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Research Protocol

Echo Intensity and Shear Wave Elastography in Athletes with Previous Hamstring Injury: A Systematic Review Protocol

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Abstract

Background: Hamstring strain injury remains persistently high in sports, highlighting the need for additional investigation of its predisposing variables. Despite hamstring injury being well investigated, there's a lack of studies on changes in echo intensity and shear wave elastography of hamstrings among athletes with a history of injury, which could be considered modifiable risk variables. **Objectives**: To examine echo intensity and shear wave elastography characteristics of previously injured hamstrings among athletes, assessing the differences between the injured leg and controls. **Methods:** This systematic review will focus on studies reporting echo intensity and shear wave elastography characteristics of athletes with a history of hamstring strain injury compared to a control group. The search strategy will locate studies written in English from 1990 to 2023 using four electronic databases: PubMed, EBSCO (CINAHL and Medline), Science Direct, and Web of Science. Studies reporting measures using imaging other than ultrasound and where no diagnosis of hamstring strain has been made will be excluded. Two independent reviewers will screen and critically appraise the studies using the McMasters Critical Review Form. Two reviewers will independently extract relevant data and present a descriptive synthesis. A meta-analysis will be conducted when two or more studies provide data for the same outcome measure. **Expected Results:** This review can better understand hamstring maladaptation to injury. Utilizing echo-intensity and shear wave elastography as objective outcome measures can inform clinical practice toward developing an effective rehabilitation program for injury prevention.

Key Words: *injuries, sports, ultrasound, rehabilitation*

INTRODUCTION

Hamstring strain injuries, defined as sudden posterior thigh pain that requires an instant cessation of practice or competition, are severe for athletes engaged in running-based sports.[1–3] It is the most frequent non-contact injury in professional sports, accounting for 37% of all muscle traumas.[4,5] With a high recurrence rate of 14% to 63% within two years of the first injury and 59% occurring within a month of returning to the sport, more playing time is lost, and greater recovery time is required for recurring injuries compared to the first episode.[6,7] A prior history of strain injury is the most critical predictor of re-injury, so a greater understanding of the consequences of maladaptation after muscle damage is required.[7]

Ultrasound has been the preferred imaging technique to visualize alterations in muscle tissue because it is safe, inexpensive, and widely available.[8] Fascicle length, pennation angle, cross-sectional area, and muscle thickness are conventional sonographic features used in analyzing muscular changes after injury. However, newer techniques such as echo intensity and shear wave elastography are being investigated to determine muscle quality and stiffness changes, respectively. Echo intensity is a quantitative parameter derived from ultrasound that measures the amount of sound waves a tissue reflects. It is determined by calculating the average intensity of black and white pixels in an image expressed in arbitrary units from 0 to 255, respectively, using software programs such as ImageJ.[9] Lower echo intensity values indicate better muscle quality since fat and connective tissue are more reflective than muscle, leading to higher values in areas with higher fat and connective tissue content. Echo intensity is a valuable tool for tracking the progress of rehabilitation and an indirect measure of muscle quality and damage since muscle damaged by exercise or injury is more echogenic than normal muscle.[10]

Shear wave elastography is an ultrasound technique that measures the stiffness or elasticity of tissues in meters per second or Young's modulus in pascals.[11] It involves generating and tracking shear waves within the tissue to assess their mechanical properties, wherein stiffer tissue propagates the shear wave faster.[12] Shear wave elastography is a novel technology that characterizes stiffness in muscle diseases such as Duchenne Muscular Dystrophy, cerebral palsy, and Parkinson's disease. In sports, understanding muscle elasticity is integral to injury prevention, enhancement of muscle performance, and overall athletic capabilities.[8]

Strain injury causes sequential phases of the healing process, starting with myofiber necrosis and hematoma, inflammation, muscle regeneration, remodeling, fibrosis, and scar tissue formation.[13] Most studies investigating the validity and clinical potential of ultrasound echo intensity and shear wave elastography to monitor changes after an injury were performed as experimental animal studies.[12,13] These studies would induce injury in rats and rabbits and monitor changes in muscle quality and stiffness after injury. According to Peixinho et al.'s 2013 study, the average mean pixel intensity for the injured region of the rat's leg was significantly lower immediately following the injury and significantly higher at day 28.[13] This increase in echogenicity is linked to the development of scar tissue, which gives the initial strength it needs to withstand contraction forces before the repair process is complete.[13] Similar findings at day 28 post-injury were seen in the study of Zhou et al. 2018 for the injured region of the rabbit's leg. Young's modulus value was significantly correlated with scar tissue formation and histopathological findings of increased collagen fibers.[12]

Scar tissue among athletes has been identified adjacent to the injured area as early as six weeks and as late as 23 months after the initial injury.[14] A study comparing the effects of early versus delayed loading following muscle strain injuries reported that a delay in loading of damaged muscle tissue considerably prolongs return to sport.[15] Hence, evaluation of echo intensity can provide better insight regarding muscle loading following strain injury. Scar tissue formation as part of the healing process in a strain injury may render the musculotendon unit stiffer, assessment of which might help estimate the amount of muscle damage.[16] Elastography could aid in identifying stiffer muscles such that stretching interventions may target these muscles during rehabilitation.

Despite hamstring injury being well investigated, there are continued controversial findings and a need for more consensus on its modifiable risk variables.[17] A systematic review on the effect of previous injury on hamstring muscle architecture characteristics such as fascicle length, pennation angle, cross-sectional area, and muscle thickness using ultrasound and magnetic resonance imaging has been published recently, but it did not include elastography and echo intensity as part of the outcome measures.[18]

To our knowledge, alterations in echo intensity and shear wave elastography of hamstring muscle after a previous injury have yet to be systematically reviewed. It is essential to determine whether the injury affects only the injured leg so that the function of the uninjured leg can be used as a reference for rehabilitation or if individuals with a history of strain exhibit differences in quality and stiffness compared to those without injury. If differences and associations are identified, screening athletes for these changes could provide better insight to clinicians and health-allied professionals involved in the care of athletes into designing an effective rehabilitation program and training to prevent injuries. Therefore, this study aims to examine echo intensity and shear wave elastography characteristics of previously injured hamstrings among athletes, looking at the differences between the injured and non-injured and injured leg with controls.

METHODS

This systematic review protocol is based on the Preferred Reporting Items for Systematic Review and meta-analysis protocols (PRISMA-P).[19] The review protocol was prospectively registered on the database for Open Science Framework https://osf.io/5ckdh.

Database Sources and Search Criteria. The following databases will be searched from 1990 until 2023: PubMed, EBSCO (CINAHL and Medline), Science Direct, and Web of Science. Searches will be limited to the English language. The search terms will be developed using the PICO (Population, Investigated condition, Comparison condition, Outcome) framework. This will include population: adult athletes; investigated condition: hamstring strain injury; comparison condition: athletes with hamstring strain injury to those without injury or athletes' injured leg with their healthy contralateral leg; outcome: echo intensity and shear wave elastography characteristics of injured hamstring. The following search terms will be used for all databases: (Athletes [Mesh] OR athlete*) AND (Hamstring* OR semitendinosus OR semimembranosus OR "biceps femoris" OR "posterior thigh") AND (Injur* OR strain) AND ("echo intensity" OR "shear wave elastography"), truncated as required. An example of the search terms used for PubMed is below (Table 1).

Table 1. Sample search strategy from PubMed

Search strategy	Results
1. (Athletes [Mesh] OR athlete*)	74,226
2. Hamstring* OR semitendinosus OR semimembranosus OR "biceps femoris" OR "posterior thigh"	18,761
3. injur* OR strain	2,568,174
4. "echo intensity" OR "shear wave elastography"	4,495
5. ((Athletes [Mesh] OR athlete*) AND (Hamstring* OR semitendinosus OR semimembranosus OR "biceps femoris" OR "posterior thigh") AND (injur* OR strain) AND ("echo intensity" OR "shear wave elastography"))	6

**Date last searched: December 9, 2023*

Inclusion and Exclusion Criteria. The following study designs will be included for review: randomized controlled trials, non-randomized controlled trials, analytical observational studies, case-control studies, and cross-sectional studies.

Studies will be included if published in peer-reviewed journals, and participants are athletes aged 18 years or older. Non-human studies, studies not diagnosing a hamstring strain, and studies using children will be excluded. Table 2 displays full inclusion and exclusion criteria. (Table 2.)

Table 2. Selection criteria

Inclusion	Exclusion
• Participants are adult athletes (aged 18 years or older) with hamstring strain injury compared to a control group (without injury or their contralateral uninjured leg) • Conducted any of the outcome measures using ultrasound: echo intensity, shear wave elastography • Peer-reviewed publication • Written in the English language	• Measures other than diagnostic ultrasound • Studies where no diagnosis of hamstring strain has been made • Animal studies

Study Screening. The electronic search will be performed independently by two authors (B.F. and C.R.) with citations exported to reference management software. After the removal of duplicates, relevant studies will be imported into Covidence software (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia), where the title and abstracts will be independently screened for eligibility by two authors (B.F. and C.R.) following the inclusion and exclusion criteria. Full texts that meet the inclusion criteria will be further assessed independently by two authors (B.F. and C.R.). The references of included studies will be reviewed to identify additional pertinent studies. Any disagreements between the included and eliminated studies will be settled by discussion and consensus with another reviewer (C.S.) if needed.

Quality Assessment. The methodological quality of the included studies will be independently evaluated by two reviewers (B.F. and C.R.) using the McMasters Critical Review Form of Quantitative studies.[16] An inter-rater reliability will be performed to assess the agreement of the two assessors. Standardized rules for each item's interpretation and scoring will be applied.[16] Items will be scored 1 (fulfills the requirement entirely) or 0 (does not completely fulfill the criterion). Each reviewer will independently score the risk of bias, with differences in scoring to be settled by discussion or with another reviewer (C.S.) if needed. A total quality score will be calculated from the 16 closed-ended questions. It will then arbitrarily be divided into five categories: poor (scoring 6–8), fair (score 9–10), good (score 11–12), very good (score 13–14), and excellent (score 15–16).17 A study with a poor score of 8 or less over 16 will be excluded from the review.

Data extraction. Two reviewers (B.F. and C.R.) will extract relevant data from the included studies using a purpose-built extraction tool. Any reviewer differences will be settled by discussion and consensus with another reviewer (C.S.) if needed. A pilot test will be performed for the data extraction form with five articles for data validation and reviewer validity. The following data will be collected from the included studies: authors and year publication; aims of the study; study design; characteristics of the participants in the study (age, gender, sports activity, height, weight, body mass index); ultrasound outcome measure assessed; injured muscle tested; description of the control group; results of echo intensity and shear wave elastography including values and primary outcomes (means and standard deviation, p-value) for the injured and control groups and conclusion. The secondary outcome to be collected is the imaging methodology (patient preparation, machine used, probe positioning, anatomic landmark, and state of muscle tested). The authors will be contacted for missing data and the need for additional information.

Data Synthesis. Results will be reported using a narrative synthesis and tables to incorporate the included studies' methodological quality scores and general characteristics. A meta-analysis will be done when two or more studies provide data for the same outcome measure of the same muscle to compare the injured and uninjured limbs of athletes with a previous hamstring strain and between athletes with hamstring strain injury and controls. It will be conducted by applying the random-effects model to account for potential methodological heterogeneity. The standardized mean differences and 95% confidence intervals will be calculated. The heterogeneity of the included studies will be assessed using the I^2 statistic. A best-evidence synthesis will be conducted if meta-analysis will not be possible.

EXPECTED RESULTS

This systematic review will provide evidence of significant differences in the quality and stiffness of the injured hamstring compared to the uninjured leg or healthy controls. Screening athletes for these changes could give clinicians and health-allied professionals involved in the care of athletes better insight into designing an effective rehabilitation program and training to prevent injuries.

Supplementary Files

Supplementary Material A: PRISMA-P Checklist

Supplementary Material B: Data extraction instrument

Individual Author's Contributions

All authors contributed equally to developing and writing this systematic review protocol.

Disclosure Statement

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Conflicts of interest

CS is part of the Philippine Journal of Allied Health Sciences editorial advisory board.

References

1. Orchard J, Marsden J, Lord S, Garlick D. Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. American Journal of Sports Medicine. 1997;25(1):81-85. DOI:10.1177/036354659702500116
2. Yeung SS, Suen AMY, Yeung EW. A prospective cohort study of hamstring injuries in competitive sprinters: Preseason muscle imbalance as a possible risk factor. British Journal of Sports Medicine. 2009;43(8):589-594. DOI:10.1136/bjsm.2008.056283
3. Hoskins W, Pollard H. The management of hamstring injury - Part 1: Issues in diagnosis. Manual Therapy. 2005;10(2):96-107. DOI:10.1016/j.math.2005.03.006
4. Alonso-Fernandez D, Docampo-Blanco P, Martinez-Fernandez J. Changes in muscle architecture of biceps femoris induced by eccentric strength training with Nordic hamstring exercise. Scandinavian Journal of Medicine & Science in Sports. 2018;28(1):88-94. DOI:10.1111/sms.12877
5. Cuthbert M, Ripley N, McMahon JJ, Evans M, Haff GG, Comfort P. The Effect of Nordic Hamstring Exercise Intervention Volume on Eccentric Strength and Muscle Architecture Adaptations: A Systematic Review and Meta-analyses. Sports Medicine. 2020;50(1):83-99. DOI:10.1007/s40279-019-01178-7
6. Kawai T, Takahashi M, Takamoto K, Bito I. Hamstring strains in professional rugby players result in increased fascial stiffness without muscle quality changes as assessed using shear wave elastography. Journal of Bodywork and Movement Therapies. 2021;27:34-41. DOI:10.1016/j.jbmt.2021.03.009
7. Fyfe JJ, Opar DA, Williams MD, Shield AJ. The role of neuromuscular inhibition in hamstring strain injury recurrence.Journal of Electromyography and Kinesiology. 2013;23(3):523-530. DOI:10.1016/j.jelekin.2012.12.006
8. Ryu JA, Jeong WK. Current status of musculoskeletal application of shear wave elastography. Ultrasonography. 2017;36(3):185-197. DOI:10.14366/usg.16053
9. Yamauchi T, Yamada T, Satoh Y. Relationship between muscle echo intensity on ultrasound and isokinetic strength of the three superficial quadriceps femoris muscles in healthy young adults.Journal of Physical Therapy Science. 2021;33(4):334-338. DOI:10.1589/jpts.33.334
10. Radaelli R, Bottaro M, Wilhelm EN, Wagner DR, Pinto RS. Time course of strength and echo intensity recovery after resistance exercise in women.Journal of Strength & Conditioning Research. 2012;26(9):2577-2584. DOI:10.1519/JSC.0b013e31823dae96
11. Creze M, Nordez A, Soubeyrand M, Rocher L, Maître X, Bellin MF. Shear wave sonoelastography of skeletal muscle: basic principles, biomechanical concepts, clinical applications, and future perspectives. Skeletal Radiology. 2018;47(4):457-471. DOI:10.1007/s00256-017-2843-y
12. Zhou X, Wang C, Qiu S, Mao L, Chen F, Chen S. Non-invasive Assessment of Changes in Muscle Injury by Ultrasound Shear Wave Elastography: An Experimental Study in Contusion Model. Ultrasound in Medicine and Biology. 2018;44(12):2759-2767. DOI:10.1016/j.ultrasmedbio.2018.07.016
13. Peixinho CC, De Oliveira LF, Machado JC. Following-up the regeneration of injured rat muscle through the average pixel intensity of ultrasound biomicroscopic images. In2013IEEE International Ultrasonics Symposium (IUS) 2013Jul21 (pp.888-890).IEEE
14. Sanfilippo JL, Silder A, Sherry MA, Tuite MJ, Heiderscheit BC. Hamstring strength and morphology progression after return to sport from injury. Medicine & Science in Sports & Exercise. 2013;45(3):448-454. DOI:10.1249/MSS.0b013e3182776eff
15. Bayer ML, Hoegberget-Kalisz M, Svensson RB, et al. Chronic Sequelae After Muscle Strain Injuries: Influence of Heavy Resistance Training on Functional and Structural Characteristics in a Randomized Controlled Trial. American Journal of Sports Medicine. 2021;49(10):2783-2794. DOI:10.1177/03635465211026623
16. Le Sant G, Ates F, Brasseur J-L, Nordez A. Elastography Study of Hamstring Behaviors during Passive Stretching. Public Library of Science onePublished online 2015. DOI:10.1371/journal.pone.0139272
17. Kellis E. Biceps femoris and semitendinosus tendon/aponeurosis strain during passive and active (isometric) conditions. Journal of Electromyography and Kinesiology. 2016;26:111-119. DOI:10.1016/j.jelekin.2015.11.007
18. Kellis E, Sahinis C. Is Muscle Architecture Different in Athletes with a Previous Hamstring Strain? A Systematic Review and Meta-Analysis.Journal of Functional Morphology and Kinesiology. 2022;7(1). DOI:10.3390/jfmk7010016
19. Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (prisma-p) 2015: Elaboration and explanation. British Medical Journal. 2015;349(January):1-25. DOI:10.1136/bmj.g7647