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Original Article

Significant Muscle Strength Deficits Persist One Year After ACL Reconstruction with Hamstring Tendon Autografts

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ABSTRACT

Objective: Hamstring tendon (HT) autografts are frequently used in anterior cruciate ligament (ACL) reconstruction, but their impact on muscle strength recovery and knee functionality remains a concern.

Materials and Methods: This study aimed to evaluate the changes in muscle strength and recovery dynamics in patients undergoing anterior cruciate ligament (ACL) reconstruction using hamstring tendon autografts. The primary focus was on assessing quadriceps and hamstring strength, hamstring-to-quadriceps (H/Q) ratios, and Limb Symmetry Index (LSI) before and one year post-surgery. Additionally, the study examined clinical outcomes using the International Knee Documentation Committee (IKDC) and Lysholm Knee Scores. Seventeen male patients (mean age 25.1±7.1 years) who underwent ACL reconstruction with hamstring autografts were included. Isokinetic testing assessed muscle strength preoperatively and at 12 months postoperatively. Outcome measures included concentric and eccentric peak torque values for quadriceps and hamstrings, H/Q ratios, LSI, and functional outcomes measured by the International Knee Documentation Committee (IKDC) Score and the Lysholm Knee Score. Statistical analysis compared preoperative and postoperative data. Study Design: Prospective cohort study; Level of evidence; 2.

Results: Significant preoperative disparities were observed in concentric quadriceps strength between injured and uninjured sides, with persistent deficits postoperatively. Eccentric quadriceps strength showed stability, but hamstring strength significantly decreased post-surgery. Conventional and functional H/Q ratios worsened postoperatively, failing to meet normal benchmarks. LSI for both quadriceps and hamstrings remained below the 90% threshold postoperatively, indicating persistent strength deficits. Despite these muscle imbalances, significant improvements were observed in knee function, with increased IKDC and Lysholm scores.

Conclusion: One year after ACL reconstruction with hamstring tendon autografts, patients exhibit substantial deficits in quadriceps and hamstring strength, reflected in lowered H/Q ratios and LSI values. Despite these deficits, significant improvements in knee function and stability are observed. Extended and targeted rehabilitation focusing on concentric and eccentric muscle strengthening may be necessary for optimal recovery.

Keywords: ACL reconstruction, hamstring tendon autografts, H/Q ratio, Limb Symmetry Index, muscle strength recovery

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INTRODUCTION

Anterior cruciate ligament (ACL) rupture is a prevalent injury, particularly in young individuals engaged in contact sports.[1] This debilitating injury can have significant consequences for athletes, potentially leading to the end of their sporting careers. ACL reconstruction (ACLR) is essential for restoring knee stability and function, and is often necessary for returning to sports.[2-4] Early surgery, combined with postoperative rehabilitation, is crucial for restoring knee joint stability and function, effectively preventing further complications.[5, 6] There is a wide variety of graft options available for ACLR, including allografts, synthetic grafts, hamstring tendons (HT), quadriceps tendon (QT), bone-patellar tendon-bone (BPTB), and peroneus longus tendon autografts. Each of these graft options has its own advantages and disadvantages. Moreover, graft selection may influence surgical outcomes and the postoperative rehabilitation processes.

The BPTB graft was historically favored for its initial strength and reliable healing properties.[7, 8] However, the BPTB grafts are associated with several complications, including anterior knee pain, patellar tendon rupture, patellar fracture, and knee extensor dysfunction.[9] Among other alternative graft options, HT autografts have gained considerable popularity and have emerged as the most commonly used autograft.[10] HT grafts have several advantages, including ease of harvest, minimal invasiveness, low risk of donor site morbidity, and lack of extensor mechanism dysfunction.[11] Despite the advantages of HTAs, they are not without downsides. One significant concern is their association with hamstring muscle strength deficits.[12] This weakness can significantly impact rehabilitation and increase re-injury risk, as these muscles play a protective role for the ACL and compensate for stability loss in ACL-deficient knees.[8] Furthermore, hamstrings provide a stabilizing effect against valgus stress in MCL injuries, and hamstring weakness is directly associated with decreased knee function following ACL injury.[13] Consequently, this weakness affects the recovery process and raises significant questions about the optimal timing for a safe return to sports.

Given the potential impact of hamstring weakness, it's essential to investigate the muscle strength recovery process after ACLR using HT grafts. The primary aim of this study focuses on evaluating the changes in muscle strength and the dynamics of recovery in patients undergoing ACL reconstruction using HT autografts. The objective is to provide a comprehensive assessment of muscle function, specifically looking at the quadriceps and hamstring strength, hamstring-to-quadriceps (H/Q) ratios and the Limb Symmetry Index (LSI), before and one year after the surgery. This period allows for a substantial phase of rehabilitation, offering insights into the long-term effects of the surgical technique on muscle strength and knee functionality. The secondary aim of the study examines the correlation between these muscle strength measures and clinical outcomes, as assessed by the International Knee Documentation Committee (IKDC) Score and the Lysholm Knee Score, to understand the broader implications of hamstring tendon harvesting on post-surgical recovery. By evaluating these parameters, the study seeks to elucidate the real-world implications of ACLR with HT grafts on an individual's return to sports, ensuring that the surgical advances continue to align with optimal long-term health outcomes.

MATERIALS AND METHODS

Patients and Study Design

This prospective study was conducted on patients who underwent isolated ACLR using quadruple HT autograft. Patients with concurrent meniscal tears, cartilage injuries, and additional ligament injuries were excluded from the study since they would significantly alter postoperative rehabilitation. In addition, patients with a previous history of injury or surgical procedure in the contralateral knee were also excluded from the study. Finally, patients who underwent ACLR more than three months after the initial ACL injury were excluded. All patients scheduled for ACLR between 2020 and 2021 were prospectively evaluated. Seventeen males aged between 18 and 42 who met the specified criteria were included in the study. This study was conducted according to the ethical standards of the 1964 Helsinki Declaration and its subsequent amendments, and the institutional review board (IRB) approved the study protocol (IRB approval date/no: 2019/138.12/2).

Surgical Technique and Postoperative Rehabilitation

All patients underwent anatomic single-bundle arthroscopic ACLR under spinal anesthesia. The hamstring tendons (gracilis and semitendinosus) were harvested using an anteromedial oblique incision and prepared in a quadruple fashion. The femoral tunnel was drilled using the anteromedial portal technique to target the native ACL femoral footprint. The tibial tunnel was placed in line with the posterior border of the anterior horn of the lateral meniscus using a 55-degree tibial guide. An endobutton suspension system was utilized for femoral fixation, while a bioabsorbable interference screw and post-fixation titanium U-staple were employed for tibial fixation. A suction drain was placed within the joint and was removed at 24 hours postoperatively.

ACL postoperative rehabilitation is an extensive process intended to ease pain, reduce swelling, and minimize inflammation following surgery. The main objectives are to regain full range of motion, reestablish neuromuscular function, and eventually ensure a safe return to previous levels of physical activity or sports performance.[14] To achieve these goals more efficiently, accelerated rehabilitation following anterior cruciate ligament (ACL) reconstruction has been

introduced as a modern approach. This method aims to speed up recovery and facilitate an early return to functional activities.[15] In line with this approach, an accelerated rehabilitation program was implemented for all patients in this study undergoing ACL reconstruction. Early mobilization and progressive exercises were focused on, starting immediately post-surgery with pain management, edema reduction and knee mobility exercises. In weeks 2-4, the protocol emphasized maintaining knee extension, improving knee flexion, and strengthening the thigh, hip, and trunk, while incorporating low-impact aerobic exercises. From weeks 5-12, efforts continued to normalize knee movements and strengthen musculature, with an increase in the complexity and impact of aerobic and proprioceptive exercises. The final phase (weeks 13-24) aimed at restoring symmetrical strength, introducing plyometrics, and advancing aerobic activities based on individual tolerance, concluding with sport-specific drills to ensure a safe return to athletics.

Isokinetic Testing and Outcome Measurements

Isokinetic testing was conducted on patients to assess muscle strength before and 12 months after surgery, at which point all participants had completed the standard rehabilitation regimen. This isokinetic evaluation was performed with a "Cybex Norm" (CSMI Humac Norm, USA). The same sports medicine physician performed all test procedures. Dynamometers were calibrated according to the operating manual. Before strength testing, participants performed a general cardiovascular warm-up on a Monark cycle ergometer for at least 5 min at a moderate pace (50-100 W). Tests were performed in a predefined ROM of 90°–0°. The gravitational correction was performed at 45^0 of knee flexion. At the beginning of the test procedures, participants were allowed three submaximal contractions of the hamstring or quadriceps muscle group to familiarize themselves with the test conditions. Next, they were given three trial contractions to perform four maximal contractions at the angular velocity of 60 °/sec. Then, they performed eccentric knee extension and flexion four times at the same selected angular velocity in three trials. Subjects were encouraged verbally during the test to ensure maximal participation. The tests were first performed on the non-injured side leg. A 30-second rest period was given between trial repetitions and the test, and a 2-minute rest interval after each test. The best concentric (Con) and eccentric (Ecc) muscle peak torque values were recorded for the hamstring and quadriceps muscle groups. Additionally, limb symmetry index (LSI), conventional hamstring-to-quadriceps ratio (conH/conQ), and functional hamstring-to-quadriceps ratio (eccH/conQ) were calculated and utilized for data analysis (ConQ representing concentric quadriceps, ConH representing concentric hamstring, EccQ representing eccentric quadriceps, and EccH representing eccentric hamstring). The H/Q ratio is calculated in two primary ways, each offering insights into different aspects of muscle function. The conventional H/Q ratio measures the peak concentric forces between the hamstrings and quadriceps, whereas the functional H/Q ratio (formerly known as the Dynamic Control Ratio) evaluates the relationship between the eccentric strength of the hamstrings and the concentric strength of the quadriceps, expressed as a percentage.[16] Traditional guidelines and most recent systematic reviews have benchmarked the conventional hamstring-to-quadriceps (H/Q) ratio at 60% and the functional H/Q ratio at 80%.[16,17]

The Limb Symmetry Index (LSI), expressed as the percentage ratio of the operated limb's strength or performance to that of the unaffected limb (LSI: operated limb/unaffected limb x 100), serves as a quantifiable indicator of functional restoration and bilateral symmetry following anterior cruciate ligament (ACL) reconstruction.[18] Achieving an LSI of ≥90% indicates successful rehabilitation, with strength in the injured limb approaching that of the uninjured side.[19]

The functional outcomes of the patients were assessed using two established scoring systems: the International Knee Documentation Committee (IKDC) Score and the Lysholm Knee Score.[20, 21] Preoperative scores were recorded for each patient before surgery, and postoperative scores were collected 12 months after surgery; at this point, all participants had completed the standard rehabilitation regimen.

Statistical Analysis

Continuous variables were reported as mean, median, and standard deviation, while categorical variables were expressed in terms of percentages and frequency distribution. Continuous variables were compared between independent groups using either the Student's t-test or the Mann-Whitney U test, depending on the results of normality testing. Categorical data were compared using the chi-square test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The study included seventeen male patients with a mean age of 25.1±7.1 years (range, 18.0 - 42.0). A summary of the patient characteristics is presented in Table 1. In the preoperative assessment, the injured leg demonstrated significantly weaker concentric strength in both the quadriceps (156.6±40.8 Nm vs. 185.0±37.1 Nm, p=0.011) and the hamstrings (75.7±26.5 Nm vs. 87.5±25.8 Nm, p=0.012) compared to the uninjured leg. This discrepancy persisted postoperatively, with the injured leg failing to demonstrate a significant improvement in either muscle group over the study period (p=0.006 for quadriceps; p=0.012 for hamstrings). Notably, the hamstrings of the injured leg demonstrated a further decline in strength postoperatively (75.7±26.5 Nm vs. 87.5±25.8 Nm, p=0.012), while the

Table 1. Demographics and clinical characteristics of patients

Variables	Values
Age, years±SD (min-max)	25.1±7.1 (18.0 - 42.0)
Height, cm±SD (min-max)	176.4±6.4 (168.0 – 189.0)
Weight, kg±SD (min-max)	79.9±14.1 (62.0 – 112.0)
BMI, kg/m^2±SD (min-max)	25.5±3.1 (21.8 – 33.8)
Side, n (%)	
Right	7 (41.2)
Left	10 (58.8)
The time between rupture and ACLR, months±SD (min-max)	2.2±0.6 (1-3)

SD: Standart deviation; min: minimum; max: maximum.

quadriceps exhibited a minor, non-significant improvement (160.4±41.4 Nm vs. 156.6±40). There was no significant difference in the strength of the quadriceps muscles when performing eccentric contractions before surgery (p=0.906). However, following surgery, the strength of the injured side decreased, while the strength of the uninjured side increased significantly (p=0.000). Similarly, there was no significant difference in eccentric contractions of the hamstrings between the injured and uninjured sides before surgery (p=0.660). However, following surgery, the injured side demonstrated a significant decrease in strength (p=0.000), while the uninjured side exhibited an increase (p=0.024), resulting in a significant difference between the two sides (p=0.001).

With regard to the H/Q ratios, both conventional and functional, there were discernible changes over time, with the most remarkable alterations observed on the injured side. The conventional H/Q ratio exhibited a significant decline following surgery on the injured side (p=0.004), while the functional H/Q ratio, initially demonstrating a notable difference in values between the injured and uninjured sides (p=0.042), also demonstrated a significant decline post-surgery (p=0.000). This resulted in a persistent difference between the injured and uninjured sides (p=0.019), with the uninjured side exhibiting a higher ratio postoperatively. However, neither ratio reached the recommended typical values (60% for conventional and 80% for functional) on either side. Regarding Limb Symmetry Indices (LSIs), all indices for both concentric and eccentric contractions failed to reach the 90% threshold considered normal postoperatively. Notably, the eccentric LSI for both the quadriceps and hamstrings demonstrated a significant decline following surgery (p=0.010 and p=0.000, respectively), indicating persistent deficits in muscle function. (For a detailed account of these results, please refer to Table 2).

Table 2. Results of the comparison between injured and uninjured sides in the preoperative and postoperative period

	Con Q		
	Injured	**Uninjured**	**p**
Preoperative	156.6±40.8	185.0±37.1	0.011[2]
Postoperative	160.4±41.4	185.7±44.7	0.006[2]
p-value	n.s[2]	n.s[2]	
	Con H		
	Injured	**Uninjured**	**p**
Preoperative	88.2±25.5	96.4±25.7	0.047[2]
Postoperative	75.7±26.5	87.5±25.8	0.012[2]
p-value	0.042[2]	n.s[2]	
	Ecc Q		
	Injured	**Uninjured**	**p**
Preoperative	177.1±58.9	175.5±53.9	n.s[1]
Postoperative	172.7±67.6	186.3±60.6	n.s[1]
p-value	n.s[1]	0.000[1]	
	Ecc H		
	Injured	**Uninjured**	**p**
Preoperative	111.8±35.1	115.9±39.3	n.s[2]
Postoperative	82.1±37.4	120.2±42.5	0.001[2]
p-value	0.000[2]	0.024[2]	
	ConH/ConQ Ratio		
	Injured	**Uninjured**	**p**
Preoperative	0.57±0.11	0.51±0.11	n.s[1]
Postoperative	0.46±0.10	0.47±0.08	n.s[1]
p-value	0.004[1]	n.s[1]	
	EccH/ConQ Ratio		
	Injured	**Uninjured**	**p**
Preoperative	0.71±0.17	0.62±0.17	0.042[2]
Postoperative	0.51±0.20	0.65±0.21	0.019[2]
p-value	0.000[2]	n.s[2]	
	LSI		
	Preoperative	**Postoperative**	**p**
LSI Con Q	0.85±0.17	0.84±0.16	n.s[1]
LSI Con H	0.92±0.16	0.87±0.20	n.s[1]
LSI Ecc Q	1.01±0.18	0.86±0.24	0.010[2]
LSI Ecc H	0.98±0.15	0.70±0.26	0.000[1]

[1]Paired Sample T Test; [2]Wilcoxon Test; SD: Standart deviation.

Table 3. Comparison of preoperative and postoperative knee functional outcome score

	Pre-operative Score	Post-operative Score	p
IKDC Score	61.8±7.6	85.6±5.6	0.000[1]
Lysholm Knee Score	69.4±5.4	85.3±5.1	0.000[1]

[1]Paired Sample T-Test.

Notwithstanding the persistent muscular imbalances, there were notable improvements in knee function postoperatively, as evidenced by increased IKDC and Lysholm scores ($p<0.001$ for both). The IKDC averaged 85.6±5.6, while the Lysholm averaged 85.3±5.1, indicating favorable outcomes. (Functional outcomes are presented in Table 3).

DISCUSSION

This study aimed to elucidate the changes in muscle actions in individuals one year following anterior cruciate ligament (ACL) reconstruction using a hamstring tendon autograft. The results demonstrated that there were persistent challenges in muscle strength recovery. Notably, concentric quadriceps strength was significantly weaker than the uninjured leg, whereas eccentric strength demonstrated greater stability, indicating less impact from the surgery. There was a marked decline in both concentric and eccentric hamstring strength, likely due to harvesting the tendon for the graft. Furthermore, conventional and functional hamstring-to-quadriceps (H/Q) ratios declined following surgery, falling below the recommended normal values. This highlights a significant imbalance that may impact joint stability. Consequently, limb symmetry indices (LSIs) for both muscle contractions remained below the 90% threshold, which is considered normal, thereby underscoring persistent deficits in muscle function. Moreover, the IKDC and Lysholm Knee scores demonstrated substantial improvements from preoperative to postoperative evaluations. These improvements reflected significant enhancements in knee function, stability, pain, and mechanical function, which were statistically significant.

The hypothesis that quadriceps strength is significantly reduced following an ACL injury is supported by the findings of this study. This aligns with the existing literature highlighting atherogenic muscle inhibition as a compensatory mechanism to mitigate the risk of anterior subluxation and subsequent knee damage.[22] Before surgery, there was a notable discrepancy between the strength of the injured and uninjured sides. Following surgery, there was a modest increase in strength on the injured side. Despite a slight increase in strength postoperatively, the injured side did not achieve the strength levels of the uninjured side. This ongoing weakness is primarily attributed to neuromuscular dysfunction and diminished activity levels following ACL injury, further exacerbated by a restricted range of motion during recovery.[20] These findings are consistent with studies that have documented quadriceps muscle strength deficits of 10–27% one-year post-surgery, with deficiencies persisting at 6–10% even beyond five years following the procedure.[8, 20] These persistent deficits can have a negative impact on functional outcomes and increase the risk of re-injury.[20]

Given the potential biomechanical benefits, it is postulated that augmented hamstring strength confers advantages in patients presenting with anterior cruciate ligament (ACL) tears. The hamstrings' contraction can counteract anterior tibial translation, thereby reducing the stress placed upon the injured ligament.[23] Furthermore, it can enhance knee joint compression and provide resistance against external varus/valgus loads, thereby promoting overall stability.[23] It is notable that a decline in hamstring muscle strength on the injured side before surgery was observed in this study, in contrast with the anticipated maintenance or enhancement of hamstring strength due to its compensatory role in ACL deficiency. This may indicate the potential implications of using hamstring tendons for grafting. Moreover, the recovery of hamstring strength appeared less promising. The postoperative strength on the injured side was found to significantly decrease from the preoperative measure, reflecting the substantial impact of HT autografts on knee flexor strength, as previously reported.[24] This evidence supports the hypothesis that HT autografts result in more pronounced deficits in knee flexor strength, which must be addressed more assertively in rehabilitation protocols.

The current study also investigated the effects of ACLR on the H/Q ratios, which are paramount in evaluating the equilibrium between hamstring and quadriceps strength following surgery. The H/Q ratio, a pivotal metric in rehabilitation, indicates the equilibrium between hamstring and quadriceps strength.[25] Two primary assessment methods were employed to evaluate the hamstring-to-quadriceps (H/Q) strength ratio. The conventional H/Q ratio compares peak isokinetic torque values of the hamstrings and quadriceps during concentric contraction. In contrast, the functional H/Q ratio assesses the ratio of peak eccentric hamstring torque to peak concentric quadriceps torque. This functional ratio is designed to reflect how these muscles function more accurately in dynamic activities such as landing and running. Establishing definitive cutoff values for a healthy H/Q ratio remains a challenging task. Studies have reported varying values for the conventional H/Q ratio, ranging from 0.47 to 0.66, and for the functional H/Q ratio, ranging from 0.78 to 1.05, across different speeds. This variability is likely attributable to differences in the

methodology employed to determine these cutoff values and variations in the size and characteristics of the populations examined. The conventional H/Q ratio has frequently been established at 60%, originating from the work of Klein and Allman. Subsequently, it gained prominence following Heiser et al.'s[17] demonstration of its efficacy in reducing injuries among American football players.[26, 27] This benchmark has been further supported by a systematic review by Baroni et al.,[16] which concluded that conventional H/Q ratio scores close to the typical reference landmark of 60% are considered suitable. The 100% cutoff has been commonly used to assess agonist-antagonist strength imbalance in athletes, yet there is no support from prospective studies for this normative value.[27] Moreover, findings from the same systematic review conducted by Baroni et al.[16] indicate that H/Q functional ratio scores around 80% should be expected in individuals returning to sports. A low H/Q ratio has been associated with a greater likelihood of experiencing lower limb injuries, such as ACL ruptures and hamstring strains.[24] Understanding these relationships can guide rehabilitation strategies to optimize knee health and reduce reinjury. The findings revealed significant changes in both H/Q ratio types following surgery. These changes highlight the complex and ongoing process of muscle strength recovery after ACL surgery. In line with previous research,[28] it was found that the conventional H/Q ratio, which reflects concentric muscle strength, did not significantly differ between the injured and uninjured sides preoperatively. This suggests a balanced concentric strength profile before ACLR. However, postoperatively, a significant decrease in the conventional H/Q ratio on the injured side was observed. This finding corresponds with the broader literature indicating that ACLR with hamstring tendon autografts can lead to a relative decrease in hamstring strength compared to quadriceps strength.[24] Interestingly, it was found that the functional H/Q ratio was significantly higher in the injured limbs compared to the uninjured limbs preoperatively. This observation resonates with the emerging idea that injuries such as ACL rupture could potentially disrupt the intricate interplay of agonist and antagonist muscles, possibly prompting compensatory changes in eccentric hamstring control to protect the vulnerable joint.[29] Even more striking was the significant reduction in the functional H/Q ratio of the injured limb postoperatively. This suggests a reduction in the relative eccentric strength of the hamstrings compared to the concentric strength of the quadriceps. The specific decrease in the functional H/Q ratio post-surgery is of particular interest. It is plausible that using HT autografts in ACLR contributes to this reduction. This could be due to the harvesting of hamstring tendons, which may affect the eccentric strength capacity of the hamstrings. The postoperative rehabilitation process might also emphasize quadriceps strengthening over hamstring strengthening, further influencing the H/Q ratio.

In the current study, the desired conventional and functional H/Q ratios during the postoperative period could not be achieved. This is likely because these H/Q benchmarks are primarily derived from studies involving professional athletes. The study population consisted of non-professional athletes who likely did not have access to the same intensive and specialized rehabilitation level. Professional athletes often benefit from more frequent rehabilitation sessions, advanced training techniques, and personalized care plans to optimize recovery and performance. Their typically higher baseline conditioning and motivation levels may also contribute to better rehabilitation outcomes. Our rehabilitation protocols, while comprehensive, lacked the same level of personalization and advanced techniques typically afforded to professional athletes, possibly impacting the efficacy of recovery measures. Therefore, the lower H/Q ratios observed in our postoperative patients could reflect these disparities.

Additionally, the Limb Symmetry Index (LSI) was assessed post-ACL reconstruction, highlighting the recovery patterns of muscle strength in concentric and eccentric movements. The literature emphasizes the role of muscle strength restoration in knee extensors and flexors for a successful return to activities that demand significant knee function.[16] Achieving an LSI of ≥90% indicates successful rehabilitation, with strength in the injured limb approaching that of the uninjured side.[19] Grindem et al.[30] highlighted the increased risk of further knee injury when returning to sport with reduced quadriceps strength (LSI<90%). The results indicate that while concentric muscle strength in both quadriceps and hamstrings neared the 90% threshold, displaying relative stability, the eccentric strength remained significantly lower, especially in the hamstrings. This discrepancy highlights a challenge in achieving full recovery in eccentric muscle strength, which is critical given the hamstrings' role in limiting excessive anterior translation of the tibia and preserving rotational stability within the knee.[31, 32]

Furthermore, the choice of autograft significantly influences rehabilitation outcome. The study, focusing on HT autografts, aligns with existing literature that reports greater deficits in knee flexor strength with HT autografts compared to patellar or quadriceps tendon autografts.[33] This information is critical as it suggests that each autograft type may necessitate tailored rehabilitation strategies.

Significantly, a systematic review and meta-analysis by Högberg et al.[34] revealed that while knee flexor strength deficits, defined as less than 90% LSI, are common at one year postoperatively, there is potential for recovery beyond the first year following ACL reconstruction with HT autografts. Moreover, patients following an accelerated rehabilitation

protocol showed promising results, achieving ≥90% LSI in knee flexor strength as early as six months postoperatively without adverse events.[35, 36] These findings suggest that earlier and more intensive rehabilitation, particularly of the knee flexors, might be essential for optimal recovery.

Given these insights, the recommendations for future rehabilitation protocols are twofold. First, considering the significant deficits in eccentric hamstring strength observed at the one-year mark, rehabilitation programs should not only continue beyond the first year but also incorporate specific exercises to enhance eccentric strength. Second, the evidence supports the implementation of accelerated rehabilitation protocols emphasizing early and intensive strength training of the knee flexors. This approach could expedite recovery times and improve long-term functional outcomes for patients undergoing ACL reconstruction with HT autografts.

Finally, the study highlights the correlation between muscle strength and knee function outcomes. Notably, a significant decline in hamstring strength, involving both concentric and eccentric contractions, was observed, contrasting with earlier studies that indicated a correlation between IKDC scores and maintained hamstring strength.[37] Similarly, existing research emphasizes the importance of preoperative quadriceps strength as a pivotal factor influencing postoperative outcomes.[38, 39] Studies consistently show a strong correlation between robust preoperative quadriceps strength and improved postoperative results, underscoring that the condition of this muscle before surgery significantly impacts the recovery trajectory and the ultimate restoration of knee function.[20, 40] However, the findings add a new dimension to this narrative, revealing that patients can still achieve favorable functional outcomes post-ACL reconstruction even without marked improvements in muscle strength. The results suggest that a comprehensive rehabilitation program that addresses proprioception, coordination, overall knee stability, and psychological factors can achieve good results, even without dramatic increases in muscle strength.

The study on ACL reconstruction with hamstring tendon autografts has several strengths. It uses a prospective cohort design, tracking patients over time to observe changes in muscle strength and knee function. The focus on hamstring tendon autografts provides specific insights into this popular graft choice. Comprehensive outcome measures, including isokinetic muscle testing, hamstring-to-quadriceps ratios, Limb Symmetry Index, and clinical scores (IKDC and Lysholm), offer a thorough evaluation of recovery. The detailed rehabilitation protocol ensures consistent postoperative care, and rigorous statistical analysis strengthens the reliability of the findings. However, the study also has several limitations that could affect the interpretation and broader applicability of its findings. First, the small sample size of only 17 participants, all of whom were male, may not provide a comprehensive view of the diverse populations affected by ACL injuries. This homogeneity limits the ability to apply the results to broader, more varied populations, including women or individuals from different athletic backgrounds or with different health conditions. Additionally, while prospective studies offer a robust framework for observing changes and outcomes over time, the specific follow-up period of one year in this study might not be sufficient to understand the long-term recovery processes and outcomes fully. Long-term effects, such as sustained muscle strength, rehabilitation successes, or potential chronic complications post-reconstruction, require a more extended observation period to be adequately assessed. Lastly, the absence of a control group makes it difficult to definitively attribute observed outcomes to the specific surgical technique used, limiting the ability to compare it effectively with other interventions. Future research with larger, more diverse samples, longer follow-up periods, and prospective designs could provide a more comprehensive understanding of the long-term effects of ACL reconstruction with hamstring tendon autografts and inform the development of optimized rehabilitation protocols.

The study concludes that one year after ACR using a hamstring tendon autograft, patients still struggle with muscle strength recovery, particularly in the quadriceps and hamstrings. Despite modest improvements in strength, deficits remain compared to the uninjured leg. However, there are significant postoperative improvements in knee function and stability, as indicated by higher knee scores. The findings emphasize the need for targeted rehabilitation to address these ongoing deficits effectively.

DECLARATIONS

Ethics Committee Approval: The Antalya Training and Research Hospital Scientific Research Ethics Committee approved this study (2019/138.12/2).

Informed Consent: Participants provided informed consent for inclusion.

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Peer-review: Externally peer-reviewed.

ABBREVIATIONS

ACL - Anterior Cruciate Ligament

H/Q ratio - Hamstring-to-Quadriceps (H/Q) ratio

LSI - Limb Symmetry Index

IKDC - International Knee Documentation Committee

ACLR - Anterior Cruciate Ligament Reconstruction

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