Original Article

Degree of Tendon Retraction and Younger Age Are Associated With Functional Decline Following Nonoperative Management of Complete Proximal Hamstring Ruptures

Alirio J. deMeireles, M.D., M.B.A., Robert N. Kent III, B.S.E., Asheesh Bedi, M.D., and Eileen A. Crawford, M.D.

Purpose: To characterize functional outcomes of patients with complete proximal hamstring tendon ruptures who were treated nonoperatively and determine whether there are patient characteristics associated with unfavorable outcomes. **Methods:** We retrospectively identified patients aged 18-80 (treated 1/2000-12/2019) who received nonoperative management of complete rupture of the hamstring tendon origin. Participants completed the Lower Extremity Functional Scale (LEFS), as well as Tegner Activity Scale (TAS), and a chart review was conducted to obtain demographic and medical information. Preinjury and postinjury TAS scores were compared, and additional models quantified associations between LEFS scores or changes in TAS scores (ΔTAS) and patient characteristics. **Results:** Twenty-eight subjects (mean age: 61.5 ± 1.5 years; 10 male) were included. The mean follow-up time was 5.8 ± 0.8 years (range: 2-22 years). Mean preinjury and postinjury TAS scores were 5.3 ± 0.4 and 3.7 ± 0.4, respectively, with a change of 1.5 ± 0.3 ($P = .0002$). Degree of tendon retraction showed a negative correlation with LEFS score ($P = .003$) and ΔTAS ($P = .005$). Increased follow-up time ($P = .015$) and body mass index ($P = .018$) were associated with lower LEFS scores. Moreover, increased follow-up time ($P = .002$) and younger age at injury ($P = .035$) were associated with more negative ΔTAS. Patients classified with an American Society of Anesthesiologists (ASA) score of 2 had a median LEFS score that was 20 points (95% CI: 6.9-33.6) lower than those classified as ASA 1 ($P = .015$). **Conclusions:** In this study, we found that increased degree of tendon retraction, increased follow-up time, and younger age at initial injury were associated with significantly worse self-reported functional outcomes.

Introduction

Acute hamstring injuries account for 25-30% of all muscle strains and have the potential to cause a high degree of morbidity.[1,2] These injuries typically occur either in the muscle belly or at the myotendinous junction. While minor strains are most common and respond well to conservative management (rest, ice, gentle stretching, and nonsteroidal anti-inflammatory drugs),[1-3] reports indicate that 9%-12% of hamstring injuries involve a complete rupture of the proximal hamstring tendons.[1,4,5] A complete rupture is defined as a full-thickness tear of the biceps femoris, semitendinosus, and semimembranosus, or an avulsion of their attachment sites from the ischial tuberosity.

For single-tendon ruptures or two-tendon ruptures with <2 cm of retraction, nonoperative management has been recommended.[6] Although the literature has shown favorable outcomes with early surgical intervention for complete proximal hamstring ruptures, the functional goals of the patient and morbidity associated with the procedure occasionally lead to nonoperative management of these injuries.[1,3,6-12] For example,

From the Department of Orthopedic Surgery, University of Michigan, Ann Arbor, Michigan, U.S.A.

The authors report the following potential conflicts of interest or sources of funding: E.A.C. is an unpaid consultant for Simple Therapy, Inc. A.B. has received royalty and consulting fees from Arthrex, Inc. These are not in direct conflict of interest with the research under review. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received September 28, 2022; accepted January 4, 2023.

Address correspondence to Eileen A. Crawford, M.D., Department of Orthopedic Surgery, University of Michigan, Medsport, Lobby A, Suite 1000, 24 Frank Lloyd Wright Dr., Ann Arbor, MI 48105, U.S.A. E-mail: ceileen@med.umich.edu

2666-061X/22899

https://doi.org/10.1016/j.asmr.2023.01.005

patients who have low functional demand may choose to avoid the small risk of sciatic nerve injury, as well as the disruptive postoperative weight-bearing restrictions and rigorous rehabilitation protocol. A recent review of postoperative rehabilitation protocols reported a mean of 7.1 weeks of non-weightbearing status and 21-28 weeks of physical therapy.[13] For patients who opt for nonsurgical management or have comorbidities that preclude them from surgery, there remains a paucity of data regarding expected outcomes. In a recent systematic review and meta-analysis of the 795 cases reviewed, only 28 patients were treated nonoperatively.[6]

The purposes of our study were to 1) characterize the functional outcomes of patients with complete proximal hamstring tendon ruptures who were treated nonoperatively and 2) determine whether there are patient characteristics associated with unfavorable outcomes. The authors hypothesized that nonoperative treatment would lead to inferior functional outcomes overall, with younger patients and those with greater tendon retraction experiencing worse outcomes.

Methods

This study was a retrospective review of patients who received nonoperative management of complete rupture of the hamstring origin. Each subject gave informed consent to participate in this study, and the protocol was approved by the Institutional Review Board at the authors' institution.

Patient records from two fellowship-trained orthopedic sports medicine surgeons (E.A.C. and A.B.) ranging from January 2000 to December 2019 were screened for potential subjects using an institutional electronic medical record search engine.[14] For inclusion in the study, subjects were required to have 1) a magnetic resonance imaging (MRI)- or ultrasound (US)-confirmed, complete rupture or avulsion of the proximal hamstring tendon; 2) nonoperative management; 3) age 18-80; 4) no history of prior complete tear or avulsion of the ipsilateral hamstring; and 5) a minimum of 2 years of follow-up time from the date of injury. Both acute and chronic injuries at the time of presentation were included, and patients who converted to operative treatment prior to follow-up were excluded. The decision for nonoperative treatment was based on both patient preference and surgeon recommendation after a thorough discussion of the risks, benefits, and functional expectations. In general, study participants presented with low functional demands and/or comorbidities that placed them at high risk for surgical or postsurgical complications.

Two of the authors (A.J.D. and R.N.K.) then contacted eligible subjects by telephone to recruit them for a telephone survey. Those subjects who agreed verbally to participate were required to give electronic, informed consent for participation in the study and then complete a questionnaire regarding their injury and recovery (Qualtrics XM, Provo, UT). The questionnaire included a Lower Extremity Functional Scale (LEFS) for a subjective assessment of the impact of their injury on their activities of daily living, where higher scores correspond to less difficulty with the queried activities.[15] Subjects also completed two Tegner Activity Scales (TASs) to compare their preinjury and current levels of function.[16] The TAS scale is suitable for retrospective scoring because it only requires that patients estimate their highest level of activity at the time, ranging from disability to work-heavy labor to competitive field sports.[17] As examples, Level 5 of the TAS includes activities such as "heavy labor, competitive cycling, and cross country skiing," while Level 3 of the TAS includes "light work, swimming, and walking in the forest."[16]

The subjects' electronic medical records were then reviewed to obtain basic demographic information, including age at the time of injury, BMI at the time of injury, follow-up time, current age, and sex. Additionally, pertinent medical data from the time of injury, including tendon retraction distance (cm), American Society of Anesthesiologists (ASA) score, diabetes status, smoking status, and Charlson Comorbidity Index (CCI), were tabulated.[18,19] Degree of tendon retraction was collected from the radiology report of an MRI study at the time of injury; in cases where a formal radiology report was not available, degree of tendon retraction was measured on the coronal MRI series by the senior author, a fellowship-trained sports medicine surgeon. American Society of Anesthesiologists (ASA) scores were determined by a board-certified anesthesiologist at the time of injury, according to the standard definitions of ASA physical status classifications.

Statistical analyses were performed to compare preinjury and current TAS scores in addition to exploring associations between patient characteristics and functional outcomes. Specifically, a paired, nonparametric Wilcoxon signed test compared preinjury and postinjury TAS scores ($P < .05$). Univariate linear regressions quantified associations between LEFS scores or changes in TAS score (ΔTAS) and numerical patient characteristics, such as age and CCI ($P < .05$). Finally, nonparametric Mann-Whitney *U*-tests compared LEFS or ΔTAS grouped by categorical patient characteristics, such as sex and diabetes status ($P < .05$). All data are reported as means $\pm$ SE. Although there is not a published minimum clinically important difference (MCID) for TAS, the minimal detectable change is 1.0,[20] and one study used an MCID of 0.5 based on distribution-based methods.[21]

Results

Twenty-eight patients met inclusion criteria and agreed to participate in this study. The mean age of

Table 1. Cohort Demographics and Tendon Retraction

Characteristic	Values
Number of Patients	28
Age at injury (means ± SE [95% CI]) (years)	55.7 ± 1.7 [52.3-59.1]
Sex (M:F)	10:18
BMI (kg/m^2)	29.6 ± 5.6
Follow-up time (means ± SE [95% CI]) (years)	5.8 ± 0.8 [4.2-7.3]
Charlson Comorbidity Index (mean ± SE [95% CI])	2.3 ± 0.3 [1.6-3.0]
ASA Classification (1:2:3)	10:13:5
Smoking status (never: current or former)	19:9
Diabetes status (N:Y)	24:4
Tendon retraction (means ± SE [95% CI]) (cm)	4.3 ± 0.5 [3.3-5.2]

SE, standard error.

participants at the time of injury was 55.7 ± 1.7 years (range: 38-74 years), and 18 subjects were female. The mean follow-up time was 5.8 ± 0.8 years (range: 2-22 years). The mean tendon retraction distance was 4.3 ± 0.5 cm (Table 1).

At the final follow-up, the mean LEFS score was 59.8 ± 3.7 out of a maximum possible score of 80. Immediate postinjury LEFS scores were not collected in most cases; therefore, change in LEFS score could not be calculated. Mean preinjury and current TAS scores were 5.3 ± 0.4 and 3.7 ± 0.4, respectively, with a decline of 1.5 ± 0.3 (Fig 1; $P = .0002$).

Degree of tendon retraction had a significant negative correlation with LEFS score ($P = .003$) and ΔTAS ($P = .005$) (Fig 2). Increased follow-up time was associated with both lower LEFS scores ($P = .015$) and more negative ΔTAS ($P = .002$). BMI at the time of injury correlated to lower LEFS scores at final follow-up ($P = .018$). Younger age at injury was associated with more negative ΔTAS ($P = .035$). Subjects classified as ASA 2 had a median LEFS score that was 20 points (95% CI: 6.9-33.6) lower than those classified as ASA 1 ($P = .015$); LEFS scores of subjects classified as ASA 3 were not statistically different from those of subjects with ASA scores of 1 or 2 (both $P \geq .2$) (Fig 3). CCI had no significant association with LEFS scores or ΔTAS, and stratification by sex, smoking status, and diabetes status revealed no significant differences in functional outcomes (all $P > .05$; Table 2).

Discussion

The results from this study demonstrate that subjects with complete proximal hamstring tendon rupture who elected for nonsurgical treatment experienced a significant decline in activity level, as assessed by TAS. More specifically, increased degree of tendon retraction, increased follow-up time, ASA 2 classification, and younger age at initial injury were all associated with significantly worse self-reported functional outcomes.

The available literature on the management of 3-tendon proximal hamstring ruptures supports early operative intervention.[2,5,7,8,10-12] In a 2011 systematic review, Harris and colleagues reported that when examining 18 studies totaling 298 patients, the operative cohort had significantly better subjective outcomes, higher rate of return to prior activity level, and greater strength/endurance compared with the nonoperative cohort.[22] A more recent systematic review and meta-analysis conducted by Bodendorfer et al. confirm these findings, concluding that early operative management results in superior outcomes compared with nonoperative management.[6] Additionally, Hofmann et al. reported a series of 17 patients with complete proximal hamstring avulsions treated nonoperatively and found that only 12 of the 17 patients were able to return to their previous level of activity.[3] This previous work corroborates our finding of a significant decrease in patient-reported TAS score following nonoperative management.

Importantly, the average age of the operative cohort in the review conducted by Bodendorfer et al. was 41.4 years,[6] while our mean patient age was 59.8 years at the time of injury. The largely positive results of past studies advocating early operative repair may not generalize to older populations given the changes in functional goals that tend to coincide with aging. Additionally, although the work of Bodendorfer and colleagues did advocate for surgical repair, they noted that the complication rate in the operative cohort was 23.17%, with neurological complications (i.e., sciatic nerve complications, numbness, and paresthesia) being the most common.[6] This complication rate is important to consider when discussing the risks and benefits of surgery with patients, as some may deem it unacceptably high.

An ASA classification of 2 was associated with a significantly lower LEFS score compared to patients with an ASA of 1. This result seems logical, given that

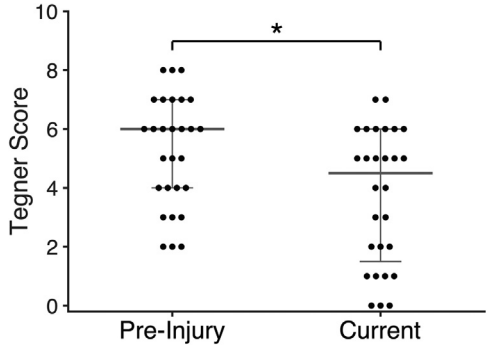

Fig 1. Comparison of preinjury and current Tegner scores. Means ± SD is denoted with gray bars. *$P = .0002$.

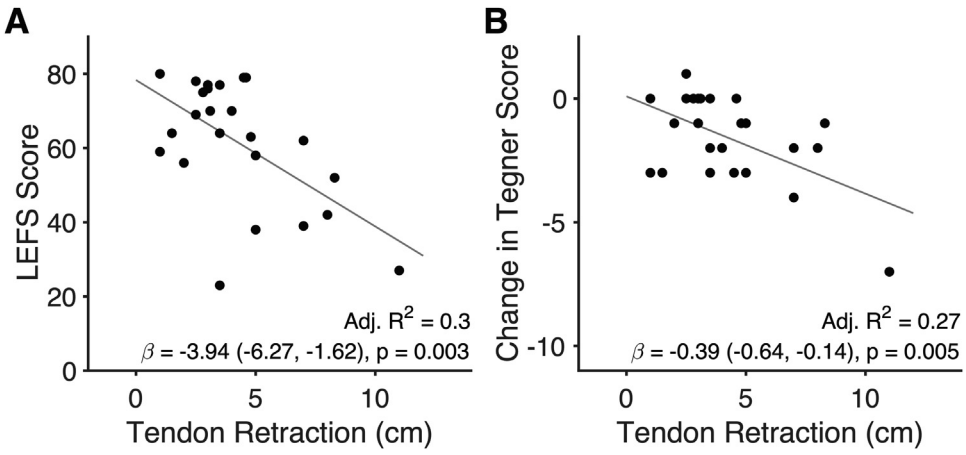

Fig 2. Univariate linear regression between tendon retraction distance and current LEFS Score (A) or change in Tegner score (B). Correlation coefficients (β) are expressed as means with 95% CI.

patients with comorbidities are relatively disadvantaged in their efforts to regain function and mobility through nonoperative management of a proximal hamstring injury. Surgical management for these patients would likely entail a recovery that is at least as challenging, although this study was not designed to comment on surgical outcomes. Interestingly, however, patients with an ASA classification of 3 reported LEFS scores that were not statistically different from those of ASA 1 patients. This was an unexpected secondary outcome and represents an opportunity for future study. Given that LEFS scores survey a patient's overall function and mobility, ASA 3 patients may have already been experiencing difficulties with many of the activities assessed in the LEFS survey at the time of their injury, skewing their responses to more positive values.

In our series, the degree of tendon retraction was the most striking injury-specific characteristic associated with lower LEFS scores and a more negative ΔTAS. Although the literature on this specific finding is limited, our data are in alignment with prior findings, suggesting that an increased degree of tendon retraction is associated with poorer prognosis.[23-25] For example, Fournier-Farley et al. conducted a systematic review, including 24 articles on the determinants of return to play after nonoperative management of hamstring injuries and found that increased distance to the ischial tuberosity was associated with a poor prognosis in the majority of included studies.[24] We also found that increased follow-up time was associated with significant decrease in TAS score, likely due, in part, to the common shift in functional ability and desired engagement in strenuous activities as the patient ages. This finding could also be partially explained by a patient's diminishing ability to compensate for hamstring weakness that occurs over an extended period of time, similar to the natural history of irreparable rotator cuff tears. BMI at the time of injury was associated with lower LEFS scores. Obesity is considered to be a relative contraindication to surgical repair of proximal hamstring ruptures,[26] but our results suggest that obesity also negatively impacts functional outcomes after nonsurgical treatment. Finally, younger age at injury was associated with a more negative ΔTAS. This finding may be explained by the likelihood that younger subjects had a higher baseline TAS than older patients, resulting in a larger negative ΔTAS than older patients with the same injury.

The results from this study provide value to practicing orthopedic surgeons by contributing to counseling and the decision-making process surrounding treatment of complete proximal hamstring tendon ruptures. For example, our data suggest that young patients with a high degree of tendon retraction may be better candidates for operative repair in the absence of other significant risk factors. Similarly, the trends in Tegner scale presented in this work can be used clinically to counsel patients on the decline in activity they may expect with nonoperative management. This work does not directly compare the outcomes of nor advocate for either operative management versus nonoperative management. Although the risks of surgery always need to be

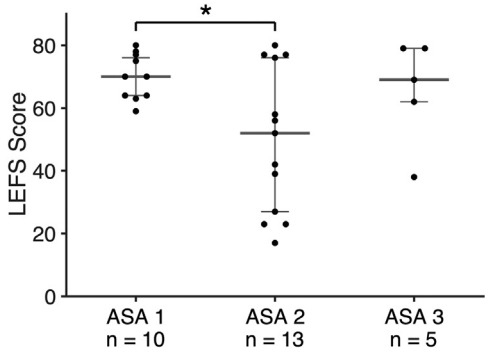

Fig 3. Comparison of LEFS scores as a function of ASA classification. Median ± 95% confidence interval is denoted with gray bars. *$P = .015$.

Table 2. Linear Regressions

Dependent Variable	Numerical Variable	β (95% CI)	Adj. R^2	*P* Value
LEFS Score	Age at injury	0.34 (-0.47 to 1.16)	−0.01	.416
	BMI (kg/m^2)	−1.56 (−2.77 to −0.35)	0.167	**.018**
	Follow-up time	−2.09 (−3.66 to −0.51)	0.18	**.015**
	Current age	−0.16 (−1.14 to 0.82)	−0.03	.751
	Charlson Comorbidity Index	−1.07 (−5.22 to 3.07)	−0.03	.616
	# of Comorbidities	−1.05 (−2.77 to 0.67)	0.02	.243
	Tendon retraction	−3.95 (−6.27 to −1.62)	0.30	**.003**
Change in Tegner Score	Age at injury	0.08 (0.01 to 0.14)	0.13	**.035**
	BMI (kg/m^2)	−0.09 (−0.21 to 0.02)	0.05	.128
	Follow-up time	−0.23 (−0.36 to −0.10)	0.29	**.002**
	Current age	0.04 (−0.05 to 0.12)	−0.01	.404
	Charlson Comorbidity Index	0.06 (−0.31 to 0.43)	−0.03	.757
	# of Comorbidities	−0.03 (−0.19 to 0.12)	−0.03	.690
	Tendon retraction	−0.39 (−0.64 to −0.14)	0.27	**.005**

β, regression coefficient (mean ± standard deviation); CI, confidence interval.

weighed against the inherent risks of nonoperative management, this study's findings can be used to help clinicians understand the impact of patient- and injury-specific characteristics to inform counseling on prognosis and treatment options. Further research involving prospective collection of outcome scores, investigation of the impact of physical therapy on outcomes in nonoperative treatment, and comparison to similar patients treated operatively would greatly enhance our current evidence-based management of patients with complete proximal hamstring tendon ruptures.

Limitations

This study had multiple limitations as expected for a retrospective review. First, the sample size was small. Second, in this retrospective case series, the results of nonoperative management were not compared with a matched cohort who received operative management. Third, the main outcome measures were two patient-reported functional outcomes scales, one of which involved a preinjury score that was subject to recall bias. However, the simplicity of the Tegner score likely makes retrospective scoring less challenging for subjects. This study did not include objective data, such as hamstring strength dynamometer testing nor single-leg hop testing that prior studies have included. Importantly, however, the study Hofmann and colleagues conducted found no correlation between a specific patient's self-reported functional status and their objective muscle strength measurements, suggesting that objective strength measurements are not a valid surrogate for patients' perception of function. Another limitation is the wide range of ages in this cohort (38 to 74 years); this sample may represent a range of injury mechanisms, where younger patients likely endured high load/energy trauma versus injuries in older patients potentiated by chronic tendinopathy. The 95% confidence interval of patient ages at the time of injury, however, was limited to 52-60 years. Moreover, we expect to see a natural decline in TAS as patients age. Thus, the magnitude of the ΔTAS may have been augmented by those patients with a large amount of time since their initial injury. Some of this study's findings are sensitive to outliers, especially given that the relatively low level of replication ($n = 28$) makes this work vulnerable to Type II error. There was one patient whose time to follow-up was an extreme outlier (22 years, >3.0 IQR above third quadrant), but exclusion of this data point changed none of the results of the study except for the correlation between 1) follow-up time and LEFS score ($P = .249$) and 2) age at injury and change in Tegner score ($P = .079$) (Supplemental Tables S1 and S2, Supplemental Figs S1-S3, and Supplementary Information). Finally, a separate patient's tendon retraction was an outlier (11 cm, >1.5 IQR above third quadrant). After exclusion of this patient, the correlation between tendon retraction distance and ΔTAS still trended toward negative; however, it was no longer statistically significant ($P = .197$). Notably, excluding this patient did not significantly diminish the correlation between tendon retraction distance and LEFS score ($P = .034$) (Supplemental Fig S4 and Supplementary Information).

Conclusions

In this study, we found that increased degree of tendon retraction, increased follow-up time, and younger age at initial injury were associated with significantly worse self-reported functional outcomes.

References

1. 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.
2. Cohen S, Bradley J. Acute proximal hamstring rupture. *J Am Acad Orthop Surg* 2007;15:350-355.

3. Hofmann KJ, Paggi A, Connors D, Miller SL. Complete avulsion of the proximal hamstring insertion: Functional outcomes after nonsurgical treatment. *J Bone Joint Surg Am* 2014;96:1022-1025.
4. Koulouris G, Connell D. Evaluation of the hamstring muscle complex following acute injury. *Skeletal Radiol* 2003;32:582-589.
5. Wood DG, Packham I, Trikha SP, Linklater J. Avulsion of the proximal hamstring origin. *J Bone Joint Surg Am* 2008;90:2365-2374.
6. Bodendorfer BM, Curley AJ, Kotler JA, et al. Outcomes after operative and nonoperative treatment of proximal hamstring avulsions: A systematic review and meta-analysis. *Am J Sports Med* 2018;46:2798-2808.
7. Birmingham P, Muller M, Wickiewicz T, Cavanaugh J, Rodeo S, Warren R. Functional outcome after repair of proximal hamstring avulsions. *J Bone Joint Surg Am* 2011;93:1819-1826.
8. Chakravarthy J, Ramisetty N, Pimpalnerkar A, Mohtadi N. Surgical repair of complete proximal hamstring tendon ruptures in water skiers and bull riders: A report of four cases and review of the literature. *Br J Sports Med* 2005;39:569-572.
9. Lempainen L, Sarimo J, Heikkila J, Mattila K, Orava S. Surgical treatment of partial tears of the proximal origin of the hamstring muscles. *Br J Sports Med* 2006;40:688-691.
10. Orava S, Kujala UM. Rupture of the ischial origin of the hamstring muscles. *Am J Sports Med* 1995;23:702-705.
11. 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.
12. Shambaugh BC, Olsen JR, Lacerte E, Kellum E, Miller SL. A comparison of nonoperative and operative treatment of complete proximal hamstring ruptures. *Orthop J Sports Med* 2017;5:2325967117738551.
13. Lightsey HM, Kantrowitz DE, Swindell HW, Trofa DP, Ahmad CS, Lynch TS. Variability of United States online rehabilitation protocols for proximal hamstring tendon repair. *Orthop J Sports Med* 2018;6:2325967118755116.
14. Hanauer DA. EMERSE: The electronic medical record search engine. *AMIA Annu Symp Proc* 2006:941.
15. Binkley JM, Stratford PW, Lott SA, Riddle DL. The lower extremity functional scale (LEFS): Scale development, measurement properties, and clinical application. North American Orthopaedic Rehabilitation Research Network. *Phys Ther* 1999;79:371-383.
16. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res* 1985:43-49.
17. Briggs KK, Lysholm J, Tegner Y, Rodkey WG, Kocher MS, Steadman JR. The reliability, validity, and responsiveness of the Lysholm score and Tegner activity scale for anterior cruciate ligament injuries of the knee: 25 years later. *Am J Sports Med* 2009;37:890-897.
18. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373-383.
19. Dripps RD, Lamont A, Eckenhoff JE. The role of anesthesia in surgical mortality. *JAMA* 1961;178:261-266.
20. Irrgang J. Summary of clinical outcome measures for sports-related knee injuries. *AOSSM Outcomes Task Force*. 2012.
21. Liu CH, Chiu CH, Chang SS, et al. Clinical and functional outcomes of isolated posterior cruciate ligament reconstruction in patients over the age of 40 years. *BMC Musculoskelet Disord* 2022;23:210.
22. Harris JD, Griesser MJ, Best TM, Ellis TJ. Treatment of proximal hamstring ruptures—A systematic review. *Int J Sports Med* 2011;32:490-495.
23. Ekstrand J, Healy JC, Walden M, Lee JC, English B, Hagglund M. Hamstring muscle injuries in professional football: The correlation of MRI findings with return to play. *Br J Sports Med* 2012;46:112-117.
24. Fournier-Farley C, Lamontagne M, Gendron P, Gagnon DH. Determinants of return to play after the nonoperative management of hamstring injuries in athletes: A systematic review. *Am J Sports Med* 2016;44:2166-2172.
25. Hsu D, Anand P, Chang K. Biceps tendon rupture of the lower limb. *StatPearls* Treasure Island, FL: StatPeals Publishing; 2020.
26. Laszlo S, Nilsson M, Pihl E, et al. Proximal hamstring tendon avulsions: A survey of orthopaedic Surgeons' current practices in the nordic countries. *Sports Med Open* 2022;8:49.