

Hamstring Strain Ultrasound Case Series: Dominant Semitendinosus Injuries in National Collegiate Athletic Association Division I Athletes

Brandon V. Hassid, MD*; Alexandra E. Warrick, MD*;
Jeremiah W. Ray, MD, CAQSM†

*Department of Physical Medicine and Rehabilitation, University of California Davis School of Medicine, Sacramento;
†Sports Medicine, Hoag Physician Partners, Foothill Ranch, CA

Authors of previous studies of patients with acute hamstring strains have reported injury to the biceps femoris and semitendinosus (ST) in 50% to 100% and 0% to 30%, respectively. This retrospective case series of hamstring injuries in National Collegiate Athletic Association Division I collegiate athletes exhibited an injury pattern on ultrasound imaging that differed from what would be expected based on prior literature. We examined ultrasound images of 38 athletes with acute hamstring strains for injury location (proximal muscle, proximal myotendinous junction, midportion of muscle, distal muscle) and affected muscles (biceps femoris,

ST, or semimembranosus). Twenty-six athletes (68.4%) injured the ST, and 9 athletes (23.7%) injured the biceps femoris long head. Most athletes (23, 60.5%) injured the proximal portion of the muscle or myotendinous junction. Though this study had many limitations, we demonstrated more frequent involvement of the ST and less frequent involvement of the biceps femoris than reported in the literature.

Key Words: biceps femoris, athletic injuries, lower extremity, thigh

Key Points

- This case series showed much more frequent involvement of the semitendinosus (68.4%) than the biceps femoris long head (23.7%), which was different from prior literature.
- Given these findings, as well as recent improvements in magnetic resonance imaging and ultrasonography, re-examining the frequency of hamstring muscle injuries and comparing the ultrasound findings with magnetic resonance imaging results may be warranted.

Acute hamstring strains are common injuries in many sports.¹ Hamstring strains may cause significant pain, disability, and time away from sport. They have been reported to make up 12% of injuries per season in British soccer and 15% of injuries per season in Australian rules football.¹ Additionally, recurrence rates of 12% and 34% were observed in these respective sports.^{2,3}

Acute hamstring strains most commonly occur during rapid eccentric activation of the hamstring, primarily during the terminal swing phase of high-speed running.^{1,4} The long head of the biceps femoris at the proximal myotendinous junction (MTJ) was the most frequent injury site.⁵ Previous authors who studied hamstring injuries reported injury to the biceps femoris in 50% to 100%, with most studies demonstrating injury to the biceps femoris in 70% to 80% of cases,^{6–12} sole or primary injury to the semimembranosus in 0% to 23.5%, and sole or primary injury to the semitendinosus in 0% to 30%.^{6–12} Although isolated injury occurs most often, simultaneous injury to multiple muscles within the hamstring muscle complex is also possible.^{5,7,9–11}

Evaluation of a patient with a hamstring injury involves a careful history, physical examination, and consideration of advanced imaging, which assists us in determining the injury

location and severity and prognosticating return-to-play timelines. Magnetic resonance imaging (MRI) is considered the criterion standard imaging modality because of its ability to reveal hamstring injuries at the muscle, tendon, and MTJ. Magnetic resonance imaging can also characterize injury during the acute, subacute, and chronic phases of injury. In comparison, conventional radiographs are more useful to evaluate osseous avulsion injuries.¹³ Imaging can also be beneficial for prognostication, as athletes with larger lesions had a higher risk of recurrent hamstring injury,^{10,14} and MRI grading of hamstring injuries correlated with return-to-play time.^{12,15} In recent years, ultrasound has become a more accessible and less costly imaging modality for evaluation of musculoskeletal injuries. Ultrasound has many advantages, including availability, relatively low cost, and dynamic assessment, such as sonopalpation. Additionally, ultrasound is now being incorporated into medical student and resident education; increasingly affordable ultrasound units allow improved access. Despite the differences between MRI and ultrasound, ultrasound had equal sensitivity in the acute setting for assessing hamstring injuries in 1 study.¹¹

To date, authors have described the semitendinosus (ST) as a less often injured hamstring muscle.^{6–11} In this case series, however, we demonstrated a markedly higher frequency of

Table. Hamstring Injuries by Muscle and Injury Location

Muscle Injured	Total No.	Injury Location			
		Proximal	Proximal Myotendinous Junction	Midportion of Muscle	Distal Muscle
Biceps femoris					
Long head	9	1	0	6	2
Short head	0	0	0	0	0
Semitendinosus	26	7	12	7	0
Semimembranosus	2	2	0	0	0
Biceps femoris long head and semitendinosus (proximal portions)	1	1	0	0	0
Total	38	11	12	13	2

ST injuries among athletes than would be expected based on the literature.

Patients

These cases are a series of 38 elite athletes from a single National Collegiate Athletic Association (NCAA) Division I intercollegiate athletics program between 2018 and 2020. We identified 61 ultrasound evaluations of the posterior thigh. Thirteen were follow-up scans of the same athletes and were excluded. Additionally, we excluded 10 either because the ultrasound scans were not characterized as representing a hamstring strain or the ultrasound evaluation was not considered diagnostic.

Interventions and Assessments

All ultrasound examinations were performed using an ultrasound device (model HM70A; Samsung) with a 3- to 16-Hz linear array transducer or a 2- to 7-Hz curvilinear transducer. Each athlete presented for evaluation in the sports medicine clinic within 1 week of the initial injury and was evaluated by the head team physician, who was fellowship trained in sports medicine and musculoskeletal ultrasound. The location and severity of each injury were identified using ultrasound, in conjunction with the athlete's history and physical examination. The ultrasound images were further classified by injury location (proximal, proximal MTJ, mid, or distal hamstring) and the muscle involved (biceps femoris short head, biceps femoris long head [BFLH], ST, or semimembranosus).

Comparative Outcomes

Of the 38 athletes examined, 26 (68.4%) injured the ST, and 9 (23.7%) injured the BFLH. Most hamstring strains (both ST and overall) involved the proximal MTJ, followed by the proximal muscle. The Table provides the injury location totals for the cases, and the Figure supplies the ultrasound images and transducer position for 1 athlete with an injury of the proximal ST.

DISCUSSION

In this case series, we demonstrated more common involvement of the ST muscle in hamstring strains than previously documented in the literature. Here, 68.4% of cases involved the ST, whereas the frequency of ST involvement as the sole or primary muscle injured has been reported as 0% to 30% of hamstring injuries.⁶⁻¹² The BFLH, however, was injured in 23.7% of the cases in this series, less than the earlier cited frequency of 50% to 100% of hamstring injuries.⁶⁻¹¹

The higher frequency of injury to the ST in hamstring strains could be explained by preferential increased loading during certain activities. De Smet et al⁹ noted that all athletes with isolated ST injury were track and field jumpers. The authors hypothesized that the combination of hip flexion and knee extension in track and field jumpers may place the ST at greater risk.⁹ Preferential activation in certain exercises¹⁶ and in sprinting has been observed.¹⁷ Higashihara et al¹⁷ identified greater ST than BFLH activation during the terminal midswing phase of a maximal sprint, which is when most hamstring injuries occur.

Several limitations to this case series exist. The first limitation was the small sample size of NCAA Division I intercollegiate athletes. The results are specific to this group and may

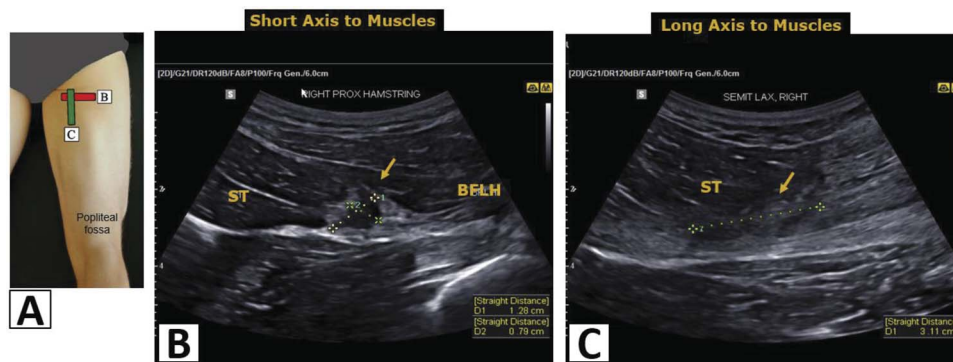


Figure. Proximal semitendinosus (ST) injury—athlete Z. A, Transducer position for B and C. B, Short axis sonographic image of the proximal hamstrings demonstrating a 1.28 × 0.79-cm tissue defect. C, Long axis ultrasound image demonstrating a 3.11-cm tissue defect. Abbreviation: BFLH, biceps femoris long head.

not be generalizable to other populations of athletes. However, in much of the prior literature on hamstring strains, authors have also studied high-level athletes, including collegiate and professional athletes.^{2,3,5,9,10,12,14,15,18,19} As this is an observational study with no comparison group, the incidence and prevalence of hamstring injuries among NCAA Division I intercollegiate athletes cannot be determined from this sample. Additionally, the athletes' histories, including the mechanism of injury, sport, position, exact time from injury to initial ultrasound evaluation, and any prior hamstring injuries, were not available for review. The lack of history, physical examination findings, and comparison with MRI findings limits the outcomes of our study, as the ultrasound results stand alone with less clinical context for interpretation or advanced imaging comparison. Overall, these restrictions curtail our ability to fully understand the clinical history or clinical outcomes, as our analysis was focused on 1 snapshot in time seen on ultrasound. Further imaging and clinical correlation would be beneficial to add broader context to interpreting these results for athletes as well as our understanding of how ultrasound may play a role in the clinical standard of care.

Despite the many limitations to the interpretation of our case series, the use of point-of-care ultrasound for athletes did provide a relatively timely, quick, and inexpensive imaging modality to assist in understanding the degree and location of hamstring injury. We acknowledge the inherent bias of 1 ultrasonographer interpreting all results, yet we provide evidence to support greater involvement of the ST than the BFLH, compared with previous studies. Although ultrasound as a diagnostic tool is a user-dependent modality, Kellis et al²⁰ reported interrater intraclass correlation coefficients between 0.83 and 0.99 (ie, good reliability), with variability of less than 4.69% in experienced sonographers after an evaluation protocol of distal BFLH strains. Several authors have described ultrasound as a valid and reliable tool for measuring the architectural features of the hamstring.^{21–23} Furthermore, in our case series, inconsistent documentation (the number of saved images, labeling, and quality of visualization) limited comparability among cases. However, we attempted to minimize this concern by excluding 5 scans that were nondiagnostic.

Connell et al¹¹ showed that MRI and ultrasound evaluation were equally sensitive for the initial diagnostic evaluation of hamstring injuries. Nonetheless, the injury extent was consistently larger on MRI due to the increased ability to detect edema, and differences between MRI and ultrasound were found when the injury was small.¹¹ They also indicated that, in several cases, abnormalities that appeared to affect the ST on sonography appeared as BFLH irregularities on MRI.¹¹ They suspected that this was likely related to the difficulties in differentiating the BFLH and ST on sonography because of their common origin.¹¹ In our case series, the interpretation of our findings was restricted by the lack of MRI comparisons.

Most published examinations of hamstring strain muscle and location predate 2008,^{6–12} with some studies published before 2000.^{7,8} In more recent literature, as well as anecdotal experience, authors have described the improved MRI resolution²⁴ as well as new ultrasound techniques for evaluating tendon injury (ie, shear wave elastography).²⁵ Although these alternative techniques were not used in our case series, such techniques in the future may improve the evaluation of hamstring injuries, including characterizing the severity and location.

Certain exercises can cause preferential activation of different hamstring muscles,^{16,17,26} yet current protocols for rehabilitation and return to play after hamstring injury do not delineate the treatment or exercise choice based on which hamstring muscle is injured.^{26,27} However, this may be because most earlier authors^{6–11} reported the BFLH as the primary injured muscle in the large majority of cases, and limited data exist on specific rehabilitation protocols based on each specific injured muscle. In the future, the ability to use ultrasound to identify the specific injured muscle may lead the athlete's physician, athletic trainer, or physical therapist to modify the rehabilitation protocol accordingly.

Clinical Bottom Line

Although prior authors described the highest incidence of hamstring strains in the BFLH, in this ultrasound case series of NCAA Division I athletes, we demonstrated most hamstring strains affected the proximal ST. Earlier authors, primarily using MRI, identified the BFLH as the most commonly injured hamstring muscle, but, given the findings of this case series as well as recent improvements in MRI and ultrasonography, re-examining the frequency of hamstring muscle injuries and comparing ultrasound findings with MRI may be warranted.

ACKNOWLEDGMENTS

Thank you to University of California Davis Athletics. Dr Warwick received research support from GID as part of the clinical trial Autologous Adipose-derived Stromal Vascular Fraction for Treatment of Knee Osteoarthritis. This work was presented as a poster at the 2022 American Medical Society for Sports Medicine Annual Meeting in Austin, Texas, on April 11, 2022.

REFERENCES

1. Brukner P, Khan K. *Clinical Sports Medicine: Australian Edition*. 4th ed. McGraw Hill Australia; 2011.
2. 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. doi:10.1136/bjism.2002.002352
3. Orchard J, Seward H. Epidemiology of injuries in the Australian Football League, seasons 1997–2000. *Br J Sports Med*. 2002;36(1):39–44. doi:10.1136/bjism.36.1.39
4. Heiderscheidt 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 (Bristol, Avon)*. 2005;20(10):1072–1078. doi:10.1016/j.clinbiomech.2005.07.005
5. Askling CM, Tengvar M, Saartok T, Thorstensson A. Acute first-time hamstring strains during high-speed running: a longitudinal study including clinical and magnetic resonance imaging findings. *Am J Sports Med*. 2007;35(2):197–206. doi:10.1177/0363546506294679
6. Koulouris G, Connell D. Evaluation of the hamstring muscle complex following acute injury. *Skeletal Radiol*. 2003;32(10):582–589. doi:10.1007/s00256-003-0674-5
7. Garrett WE Jr, Rich FR, Nikolaou PK, Vogler JB 3rd. Computed tomography of hamstring muscle strains. *Med Sci Sports Exerc*. 1989;21(5):506–514.
8. Pomeranz SJ, Heidt RS Jr. MR imaging in the prognostication of hamstring injury. Work in progress. *Radiology*. 1993;189(3):897–900. doi:10.1148/radiology.189.3.8234722

9. De Smet AA, Best TM. MR imaging of the distribution and location of acute hamstring injuries in athletes. *AJR Am J Roentgenol.* 2000;174(2):393–399. doi:10.2214/ajr.174.2.1740393
10. Slavotinek JP, Verrall GM, Fon GT. Hamstring injury in athletes: using MR imaging measurements to compare extent of muscle injury with amount of time lost from competition. *AJR Am J Roentgenol.* 2002;179(6):1621–1628. doi:10.2214/ajr.179.6.1791621
11. Connell DA, Schneider-Kolsky ME, Hoving JL, et al. Longitudinal study comparing sonographic and MRI assessments of acute and healing hamstring injuries. *AJR Am J Roentgenol.* 2004;183(4):975–984. doi:10.2214/ajr.183.4.1830975
12. Verrall GM, Slavotinek JP, Barnes PG, Fon GT. Diagnostic and prognostic value of clinical findings in 83 athletes with posterior thigh injury: comparison of clinical findings with magnetic resonance imaging documentation of hamstring muscle strain. *Am J Sports Med.* 2003;31(6):969–973. doi:10.1177/03635465030310063701
13. Brandser EA, el-Khoury GY, Kathol MH, Callaghan JJ, Tearse DS. Hamstring injuries: radiographic, conventional tomographic, CT, and MR imaging characteristics. *Radiology.* 1995;197(1):257–262. doi:10.1148/radiology.197.1.7568833
14. Koulouris G, Connell DA, Brukner P, Schneider-Kolsky M. Magnetic resonance imaging parameters for assessing risk of recurrent hamstring injuries in elite athletes. *Am J Sports Med.* 2007;35(9):1500–1506. doi:10.1177/0363546507301258
15. 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):112–117. doi:10.1136/bjsports-2011-090155
16. Beltran L, Ghazikhanian V, Padron M, Beltran J. The proximal hamstring muscle-tendon-bone unit: a review of the normal anatomy, biomechanics, and pathophysiology. *Eur J Radiol.* 2012;81(12):3772–3779. doi:10.1016/j.ejrad.2011.03.099
17. Higashihara A, Nagano Y, Ono T, Fukubayashi T. Differences in hamstring activation characteristics between the acceleration and maximum-speed phases of sprinting. *J Sports Sci.* 2018;36(12):1313–1318. doi:10.1080/02640414.2017.1375548
18. Orchard JW. Intrinsic and extrinsic risk factors for muscle strains in Australian football. *Am J Sports Med.* 2001;29(3):300–303. doi:10.1177/03635465010290030801
19. Askling CM, Tengvar M, Saartok T, Thorstensson A. Acute first-time hamstring strains during slow-speed stretching: clinical, magnetic resonance imaging, and recovery characteristics. *Am J Sports Med.* 2007;35(10):1716–1724. doi:10.1177/0363546507303563
20. Kellis E, Ellinoudis A, Intziogianni K. Reliability of sonographic assessment of biceps femoris distal tendon strain during passive stretching. *Ultrasound Med Biol.* 2017;43(9):1769–1779. doi:10.1016/j.ultrasmedbio.2017.04.018
21. Kositsky A, Gonçalves BAM, Stenroth L, Barrett RS, Diamond LE, Saxby DJ. Reliability and validity of ultrasonography for measurement of hamstring muscle and tendon cross-sectional area. *Ultrasound Med Biol.* 2020;46(1):55–63. doi:10.1016/j.ultrasmedbio.2019.09.013
22. Kellis E, Galanis N, Natsis K, Kapetanios G. Validity of architectural properties of the hamstring muscles: correlation of ultrasound findings with cadaveric dissection. *J Biomech.* 2009;42(15):2549–2554. doi:10.1016/j.jbiomech.2009.07.011
23. Chleboun GS, France AR, Crill MT, Braddock HK, Howell JN. In vivo measurement of fascicle length and pennation angle of the human biceps femoris muscle. *Cells Tissues Organs.* 2001;169(4):401–409. doi:10.1159/000047908
24. Gold G, Shapiro L, Hargreaves B, Bangerter N. Advances in musculoskeletal magnetic resonance imaging. *Top Magn Reson Imaging.* 2010;21(5):335–338. doi:10.1097/RMR.0b013e31823cd195
25. Lin CY, Ooi CC, Chan E, Chew KT. Emerging technological advances in musculoskeletal ultrasound. *PM R.* 2018;10(1):112–119. doi:10.1016/j.pmrj.2017.08.444
26. Bourne MN, Timmins RG, Opar DA, et al. An evidence-based framework for strengthening exercises to prevent hamstring injury. *Sports Med.* 2018;48(2):251–267. doi:10.1007/s40279-017-0796-x
27. Wangenstein A, Askling C, Hickey J, Purdam C, van der Made AD, Thorborg K. Rehabilitation of hamstring injuries. In: Thorborg K, Opar D, Shield A, eds. *Prevention and Rehabilitation of Hamstring Injuries.* Springer International Publishing; 2020:225–270.

Address correspondence to Alexandra E. Warrick, MD, Department of Physical Medicine and Rehabilitation, University of California Davis School of Medicine, 3301 C Street, Suite 1600, Sacramento, CA 95816. Address email to aewarrick@ucdavis.edu.