

# Anterior Cruciate Ligament Reconstruction in 107 Competitive Wrestlers

## Outcomes, Reoperations, and Return to Play at 6-Year Follow-up

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**Background:** Wrestling is a physically demanding sport, with young athletes prone to anterior cruciate ligament (ACL) injuries. There is a paucity of data evaluating the results of ACL reconstruction (ACLR) in this cohort.

**Purpose:** To assess return to sport (RTS), patient-reported outcomes, reoperation rates, and graft survival after ACLR in a large cohort of competitive wrestlers at midterm follow-up.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** We identified all competitive wrestlers (club, high school, collegiate, or professional) with a history of an ACLR at a single institution between 2000 and 2019. Graft failure was defined as a retear (as determined via clinical or advanced imaging evaluation) and/or revision ACLR. All patients were contacted for determination of reinjury rates; current sport status; and pain visual analog scale, International Knee Documentation Committee, and Tegner activity scores.

**Results:** Included were 107 knees in 103 wrestlers, with a median follow-up time of 5.9 years (interquartile range [IQR], 3.9-10.3 years). The median age was 17 years (IQR, 15-18 years), with 106 (99%) male patients, and the distribution of bone-patellar tendon-bone (BTB) and hamstring tendon (HT) autografts was 64 (60%) and 43 (40%), respectively. At final follow-up, 80% of athletes were able to RTP at a median of 280 days (IQR, 212-381 days). Graft failure occurred in 14 (13%) knees at a median time of 1.8 years (IQR, 0.7-5.3 years) after the index ACLR. BTB autograft demonstrated a lower failure rate compared with HT autograft (8% vs 21%;  $P = .044$ ) and was associated with better survival compared with HT autograft up to 15 years after the index ACLR (90.4% vs 76.3%;  $P = .030$ ). When compared by graft diameter, HT autografts of at least 7.5 mm were not associated with a lower graft failure than BTB constructs of all sizes ( $P = .205$ ).

**Conclusion:** Return to competitive wrestling was observed in 80% of athletes after ACLR, with 14% of wrestlers experiencing graft failure. BTB autograft was associated with better survival than HT autograft.

**Keywords:** ACL reconstruction; anterior cruciate ligament rupture; bone-patellar tendon-bone; return to sport; wrestling

The sport of wrestling dates its origins to 5000 BCE, with inclusion in the first Olympic games in 708 BCE.<sup>4,27</sup> Subsequent modern disciplines of Greco-Roman and freestyle wrestling made their Olympic debuts in 1896 and 1904, respectively.<sup>4,27,34</sup> Wrestling continues to be a premier world sport, with >2.5 million active participants across amateur, high school, collegiate, Olympic, and professional ranks.<sup>2,4,27,33,39</sup> Competitive wrestling is second only to football in rates of orthopaedic injuries.<sup>1,2,4,27,33,34,39,44</sup>

Knee injuries occur commonly in wrestlers and often require surgical treatment.<sup>1,4,27,33</sup> Anterior cruciate ligament (ACL) injuries in wrestlers are generally associated with rotation on a planted foot with the leg in or near full extension, usually during a takedown.<sup>22,25</sup> Previous investigations have estimated the rate of ACL injuries in wrestlers, ranging from 0% to 10.4% of knee injuries.<sup>1,25</sup> Despite this, ACL injuries remain relevant due to the elevated need for surgical intervention.<sup>25,33</sup>

ACLR reconstruction (ACLR) has become a reliable treatment option with successful outcomes in the general population.<sup>5,12,13,32</sup> Athletes have a high level of clinical success and return to sport (RTS), with both at varying

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rates depending on the sport, level of competition, and graft choice.<sup>7,8,11,26,29,41</sup> There remains a lack of data evaluating the effect of ACL injuries with subsequent ACLR in wrestlers. The purpose of this study was to assess return to play (RTP), patient-reported outcomes, reoperation rates, and graft survival after ACLR in a large cohort of competitive wrestlers at midterm follow-up. It was hypothesized that ACLR would improve pain and function, with a high rate of RTS. In addition, we hypothesized there would be no differences in failure rates between autograft types after the index ACLR.

## METHODS

After we received institutional review board approval, we queried the patient records according to Current Procedural Terminology code 29888 to identify patients who underwent primary ACLR between 2000 and 2019. A test-string search was subsequently performed within the patient records to identify those with a documented history of wrestling before ACLR. Charts were then reviewed individually to confirm participation in competitive wrestling, defined as athletes who trained and participated in athletic competition, and level of competition (club, high school, collegiate, Olympic, or professional). All common styles of wrestling were included (folk style, freestyle, Greco-Roman, and mixed martial arts). Professional wrestlers were defined as individuals receiving compensation as wrestlers. Club sport wrestlers were defined as competitors who were not professional or part of a high school or college league.

Medical records were then reviewed to obtain patient age, sex, laterality of ACL tear, chronicity of injury, concomitant injuries, and contralateral ACL tear. Acute injury was defined as <3 months between injury and surgery. Informed consent was obtained prior to surgery. Operative details included graft type and concomitant procedures. Postoperative data included graft failures, subsequent reoperations, and return to competitive wrestling. Data were collected from pre- and postoperative periods to obtain baseline and postoperative characteristics and outcomes. For preoperative documentation, we used consultation notes and history and physical documentation closest to the time of surgery. For postoperative documentation, we used operative notes, 2-year follow-up visits, and the most recent

follow-up visits. Telephone calls were made for any patients who did not have at least 2 years of clinical follow-up. Patients were included in the final analysis if they had at least 2 years of clinical follow-up or if they experienced graft failure before 2 years. Exclusion criteria consisted of a previous ACL rupture treated elsewhere, concomitant posterior cruciate ligament or posterolateral corner injury, periarticular fractures, or osteotomies. Allograft ACLRs were also excluded because of the small number identified and limited modern indications in this athletic cohort.

## Surgical Procedures

All surgical procedures involved single-bundle ACLR by 1 of 6 sports medicine fellowship-trained surgeons (C.L.C, B.A.L, M.J.S, A.J.K). Graft selection and fixation method were driven by a combination of the injury pattern, physical examination, patient goals, and surgeon preference. In general, bone–patellar tendon–bone (BTB) autografts were favored unless relative contraindications, such as patella alta, patellofemoral disorder, or Osgood-Schlatter disease, were present. In addition, given the increased occurrence of kneeling in wrestlers, those with anterior preexisting anterior knee pain had additional consideration for hamstring autografts. Final autograft constructs consisted of a BTB, quadrupled semitendinosus tendon, or combined quadrupled semitendinosus and gracilis tendon graft. The tibial tunnel was drilled with the knee in flexion using a conventional guide. The femoral tunnel was drilled using an outside-in technique. All grafts were fixed first in the femur, tensioned manually, and then fixed in the tibia.

All patients followed a standardized rehabilitation protocol with immediate weightbearing and range of motion as tolerated while using a hinged knee brace and crutches. Athletes were allowed to participate in running and light activity at 3 to 4 months. Return to cutting, pivoting, and wrestling occurred anywhere from 7 to 12 months as determined by satisfactory progress via evaluation by the physical therapist and orthopaedic surgeon.

## Outcome Measures

For the return to wrestling (RTW) analysis, patients were excluded if they graduated shortly after their ACLR, making them ineligible to return. The date of return was recorded as the date of clearance by the orthopaedic sports

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medicine specialist, and patient charts were reviewed to confirm return to competition. We then assessed reinjury rates and outcome measures including visual analog scale (VAS) for pain (0-10 scale, 10 = worst pain), International Knee Documentation Committee (IKDC) subjective evaluation, and Tegner activity scores at final follow-up.<sup>18,19,42,43</sup> Failure was defined as reinjury of the operated knee resulting in a graft tear determined via a combination of clinical evaluation, advanced imaging examination, and/or revision ACLR. Subgroup analysis was performed based on the 2 most common graft types (patellar tendon [PT] autograft and hamstring tendon [HT] autograft) to compare patient-reported outcomes and failure rates. In addition, subgroup analysis was performed to compare patients with isolated ACL injury with those who underwent concomitant procedures.

### Statistical Analysis

Data were collected and stored using Microsoft Excel (2010; Microsoft Corp) and analyzed using JMP Pro (Version 14.1.0; SAS Institute). Baseline patient characteristics were presented as means, medians, percentages, and standard deviations or interquartile ranges (IQRs) when appropriate. Data were analyzed for parametric assumptions. For continuous variables, 2-sample *t* tests were used if the variable was distributed normally (ie, age, body mass index). For nonnormally distributed items, we used Wilcoxon rank sum and Mann-Whitney *U* tests (ie, time to RTW, VAS pain, IKDC scores). Categorical variables were analyzed using chi-square analysis or Fisher exact test. Graft failure was compared using a 1-way analysis of variance with pairwise *t* test comparisons among the types. The effect of graft type and diameter on the rate of graft failure was assessed using generalized linear models with a binomial distribution and log-link function. Specifically, analyses based on increasing graft diameter were used to maximize the size of the individual graft diameter groupings and minimize the potential for type 2 error. A Kaplan-Meier survival analysis was performed to evaluate progression to failure after ACLR and to compare survivorship of the different graft types. Subsequently, a log-rank test (Mantel-Cox; 95% CI) of the 2 Kaplan-Meier curves was then used to define whether there was a statistically significant difference in survivorship between these graft types. *P* values <.05 were considered statistically significant.

## RESULTS

A total of 184 patients had documentation of wrestling involvement before ACLR. Exclusions consisted of 48 patients without competitive participation, 11 treated with allograft reconstruction, and 22 with <2 years of clinical follow-up. A total of 107 knees in 103 patients (4 bilateral) were included for final analysis at a median follow-up of 5.9 years (IQR, 3.9-10.3 years; mean [range], 6.7 years [2.0-20.8 years]). Graft choice for reconstruction was determined by surgeon preference and consisted of 64 (60%) BTB autografts, and 43 (40%) HT autografts (Table 1). A total of

30 (29%) knees had isolated ACLR, while 77 (72%) had a concomitant procedure performed. No differences in associated concomitant procedures were noted when comparing BTB autograft with HT autograft (*P* < .199). Baseline characteristics were relatively similar among groups and are highlighted in Table 1, with additional operative details in Table 2. Notable differences between groups included an increased age (17 vs 16 years; *P* = .034) and larger mean graft size (10 vs 8.4 mm; *P* < .001) with BTB compared with HT autografts.

### Patient-Reported Outcomes

Of the 80 eligible patients, 69 (86%) returned to competitive sports, and 64 (80%) returned to competitive wrestling at a median of 280 days (IQR, 212-381 days) after the index procedure. No differences were observed in RTW between BTB autograft versus HT autograft specifically (74% vs 90%; *P* = .064). When evaluated by level of competition, RTS rates were 100%, 90%, 84%, and 90% for professional, collegiate, high school, and club wrestlers, respectively. RTW by level of competition was 100%, 90%, 78%, and 80%, for professional, collegiate, high school, and club wrestlers, respectively. Patient-reported outcomes were available for 101 knees (94%) at final follow-up with a median (IQR) IKDC score of 94.3 (86.2-98.9), Tegner activity level of 7 (5-9), and VAS pain score of 0 (0-0). Comparing across BTB autograft versus HT autograft, we observed no differences between BTB and HT autograft for IKDC (93.7 vs 95.4; *P* = .461), Tegner activity level (7 vs 7; *P* = .975), and VAS (0 vs 0; *P* = .955) scores. Additionally, no differences were observed in comparisons of those with isolated ACL injuries versus concomitant injuries with respect to IKDC (91.7 vs 90.2; *P* = .565), Tegner (7 vs 7; *P* = .896), and VAS (0 vs 0; *P* = .707) scores.

### Clinical Complications and Graft Failure

Clinical complications leading to reoperations were observed in 26 (24%) knees at a median time to reoperation of 570.5 days (IQR, 221-1840 days). Subsequent operations included 11 (10%) revision ACLR, 4 (4%) revision partial medial meniscectomies (3 previous repairs and 1 previous partial meniscectomy), 3 (3%) revision partial lateral meniscectomies (PLMs) (all previous repairs), 3 (3%) new tear medial meniscal repairs (MMRs), 2 (2%) revision lateral meniscal repairs (LMRs) (1 previous meniscectomy and repair), 2 (2%) intra-articular infections treated with irrigation and debridement, 2 (2%) arthroscopic debridement for arthrofibrosis, 1 (1%) new tear LMR, 1 (1%) new tear PLM, 1 (1%) revision MMR (previous repair), 1 (1%) quadriceps tendon repair, 1 (1%) removal of symptomatic hardware, and 1 (1%) peroneal neurolysis in a patient with concomitant lateral collateral ligament reconstruction. Of note, 8 (7%) knees sustained a contralateral ACL tear during the study period. These occurred in 5 (8%) BTB autografts and 3 (7%) HT autografts with no differences between the groups (*P* = .872).

When classified by index graft choice, rates of reoperation were similar across BTB (*n* = 15; 23%) versus HT (*n* = 11;

TABLE 1  
Baseline Descriptive and Clinical Data<sup>a</sup>

	Entire Cohort (N = 107)	BTB Autograft (n = 64)	HT Autograft (n = 43)	<i>P</i>
Age, y	17 (15-18)	17 (16-18)	16 (15-18)	<b>.034</b>
Sex				
Male	106 (99)	64 (100)	42 (98)	.402
Female	1 (1)	0 (0)	1 (2)	
Level of competition				<b>.006</b>
High school	85 (79)	56 (88)	29 (67)	
Collegiate	9 (8)	6 (9)	3 (7)	
Club	11 (10)	2 (3)	9 (21)	
Professional	2 (2)	0 (0)	2 (5)	
Laterality of injured knee				.430
Left	58 (54)	37 (58)	21 (49)	
Right	49 (46)	27 (42)	22 (51)	
Chronicity of injury				.498
Acute	81 (76)	50 (78)	31 (72)	
Chronic	26 (24)	14 (22)	12 (28)	
Follow-up, y	5.9 (3.9-10.3); range, 2.0-20.8	5.7 (3.5-12.6); range, 2.0-20.8	6.3 (4.1-9.5); range, 2.0-18.7	.181
Concomitant injuries and associated treatment				.199
LM	42 (39)	28 (44)	14 (33)	.314
Repair	21 (20)	13 (20)	8 (19)	
Partial meniscectomy	21 (20)	15 (23)	6 (14)	
MM	31 (29)	19 (30)	12 (28)	.931
Repair	20 (19)	11 (17)	9 (21)	
Partial meniscectomy	11 (10)	8 (13)	3 (7)	
MCL	10 (9)	9 (14)	1 (2)	.276
Repair	3 (3)	2 (3)	1 (2)	
Reconstruction	2 (2)	2 (3)	0 (0)	
Nonoperative	5 (5)	5 (8)	0 (0)	
Chondroplasty	3 (3)	2 (3)	1 (2)	.999
LFC	1 (1)	0 (0)	1 (2)	
MFC	1 (1)	1 (2)	0 (0)	
LTP	1 (1)	1 (2)	0 (0)	
LCL	3 (3)	3 (5)	0 (0)	.272
Repair	1 (1)	1 (2)	0 (0)	
Reconstruction	1 (1)	1 (2)	0 (0)	
Nonoperative	1 (1)	1 (2)	0 (0)	

<sup>a</sup>Data are reported as median (interquartile range) or n (%) unless otherwise indicated. Bolded *P* values indicate statistically significant difference between BTB and HT autograft groups ( $P < .05$ ). BTB, bone–patellar tendon–bone; HT, hamstring tendon; LCL, lateral collateral ligament; LFC, lateral femoral condyle; LM, lateral meniscus; LTP, lateral tibial plateau; MCL, medial collateral ligament; MFC, medial femoral condyle; MM, medial meniscus.

26%) autografts ( $P = .802$ ). When classified by isolated ACL injury versus ACL and concomitant injuries, rates of reoperation were not different (20% versus 26%;  $P = .512$ ). Graft failure occurred in 14 (13%) knees at a median time of 1.8 years (IQR, 0.7-5.3 years) after the index ACLR. No statistical difference in graft failure was observed when comparing isolated ACLR to ACLR and concomitant procedures (17% vs 12%;  $P = .493$ ). However, HT autograft had a significantly larger number of failures with 9 of 43 (21%) compared with BTB autograft with 5 of 64 (8%) ( $P = .044$ ).

A subanalysis was performed comparing HT and BTB graft failure rates by type and diameter. There was no significant difference in the risk of failure between HT autografts with a diameter of  $\leq 7$  mm (relative risk [RR], 3.08 [95% CI, 1.04-9.12];  $P = .059$ ),  $< 8$  mm (RR, 2.64 [95% CI,

0.87-7.99];  $P = .091$ ), or  $< 9$  mm (RR, 2.52 [95% CI, 0.59-10.74];  $P = .179$ ) compared with larger HT autografts (Table 3). Similarly, there was no difference in the risk of graft failure in patients treated with BTB autografts with a diameter of  $< 10$  mm versus  $\geq 10$  mm (RR, 2.38 [95% CI, 0.44-12.88];  $P = .339$ ). In comparing HT autografts of increasing diameter to BTB grafts of all sizes, only HT autografts  $\geq 6.0$  mm (RR, 2.67 [95% CI, 1.26-7.45];  $P = .044$ ) and HT autografts  $\geq 7.0$  mm (RR, 2.74 [95% CI, 1.18-7.62];  $P = .043$ ) demonstrated an increased failure rate compared with BTB grafts of all sizes (Table 4).

Kaplan-Meier survivorship analysis for the entire cohort indicated that the percentage of patients who were free from graft failure was 96.3% at 1 year, 92.5% at 2 years, 89.8% at 5 years, 84.6% at 10 years, and 77.6%

TABLE 2  
Operative Data<sup>a</sup>

	Entire Cohort (N = 107)	BTB Autograft (n = 64)	HT Autograft (n = 43)	P
Drilling technique				<b>.039</b>
Anteromedial	101 (94)	58 (91)	43 (100)	
Transtibial	6 (6)	6 (9)	0 (0)	
Graft size, mm	9.4 (1.1)	10.0 (0.6)	8.4 (0.1)	<b>&lt;.001</b>
6.0-6.99	1 (1)	0 (0)	1 (20)	
7.0-7.99	9 (8)	0 (0)	9 (21)	
8.0-8.99	15 (14)	0 (0)	15 (35)	
9.0-9.99	30 (28)	14 (22)	16 (37)	
10.0-10.99	41 (38)	39 (61)	2 (5)	
≥11	11 (10)	11 (17)	0 (0)	
HT autograft type				
Quadrupled STG	N/A	N/A	32 (74)	
Quadrupled ST	N/A	N/A	11 (26)	
Femoral fixation				<b>&lt;.001</b>
Interference screw	64 (60)	63 (98)	0 (0)	
Suspensory fixation	44 (40)	1 (2)	43 (100)	
Tibial fixation				<b>&lt;.001</b>
Interference screw	85 (79)	64 (100)	21 (49)	
Screw and washer	15 (14)	0 (0)	15 (35)	
Suspensory fixation	7 (7)	0 (0)	7 (16)	
Backup suspensory anchor tibial fixation	46 (43)	26 (41)	20 (47)	.547

<sup>a</sup>Data are reported as n (%) unless indicated otherwise. Bolded P values indicate statistically significant difference between BTB and HT autograft groups ( $P < .05$ ). BTB, bone–patellar tendon–bone; HT, hamstring tendon; N/A, not applicable; ST, semitendinosus; STG, semitendinosus and gracilis.

TABLE 3  
ACL Graft Failure Rate by Graft Type and Diameter<sup>a</sup>

Comparison	Subset Size, n (% of Cohort)	Failure Rate Comparison, %	RR (95% CI)	P
HT vs BTB	43 (100) vs 64 (100)	21 vs 8	2.67 (1.26-7.45)	<b>.044</b>
HT ≤ 7 mm vs HT > 7 mm	6 (14) vs 37 (86)	50 vs 16	3.08 (1.04-9.12)	.059
HT < 8 mm vs HT ≥ 8 mm	10 (23) vs 33 (77)	40 vs 15	2.64 (0.87-7.99)	.091
HT < 9 mm vs HT ≥ 9 mm	25 (58) vs 18 (42)	28 vs 11	2.52 (0.59-10.74)	.179
BTB < 10 mm vs BTB ≥ 10 mm	14 (22) vs 50 (78)	14 vs 6	2.38 (0.44-12.88)	.339

<sup>a</sup>Bolded P value indicates statistically significant difference between groups compared ( $P < .05$ ). ACL, anterior cruciate ligament; BTB, bone–patellar tendon–bone; HT, hamstring tendon; RR, relative risk.

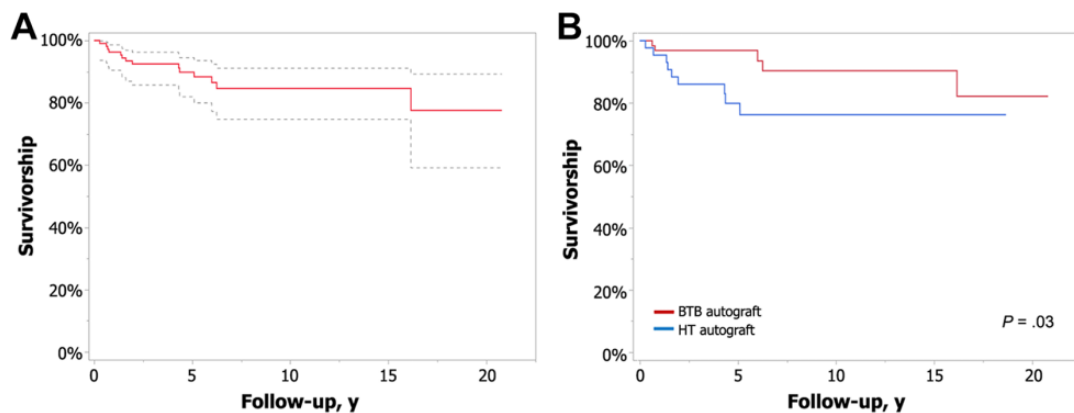
TABLE 4  
ACL Graft Failure Rate Comparing HT of Increasing Diameter Versus BTB<sup>a</sup>

Comparison	Subset Size, n (% of Cohort)	Failure Rate Comparison, %	RR (95% CI)	P
HT ≥ 6.0 mm vs BTB	43 (100) vs 64 (100)	21 vs 8	2.67 (1.26-7.45)	<b>.044</b>
HT ≥ 7.0 mm vs BTB	42 (98) vs 64 (100)	21 vs 8	2.74 (1.18-7.62)	<b>.043</b>
HT ≥ 7.5 mm vs BTB	37 (86) vs 64 (100)	16 vs 8	2.08 (0.68-6.33)	.205
HT ≥ 8.0 mm vs BTB	33 (77) vs 64 (100)	15 vs 8	1.94 (0.60-6.23)	.272
HT ≥ 8.5 mm vs BTB	29 (68) vs 64 (100)	14 vs 8	1.77 (0.51-6.10)	.453
HT ≥ 9.0 mm vs BTB	18 (42) vs 64 (100)	11 vs 8	1.42 (0.30-6.72)	.645

<sup>a</sup>Bolded P values indicate statistically significant difference between groups compared ( $P < .05$ ). ACL, anterior cruciate ligament; BTB, bone–patellar tendon–bone; HT, hamstring tendon; RR, relative risk.

at 20 years (Figure 1A). Specific comparison of BTB versus HT autograft demonstrated survivorship rates of 96.9% versus 93% at 1 year, 96.9% versus 86.1% at 2 years,

96.9% versus 79.9% at 5 years, 90.4 versus 76.3% at 10 years, and 90.4% versus 76.3% at 15 years ( $P = .030$ ) (Figure 1B).



**Figure 1.** Kaplan-Meier survivorship curve demonstrating progression to graft failure of (A) the entire cohort and (B) bone-patellar tendon-bone (BTB) autograft versus hamstring tendon (HT) autograft.

## DISCUSSION

The principal findings of this study were the following: 13% of patients sustained graft failure after their index surgery, and HT autograft reconstruction resulted in a disproportionately elevated risk of failure when compared with BTB autograft reconstruction (21% HT vs 8% BTB;  $P = .044$ ). In addition, BTB autograft was associated with better survival than HT autograft of all sizes up to 15 years after index ACLR (90.4% vs 76.3%;  $P = .030$ ).

Similar findings have also been demonstrated in a recent investigation by Spindler et al,<sup>41</sup> where HT autograft was associated with a 2.1 times higher incidence of ACL graft revision at 6 years when compared with a BTB autograft in high school and college-aged athletes. Some authors have noted that HT autografts have shown higher failure rates when compared with BTB autografts.<sup>20,35-37</sup> In 2010, Reinhardt et al<sup>36</sup> performed a level 1 systematic review demonstrating a graft failure rate of 15.8% (26/165) in the HT group as compared with 7.2% (11/153) in the BTB group. Subsequently, Persson et al<sup>35</sup> analyzed 12,643 primary ACLRs from the 2004 to 2012 Norwegian Cruciate Ligament Registry, observing a 2.3 times elevated risk of revision with HT autograft compared with BTB autograft even when adjusting for sex, age, and type of graft. Shortly afterward, Gifstad et al<sup>14</sup> reported on a large cohort of 45,998 primary ACLRs from the Scandinavian ACL registries, in which the majority of ACLRs are performed using HT autografts, noting a higher risk of revision in HT autografts compared with BTB autografts (4.2% vs 2.8%;  $P < .001$ ). More recently, Ho et al<sup>17</sup> examined their institutional 10-year experience of 561 ACLRs in patients with an average age of 15.4 years (range, 5-19 years). They observed that soft tissue grafts (not including quadriceps tendon) were twice as likely to fail compared with BTB grafts (13% vs 6%;  $P < .001$ ). These findings support the present study, which observed an elevated rate of graft failure in wrestlers receiving hamstring autografts (21%), as compared with those receiving BTB autografts (8%).

Graft disruption is a devastating complication for a young active cohort; therefore, optimal graft choice is

important to achieve the best possible outcome. Relevant considerations include young wrestlers with open growth plates, in whom soft tissue grafts and technique modifications may be indicated to mitigate the risk of physeal injury.<sup>38</sup> In the present cohort, a slightly younger age was observed in the HT autograft cohort compared with BTB autograft (16 vs 17 years;  $P < .034$ ); however, a multivariate analysis of failure controlling for age was not performed. In addition, kneeling pain and donor-site morbidity are key discussion items in wrestlers, given the elevated activity and direct effect on knees. Although anterior knee pain and donor-site pain have been well studied to date, a recent investigation of 200 consecutive BTB autografts demonstrated that around 13.9% of patients can expect some anterior knee pain with activity but only 3.7% reported an inability to kneel on hard surfaces.<sup>16</sup> In addition, donor-site morbidity at 2 years of follow-up was minimal, with up to 75.4% of patients reporting a perfect donor-site morbidity score.<sup>16</sup>

A more recent area of discussion within ACL graft selection is with respect to graft diameter. In 2019, Snaebjörnsson et al<sup>40</sup> published a retrospective review of the national knee ligament registries of Norway and Sweden, where they identified 18,425 patients who underwent an ACLR with 1329 PT and 17,096 HT autografts. In this cohort, they demonstrated no significant difference in 2-year revision ACLR among those treated with PT and HT autografts. Furthermore, thicker HT autografts yielded a lower risk of revision ACLR than smaller HT autografts, and HT autografts of at least 9.0 or 10.0 mm in diameter had a lower risk of 2-year ACL revision compared with patients treated with PT autografts of any size.

More recently, Murgier et al<sup>31</sup> performed a similar investigation evaluating 992 patients aged  $\leq 20$  years who underwent ACLR. In their series, failure rate was not statistically influenced by graft diameter. Furthermore, female patients with ACLRs with BTB grafts had a significant lower failure rate compared with those with HT autografts. In the present study, when evaluated by graft diameter, HT autografts  $\geq 6$  mm and  $\geq 7$  mm were associated with a significantly lower graft failure rate than were

BTB constructs of all sizes, but HT autografts  $\geq 7.5$  mm were not associated with a significantly lower graft failure than were BTB constructs of all sizes. These findings may suggest that smaller graft diameter could play a role in graft failure between BTB and HT in this athletic cohort. However, these results must also be interpreted in the context of small subset sample sizes, which could be underpowered, thus leading to a false impression that larger HT graft sizes are less prone to failure.

RTS in competitive wrestlers after ACL injuries with mid- to long-term follow-up remains underreported. Lightfoot et al<sup>25</sup> first described a case series of 6 collegiate wrestlers who sustained ACL tears in 1 season. Of these athletes, RTW was observed in 4 athletes (66.7%), with 1 wrestler competing with an ACL-deficient knee and 3 others performing extensive rehabilitation before their return to competition that season. Otero et al<sup>33</sup> later reported a 73.3% RTS rate among collegiate athletes who received ACLR within their eligibility period. RTS rates vary widely, with reports of 55% to 97% of athletes participating in their primary sport after ACLR.<sup>3,10,29</sup> Noted discrepancies across studies are often based on age, sex, specific sport, level of participation, and differences in surgical technique and postoperative rehabilitation.<sup>6,21,24,28-30</sup> Ardern et al<sup>3</sup> examined a cohort of 314 competitive athletes, demonstrating 93% RTS at both the competitive and the recreational levels. Lai et al<sup>24</sup> found that, in general, 83% of elite athletes (professional, National Collegiate Athletic Association Division I, or highest level of competition for their sport) were able to RTS after ACLR within 12 months. The present investigation demonstrated an 80% RTS rate at a median of 9 months after ACLR. This suggests that RTS after ACLR can be expected for most athletes. However, when discussing nonoperative and operative options, clinicians should educate these athletes that surgery does not guarantee a successful RTS in all cases. Several factors play a role in RTS outside of the surgical episode, including voluntary discontinuation of the sport at the next scholastic level and psychological readiness to RTS after ACLR.<sup>9</sup>

Several investigations analyzing patient-reported functional outcomes—namely, the IKDC questionnaire—have indicated that 86% of patients reported normal, or nearly normal, knee function by 2 years after ACLR.<sup>10,15</sup> Likewise, the Tegner activity score is a psychometric measure that has been reported as a potential predictor of RTS. The present study observed excellent postoperative patient-reported outcomes, with VAS pain scores of 0, IKDC scores of 94.3, and Tegner activity ratings of 7. Furthermore, no differences were observed between BTB and HT autografts for IKDC (93.7 vs 95.4;  $P = .461$ ), Tegner activity level (7 vs 7;  $P = .975$ ), and VAS (0 vs 0;  $P = .955$ ). These findings support previous reports of ACLR leading to improved patient-reported outcomes and no significant differences between BTB autograft and HT autograft at short- or long-term follow-up.<sup>23,24,35</sup>

### Limitations

There are several limitations inherent to this study. Foremost, this was a nonrandomized retrospective

investigation, which allows for the possibility of selection bias. Second, the investigation included a single institutional experience spanning 19 years and 6 surgeons. As such, the early years of the study may not have been optimally informed on the current understanding of ACLR evidenced via allograft use, transtibial drilling, and other techniques, which may introduce a performance bias to the analysis. Third, the investigation may be underpowered. A post hoc power analysis was performed and demonstrated that 121 wrestlers in each treatment group was the ideal sample size to obtain an alpha of .05 and power of 0.80. In addition, the subanalysis by graft diameter involved even smaller numbers, which limited the ability to perform adjusted analyses allowing for confounders to influence the results. More specifically, the subset comparisons of HT autografts by diameter of increasing size may be prone to type 2 error, resulting in a false impression of immunity from failure. Fourth, there was a lack of comparison with preoperative functional outcomes, which may provide additional insight into baseline activity level. Finally, athletes with varying levels of competition were included and treated at a single tertiary institution with standardized perioperative protocols. While this enabled intergroup comparisons, the results may not be as generalizable to different practice types, such as those with only elite athletes.

### CONCLUSION

ACLR improved patient-reported outcomes and activity levels in wrestlers at midterm follow-up. RTW was observed in 80% of athletes at a median of 9 months after ACLR. Unique challenges still exist in this cohort, with 14% of athletes experiencing graft failure after index surgery. PT autograft reconstruction is a more durable graft with lower rates of failure when compared with HT autograft even up to 15 years after surgery.

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