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Self-Reported and Performance Based Functional Outcome After Surgical Repair of Proximal Hamstring Avulsion

ABSTRACT

Background: Because a proximal hamstring avulsion results in residual loss of function, surgical repair is recommended. Few studies have investigated postoperative function with validated outcomes.

Purpose: To examine lower extremity function after surgical repair of proximal hamstring avulsions using validated self-reported and performance-based functional outcomes.

Study Design: Case series

Methods: Operative records from 2006 to 2010 were retrospectively reviewed in 3 hospitals. A total of 39 patients who undergone surgical repair of proximal hamstring avulsion were identified and 36 met the inclusion criteria. Thirty-one patients completed questionnaires with demographic background data and quality of life related questions, Lower Extremity Functional Scale (LEFS) and Proximal Hamstring Injury Questionnaire (PHIQ). Thirty patients were evaluated using a Biodex dynamometer for isokinetic quadriceps and hamstring strength measurement at a velocity of 60 deg/s, and 27 patients performed 4 single-legged hop tests.

Results: Twenty-eight repairs were acute (< 4 weeks), and 3 were chronic. There were complete ruptures of all 3 tendons in 17 (55%) cases. The mean follow-up was 30 months. Most patients experienced little or no pain or limitations during activities of daily living. The mean LEFS score was 89%, and 29 (94%) of the 31 patients were satisfied with the result

after surgery. Eighteen (58%) of the 31 patients had returned to their pre-injury activity level. Significant differences in the mean hamstring strength (peak torque) ($P < .001$) and single hop for distance ($P = .01$) between the uninvolved and the involved leg were found. Twenty-two (71%) of the 31 patients did not fully trust their operated leg during physical activities and feared for sustaining a hamstring injury. Return to activity significantly correlated with the single hop for distance test, LEFS and the questions regarding trust and fear.

Conclusion: In this study, using both validated self-reported and performance-based outcome measures after surgical repair of proximal hamstring tendon avulsion, minor pain and limitations to activities of daily living were seen. Isokinetic hamstring muscle strength in the operated leg was significantly lower compared to the nonoperated leg, and a majority of the patients did not trust the operated leg completely during physical activity

Key Terms: hamstring injury, complete tear, avulsion, surgical repair, function

INTRODUCTION

A hamstring strain injury is one of the most common musculoskeletal injuries in athletes.^{17,21} The most serious injury is a complete rupture of the proximal hamstring tendons. The hamstring muscle crosses both the hip and the knee joint. A proximal rupture is commonly a result of eccentric overload of the tendon insertion during a forceful hip flexion with an extended knee.^{10,13} A proximal hamstring avulsion is defined as complete when all 3 hamstring tendons are separated from the ischial tuberosity and incomplete (partial) when a segment of the tendon complex is in continuity with the ischial tuberosity.^{29,41} A proximal hamstring avulsion is often reported in sports such as water skiing, soccer, gymnastics, martial arts, tennis, and cross-country skiing, but it can also occur in non-sports-related trauma such as sliding and falling.²⁰ Patients usually experience a pop or a snap and severe

pain in the buttock when the injury occurs, followed by swelling and bruising of the thigh, hamstrings weakness, and decreased function in the injured lower limb.^{14,36}

Surgical repair is recommended when at least 2 tendons are ruptured and retraction of the ruptured tendons is ≥ 2 cm.^{7,12,13} A recent systematic review by Harris et al.²⁰ showed that acute repair (within 4 weeks) resulted in significantly better patient satisfaction, subjective outcomes, pain relief, strength and endurance, and a higher rate of return to sport compared with chronic repair (after 4 weeks). The mean follow-up was 29.4 months (minimum 12 months) for both surgical and nonsurgical treatments.²⁰ Nonsurgical treatment is reported to result in reduced patient satisfaction with significantly lower rates of return to preinjury level of sport than both acute and chronic repairs.²⁰ Reports on secondary problems with nonsurgical treatment such as disabling hamstring muscle weakness and sciatic nerve symptoms favor surgical repair.^{12,22,39,40}

The surgical procedure and self-reported postoperative outcomes are described in several works.^{13,14,26,36} Return to preinjury level of sport and patient satisfaction are usually used as main outcomes after undergoing repair of proximal hamstring tendon rupture.^{9,28,37,41} Isokinetic muscle strength has been used as a performance-based outcome, showing a mean limb symmetry index (LSI) between 80% and 95%, although most of the studies have included few patients.^{9,18,27,36} Only 2 previous studies have assessed performance-based outcomes after surgical treatment in a larger population ($n > 20$).^{7,41} The patients' subjective feeling of confidence is important for a return to their preinjury level of activity.^{2,3,16,25} To our knowledge, no previous study has examined physical function using validated questionnaires and performance-based functional tests, with additional registration of the patients' feeling of security during activities.

The main purpose of this study was to investigate self-reported and performance-based function at 1 to 5 years after surgical repair of a proximal hamstring avulsion. Additionally,

we wanted to investigate whether patients who had undergone surgical treatment of a proximal hamstring tendon avulsion trusted their injured leg after surgical treatment.

MATERIALS AND METHODS

This retrospective case series includes patients who underwent surgical treatment of a proximal hamstring tendon avulsion between January 2006 and July 2010 in 3 different hospitals in the counties of Oslo and Akershus, Norway

Patients

Operative records at 2 large university hospitals and 1 smaller regional hospital were retrospectively reviewed. The inclusion criteria were a proximal hamstring tendon rupture treated with surgical repair. The exclusion criteria were an inability to understand Norwegian or a systemic/central neurological condition believed to impair rehabilitation.

Surgical Technique and Postoperative Protocol

One hospital used a transverse incision in the gluteal crease ($n = 9$), while a longitudinal incision, made from the gluteal crease and straight down 7 to 8 cm, was used in the 2 other hospitals ($n = 22$). The posterior femoral cutaneous nerve and inferior gluteal nerve were identified. The gluteus maximus muscle was dissected and retracted superiorly. The fascia over the hamstring was incised or divided bluntly if not ruptured, and the hematoma was evacuated. The sciatic nerve was protected. The bone on the footprint on the ischial tuberosity

was freshened and 2 to 5 suture anchors (5-mm Twinfix, Smith and Nephew, London, United Kingdom, or Mitec GII, DePuy Orthopaedics, Warsaw, Indiana) with double strands were inserted. The tendon bundle was then identified, equally freshened, and sutured in close contact with the bone.

The postoperative regime varied between hospitals, although all of them included no use of brace but restriction in flexing the hip with a straight knee, avoidance of deep sitting for 2 weeks postoperatively and gradual return to normal sitting dependent on pain and discomfort. Crutches were advocated for 6 to 12 weeks, and gradually, full weightbearing was allowed from 4 to 6 weeks. Rehabilitation in an outpatient clinic was initiated from week 5 to 7, and progressive strengthening exercises, running and jumping could be started after 12 weeks.

Data Collection

The data collection period was from August to September 2011 and included self-reported questionnaires, isokinetic muscle strength measurements, and 4 single-legged hop tests.

Performance-based functional tests were conducted by 2 experienced physical therapists at a sport injury rehabilitation clinic in Oslo. Before the isokinetic muscle strength test, each subject completed a 15-minute warm up period on a stationary bicycle. The 4 single-legged hop tests were performed after a 5-minute rest after the isokinetic strength testing.

Self-reported Questionnaires

Demographic data and information about the postoperative rehabilitation were collected. Two questions related to quality of life were included from a hamstring injury questionnaire.¹⁶ To evaluate self-reported function, we used 2 different questionnaires: the Lower Extremity

Functional Scale (LEFS)⁶ and the Proximal Hamstring Injury Questionnaire (PHIQ).³⁶ The LEFS was the main outcome and has been evaluated in a heterogeneous population with lower limb conditions and was found to have high internal consistency ($\alpha = .96$) and high test-retest reliability ($r = 0.86$).⁶ The LEFS has also been examined in populations with a single condition, generally demonstrating robust results of internal consistency and construct validity.³⁰ The LEFS has a maximal score of 80 points, and the higher score the better function. The PHIQ has been developed specially for patients with hamstring injury and surgical repair of the proximal hamstring junction.³⁶ The PHIQ questionnaire is more specific and contains both function and pain items but is not tested for reliability or validity. Both the LEFS and the PHIQ were translated forward and backward into Norwegian according to current recommendations.⁵

Isokinetic Muscle Strength Measurements

Isokinetic hamstring strength measurements were performed using a Biodex 6000 dynamometer (Biodex Medical Systems Inc, Shirley, New York). A standardized protocol with angular velocity of 60 deg/s was utilized.¹⁵ The angular velocity of 60 deg/s was chosen because it is regarded the most reliable velocity for evaluation of maximal force development in knee extension and flexion.^{24,38} Muscle strength was expressed as peak torque in Newton-meters (N-m) and total work in joules (J). Peak torque is the highest force produced during knee flexion from 0° to 90°. ³³ Total work reflects the ability of the muscle to produce force throughout the range of motion (ROM). ³³ Range of motion was set from 0° to 90° of knee flexion, which is the established ROM for evaluation of isokinetic hamstring muscle strength. ³⁴ This test has been found to be reliable for evaluation of knee extension and flexion strength in injured as well as healthy patients. ^{8,24,38} Positioning of the chair, placement of the

dynamometer, and length of the attachment arm were individually adjusted. The effect of gravity was corrected. A standardized trial session of 4 repetitions with submaximal effort was performed to allow the patients to familiarize themselves with the testing procedure. The uninjured leg was tested first. There was a standardized 1-minute pause before the test started. The test consisted of 5 repetitions with maximal effort. No oral cues were given during testing other than counting from 1 to 5. The same procedure was performed on the injured leg. The results were registered in the Biodex software.

Single-Legged Hop Tests

Four single-legged hop tests; single hop for distance, triple crossover hop for distance, triple hop for distance and 6-meter timed hop, were performed to evaluate lower extremity function. These tests are easy to use in a clinical setting and have been reported to reflect an accurate assessment of lower extremity function and provide information regarding muscle control.³¹ Hamstring muscle strength may also play an important role during the propulsive phase of a jump.³² Single-legged hop tests are valid and reliable as performance based measurement outcomes.³⁵ A metric tape measure taped on the floor was used to measure the absolute hop distance of the single hop for distance, triple crossover hop for distance and triple hop for distance tests. The patient had 1 practice trial and 2 test trials on each leg. All tests started with the uninjured leg. An approved jump required that the patient managed a well-balanced landing on one foot. For the 6-m timed hop test, a manual stopwatch was used to time patients hopping 6 m, and the absolute time was given in seconds.

Statistical Analysis

Descriptive data characterizing the group and the results from the questionnaires were calculated as frequencies (%) and means \pm standard deviations (SDs) and ranges. The results of the 2 questions related to quality of life were divided into “yes” or “no” answers. The LEFS sum score was presented in percentage of the total score (total, 80) \pm SD and range. The LSI was calculated as the percentage of performance on the injured leg compared to the uninjured leg for both the Biodex test and 4 single-legged hop tests. The LSI was tested with a paired-samples *t* test. The level of statistical significance was set to .05, and 95 % confidence intervals were reported. Spearman correlation coefficients were calculated to evaluate bivariate relationships between return to activity and functional outcomes. Statistical Package for Social Sciences version 18.0 (SPSS Inc., Chicago; Illinois) was used to analyze the data.

Source of Funding

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Ethics

This study was approved by the Regional Ethics Committee of Eastern Norway (2011/171).

RESULTS

Sociodemographics

Thirty-six patients met the inclusion criteria and were invited to participate in the study (Figure 1). Five patients were excluded, and 31 patients were available for follow-up: 16 men and 15 women with a mean age of 51 years (range, 27-73 years; mode, 41 and 54 years). The mean time between surgery and follow-up was 30 months (range, 12-66 months). There were 28 patients with acute surgical repair (≤ 4 weeks) and 3 patients with chronic surgical repair (> 4 weeks) of the proximal hamstrings. Experienced orthopedic surgeons performed the operative procedures. Three of the surgeons did 27 (87%) of the 31 procedures. All were general orthopaedic surgeons: 2 with a special interest in sports medicine and 1 in orthopaedic trauma. General orthopaedic surgeons, trained by 1 of these 3, performed the remaining surgeries. Seventeen of the 31 patients (55%) had a complete rupture, and 14 of the 31 patients (45%) had an incomplete rupture (9 with 2-tendon rupture and 5 with 1-tendon rupture) with ≥ 2 -cm retraction. The 5 patients with 1-tendon rupture all had ruptures in the long head of the biceps femoris muscle, and the 9 patients with 2-tendon ruptures all had ruptures in the biceps and semitendinosus. The tendon retraction was, on average, 4 cm (range, 2-10 cm). The mean interval from injury to surgery was 17 days (range, 4-54 days). Twenty (65%) of the 31 patients had the proximal hamstring avulsion on the left side and 11 (35%) on the right side. Twenty-six of the 31 patients were recreational athletes, and 5 were competitive level athletes. There were no professional athletes. Most of the injuries were caused by slipping and sliding while cross-country skiing ($n = 10$) or running outdoors ($n = 7$). One person experienced a tendon rupture while boarding a boat and 2 while water skiing. The remaining patients ($n = 11$) were injured during soccer, tennis, badminton, floor-ball, judo, climbing, handball (goalkeeper), ice-skating and bicycling. There were 3 surgical complications: 2 patients had superficial wound infection, and 1 had an injury of the posterior femoral cutaneous nerve. There were no reruptures in any patient. Sixteen (52%) of the 31 patients had musculoskeletal problems before the hamstring injury: 3 from the lower back, 10

from the knee and ankle, 2 from a hamstring injury in the same limb and 1 from a hamstring rupture in the contralateral limb. Additional sociodemographic data, post surgical physical therapy and activity level are presented in Table 1.

Self-Reported Questionnaires

The mean LEFS score was $89\% \pm 13\%$ (see the Appendix). Fifty percent of the 31 patients scored $\geq 95\%$, and 20% scored $< 75\%$ of the total score. Sitting, running, hopping and making sharp turns while running had the lowest scores while patients scored high on ordinary activities of daily living. On the PHIQ, 12 (39%) of the 31 patients reported pain and limitations during strenuous sports and work activities. Of the 31 patients, 15 (46%) did not participate in running long distances, and 10 (32%) did not participate in sprinting. The mean pain experienced in the injured leg the last week from the day of testing, was estimated by the patients to be on average 1.4 ± 2.0 on the numeric rating scale, and 25 (81%) did not take any pain medication at all. Twenty (65%) of the 31 patients estimated their recovery after surgery to be $\geq 75\%$ and 29 (94%) were satisfied with the result of the surgery. Seven of the 31 patients reported numbness and/or tingling in the injured leg below the knee, and 3 of them had constant symptoms. On the quality of life-related questions, 22 (71%) of the 31 patients reported that they did not totally trust their injured hamstring during physical activity and were afraid of maximum performance because of concerns of sustaining a hamstring injury.

Isokinetic Muscle Strength and Single Leg Hop Tests

The isokinetic muscle test showed a statistically significant difference between involved and uninvolved leg in both quadriceps and hamstring strength for peak torque and total work

(Table 2). Eighteen of the 30 tested patients (60%) had an LSI <85% for peak torque hamstring strength. The mean quadriceps/hamstring ratio was <50% in both the uninvolved leg (45%) and in the involved leg (40%). There was a statistically significant difference between the involved and uninvolved leg for the single hop for distance test ($p = .008$) and the 6-m timed hop test ($P = .029$), while the mean LSI was >90% in all 4 single-legged hop tests (Table 3).

Correlations Between Self-Reported Questionnaires and Functional Outcomes

Return to activity was significantly correlated with single hop for distance test ($P = .009$, $r = 0.49$), but not with hamstring strength ($P = .055$, $r = 0.35$). However, a highly significant correlation was found between return to activity and the LEFS score ($p < 0.001$, $r = .72$). Also, a significant correlation was found between return to activity and the questions regarding not totally trusting the injured leg and being afraid of maximum performance ($P = .026$, $r = 0.40$). Furthermore, hamstrings strength significantly correlated with LEFS score ($P = .007$, $r = 0.48$) and single hop for distance test ($P = .05$, $r = 0.37$).

DISCUSSION

This is the first study, to our knowledge, to use both validated self-reported and performance-based functional outcomes in patients who have undergone surgical repair of a proximal hamstring avulsion. The results showed that most of the patients experienced minor pain and limitations in activities of daily living and were satisfied with the overall result after surgery. However, 12 (39%) of the 31 patients reported some pain and limitations when performing

strenuous activities, and 22 (71%) patients did not fully trust their injured lower limb during physical activities. Isokinetic muscle strength tests showed a statistically significant difference in mean hamstring strength (peak torque and total work) between the injured and the uninjured leg. Statistically significant differences in the LSI were also found for the single hop for distance and the 6-m timed hop tests. Eighteen (58%) of the 31 patients had returned to their preinjury activity level

Cohen et al.¹³ published results using the LEFS in patients with repaired proximal hamstring ruptures at a mean follow-up of 33 months (range, 12-76 months). They included 52 patients with a mean age of 47 years (range, 17-66years) and found a mean LEFS score of 75 (range, 50-80), which is comparable with our results (mean LEFS score of 71; range, 48-80). As the LEFS is a questionnaire for the lower extremity in general, and has been reported to indicate high ceiling effects for repaired proximal hamstring ruptures,¹⁰ we also used the PHIQ, which contained more specific items for these patients. Sallay et al.³⁶ tested 25 patients (18 acute and 7 chronic repairs) with a mean age of 44 years, using the PHIQ at a mean of 53 months (range 10-140 months) after surgery. Our results concerning pain and patient satisfaction with the surgical repair were in accordance with their results.³⁶ Despite this, there was variation in the estimated overall recovery. Sallay et al found³⁶ that 96% of the patients estimated their overall recovery to be $\geq 75\%$, while only 65% of the patients in our study estimated their recovery to be $\geq 75\%$. There may be different explanations for this difference. The follow-up rate in our study was 86% compared to 60% in the study by Sallay et al.³⁶ In our study, previous musculoskeletal problems were reported in nearly 50% of the patients, which may have influenced rehabilitation. Preinjury musculoskeletal problems were not reported the study by Sallay et al.³⁶

Colosimo et al¹⁴ have recommended both isokinetic and functional testing before return to sport. They recommended the injured hamstring strength to be at least 85% of the uninjured

leg at both slow and fast isokinetic velocities and the quadriceps/hamstring ratio should be between 50% and 60% for the injured leg at 60 deg/s before returning to preinjury level of sport. Single-legged hop testing is recommended as functional tests. Colosimo et al¹⁴ found the single hop for distance and 6-m timed hop tests as the most accurate reflection of function. Our results concerning isokinetic strength are comparable to previous studies in which the same isokinetic velocities have been used.^{9,18,27} The mean peak torque of the injured leg for knee flexion was 84% of the uninjured, while the mean total work of the injured leg for knee flexion was 81%. Eighteen (60%) patients had a LSI of < 85% for peak torque hamstring strength. Brucker & Imhoff⁹ reported on 8 patients (mean, 40 years; range 23-60 years) with a mean isokinetic strength of 88% at a mean follow-up of 33 months. In their study hamstring/quadriceps ratio was 55% in the injured leg and 61% in the uninjured leg, which is higher compared to our mean ratios of 40% and 45%, respectively. Our mean isokinetic results were below the recommended level for returning to preinjury sport. Other studies have tested patients with a Cybex dynamometer but have used different velocities⁷ or have not described the isokinetic velocity.^{11,26,36} It has been reported that higher isokinetic velocity could result in an increased hamstring/quadriceps ratio.^{1,23} Birmingham et al⁷ tested 23 patients (9 acute and 14 chronic repairs) with a mean age of 46 years (range, 19-65 years) with a velocity of 240 and 180 deg/s. They reported a mean strength of the injured hamstring, at a mean follow-up of 43 months, of 93% and 90% respectively, while the hamstring/quadriceps ratio was reported to be 56% and 48%, respectively. Birmingham et al⁷ also conducted the single hop for distance test between the uninjured and injured leg and found symmetric results, whereas we found statistically significant differences in the single hop for distance test between the legs.

Return to preinjury activity level is a commonly used outcome measure for treatment success.^{7,27-29,41} In the present study, 18 (58%) of the patients reported that they had regained

preinjury activity level at a mean of 9 months (range, 3-18 months). Previous studies with similar populations have reported that 70% to 80% of the patients returned to their preinjury activity level in 6 to 12 months.^{7,13,37,41} Chahal et al¹⁰ showed that even if their 13 tested patients had good functional outcomes, low pain rating, high satisfaction rates and excellent healing rates on magnetic resonance imaging at 37 months after surgical repair, they did not fully regain hamstring function, and 45% did not return to their previous activity level. An important issue concerning whether patients do return to their preinjury level of performance is psychological factors.² We found that 22 (71%) of the patients felt fear for sustaining a hamstring injury and thus consciously kept from performing at 100%. Folsom and Larson¹⁸ and Cohen et al¹³ reported concerns of reinjury as one of the reasons why the patients did not return to all preinjury activities after surgical repair of proximal total hamstring rupture. Additionally, a study in sprint athletes and dancers with hamstring strain injuries showed that despite restored strength and flexibility test values, the athletes were not always psychologically ready to return to sport.² This corresponds with our findings in which a return to activity significantly correlated with fear but not with hamstrings strength.

Konan and Haddad²⁷ concluded that early surgical repair and physical therapy are associated with good outcomes and an early return to high-level sports. In our study, 11(41%) of 27 patients responded that they felt their physical therapist did not have sufficient knowledge about their hamstring injury and hamstring-specific rehabilitation. This might be part of the reason for the observed low isokinetic strength results, the lack of confidence, and the low return to previous activity level in our study. Descriptions of detailed rehabilitation programs for operated proximal hamstring rupture has been lacking in the literature and only few works have been published.^{4,19,25} Brief postoperative rehabilitation protocols have been described in most works on surgical repair of proximal hamstring avulsion injuries, but vary

widely. No study has, to our knowledge, explored the type or dose of rehabilitation exercises necessary to regain optimal function.

One strength of this study was the relatively large sample size of patients tested with both self-reported questionnaires and performance-based tests validated for lower limb conditions. Another strength was that a single reconstructive technique with suture anchors was used. The use of 2 different incisions, different institutions, and different surgeons could be considered as limitations of the study. On the other hand, different institutions and different surgeons might also be considered as a strength regarding clinical practice and generalizability. We included both acute and chronic tears, however only 3 patients had undergone surgery more than 30 days after injury. The limitations were the retrospective nature of the study and the lack of a standardized rehabilitation program. About half of the patients reported previous musculoskeletal problems, which might have influenced on the functional outcomes.

CONCLUSION

Patients experienced low levels of pain and limitations to activities of daily living after surgical repair of a proximal hamstring avulsion injury. Despite this, many patients did not fully regain hamstring strength and function or return to preinjury activity level. Fear of sustaining a new injury and not trusting the leg completely during physical activity were common among these patients.

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FIGURES AND TABLES

Figure 1.

Flow Chart

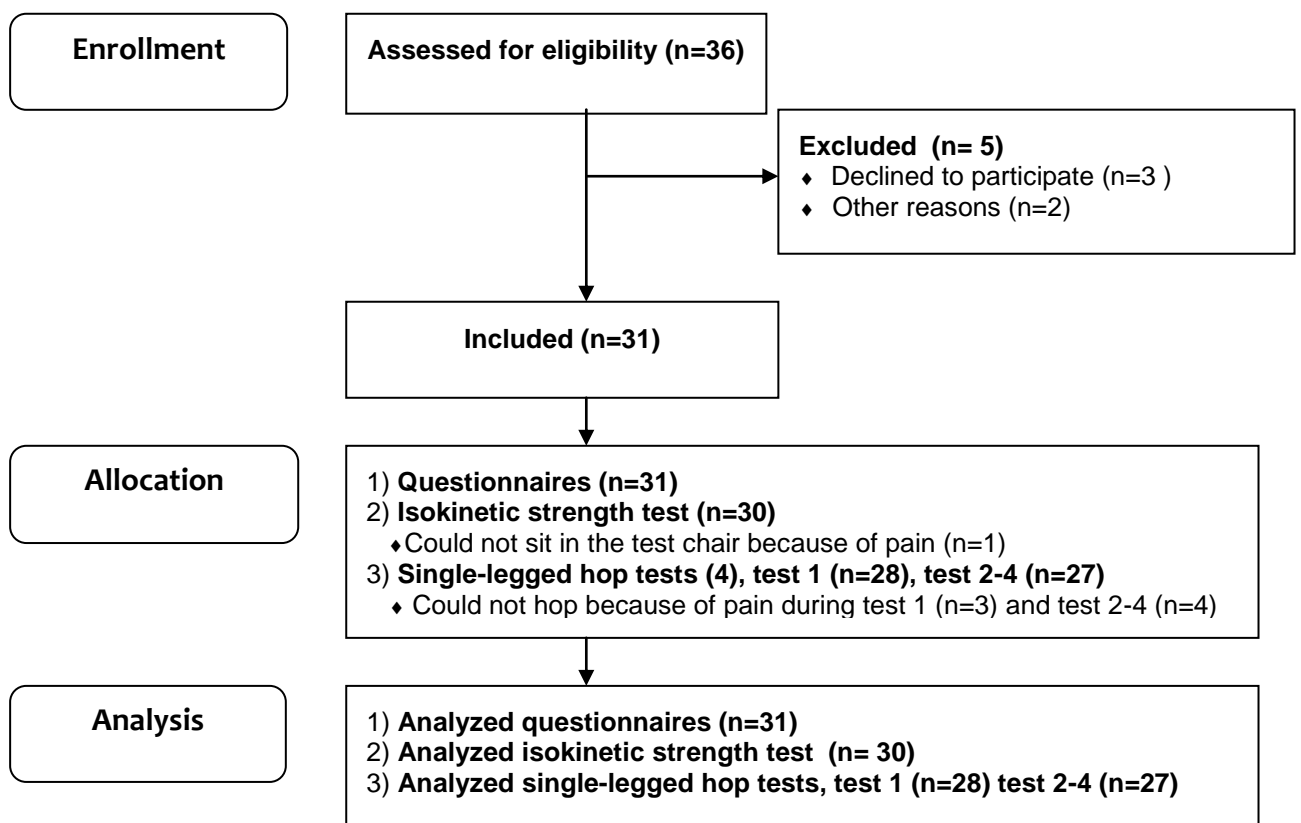


TABLE 1 Patients' Descriptive Characteristics (N 31)

	n (%)	Mean (Range)
Demographic data		
Body mass index		26 (20-35)
Education, y		15 (7-21)
Sick leave after surgery (n = 27), wk		25 (2-104)
Returned to preinjury work (n=27)	24 (89)	
Smoking	2 (6)	
Postsurgical physical therapy (n=27)		
Weeks of postsurgical physical therapy		28 (4-124)
Physical therapy visits per week		2 (1-3)
Continuing with hamstring-specific exercises after finishing physical therapy ("yes" response)	15 (56)	
Physical therapist had knowledge about the injury and the rehabilitation ("yes" response)	16 (59)	
Activity level		
Exercising regularly before injury ("yes" response)	27 (87)	
- Number of times per week		4 (1-9)
Return to the same activity level as before the injury ("yes" response)	18 (58)	
- Weeks before back on the same activity level		36 (12-78)

TABLE 2 Isokinetic Strength Measurements*

	n	Involved leg Mean ± SD	Uninvolved leg Mean ±SD	Mean ± SD	LSI %	
					Range	P Value (95% CI)
Peak torque Knee extension, N-m	30	170.7 ± 50.0	186.3 ± 58.9	93.2 ± 12.7	59.6 -118.9	.006 (-26.4 to -4.8)
Peak torque Knee flexion, N-m	30	68.3 ± 24.4	83.4 ± 25.9	83.6 ± 22.3	49.0 -150.9	.000 (-22.4 to -7.9)
Total work Knee extension, J	30	807.7 ± 275.1	848.9 ± 276.5	95.9 ± 15.0	68.5 - 150.7	.084 (-88.2 to - 5.8)
Total work Knee flexion, J	30	359.4 ± 140.7	449.6 ± 149.1	80.7 ± 21.1	36.0 - 127.4	.000(-128.6 to -51.8)
H/Q ratio %	30	39.7 ± 9.1	45.4 ± 7.8	90.0 ± 26.8	57.0 -196.6	.009 (-9.7 to -1.5)

*CI = Confidence Interval, H/Q = Hamstring/Quadriceps, J = Joule, LSI = Limb Symmetry Index, N-m = Newton-meter, SD = Standard Deviation

TABLE 3 Single-Legged Hop Tests*

	n	Involved leg Mean ± SD	Uninvolved leg Mean ± SD	Mean ± SD	LSI %	
					Range	P Value (95% CI)
Single hop, cm	28	94.6 ± 39.1	103.3 ± 35.3	90.5 ± 20.7	26.0 - 146.0	.008 (2.5 to 15.0)
Triple cross hop, cm	27	287.7 ± 105.3	291.2 ± 96.7	99.6 ± 14.3	68.0 - 131.0	.673 (-13.2 to 20.0)
Triple hop, cm	27	351.0 ± 103.2	357.2 ± 98.7	98.1 ± 8.6	74.0 - 113.0	.347 (-7.1 to 19.5)
6 meter timed hop, s	27	2.6 ± 0.72	2.5 ± 0.6	95.0 ± 11.7	73.0 - 123.0	.029 (-0.30 to -0.02)

*CI = Confidence Interval, LSI = Limb Symmetry Index, SD = Standard Deviation

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APPENDIX

Lower Extremity Functional Scale (LEFS)

n =31	n (%)				
Today, do you or would you have any difficulty at all with:	Extremely difficulty or unable to perform activity 0 point	Quite a bit of difficulty 1 point	Moderate difficulty 2 point	A little bit of difficulty 3 point	No difficulty 4 point
Any of your usual work, housework or school activities			3 (10)	3 (10)	25 (81)
Your usual hobbies, recreational or sporting activities		2 (6)	6 (19)	8 (26)	15 (48)
Getting into or out of the bath			3 (10)	1 (30)	27 (87)
Walking between rooms					31(100)
Putting on your shoes or socks	1 (3)		3 (10)	7 (23)	20 (64)
Squatting		1 (3)	2 (6)	10 (32)	18 (58)
Lifting an object, like a bag of groceries from the floor				5 (16)	26 (84)
Performing light activities around your home	1 (3)				30 (97)
Performing heavy activities around your home		1 (3)	2 (6)	5 (16)	23 (74)
Getting into or out of a car		1 (3)		5 (16)	25 (81)
Walking 2 blocks				1 (3)	30 (96)
Walking a mile		1 (3)			30 (96)
Going up or down 10 stairs (about a flight of stairs)				3 (9)	28 (90)
Standing for 1 hour	1 (3)	1 (3)	2 (6)	5 (16)	22 (71)
Sitting for 1 hour	2 (6)	2 (6)	1 (3)	6 (19)	20 (64)
Running on even ground	4 (13)	2 (6)	1 (3)	4 (13)	20 (64)
Running on uneven ground	5 (16)	1 (3)	2 (6)	2 (6)	21 (68)
Making sharp turns while running fast	5 (16)	3 (10)	3 (10)	8 (25)	12 (39)
Hopping	2 (6)	1 (3)	6 (19)	5 (16)	17 (55)
Rolling over in bed				1 (3)	30 (97)
LEFS SUM Mean 71(SD10) points, Range (47-80)	Mean \pm SD %			Range %	
Sum in percentage of highest score (80 points)	89 \pm 13			59 -100	