Proximal Hamstring Repair Strength

A Biomechanical Analysis at 3 Hip Flexion Angles

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Background: Proximal hamstring repair for complete ruptures has become a common treatment. There is no consensus in the literature about postoperative rehabilitation protocols following proximal hamstring repair. Some protocols describe bracing to prevent hip flexion or knee extension while others describe no immobilization. There are currently no biomechanical studies evaluating proximal hamstring repairs; nor are there any studies evaluating the effect of different hip flexion angles on these repairs.

Hypothesis: As hip flexion increases from 0° to 90°, there will be a greater gap with cyclical loading.

Study Design: Controlled laboratory study.

Methods: Proximal hamstring insertions were detached from the ischial tuberosity in 24 cadavers and were repaired with 3 single-loaded suture anchors in the hamstring footprint with a Krakow suture technique. Cyclic loading from 10 to 125 N at 1 Hz was then performed for 0°, 45°, and 90° of hip flexion for 1500 cycles. Gap formation, stiffness, yield load, ultimate load, and energy to ultimate load were compared between groups using paired *t* tests.

Results: Cyclic loading demonstrated the least amount of gap formation ($P < .05$) at 0° of hip flexion (2.39 mm) and most at 90° of hip flexion (4.19 mm). There was no significant difference in ultimate load between hip flexion angles (326, 309, and 338 N at 0°, 45°, and 90°, respectively). The most common mode of failure occurred with knot/suture failure (n = 17).

Conclusion: Increasing hip flexion from 0° to 90° increases the displacement across proximal hamstring repairs. Postoperative bracing that limits hip flexion should be considered.

Clinical Relevance: Repetitive motion involving hip flexion after a proximal hamstring repair may cause compromise of the repair.

Keywords: hamstring; biomechanics; repair; rehabilitation

Complete proximal hamstrings ruptures are infrequent in adults. However, when they do occur in healthy active adults, they often require surgical repair.[5,15] Radiographic studies may be negative or may indicate an avulsion of the ischial tuberosity. Magnetic resonance imaging (MRI) is important in assessing the extent of the injury to the hamstring tendons, the degree of tendon retraction, as well as the surrounding soft tissue damage.[5] The ruptured tendons are repaired back onto their anatomic origin, the ischium, with the use of suture anchors. Increasing evidence supports surgical treatment of proximal hamstring ruptures as nonoperative treatment has led to continued pain, loss of strength, and decreased return to sports.[2,5,6,14]

There is no consensus regarding the optimal postoperative rehabilitation protocol. The theoretical benefits of bracing would be to avoid increased tension across the repair site. One option, which is commonly used, is a hinged hip brace locked in extension for 4 to 6 weeks. However, this can be associated with morbidity such as increased risk for deep venous thrombosis (DVT) and irritation from the brace. In addition, the brace does not allow one to sit, imposing great inconveniences with regard to activities of daily living and many occupations.

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One or more of the authors has declared the following potential conflict of interest or source of funding: This study received financial support from an internal grant from New England Baptist Hospital.

The Orthopaedic Journal of Sports Medicine, 3(4), 2325967115576910
DOI: 10.1177/2325967115576910

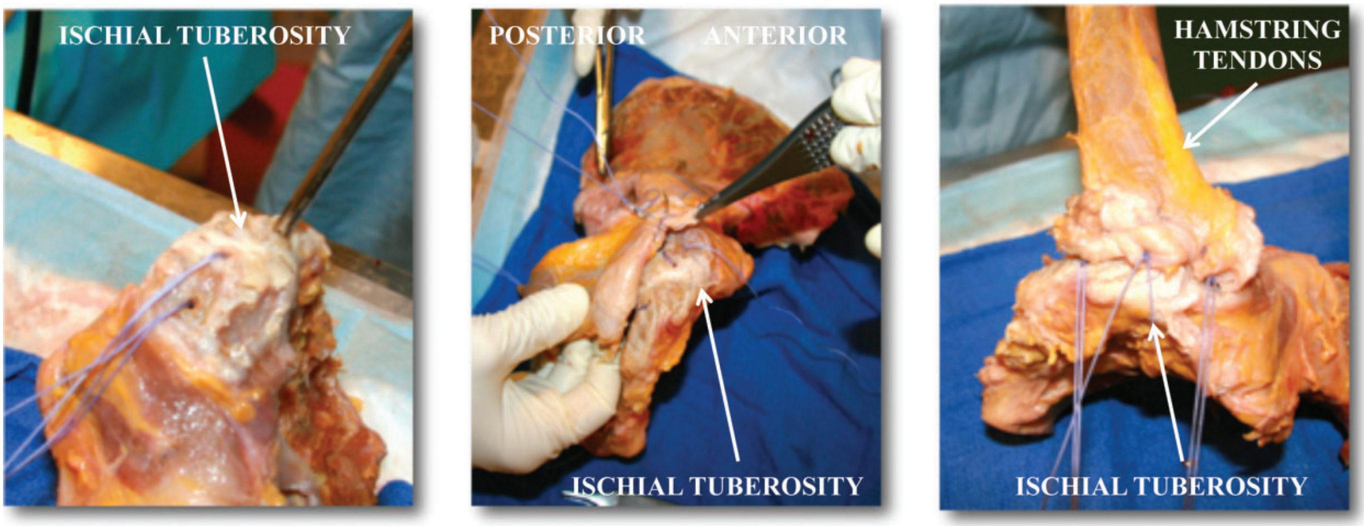

Figure 1. Repair performed with bioabsorbable anchors in the anatomic footprint.

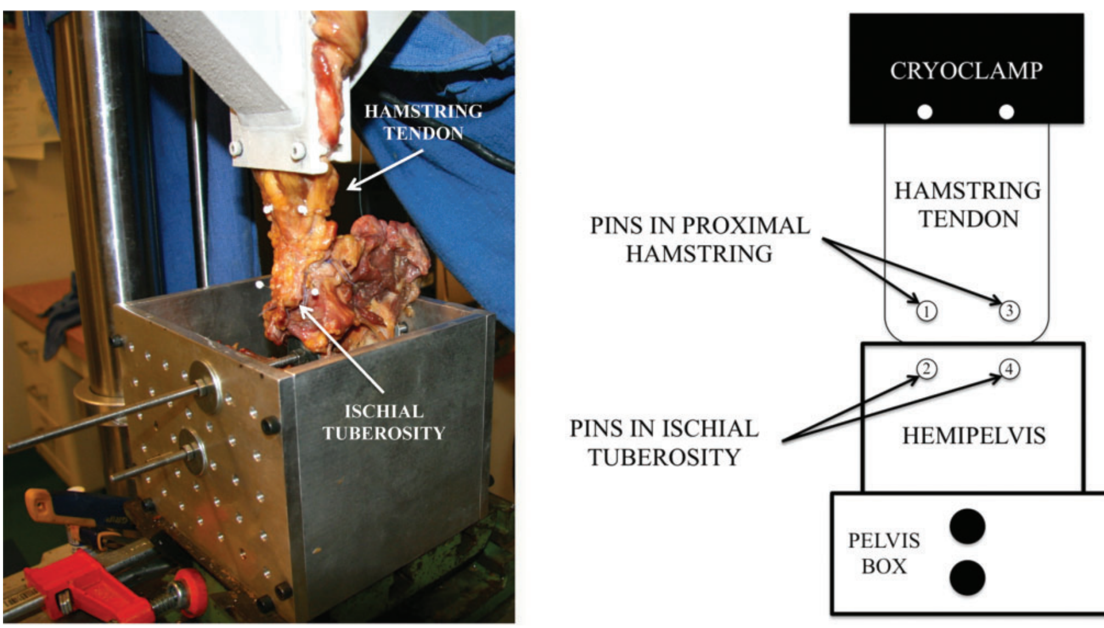

Figure 2. Setup of the pelvic box with the pelvis rigidly fixed to the material testing system (MTS) machine.

The purpose of this biomechanical study was to determine whether there is a difference in displacement and determine load to failure of proximal hamstring repairs at varying hip flexion angles: 0°, 45°, and 90°.

METHODS

Twenty-four randomly allocated fresh-frozen hemipelvis specimens were thawed at room temperature for 24 hours and dissected down to the ischial tuberosity and hamstring musculotendinous junction. The insertion of the proximal hamstring was then sharply removed from the ischial tuberosity, repaired using 3 equally spaced 2.9-mm single-loaded biocomposite anchors (Lupine; Mitek) placed in the anatomic footprint. A locking Krakow suture was placed through the tendon using a No. 2 Orthocord with 4 throws on each side of the tendon.[8] Each suture was tied to the suture anchor with 5 alternating half-hitch knots (Figure 1).

The specimens were secured with pins into a revolving custom-made pelvis box, allowing for pelvic tilting to simulate 0°, 45°, and 90° of hip flexion. The 0° angle position was achieved by aligning the anterior superior iliac spine with the pubic tubercle. The proximal hamstring was secured at the myotendinous junction with a cryoclamp to the loading actuator from above such that the loading vector was

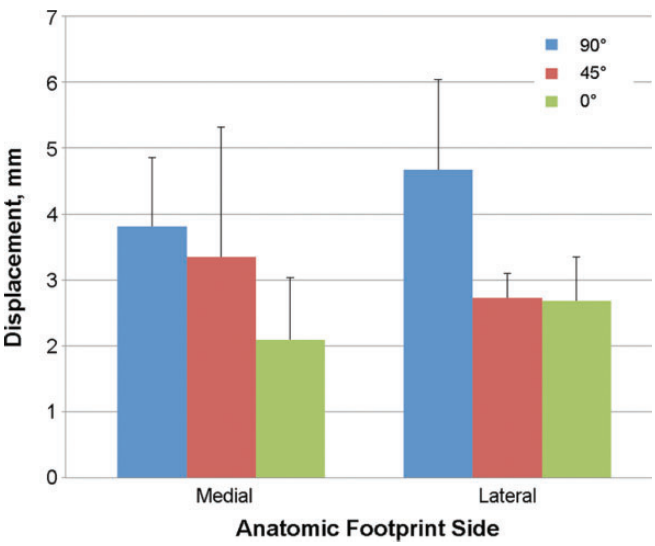

Figure 3. Comparison of cyclic displacement at the medial and lateral aspects of the anatomic footprint with varying hip flexion angles.

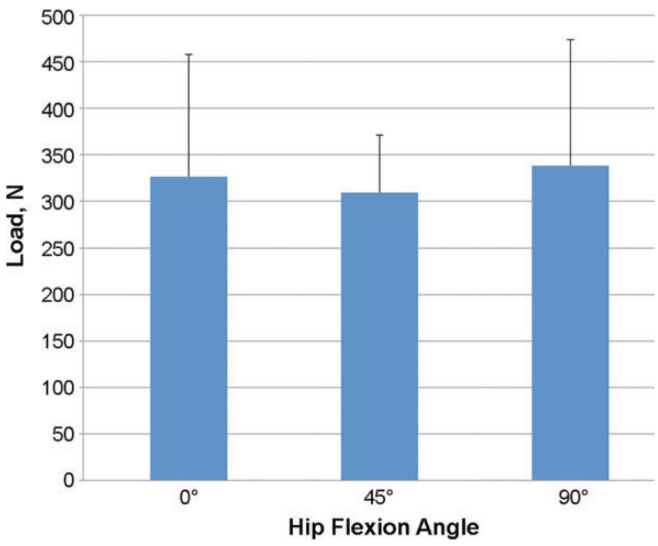

Figure 4. Comparison of peak loads between the varying hip flexion angles.

constantly vertical and allowed for visualization of the repair site (Figure 2). A material testing system machine (MTS 858 Mini-Bionix; MTS) was used to test the biomechanical properties of this repair. This structure allowed for tilting of the specimen to 0°, 45°, and 90° of hip flexion. Each specimen was inverted and the ilium secured into the fixture to allow loading of the hamstring tendon from above. The specimens were secured by threading pins through holes in the side of the box into the bony structures, allowing for exact positioning of each specimen so that the angle of load on the hamstring was equal across all trials. Specimens were preloaded at 5 N and held for 5 seconds, then cyclically loaded from 10 to 125 N at 1 Hz for 1500 cycles. This properly simulates the stretch-shortening cycles the hamstrings undergo during sprinting, as described by Schache et al,[16] who determined that maximal hamstring stretch occurs during terminal swing and shortening begins just before foot strike and continues through stance. After the 1500th cycle, load-to-failure testing was done. Specimens were loaded at a constant rate of 120 mm/min, and failure determined if displacement was greater than 3 mm. Previous studies have used 5 to 10 mm as the parametric range.[3,17,19] There is no known gap size verified by either in vivo animal studies or human clinical studies that leads to definite mechanical failure of the hamstring. These same parameters were used at the 45° and 90° positions.

Statistical Analysis

A pretesting power analysis concluded that 8 specimens would be required in each group. The cyclic displacement and peak load to failure were analyzed using a 1 × 3 analysis of variance and the Tukey-Kramer post hoc test. Statistical significance was set at $P = .05$, with β error at 0.80 and α at 0.05. All analyses were performed with Minitab version 16.2.20 software (Minitab Inc).

RESULTS

Cyclic Loading Displacement

The result of cyclic loading demonstrated the least amount of gap formation ($P < .05$) at 0° of hip flexion (2.39 mm), followed by 45° (3.03 mm), and most at 90° of hip flexion (4.19 mm) (Figure 3).

Load to Failure

The results of load to failure demonstrated failure at a peak load of 326 N for the specimens designated to the 0° group, 309 N for specimens designated to the 45° group, and 338 N for the specimens designated to the 90° group. However, there was no statistically significant difference in the ultimate load between the hip flexion angles (Figure 4).

Mechanism of Failure

Knot/suture failure was the most common mode of failure (n = 17). Others specimens failed with anchor pull out (n = 6).

DISCUSSION

Rupture of the proximal hamstring complex has become an increasingly more recognized injury. In an appropriate patient population, the orthopaedic literature supports surgical repair. Good functional outcomes, high satisfaction rates, and higher rates of return to sports have been reported.

After surgical reconstruction, the goal is to return the patient to preinjury level as safe and as soon as possible.

The hamstring musculotendinous unit is complex in its anatomy in that it is one of a few muscles that crosses 2 joints. Because of the complexity of anatomy, variable postoperative protection of proximal hamstring repairs have been described using protection at the knee and the hip to avoid placing too much strain on the repair site and placing the repair at an unfavorable loading angle. These protocols have been largely based on surgeon experience, as there have been no comparative trials. Cohen and Bradley[5] described immobilization at the hip in 30° to 40° of flexion. Others have described immobilization at 0° of hip flexion anywhere from 4 to 8 weeks postoperatively. Alternatively, some have described immobilization of the knee. Konan and Haddad[7] described immobilization of the knee at 90° for 2 weeks with progression of knee extension until 6 weeks. Sallay et al[14] and Rust et al[12] described immobilization of the knee at 90° for 4 to 6 weeks. Lefevre et al[9,10] and Chahal et al[4] described immobilization of the knee at 30° for 6 weeks. Mansour et al[11] described using a hinged knee brace to limit extension for a minimum of 2 weeks. Askling et al[1] and Skaara et al[18] have reported successful outcomes with no use of a brace to immobilize the patient postoperatively.

Regardless of the method chosen, all types of immobilization at the hip and knee can be cumbersome for activities of daily living and can be associated with morbidity. The senior author (S.M.) has had several incidences of postoperative DVT using knee immobilization postoperatively despite oral prophylaxis. Two articles in the literature discuss postoperative DVT. Cohen and Bradley[5] had 1 DVT in 52 cases, and Sallay et al[13] reported 1 DVT in 25 cases. We sought to determine whether any significant displacement occurred with cyclical loading at different hip flexion angles after proximal hamstring repair and to determine load to failure for a proximal hamstring repair. To the best of our knowledge, this is the first biomechanical study that has been performed on the proximal hamstring muscle tendon unit.

Biomechanical testing demonstrated a statistically significant increase in gapping of repairs as the hip flexion angle increased from 0° to 90°. Repetitive sitting and standing in a postoperative patient could cause gapping of the repair. This repetitive strain could lead to compromise of repair. Postoperative bracing that limits hip flexion appears to be a reasonable recommendation after a proximal hamstring repair.

There are several limitations to this biomechanical study. Cadaveric hemipelvis specimens were used; thus, the knee joint was not attached. Therefore, no conclusions can be made regarding the influence that the knee position may have on the results. There was no direct comparison between our repair technique versus another anchor or surgical technique. As this is a biomechanical study, our results were simply limited in detecting differences in displacement at the anchor sites and peak load to failure. Since cadaveric specimens were used, the biological effects of healing and the physiological effects of loading on the repair site are unknown. The study is performed at time zero, as no healing has occurred after the surgical repairs.

The strength of this study is that this is the first biomechanical analysis addressing proximal hamstring repairs. Additional strengths are that a single surgeon performed the hamstring repair on all specimens, and the specimens were randomized to each group to avoid bias. This was a large biomechanical study that analyzed not only cyclic displacement but also the load to failure of the repairs. The study was performed using the same testing equipment to avoid inaccuracies in the results.

CONCLUSION

This was a biomechanical study assessing the effect that varying hip flexion angle has on displacement of proximal hamstring repairs during cyclic loading. The data collected demonstrate that limiting hip flexion can minimize displacement at the repair site.

REFERENCES

1. Askling CM, Koulouris G, Saartok T, Werner S, Best TM. Total proximal hamstring ruptures: clinical and MRI aspects including guidelines for postoperative rehabilitation. *Knee Surg Sports Traumatol Arthrosc*. 2013;21:515-533.
2. Birmingham P, Muller M, Wickiewicz T, Cavanaugh J, Rodeo S, Warren R. Functional outcome after repair of proximal hamstring avulsions. *J Bone Joint Surg*. 2011;93:1819-1826.
3. Burkhart SS, Diaz Pagan JL, Wirth MA, Athanasiou KA. Cyclic loading of anchor-based rotator cuff repairs: confirmation of the tension overload phenomenon and comparison of suture anchor fixation with transosseous fixation. *Arthroscopy*. 1997;13:720-724.
4. Chahal J, Bush-Joseph CA, Chow A, et al. Clinical and magnetic resonance imaging outcomes after surgical repair of complete proximal hamstring ruptures: does the tendon heal? *Am J Sports Med*. 2012;40:2325-2330.
5. Cohen S, Bradley J. Acute proximal hamstring rupture. *J Am Acad Orthop Surg*. 2007;15:350-355.
6. Harris JD, Griesser MJ, Best TM, Ellis TJ. Treatment of proximal hamstring ruptures—a systematic review. *Int J Sports Med*. 2011;32:490-495.
7. Konan S, Haddad F. Successful return to high level sports following early surgical repair of complete tears of the proximal hamstring tendons. *Int Orthop*. 2010;34:119-123.
8. Krackow KA, Thomas SC, Jones LC. Ligament-tendon fixation: analysis of a new stitch and comparison with standard techniques. *Orthopedics*. 1988;11:909-917.
9. Lefevre N, Bohu Y, Klouche S, Herman S. Surgical technique for repair of acute proximal hamstring tears. *Orthop Traumatol Surg Res*. 2013;99:235-240.
10. Lefevre N, Bohu Y, Naouri JF, Klouche S, Herman S. Returning to sports after surgical repair of acute proximal hamstring ruptures. *Knee Surg Sports Traumatol Arthrosc*. 2013;21:534-539.
11. Mansour AA 3rd, Genuario JW, Young JP, Murphy TP, Boublik M, Schlegel TF. National Football League athletes' return to play after surgical reattachment of complete proximal hamstring ruptures. *Am J Orthop (Belle Mead NJ)*. 2013;42:E38-E41.
12. Rust DA, Giveans MR, Stone RM, Samuelson KM, Larson CM. Functional outcomes and return to sports after acute repair, chronic repair, and allograft reconstruction for proximal hamstring ruptures. *Am J Sports Med*. 2014;42:1377-1383.
13. Sallay PI, Ballard G, Hamersly S, Schrader M. Subjective and functional outcomes following surgical repair of complete ruptures of the proximal hamstring complex. *Orthopedics*. 2008;31:1092.

14. Sallay PI, Friedman RL, Coogan PG, Garrett WE. Hamstring muscle injuries among water skiers: functional outcome and prevention. *Am J Sports Med*. 1996;24:130-136.
15. Sarimo J, Lempainen L, Mattila K, Orava S. Complete proximal hamstring avulsions: a series of 41 patients with operative treatment. *Am J Sports Med*. 2008;36:1110-1115.
16. Schache AG, Dorn TW, Blanch PD, Brown NA, Pandy MG. Mechanics of the human hamstring muscles during sprinting. *Med Sci Sports Exerc*. 2012;44:647-658.
17. Schneeberger AG, von Roll A, Kalberer F, Jacob HA, Gerber C. Mechanical strength of arthroscopic rotator cuff repair techniques: an in vitro study. *J Bone Joint Surg Am*. 2002;84-A:2152-2160.
18. Skaara HE, Moksnes H, Frihagen F, Stuge B. Self-reported and performance-based functional outcomes after surgical repair of proximal hamstring avulsions. *Am J Sports Med*. 2013;41:2577-2584.
19. Waltrip RL, Zheng N, Dugas JR, Andrews JR. Rotator cuff repair. A biomechanical comparison of three techniques. *Am J Sports Med*. 2003;31:493-497.