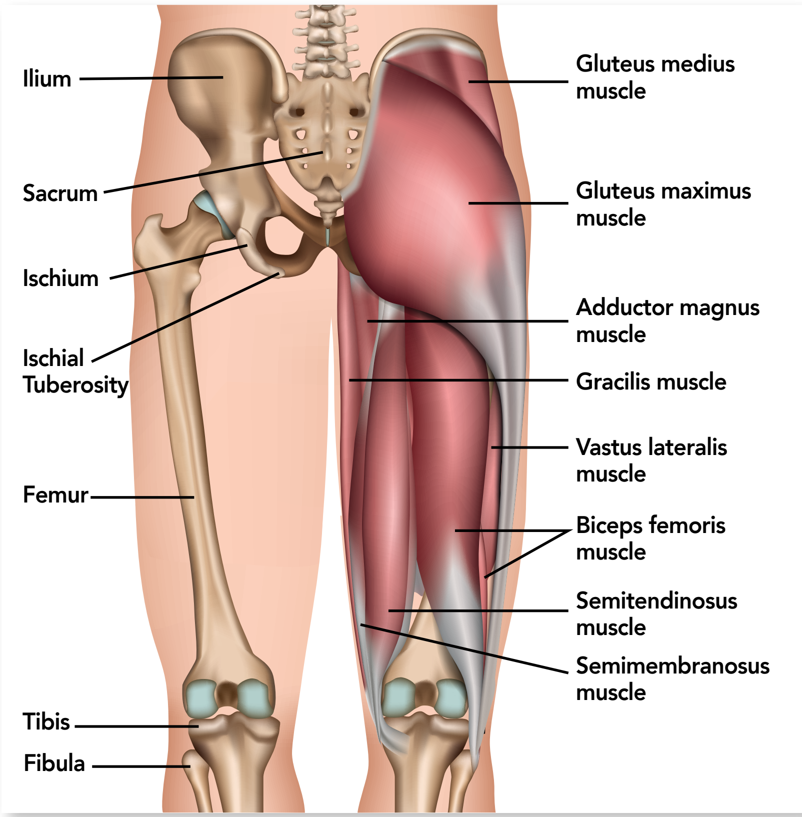

Figure 1: Anatomy of the hamstring muscles

●● THE HAMSTRINGS, AS BIARTICULAR MUSCLES, HAVE AN IMPORTANT FUNCTION DURING BOTH RUNNING AND LIFTING-TYPE ACTIONS ●●

bends forwards, its descent is initially controlled by eccentric action of both the spinal extensors and hamstrings; however, towards the end of mid-range, activity of the spinal extensors ceases and elastic resistance of the spinal extensors and posteriorly placed spinal soft tissues limits movement range (8*). Near end range, activity of the hamstrings also ceases and the final angle of pelvic tilt is limited by elastic resistance of these muscles and tension of other posteriorly placed soft tissues. At the initiation of body lifting, little muscle contraction is seen, the trunk being raised by elastic recoil of the posterior tissues. The point at which this occurs (critical point) varies, and the FRR of both the erector spinae and hamstrings may be altered or obliterated in subjects with chronic low back pain (CLBP), perhaps representing an inability to relax the muscles as part of pain behaviour. EMG biofeedback training has been used to decrease lumbar paraspinal muscle activity and increase motion range in patients with CLBP. In this study a decreased fear of movement was noted leading the authors to suggest that initial movement limitation may have been modulated by fear avoidance (15*). Surface EMG has also successfully been used to assist a home-based stretching programme aimed at lengthening the paraspinal muscles in CLBP subjects (16), again suggesting that increased tone in these muscles may be part of the pain phenomenon of CLBP.

There are several important considerations with respect to injury recovery and rehabilitation with the bending action. Firstly, the lumbar spine and pelvis must work in a coordinated fashion and following injury this coordination often breaks down and must be retrained. Secondly, although both the back muscles and hamstrings must be strong enough to lift a subject's own body weight and the weight of any object being held (these muscles often weaken after injury), they must also be able to relax at the right point when bending. If they stay active throughout the bending action, without switching off, they will tire and become painful.

Running

During the running cycle, the hamstrings are said to contract eccentrically to decelerate the leg in late forward swing, an action which also helps to stabilise the knee. Although lengthening (as the distance between the muscle insertion points increases), tension in mid forward swing is primarily through recoil of parallel and series elastic components within the muscle. In later forward swing an isometric contraction occurs at knee extension (17). During the support phase, the hamstrings act concentrically to extend the hip, and continue to stabilise the knee by preventing knee extension. During push-off, the hamstrings and gastrocnemius, both biarticular muscles, paradoxically extend the knee. EMG studies have demonstrated differences between the medial and lateral hamstrings during knee flexion (isokinetic dynamometry) with BF showing maximal activation early on (15–30°) and SM and ST later (90–105°) in knee flexion (18). BF is subjected to the greatest muscle-tendon stretch in the terminal swing phase of high-speed running, perhaps explaining the increased incidence of injury to this muscle. BF and ST are maximally active eccentrically throughout the swing phase of running, but their neuromuscular coordination patterns show BF more active in the middle-to-late swing and ST in the terminal swing phase only (19). It has been suggested that a reduced endurance capacity of the ST is compensated by increased activity of the BF, as muscle functional MRI (mfMRI) has shown increased metabolic activity in the ST compared to BF following injury (2*).

Injury

Hamstring injuries tend to occur in two main categories: high-speed running, which typically involves the BF long head; and slower extended lengthening (high kick or splits action), which often implicates the proximal tendon of SM (20). In addition, posterior thigh pain showing no local structural injury (MRI-negative injury) may be due to referred pain from the lumbar spine or pelvis (21*). The orientation of fibres within the hamstrings is an important consideration in both injury and rehabilitation. The ST and BL have a common origin with the ST fibres originating close to the ischial tuberosity. The BF long head has fibres which originate from the common tendon but 5–6cm below the ischial tuberosity. The semimembranosus has a long proximal free tendon some 10cm long, with the short head attaching from the linea aspera of the femur (and as such has no direct action on the hip). The proximal and distal tendons of the BF extend to almost 60% of the total muscle length, so that the muscle-tendon (MT) junctions are in two parts. The proximal MT junction is along the medial aspect of the muscle, the distal MT junction along the lateral. An area of overlap is seen in the centre of the muscle belly. The muscle fascicles (bundles of fibres) attach at an angle (pennation angle) to the tendon with effects on pennation angle and fascicle length often being important outcome measures of exercises in research studies.

The injuries may be classified according to the Munich consensus statement (22*). Muscle injury may be direct or indirect, and graded from 1 to 4. Grades 1 and 2 are functional muscle disorders due to overexertion and/or fatigue, with grade 2 representing delayed onset muscle soreness (DOMS) or MRI-negative injury resulting from referred posterior thigh pain. Grade 3 injury is a minor or partial tear, whereas grade 4 is a total or complete tear or avulsion. Grades 3 and 4 represent structural injuries (Table 1). The Munich consensus muscle classification system has been extended into the British Athletics system with reference to MRI views of hamstring injuries (23). Grades 1–4 of the Munich consensus are still applied, but the site and depth of the injury are assessed on MRI and given a suffix.

Table 1: Munich classification of muscle injuries in sport (Modified from Mueller-Wohlfahrt et al. Terminology and classification of muscle injuries in sport: The Munich consensus statement. British Journal of Sports Medicine 2013;47:342–350 (22*))

Indirect	Functional	Type 1: overexertion related	1A: fatigue induced 1B: DOMS
		Type 2: neuromuscular	2A: spine related 2B: muscle related
	Structural	Type 3: partial tear	3A: minor 3B: moderate
		Type 4: (sub)total	Subtotal or complete tear Tendinous avulsion
Direct		Contusion Laceration	

Where the injury is to the superficial aspect of the muscle (myofascial injury) the suffix 'a' is used, 'b' for an injury extending into the muscle belly and 'c' for injuries extending to the tendon. Further, the site of the injury is described (proximal, central or distal third).

Recovery from injury and return to the activities of daily living or RTP may partially be determined by the site of injury and the amount of tissue damage. However, although studies suggest that closer proximity to the ischial tuberosity is likely to imply greater recovery time (24*,25*), MRI and US studies show no association between scan findings and RTP (26,27). RTP before full rehabilitation has taken effect can be an important factor in reinjury. Reduction of eccentric strength and delayed rate of torque development may suggest neural function change following injury, especially at longer muscle lengths (28). Pain inhibition following injury may produce a structural and functional maladaptation within the muscle, meaning that early pain management may be important to reduce inhibition and encourage early muscle activation (21*).

Healing rates of different portions of the hamstring unit vary and responses to rehabilitation may be different (23). Fascia consists of collagen tissue layers with hyaluronic acid between the layers to enable sliding. Healing is through inflammation followed by fibrosis, with collagen synthesis peaking at 7 days post-injury and full strength returning after 21 days (29*). Little damage occurs to the contractile portion of the muscle in this type of injury, with the main effect being oedema, which tracks between the fascial layers. Pain may occur locally to palpation, but manual muscle testing often demonstrates full strength. Where muscle tissue is affected, manual muscle testing will usually show pain and weakness. Healing of muscle is through satellite cell activity with the healing tissue maximising after 10 days (For a review of muscle healing see 30). Intratendon injuries typically occur in high-force movement (running or ballistic stretching), and present with significant loss of both ROM and strength. Tendon tissue heals more slowly than either fascia or muscle. Healing is through deposition of extracellular matrix followed by collagen type III synthesis. Remodelling occurs as collagen type III is replaced by collagen type I after about 6 weeks post-injury. During this time, high-load eccentric actions (which increase fascicle length) should be delayed avoiding excessive elastic strain on healing tendon tissue (25*).

References

1. Ekstrand J, Healy JC, Waldén M et al. Hamstring muscle injuries in professional football: the correlation of MRI findings with return to play. **British Journal of Sports Medicine 2012;46:112–117** Open access https://bit.ly/3glFJkU

2. Schuermans J, Van Tiggelen D, Danneels L et al. Biceps femoris and emitendenosus --teammates or competitors? New insights into hamstring injury mechanisms in male football players: a muscle functional MRI study. **British Journal of Sports Medicine 2014;48(22):1599–1606** Open access https://bit.ly/3glFEO8

3. 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. **British Journal of Sports Medicine 2014;48:929–938** Open access https://bit.ly/2LYTZSO

4. Askling CM, Tengvar M, Saartok T et al. Acute first-time hamstring strains during slow-speed stretching: clinical, magnetic resonance imaging, and recovery characteristics. **American Journal of Sports Medicine 2007;35(10):1716–1724**

5. Myers TW. Anatomy trains: myofascial meridians for manual and movement therapists, 3rd edn. **Churchill Livingstone 2013**. ISBN 978-0702046544 (Print £45.38 Kindle £22.84) Buy From Amazon https://amzn.to/3cZveBC

6. Burkett LN. Investigation into hamstring strains: the case of the hybrid muscle. **Journal of Sports Medicine 1975;3(5):228–231**

7. Garrett WE Jr, Rich FR, Nikolaou PK et al. Computed tomography of hamstring muscle strains. **Medicine and Science in Sports and Exercise 1989;21:506–514**

8. Brukner P, Connell D. 'Serious thigh muscle strains': beware the intramuscular tendon which plays an important role in difficult hamstring and quadriceps muscle strains. **British Journal of Sports Medicine 2016;50:205–208** Open access https://bit.ly/3c4E8fU

9. Burkholder TJ, Lieber RL. Sarcomere length operating range of vertebrate muscles during movement. **Journal of Experimental Biology 2001;204:1529–1536** Open access https://bit.ly/3d2RWbZ

10. Rasch PJ, Burke RK. Kinesiology and applied anatomy: the science of human movement. **Lea and Febiger 1989**. ISBN 978-0812111323

11. Enoka RM. Neuromechanical basis of kinesiology, 2nd edn. **Human Kinetics 1994**. ASIN B005P2FT40

12. van Ingen Schenau GJ, Bobbert MF, van Soest AJ. The unique action of bi-articular muscles in leg extensions. In: Winters JM, Woo SL-Y, Delp I (eds) **Multiple muscle systems: biomechanics and movement organisation. Springer 1990**. ISBN 978-0387973074 (£149.99) Buy from Amazon https://amzn.to/2yzjk2w

13. Cleather DJ, Southgate D, Bull AM. The role of the biarticular hamstrings and gastrocnemius muscles in closed chain lower limb extension. **Journal of Theoretical Biology 2015;365:217–225**

14. Toussaint HM, van Baar CE, van Langen

HEALING RATES OF DIFFERENT PORTIONS OF THE HAMSTRING UNIT VARY

PP et al. Coordination of the leg muscles in backlift and leglift. **Journal of Biomechanics 1992;25:1279–1289**
15. Pagé I, Marchand AA, Nougarou F et al. Neuromechanical responses after biofeedback training in participants with chronic low back pain: An experimental cohort study. **Journal of Manipulative and Physiological Therapeutics 2015;38:449–457** Open access https://bit.ly/30oB2Bn
16. Moore A, Mannion J, Moran RW. The efficacy of surface electromyographic biofeedback assisted stretching for the treatment of chronic low back pain: a case series. **Journal of Bodywork and Movement Therapies 2015;19(1):8–16**
17. Van Hooren B, Bosch F. Is there really an eccentric action of the hamstrings during the swing phase of high-speed running? Part I: A critical review of the literature. **Journal of Sports Science 2017;35(23):2313–2321**
18. Onishi H, Yagi R, Oyama M et al. EMG-angle relationship of the hamstring muscles during maximum knee flexion. **Journal of Electromyography and Kinesiology 2002;12(5):399–406**
19. Higashihara A, Ono T, Kubota J et al. Functional differences in the activity of the hamstring muscles with increasing running speed. **Journal of Sports Sciences 2010; 28(10):1085–1092**
20. Askling CM, Malliaropoulos N, Karlsson J. High-speed running type or stretching-type of hamstring injuries makes a difference to treatment and prognosis. **British Journal of Sports Medicine 2012;46(2):86–87**
21. Brukner P. Hamstring injuries: prevention and treatment—an update. **British Journal of Sports Medicine 2015;49:1241–1244** Open access https://bit.ly/2zkjc7z
22. Mueller-Wohlfahrt HW, Haensel L, Mithoefer K et al. Terminology and classification of muscle injuries in sport: The Munich consensus statement. **British Journal of Sports Medicine 2013;47:342–350** Open access https://bit.ly/2ZvUuvz
23. Macdonald B, McAleer S, Kelly S et al. Hamstring rehabilitation in elite track and field athletes: applying the British Athletics Muscle Injury Classification in clinical practice. **British Journal of Sports Medicine 2019;53(23):1464–1473**
24. Askling CM, Tengvar M, Thorstensson A. Acute hamstring injuries in Swedish elite football: a prospective randomised controlled clinical trial comparing two rehabilitation protocols. **British Journal of Sports Medicine 2013;47:953–959** Open access https://bit.ly/3el8f47
25. Silder A, Sherry MA, Sanfilippo J et al. Clinical and morphological changes following 2 rehabilitation programs for acute hamstring strain injuries: a randomized clinical trial. **Journal of Orthopaedic and Sports Physical Therapy 2013;43:284–299** Open access https://bit.ly/2zjd7lv
26. Reurink G, Brilman EG, de Vos RJ et al. Magnetic resonance imaging in acute hamstring injury: can we provide a return to play prognosis? **Sports Medicine 2015;45:133–146**
27. Petersen J, Thorborg K, Nielsen MB et al. The diagnostic and prognostic value of ultrasonography in soccer players with acute hamstring injuries. **American Journal of Sports Medicine 2014;42:399–404**
28. Fyfe JJ, Opar DA, Williams MD et al. The role of neuromuscular inhibition in hamstring strain injury recurrence. **Journal of Electromyography and Kinesiology 2013;23:523–530**
29. Zügel M, Maganaris CN, Wilke J et al. Fascial tissue research in sports medicine: from molecules to tissue adaptation, injury and diagnostics: consensus statement. **British Journal of Sports Medicine 2018;52(23):1497** Open access https://bit.ly/2AWXQgJ
30. Norris CM. Muscle injury and rehabilitation. **sportEX medicine 2012;51(January):22–27**. https://bit.ly/30qdR9A.

KEY POINTS

- Hamstring injuries are common in sport and frequently recur.
- Good rehabilitation is key for recovery from hamstring injury.
- The hamstrings consist of three muscles: the biceps femoris, the semimembranosus and semitendinosus.
- The hamstrings are biarticular muscles and have functions over the pelvis, hip and knee.
- Biarticular muscles do not allow full movement simultaneously at both of the joints that they span; however, they do have advantages over monoarticular equivalents.
- As the hamstrings are part of the hip extensors, and so are involved in forward bending, correct functioning of these muscles may be needed in rehabilitation with a bending action.
- Hamstring muscle injuries are graded 1–4 on the Munich consensus statement and the British Athletics system adds further information according to the part of the muscle that is injured and the site of injury.
- Healing rates vary, but return to play before full rehabilitation has happened may be a factor in reinjury.

RELATED CONTENT

- Role of the Thorax in Treatment of Recurrent Hamstring Injury [Article] https://bit.ly/2LT8zex
- The Hamstring Hustle: Rapid Return to Sport Versus Recurrence [Article] https://bit.ly/2yALD0A
- Hamstring Injury Patient Information Resources https://bit.ly/2yuUiS2

DISCUSSIONS

- Refresh your knowledge of hamstring anatomy. Can you describe the hamstring muscles (and their insertion and attachment points) and innervations from memory?
- Discuss what is meant by a biarticular muscle. What are their advantages over monoarticular muscles?
- Discuss the common mechanisms of hamstring injury – which have you most often seen in your own patients?

THE AUTHOR

Dr Chris Norris PhD, MCSP is a physiotherapist with over 35 years' experience. He has an MSc in Exercise Science and a PhD in Backpain Rehabilitation, together with clinical qualifications in manual therapy, orthopaedic medicine, acupuncture, and medical education.

Chris is the author of 12 books on physiotherapy, exercise, and acupuncture and lectures widely in the UK and abroad. He is a visiting lecturer and external examiner to several universities at postgraduate level.

He runs private clinics in Cheshire and Manchester and his postgraduate courses for therapists are on his website.

Email: cmn@norrishealth.co.uk
Twitter: https://twitter.com/NorrisHealth
YouTube: https://www.youtube.com/channel/UC0VExulacEqFW7gahk98Tuw
Website: http://www.norrishealth.co.uk/

Want to share on Twitter?

Here are some suggestions

Tweet this: Hamstring injury is common in sport and it is the most common muscle injury in male footballers https://bit.ly/2XMH5Og

Tweet this: Good rehab is key in hamstring injury recovery, affecting both recurrence and return to play https://bit.ly/2XMH5Og

Tweet this: The site of a hamstring injury and amount of tissue damage may affect the time to return to play https://bit.ly/2XMH5Og