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# Clinical and Functional Outcomes of Anterior Cruciate Ligament Reconstruction Using Hemi-Peroneus Longus Tendon Graft: A Prospective One-Year Follow-Up Study

Jayanta K. Laik<sup>1</sup>, Ritesh Kumar<sup>2</sup>, Ashutosh Mishra<sup>3</sup>, Rajesh Thakur<sup>1</sup>, Sameer Wooly<sup>3</sup>

1. Department of Joint Replacement and Orthopedics, Tata Main Hospital, Jamshedpur, IND 2. Department of Joint Replacement and Orthopedics, Tata Main Hospital/Manipal-Tata Medical College, Jamshedpur, IND 3. Department of Orthopedics, Manipal-Tata Medical College, Jamshedpur, IND

Corresponding author: Ritesh Kumar, ritesh.kumar3@tatasteel.com

## Abstract

### Background

The hemi-peroneus longus tendon (HPLT) is an alternative autograft for anterior cruciate ligament (ACL) reconstruction intended to preserve part of the donor tendon. This study evaluated knee function, donor-site morbidity, and objective limb recovery during the first postoperative year.

### Methods

This prospective single-arm, single-center cohort included only 23 patients aged 18–45 years with isolated ACL rupture in whom the HPLT alone provided an adequate graft construct. The International Knee Documentation Committee (IKDC) score, Lysholm, Tegner, knee and ankle visual analogue scale (VAS), American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score, Foot and Ankle Disability Index (FADI), single-leg hop distance, limb symmetry index (LSI), and calf circumference were evaluated. Longitudinal outcomes were analyzed with Friedman tests, followed by Holm-adjusted Wilcoxon signed-rank comparisons. All patients were retained in the primary analysis.

### Results

Mean IKDC increased from  $30.39 \pm 3.93$  preoperatively to  $91.57 \pm 5.03$  at 12 months, and Lysholm increased from  $39.52 \pm 5.12$  to  $93.70 \pm 6.46$  (both overall  $p < 0.001$ ). Tegner improved from  $1.04 \pm 0.82$  preoperatively to  $6.57 \pm 1.20$  at 12 months; 18 patients (78.3%) regained or exceeded their pre-injury level. AOFAS decreased from  $95.65 \pm 2.19$  preoperatively to  $67.91 \pm 4.76$  at three months and recovered to  $92.30 \pm 3.36$  at 12 months. FADI followed a similar pattern, decreasing from  $97.91\% \pm 1.47\%$  to  $73.00\% \pm 2.17\%$  and recovering to  $96.52\% \pm 2.09\%$ . Mean LSI improved from  $48.12\% \pm 4.88\%$  at six months to  $89.01\% \pm 7.44\%$  at 12 months; 13 of 23 patients (56.5%) achieved LSI of  $\geq 90\%$ . One patient sustained an MRI-confirmed traumatic graft rerupture seven months postoperatively after a slip and fall on stairs.

### Conclusion

In selected patients in whom an adequate isolated HPLT graft was obtained, ACL reconstruction was associated with substantial improvement in knee-reported outcomes and the recovery of donor-ankle function toward baseline at one year. Objective hop symmetry recovered more slowly, and 43.5% of patients remained below 90% LSI. The small selected cohort, absence of a comparator, and short follow-up limit generalizability.

**Categories:** Trauma, Sports Medicine, Orthopedics

**Keywords:** anterior cruciate ligament (acl), autograft, donor-site morbidity, hemi-peroneus longus tendon, limb symmetry index, single-leg hop test

## Introduction

Anterior cruciate ligament (ACL) injury is a common cause of knee instability in young and physically active patients. Graft selection influences fixation, rehabilitation, donor-site symptoms, and functional recovery after reconstruction [1,2]. Bone-patellar tendon-bone and hamstring autografts remain widely used, while quadriceps tendon and other autografts may be selected according to patient characteristics and surgeon preference [3–5].

Each graft has potential disadvantages. Bone-patellar tendon-bone grafts may be associated with anterior knee pain, patellar fracture, and extensor-mechanism morbidity. Hamstring harvest may produce flexor weakness and can yield an inadequate graft diameter, particularly in patients with smaller anthropometric

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dimensions [6,7]. These limitations have encouraged the evaluation of the peroneus longus tendon as an alternative graft source.

Biomechanical studies have shown that peroneus longus grafts can provide clinically usable strength and stiffness. The reported ultimate load to failure of the native ACL is approximately  $2160 \pm 157$  N, while peroneus longus constructs have demonstrated substantial failure loads [8–10]. The hemi-peroneus longus tendon (HPLT) has also demonstrated mechanical properties comparable with the semitendinosus tendon in laboratory testing [8].

The peroneus longus contributes to ankle plantarflexion, eversion, and transverse-arch support [11,12]. Complete harvest may therefore raise concern regarding donor-site function [13]. Harvesting only the hemi-peroneus longus tendon may preserve tendon continuity and reduce functional disturbance while providing a graft of adequate dimensions in selected patients [8,14]. This study evaluated one-year clinical, donor-site, and objective functional outcomes after ACL reconstruction using an isolated HPLT autograft.

## Materials And Methods

### Study design and ethical approval

This prospective single-center, single-arm cohort study was conducted in the Department of Joint Replacement and Orthopedics of Tata Main Hospital, Jamshedpur. Patient recruitment and surgery occurred from May 2023 to March 23, 2025. The final 12-month follow-up was completed on March 30, 2026, and the database was locked on April 15, 2026. The study was approved by the Institutional Ethics Committee of Tata Main Hospital, Jamshedpur (approval number: TMH/IEC/176/2023; approval date: 21/02/2023). Written informed consent was obtained from all participants before enrolment.

Clinical trial registration was not obtained prospectively. At study initiation, this investigator-initiated, single-center, nonrandomized surgical outcome cohort was regarded as an evaluation of a modification of an established autograft technique used in routine clinical practice. No investigational drug or device, random allocation, or comparator intervention was introduced. The authors acknowledge that broader contemporary definitions may classify prospectively assigned surgical interventions as clinical trials; the absence of prospective registration is therefore disclosed as a study limitation.

### Eligibility and patient selection

Patients aged 18–45 years with clinical and MRI-confirmed isolated ACL rupture who consented to reconstruction were considered eligible. Exclusion criteria were associated ligament injury, clinically significant chondral lesion, meniscal injury, fracture around the knee, previous significant ankle injury or ankle instability, and inability to complete the postoperative assessments. A consecutive, criterion-based sampling approach was used. All patients assessed during the predefined study period were screened against the clinical and graft-specific eligibility criteria. Selection was based on whether the isolated HPLT produced a clinically acceptable construct; the study was not designed to estimate the success rate of hemi-tendon harvest in an unselected ACL population.

During the study period, 57 patients underwent ACL reconstruction using a peroneus longus tendon autograft. Full peroneus longus tendon harvest was planned preoperatively in 22 patients in whom an isolated half-tendon construct was considered unlikely to provide adequate graft dimensions based on the operating surgeon's clinical assessment and patient anthropometry, mainly height and sex. However, no formal height, sex, MRI, ultrasonographic, or preoperative tendon-size cutoff was prospectively defined. HPLT harvest was attempted in the remaining 35 patients. A prepared graft length of approximately 70 mm and diameter of approximately 8 mm were targeted. However, no single diameter cutoff was used in isolation; final intraoperative acceptance was based on the complete construct, including prepared length, diameter, tissue quality, and suitability for secure fixation. Twelve isolated HPLT constructs were considered inadequate and required the additional harvesting of the remaining peroneus longus tendon. These patients were excluded from the outcome cohort. The final outcome cohort comprised 23 patients in whom the hemi-peroneus longus tendon alone provided a clinically acceptable graft construct. The selection process is shown in Figure 1.

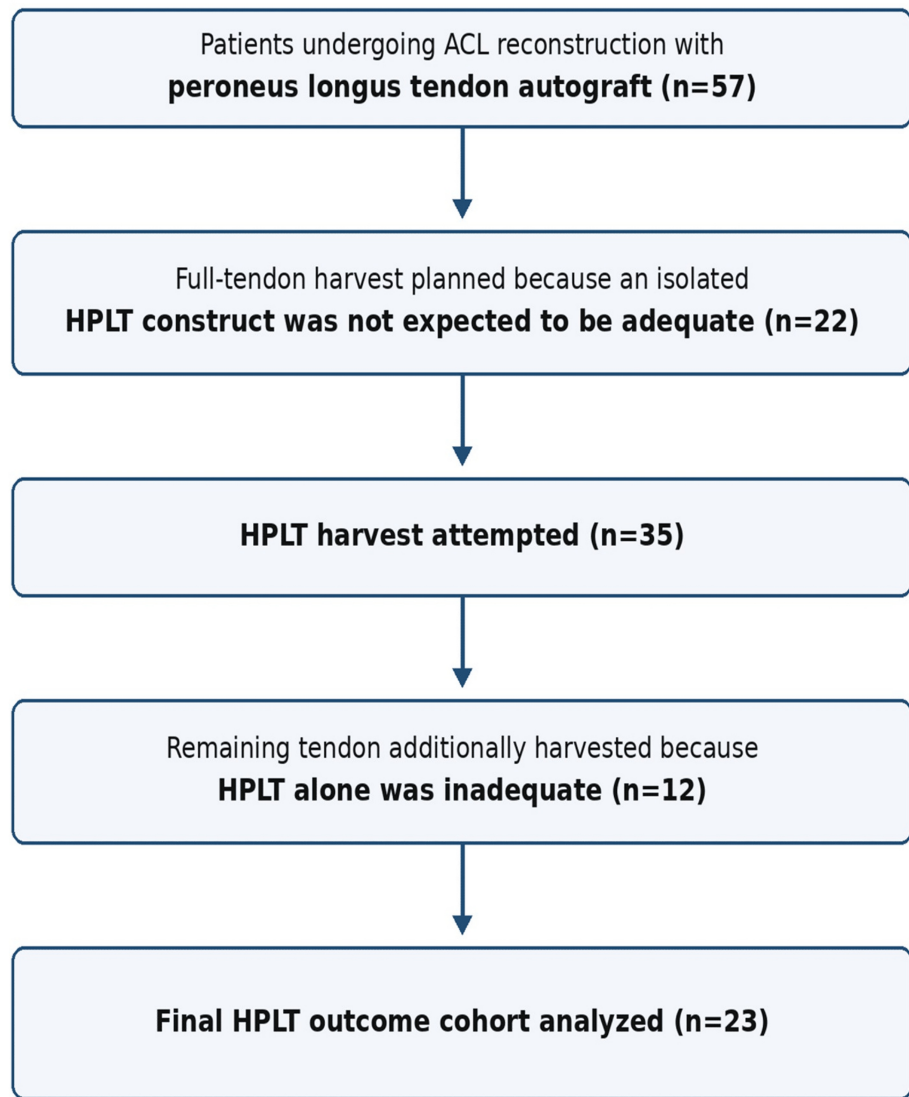


**FIGURE 1: Patient selection and graft-harvest flow for ACL reconstruction using an autologous peroneus longus tendon graft.**

The primary analysis included all 23 patients with an adequate isolated HPLT construct, including the patient who sustained a traumatic graft rerupture at seven months. The flow diagram was created by the authors using Microsoft PowerPoint for Microsoft 365 (Version 2408 Build 16.0.17928.20512), version 64-bit (Microsoft Corp., Redmond, WA). No generative artificial-intelligence tool was used.

ACL, anterior cruciate ligament; HPLT, hemi-peroneus longus tendon

## Surgical technique

All operations were performed by a single experienced surgeon with the patient supine under spinal anesthesia and a pneumatic thigh tourniquet. Standard anterolateral and anteromedial arthroscopic portals were established. Diagnostic arthroscopy confirmed ACL rupture and excluded significant associated intra-articular pathology.

A skin incision was made approximately 2-3 cm proximal and 1 cm posterior to the lateral malleolus. The peroneus longus and brevis tendons were identified, and the peroneus longus was split longitudinally into anterior and posterior halves. The anterior half of the peroneus longus tendon was secured distally and harvested proximally with a tendon stripper to approximately 4-5 cm distal to the fibular head to reduce the risk of common peroneal nerve injury. The unharvested half of the tendon was left intact; therefore, no tenodesis was performed. The donor wound was closed in layers. The procedure is shown in Figure 2.

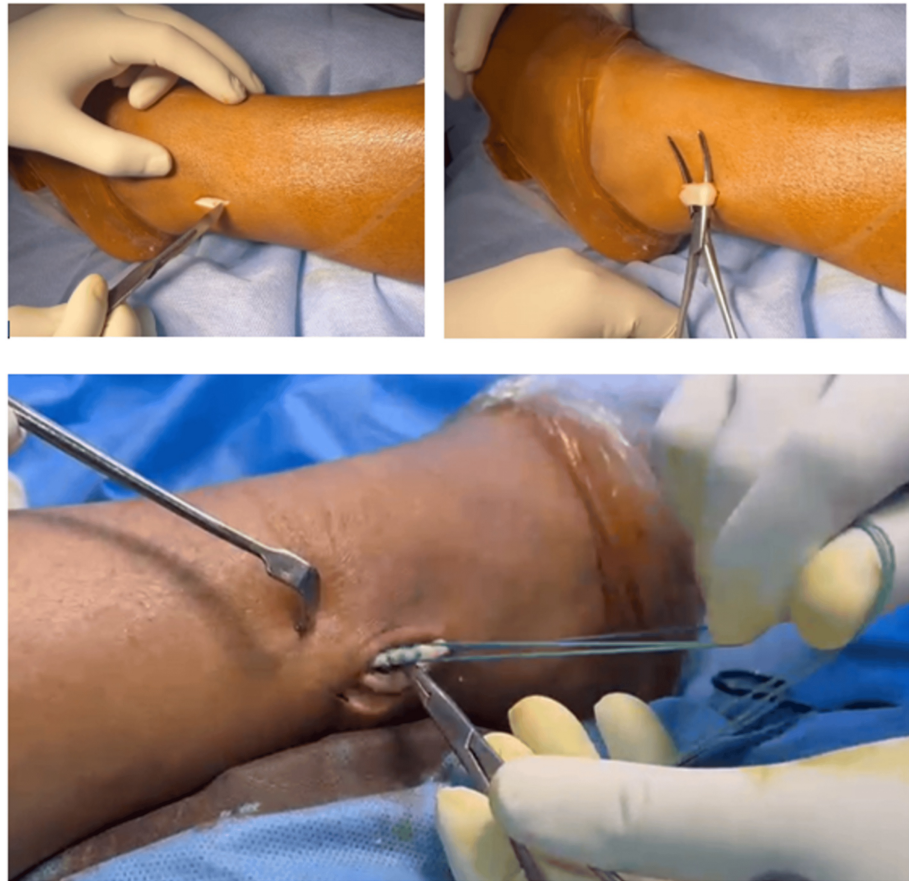


**FIGURE 2: Stages of hemi-peroneus longus graft harvest.**

(A) Identification of peroneus longus (PL) tendon. (B) Longitudinal split of the peroneus longus tendon. (C) Isolation of the anterior half of the peroneus Longus tendon. Intraoperative clinical photograph obtained by the authors during the surgical procedure. The images were assembled and labeled using Microsoft PowerPoint for Microsoft 365 (Version 2408 Build 16.0.17928.20512), version 64-bit (Microsoft Corp., Redmond, WA). No generative artificial-intelligence tool was used.

Of the 23 accepted isolated HPLT grafts, 21 were prepared as tripled constructs and two as quadrupled constructs. The prepared graft diameter ranged from 7.7 to 10.5 mm; final acceptance was based on the complete construct, including diameter, length, tissue quality, and fixation suitability. The target prepared length was approximately 70 mm. Graft preparation is shown in Figure 3.



**FIGURE 3: Stages of graft preparation.**

(A) Measurement of unfolded harvested hemi-PL graft. (B) Measurement of double-stranded hemi-PL graft. (C) Measurement of tripled hemi-PL graft. (D) Diameter measurement of tripled hemi-PL graft. Intraoperative clinical photograph obtained by the authors during the surgical procedure. The images were assembled and labeled using Microsoft PowerPoint for Microsoft 365 (Version 2408 Build 16.0.17928.20512), version 64-bit (Microsoft Corp., Redmond, WA). No generative artificial-intelligence tool was used.

PL: peroneus longus

Femoral and tibial tunnels were drilled independently at the anatomical ACL footprints. Femoral fixation was achieved using a cortical suspensory device, and tibial fixation was performed with a bioabsorbable interference screw approximately 1-2 mm larger than the graft diameter. Graft position, tension, and fixation stability were assessed arthroscopically after cyclic loading.

### Postoperative rehabilitation

Clinical and functional assessments were performed by members of the treating team rather than by independent blinded evaluators. The same standardized assessment procedures were applied at the predefined follow-up visits. Lachman testing was recorded preoperatively and postoperatively. Pivot-shift testing was performed intraoperatively to assess stability after graft fixation but was not systematically recorded at postoperative follow-up visits. Instrumented laxity assessment with a KT-1000 or similar device was not performed.

All patients followed the same standardized, supervised rehabilitation protocol. Progression between phases was based on clinical and functional criteria, including the control of pain and swelling, the restoration of

knee extension and progressive flexion, adequate quadriceps activation, normalized gait, progressive strength and neuromuscular control, and the satisfactory completion of phase-specific functional activities. The detailed phase-wise progression criteria are presented in the Appendices.

## Outcome assessment

Assessments were performed preoperatively and at three, six, and 12 months. Scheduled clinical reviews also occurred at two and six weeks. Knee outcomes included the 2000 International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form [15], Lysholm knee score and Tegner activity scale [16,17], and a 0-10 knee visual analogue scale (VAS). Pre-injury Tegner level was recorded separately. Donor-site outcomes included the 100-point American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score [18], Foot and Ankle Disability Index (FADI) expressed as a percentage [19], and a 0-10 ankle VAS.

The instruments were administered and scored according to their published methods. Only aggregate scores are reported; the complete questionnaires or copyrighted scoring forms are not reproduced in this manuscript. Permission from the relevant rights holder will be obtained if an instrument is reproduced in supplementary material.

At six and 12 months, the single-leg hop test for distance was performed after familiarization. Three valid trials were recorded for each limb under identical conditions, and the best valid distance was used. A valid attempt required a controlled single-leg landing without contralateral-foot contact or an additional hop. Limb symmetry index (LSI) was calculated as operated-limb distance divided by contralateral-limb distance  $\times 100$ ; LSI of  $\geq 90\%$  was used as the reference threshold for satisfactory symmetry [20,21].

Calf circumference was measured at a fixed point of 15 cm proximal to the lateral malleolus to provide a reproducible anatomical landmark and maintain uniformity across patients and serial follow-up assessments. Maximal calf girth was not used because the visual identification of the point of maximum circumference could vary between observers and visits. Calf circumference was interpreted as an indirect measure of muscle recovery rather than a direct measurement of muscle strength. The interlimb deficit was calculated as contralateral minus operated circumference. Graft failure was defined as recurrent ACL rupture confirmed by MRI after a new traumatic event. Patients with graft failure remained in the primary analysis, and their scheduled assessments were analyzed as observed. An exploratory post hoc sensitivity analysis excluding the patient with graft failure was performed for 12-month LSI.

## Statistical analysis

Analyses were performed using Python version 3.12.14 (Python Software Foundation, Fredericksburg, VA) with SciPy version 1.17.0. Tests were two-sided, and  $p < 0.05$  was considered significant. Data were examined for completeness, distribution, range, and potential entry errors. Because the scores were bounded or ordinal, the cohort was small, and several outcomes demonstrated floor or ceiling effects, longitudinal comparisons used nonparametric methods. Continuous variables are reported as mean  $\pm$  standard deviation (SD), with median and interquartile range (IQR) additionally presented for longitudinal outcomes. Categorical variables are reported as  $n$  (%).

IKDC, Lysholm, Tegner, AOFAS, FADI, knee VAS, and ankle VAS were compared across four time points using the Friedman test. Kendall's  $W$  quantified the overall time effect. Significant tests were followed by four prespecified Wilcoxon signed-rank comparisons: preoperative to three months, three to six months, six to 12 months, and preoperative to 12 months.  $P$  values were adjusted within each outcome using the Holm procedure. Matched-pairs rank-biserial correlation quantified pairwise effect size.

The 12-month Tegner score was separately compared with the pre-injury score. Operated and contralateral hop distances, LSI, and calf-circumference deficit were compared using Wilcoxon signed-rank tests. Proportions are reported with 95% Wilson confidence intervals (CI). Associations were examined using Spearman rank correlation. Exploratory correlations between age, height, graft dimensions, and seven 12-month outcomes were collectively Holm-adjusted. All 23 patients had complete reported data; no imputation was performed. This exploratory cohort included all eligible successful isolated HPLT constructs, and no formal hypothesis-based sample-size calculation was performed.

## Results

### Participant and graft characteristics

The cohort comprised 23 patients: 20 men (87.0%) and three women (13.0%). Mean age was  $30.39 \pm 7.50$  years, and mean height was  $168.13 \pm 4.16$  cm. Twelve reconstructions (52.2%) were right-sided, and 11 (47.8%) were left-sided. Mean graft diameter was  $8.50 \pm 0.75$  mm, and mean harvested tendon length was  $220.13 \pm 19.84$  mm (Table 1).

| Characteristic              | Result                                                        |
|-----------------------------|---------------------------------------------------------------|
| Number of patients          | 23                                                            |
| Age, years                  | 30.39 ± 7.50                                                  |
| Male sex                    | 20 (87.0%)                                                    |
| Female sex                  | 3 (13.0%)                                                     |
| Right-sided reconstruction  | 12 (52.2%)                                                    |
| Left-sided reconstruction   | 11 (47.8%)                                                    |
| Height, cm                  | 168.13 ± 4.16                                                 |
| Graft diameter, mm          | 8.50 ± 0.75 (range: 7.7-10.5)                                 |
| Harvested tendon length, mm | 220.13 ± 19.84                                                |
| Graft configuration         | Tripled construct, 21 (91.3%); quadrupled construct, 2 (8.7%) |

**TABLE 1: Demographic and graft characteristics.**

Of the 23 accepted isolated HPLT grafts, 21 (91.3%) were prepared as tripled constructs and two (8.7%) as quadrupled constructs. The prepared graft diameter ranged from 7.7 to 10.5 mm. Values are mean ± SD or n (%).

HPLT, hemi-peroneus longus tendon; SD, standard deviation

Height correlated with graft diameter ( $p = 0.790$ ;  $p < 0.001$ ) and graft length ( $p = 0.796$ ;  $p < 0.001$ ). Diameter and length were also correlated ( $p = 0.782$ ;  $p < 0.001$ ). No association between age, height or graft dimensions, and the evaluated 12-month outcomes remained significant after Holm correction. The smallest unadjusted p value concerned age and 12-month Tegner score ( $p = -0.564$ ; unadjusted  $p = 0.005$ ; adjusted  $p = 0.141$ ).

### Knee outcomes

IKDC increased from  $30.39 \pm 3.93$  preoperatively to  $91.57 \pm 5.03$  at 12 months (Friedman  $\chi^2(3) = 67.85$ ;  $p < 0.001$ ;  $W = 0.983$ ). Lysholm increased from  $39.52 \pm 5.12$  to  $93.70 \pm 6.46$  ( $\chi^2(3) = 69.00$ ;  $p < 0.001$ ;  $W = 1.000$ ). All prespecified interval comparisons for both measures remained significant after Holm correction (all adjusted  $p < 0.001$ ) (Table 2 and Figure 4).

| Outcome  | Pre-injury  | Preoperative                    | 3 months                        | 6 months                        | 12 months                       | $\chi^2$ (df = 3) | Overall p | Kendall W |
|----------|-------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|-------------------|-----------|-----------|
| IKDC     | -           | 30.39 ± 3.93 (30.0 {28.0-33.0}) | 49.17 ± 6.96 (50.0 {43.0-54.5}) | 70.39 ± 5.00 (71.0 {68.5-74.0}) | 91.57 ± 5.03 (92.0 {90.0-95.5}) | 67.85             | <0.001    | 0.983     |
| Lysholm  | -           | 39.52 ± 5.12 (39.0 {36.0-42.5}) | 57.39 ± 4.99 (58.0 {55.5-60.0}) | 77.04 ± 6.91 (76.0 {72.0-81.0}) | 93.70 ± 6.46 (96.0 {90.0-98.5}) | 69                | <0.001    | 1         |
| Tegner   | 6.83 ± 1.40 | 1.04 ± 0.82 (1.0 {0.0-2.0})     | 3.09 ± 0.90 (3.0 {2.0-4.0})     | 5.00 ± 1.13 (5.0 {4.0-6.0})     | 6.57 ± 1.20 (6.0 {6.0-7.0})     | 68.71             | <0.001    | 0.996     |
| Knee VAS | -           | 3.96 ± 2.53 (4.0 {2.0-6.0})     | 3.22 ± 1.31 (3.0 {2.0-4.5})     | 1.30 ± 0.97 (1.0 {1.0-2.0})     | 0.26 ± 0.69 (0.0 {0.0-0.0})     | 47.24             | <0.001    | 0.685     |

**TABLE 2: Serial knee outcomes.**

Values are mean ± SD and median (IQR), except pre-injury Tegner, shown as mean ± SD. Holm-adjusted pairwise comparisons appear in Table 3.

IQR, interquartile range; SD, standard deviation; df, degrees of freedom; IKDC, International Knee Documentation Committee; VAS, visual analogue scale

| Outcome   | Preoperative versus 3 months | 3 versus 6 months    | 6 versus 12 months  | Preoperative versus 12 months |
|-----------|------------------------------|----------------------|---------------------|-------------------------------|
| IKDC      | <0.001; rrb = 1.000          | <0.001; rrb = 1.000  | <0.001; rrb = 0.993 | <0.001; rrb = 1.000           |
| Lysholm   | <0.001; rrb = 1.000          | <0.001; rrb = 1.000  | <0.001; rrb = 1.000 | <0.001; rrb = 1.000           |
| Tegner    | <0.001; rrb = 1.000          | <0.001; rrb = 1.000  | <0.001; rrb = 1.000 | <0.001; rrb = 1.000           |
| Knee VAS  | 0.117; rrb = -0.385          | <0.001; rrb = -1.000 | 0.003; rrb = -0.800 | <0.001; rrb = -1.000          |
| AOFAS     | <0.001; rrb = -1.000         | <0.001; rrb = 1.000  | <0.001; rrb = 0.993 | <0.001; rrb = -1.000          |
| FADI      | <0.001; rrb = -1.000         | <0.001; rrb = 1.000  | <0.001; rrb = 1.000 | 0.001; rrb = -0.848           |
| Ankle VAS | <0.001; rrb = 1.000          | <0.001; rrb = -1.000 | 0.016; rrb = -1.000 | Not tested: identical values  |

**TABLE 3: Holm-adjusted prespecified pairwise comparisons.**

Entries are Holm-adjusted p value and matched-pairs rank-biserial correlation (rrb). The sign indicates the direction from the earlier to the later assessment.

IKDC, International Knee Documentation Committee; VAS, visual analogue scale; AOFAS, American Orthopaedic Foot and Ankle Society; FADI, Foot and Ankle Disability Index

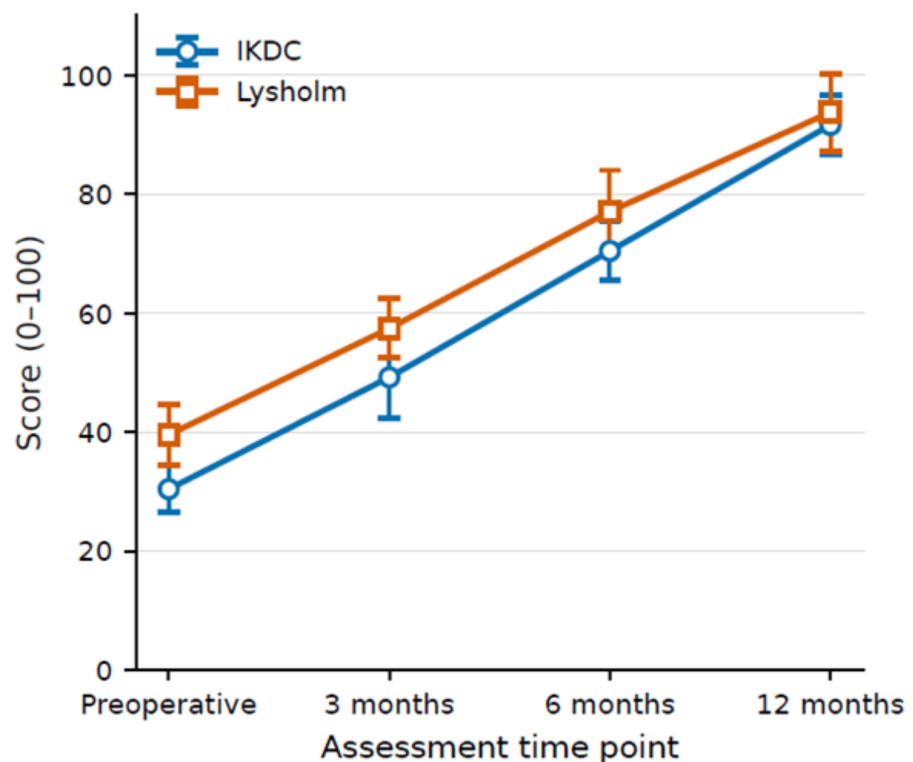


**FIGURE 4: Knee functional outcomes.**

Values are mean ± SD; n = 23. The images were assembled and labeled using Microsoft Excel for Microsoft 365 (Version 2610 Build 16.0.20527.20032, 64-bit; Microsoft Corp., Redmond, WA). No generative artificial-intelligence tool was used.

IKDC, International Knee Documentation Committee; SD, standard deviation

Tegner increased from  $1.04 \pm 0.82$  preoperatively to  $6.57 \pm 1.20$  at 12 months ( $\chi^2(3) = 68.71$ ;  $p < 0.001$ ;  $W = 0.996$ ). The pre-injury mean was  $6.83 \pm 1.40$ , and the 12-month score remained slightly lower in paired analysis ( $p = 0.034$ ). Eighteen patients (78.3%; 95% CI: 58.1%-90.3%) regained or exceeded their pre-injury activity level.

Knee VAS decreased from 3.96 ± 2.53 preoperatively to 0.26 ± 0.69 at 12 months (χ²(3) = 47.24; p < 0.001; W = 0.685). The reduction from baseline to three months was not significant after Holm correction (adjusted p = 0.117); subsequent interval reductions and the baseline-to-12-month reduction were significant.

Donor-site outcomes

AOFAS decreased from 95.65 ± 2.19 preoperatively to 67.91 ± 4.76 at three months and recovered to 92.30 ± 3.36 at 12 months (χ²(3) = 66.96; p < 0.001; W = 0.970). FADI decreased from 97.91% ± 1.47% to 73.00% ± 2.17% and recovered to 96.52% ± 2.09% (χ²(3) = 66.89; p < 0.001; W = 0.969). Although both measures recovered substantially, their 12-month values remained statistically below baseline (AOFAS adjusted p < 0.001; FADI adjusted p = 0.001) (Table 4 and Figure 5).

| Outcome   | Preoperative                    | 3 months                        | 6 months                        | 12 months                       | χ² (df = 3) | Overall p | Kendall W |
|-----------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|-------------|-----------|-----------|
| AOFAS     | 95.65 ± 2.19 (96.0 {94.0-97.5}) | 67.91 ± 4.76 (68.0 {64.5-71.0}) | 79.87 ± 4.41 (80.0 {77.0-84.0}) | 92.30 ± 3.36 (93.0 {90.0-94.5}) | 66.96       | <0.001    | 0.970     |
| FADI, %   | 97.91 ± 1.47 (98.0 {97.0-99.0}) | 73.00 ± 2.17 (74.0 {71.5-74.5}) | 85.65 ± 1.61 (86.0 {85.0-86.5}) | 96.52 ± 2.09 (97.0 {95.5-98.0}) | 66.89       | <0.001    | 0.969     |
| Ankle VAS | 0.00 ± 0.00 (0.0 {0.0-0.0})     | 1.91 ± 1.04 (2.0 {1.0-3.0})     | 0.30 ± 0.47 (0.0 {0.0-1.0})     | 0.00 ± 0.00 (0.0 {0.0-0.0})     | 57.00       | <0.001    | 0.826     |

TABLE 4: Donor-site outcomes.
Values are mean ± SD and median (IQR). AOFAS and FADI recovered toward baseline but remained statistically lower at 12 months. Holm-adjusted pairwise comparisons appear in Table 3.
AOFAS, American Orthopaedic Foot and Ankle Society; SD, standard deviation; FADI, Foot and Ankle Disability Index; VAS, visual analogue scale; df, degrees of freedom; IQR, interquartile range

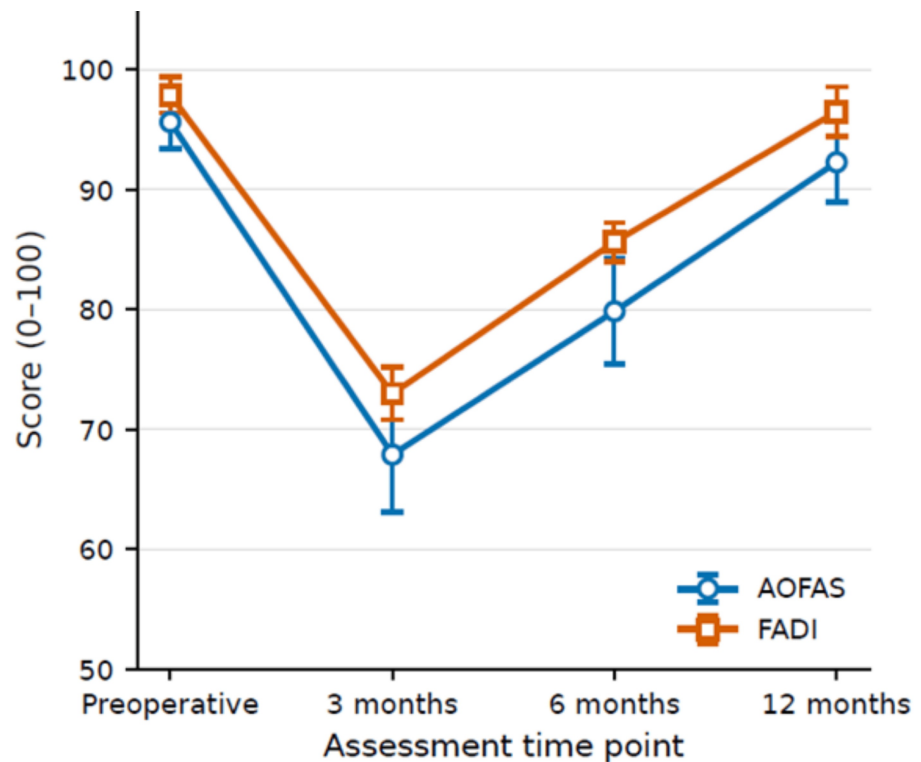


**FIGURE 5: Donor-site ankle outcomes.**

Values are mean  $\pm$  SD;  $n = 23$ . The images were assembled and labeled using Microsoft Excel for Microsoft 365 (Version 2610 Build 16.0.20527.20032, 64-bit; Microsoft Corp., Redmond, WA). No generative artificial-intelligence tool was used.

AOFAS, American Orthopaedic Foot and Ankle Society; SD, standard deviation; FADI, Foot and Ankle Disability Index

Ankle VAS increased from zero preoperatively to  $1.91 \pm 1.04$  at three months, decreased to  $0.30 \pm 0.47$  at six months, and returned to zero in every patient at 12 months ( $\chi^2(3) = 57.00$ ;  $p < 0.001$ ;  $W = 0.826$ ).

### Objective functional recovery

Operated-limb hop distance increased from  $55.22 \pm 7.76$  cm at six months to  $104.48 \pm 11.37$  cm at 12 months (median paired improvement, 50.0 cm;  $p < 0.001$ ). Mean LSI improved from  $48.12\% \pm 4.88\%$  to  $89.01\% \pm 7.44\%$  (median improvement, 42.20 percentage points;  $p < 0.001$ ). No patient achieved LSI of  $\geq 90\%$  at six months; 13 patients achieved the threshold at 12 months (56.5%; 95% CI: 36.8%-74.4%). Thus, 10 patients (43.5%; 95% CI: 25.6%-63.2%) remained below 90% at one year (Tables 5, 6 and Figure 6).

| Outcome                             | 6 months       | 12 months      | Median paired change (IQR) | Wilcoxon p | Rank-biserial correlation |
|-------------------------------------|----------------|----------------|----------------------------|------------|---------------------------|
| Operated-limb hop distance, cm      | 55.22 ± 7.76   | 104.48 ± 11.37 | +50.00 (+46.00 to +53.50)  | <0.001     | 1.000                     |
| Contralateral-limb hop distance, cm | 114.74 ± 11.31 | 117.57 ± 10.36 | +2.00 (+2.00 to +4.00)     | 0.001      | 0.768                     |
| LSI, %                              | 48.12 ± 4.88   | 89.01 ± 7.44   | +42.20 (+36.84 to +44.34)  | <0.001     | 1.000                     |
| Interlimb calf deficit, cm          | 1.82 ± 0.87    | 0.49 ± 0.28    | -1.30 (-1.90 to -0.70)     | <0.001     | -0.993                    |

**TABLE 5: Objective recovery between six and 12 months.**

Time-point values are mean ± SD; paired changes are median (IQR).

IQR, interquartile range; SD, standard deviation; LSI, limb symmetry index

| Outcome                                               | 6 months, n/N (%) | 12 months, n/N (%) | 95% Wilson confidence interval at 12 months |
|-------------------------------------------------------|-------------------|--------------------|---------------------------------------------|
| LSI ≥ 90%                                             | 0/23 (0%)         | 13/23 (56.5%)      | 36.8%-74.4%                                 |
| LSI < 90%                                             | 23/23 (100%)      | 10/23 (43.5%)      | 25.6%-63.2%                                 |
| Regained or exceeded pre-injury Tegner activity level | Not assessed      | 18/23 (78.3%)      | 58.1%-90.3%                                 |
| Traumatic graft rerupture                             | Not applicable    | 1/23 (4.3%)        | 0.8%-21.0%                                  |

**TABLE 6: Functional recovery milestones and graft rerupture following anterior cruciate ligament reconstruction using an anterior half peroneus longus tendon autograft (n = 23).**

Values are presented as n/N (%). Confidence intervals at 12 months were calculated using the Wilson method.

LSI, limb symmetry index; n/N, number of patients meeting the outcome/total number assessed

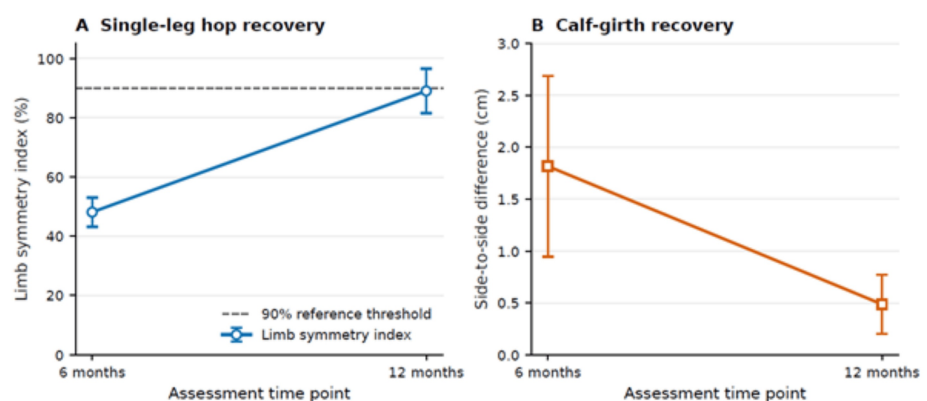


**FIGURE 6: Objective functional recovery after ACL reconstruction.**

Values are mean ± SD; n = 23. A lower calf-girth difference indicates recovery toward symmetry. The images were assembled and labeled using Microsoft Excel for Microsoft 365 (Version 2610 Build 16.0.20527.20032, 64-bit; Microsoft Corp., Redmond, WA). No generative artificial-intelligence tool was used.

ACL, anterior cruciate ligament; SD, standard deviation

The interlimb calf-circumference deficit decreased from  $1.82 \pm 0.87$  cm at six months to  $0.49 \pm 0.28$  cm at 12 months (median paired reduction, 1.30 cm;  $p < 0.001$ ). Despite improvement, operated-limb hop distance and calf circumference remained lower than the contralateral values at 12 months (both  $p < 0.001$ ).

## Complications

Two patients developed superficial donor-site wound inflammation, and six developed postoperative knee effusion. All these events resolved with conservative treatment within two to three weeks. No deep infection, persistent nerve symptoms, venous thromboembolism, clinically important range-of-motion deficit, or arthrofibrosis was recorded.

One patient sustained a new traumatic injury after slipping and falling on stairs seven months after reconstruction. MRI confirmed the rupture of the reconstructed ACL graft. The scheduled 12-month assessment was performed after rerupture, and the patient remained in the primary analysis. At 12 months, operated-limb hop distance was 78 cm versus 128 cm contralaterally, corresponding to an LSI of 60.93%. Revision ACL reconstruction was planned and was performed after database closure; its postoperative outcome was outside the study period. The observed rerupture proportion was 1/23 (4.3%; 95% CI: 0.8%-21.0%).

In the post hoc sensitivity analysis excluding this patient, mean 12-month LSI increased from  $89.01\% \pm 7.44\%$  to  $90.29\% \pm 4.33\%$  (95% CI: 88.37%-92.21%). This analysis was descriptive because the exclusion was not prespecified and concerned one patient.

## Discussion

This prospective cohort demonstrated substantial improvement in knee-reported outcomes after ACL reconstruction using an isolated HPLT autograft in selected patients. Donor-site impairment was greatest at three months and improved progressively. At one year, ankle pain had resolved in every patient, and AOFAS and FADI had recovered close to baseline, although small residual statistical differences remained. Objective recovery lagged behind subjective improvement: 43.5% of the cohort did not reach 90% hop-test symmetry at 12 months.

Common ACL autografts have distinct donor-site profiles. Bone-patellar tendon-bone grafts provide bone-to-bone healing but may be associated with anterior knee pain, kneeling difficulty, patellar tendon morbidity, and, rarely, patellar fracture. Hamstring grafts avoid extensor-mechanism harvest but may produce knee-flexor weakness and can yield an inadequate diameter. Quadriceps tendon grafts provide a large, predictable construct but may cause transient quadriceps weakness and anterior-thigh symptoms. Comparative evidence indicates lower donor-site morbidity with hamstring and quadriceps tendon grafts than with bone-patellar tendon-bone grafts, without a clear clinically important difference in failure across graft types [22,23]. HPLT preserves the knee extensor mechanism and hamstrings but introduces a different potential morbidity at the donor ankle. In this cohort, ankle symptoms and functional impairment were greatest early and largely recovered by 12 months. Because the study lacked a comparator, it cannot establish superiority over established autografts.

The mean graft diameter of 8.50 mm was clinically usable, but the data also included several constructs measuring 7.7-7.9 mm. The findings should therefore not be interpreted as evidence that every successful HPLT construct must measure at least 8 mm. Magnussen et al. associated smaller hamstring grafts with increased revision risk, but that threshold should not be transferred uncritically to HPLT grafts [24]. Height showed strong associations with graft diameter and length, consistent with prior anthropometric studies, yet no graft variable predicted the evaluated 12-month outcomes after correction for multiple comparisons [25,26].

The IKDC and Lysholm improvements were comparable in magnitude to previously published peroneus longus and conventional autograft series [8,22,23,27]. Tegner activity approached the pre-injury level, with 78.3% regaining or exceeding their individual pre-injury score. Activity participation, however, should not be equated with complete neuromuscular recovery.

The donor-site trajectory is central to interpretation. AOFAS and FADI decreased substantially at three months, followed by progressive recovery. The small persistent statistical deficits at one year contrast with the complete resolution of ankle pain and may not represent a clinically important disability. AOFAS is a clinician-based composite score with recognized measurement limitations; the concurrent FADI assessment provides complementary patient-reported information. Future studies should prioritize validated foot and ankle patient-reported outcome measures (PROMs) and objective eversion and plantarflexion strength testing.

Mean LSI reached 89.0% at 12 months, but only 56.5% achieved the conventional 90% threshold. LSI is commonly incorporated into return-to-sport batteries, although it should not be used alone because contralateral deconditioning can overestimate recovery [20,21]. Strength, movement quality, psychological readiness, sport-specific capacity, and time from surgery should also inform clearance. Failure to satisfy

comprehensive discharge criteria has been associated with increased reinjury risk [28].

The MRI-confirmed graft rerupture followed a distinct traumatic fall at seven months. This patient had Lysholm scores of 36 preoperatively, 62 at three months, 72 at six months, and 76 at 12 months. The 12-month assessment was performed after the rerupture. The modest increase between six and 12 months may reflect continued rehabilitation and improvement in other components of the composite Lysholm score; it should not be interpreted as evidence of graft integrity or the restoration of objective knee stability. The patient's post-rerupture 12-month LSI was 60.93%, and exclusion increased the cohort mean to 90.29%. This observation does not establish that reduced symmetry caused the rupture or that the graft choice was responsible. Retaining the patient in the primary analysis avoids the preferential exclusion of an adverse outcome and gives a conservative estimate of cohort recovery. The sensitivity analysis describes the influence of the event without replacing the prespecified cohort result.

Calf asymmetry improved substantially but persisted at one year. Circumference does not directly measure strength and can be influenced by measurement error and body composition. Isokinetic quadriceps, hamstring, ankle evertor, and plantarflexor strength, together with biomechanical assessment during landing and cutting, would provide a more complete evaluation of functional restoration.

## Limitations

The study has several limitations. It was a small, single-center cohort without a comparison group, and follow-up was limited to one year. HPLT harvest was not attempted systematically in all patients receiving a peroneus longus graft. Patients in whom full harvest was planned and those requiring additional harvest after an inadequate hemi-peroneus longus tendon were excluded, introducing selection bias and limiting applicability to patients in whom an adequate isolated construct was obtained. The study was not designed to estimate the overall adequacy or harvest-success rate of HPLT.

The study was not prospectively registered because it was initially regarded as a prospective outcome cohort evaluating a routine surgical graft modification rather than a controlled clinical trial. However, current International Committee of Medical Journal Editors (ICMJE) definitions may include prospectively assigned surgical interventions; the lack of prospective registration is therefore an additional limitation.

The cohort was predominantly male. Postoperative laxity measurements, isokinetic strength testing, and validated psychological readiness measures were unavailable. AOFAS has measurement limitations, and calf circumference is an indirect surrogate for muscle recovery. AOFAS and FADI reflect overall ankle-foot function but include items related to walking, gait, activity, and functional mobility that may also be influenced by the reconstructed knee, particularly during early rehabilitation. Therefore, the decline observed at three months cannot be attributed exclusively to morbidity at the tendon-harvest site. Similarly, calf-circumference reduction may reflect general postoperative disuse following knee surgery, as well as a possible donor-site effect, and these influences cannot be separated using the present data. Objective ankle eversion and plantarflexion strength, first-ray plantarflexion, and detailed biomechanical testing were not performed. Although no persistent clinically evident sural or superficial peroneal nerve complication was recorded, a formal standardized sensory assessment was not included. Consequently, the recovery of AOFAS and FADI toward baseline should not be interpreted as definitive evidence of preserved peroneal muscle strength or normal ankle biomechanics.

The single-leg hop test was not performed preoperatively, and only the single-leg hop-for-distance test was used rather than a comprehensive hop-test or return-to-sport battery. In addition, postoperative instrumented knee-laxity measurements and isokinetic strength testing were unavailable. These limitations restrict conclusions regarding mechanical knee stability, donor-site muscle strength, and complete readiness for return to sport.

Multiple exploratory correlations were tested in a small sample, although Holm correction was applied. Finally, one traumatic rerupture occurred before the 12-month assessment. Retaining the post-rerupture scores may lower group outcomes, whereas excluding the patient would bias results toward intact grafts; both the primary and exploratory sensitivity analyses are therefore presented.

## Conclusions

In appropriately selected patients in whom an adequate isolated HPLT construct was obtained, ACL reconstruction was associated with substantial improvement in knee function, pain, and activity during the first postoperative year. Donor-ankle function declined early and recovered toward baseline, with the complete resolution of ankle pain by 12 months; however, these findings should not be interpreted as definitive evidence of preserved peroneal muscle strength or normal donor-site biomechanics. Objective recovery was slower than patient-reported recovery, and 43.5% remained below 90% hop symmetry at one year. The findings support HPLT as a potential graft option in selected patients but do not establish adequacy in all patients or superiority over established autografts.

Appendices

Table 7 and Table 8 show the abbreviations used in the manuscript and the phase-wise criterion-based rehabilitation protocol after ACL reconstruction.

| Abbreviation | Definition                                  |
|--------------|---------------------------------------------|
| ACL          | Anterior cruciate ligament                  |
| AOFAS        | American Orthopaedic Foot and Ankle Society |
| FADI         | Foot and Ankle Disability Index             |
| HPLT         | Hemi-peroneus longus tendon                 |
| IKDC         | International Knee Documentation Committee  |
| IQR          | Interquartile range                         |
| LSI          | Limb symmetry index                         |
| SD           | Standard deviation                          |
| VAS          | Visual analogue scale                       |
| ROM          | Range of motion                             |

TABLE 7: Abbreviations used in the manuscript.

| Phase                          | Goals                                                                                                                            | Intervention                                                                                                                                                                                                                                         | Progression criteria                                                                                                                                                         |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phase 1 (0-2 weeks)            | Control pain/effusion; protect graft and donor site; full extension; progressive flexion; quadriceps activation; safe ambulation | Cryotherapy, compression, and elevation; patellar mobilization; heel slides; extension positioning; quadriceps sets; straight-leg raise after lag resolves; ankle pumps and gentle ROM; hip/core exercises; weight bearing as tolerated with support | Wound satisfactory; minimal effusion; full or near-full extension; flexion 90°-110°; straight-leg raise without lag; safe gait                                               |
| Phase 2 (2-6 weeks)            | Full extension and progressive flexion; normalize gait; begin strengthening; restore ankle mobility                              | Wean crutches/brace when appropriate; cycling; mini-squats; wall slides; protected-range leg press; step-ups; bridges; hip strengthening; balance; calf raises; gentle resisted ankle motion                                                         | Full extension; flexion ≥ 120°; minimal effusion; pain-free full weight bearing; normalized gait; donor wound healed                                                         |
| Phase 3 (6-12 weeks)           | Full ROM; increase knee, hip, and calf strength; improve balance and conditioning                                                | Progressive closed-chain exercise; leg press, squats, lunges, and step-downs; cautious open-chain knee extension; single-leg balance; perturbation training; cycling/elliptical/pool; resisted eversion and plantarflexion                           | Full pain-free ROM; trace or no effusion; satisfactory single-leg control; correct squat/step-down mechanics; no reactive symptoms                                           |
| Phase 4 (3-5 months)           | Develop unilateral strength/endurance; prepare for running and impact                                                            | Unilateral squats, split squats, and leg press; eccentric strengthening; advanced balance; low-level plyometrics; landing training; graded walk-jog program after criteria                                                                           | Full ROM; no clinically significant effusion; normal gait; satisfactory single-leg control; strength preferably ≥80% LSI; clearance for running                              |
| Phase 5 (5-6 months)           | Improve running tolerance, agility, and neuromuscular control; introduce sport-specific activity                                 | Progress running, acceleration/deceleration, planned change of direction, bilateral/unilateral plyometrics, hop preparation, and non-contact drills                                                                                                  | No pain, instability, or reactive effusion; running tolerated; satisfactory landing mechanics; strength preferably ≥85% LSI                                                  |
| Phase 6 (6-9 months)           | Restore strength, power, and symmetry; advanced agility; return-to-sport preparation                                             | High-level plyometrics; multidirectional agility; planned then unplanned cutting; interval running; sport conditioning; hop training; fatigue-resistant movement control                                                                             | No pain/effusion; full ROM; strength and hop LSI ≥ 90%; acceptable landing mechanics; satisfactory clinical and psychological readiness                                      |
| Phase 7 (usually ≥9-12 months) | Progress to unrestricted training and competition; reduce reinjury risk                                                          | Progress non-contact to controlled contact, full training, and competition; continue strength, plyometric, and neuromuscular prevention program 2-3 times weekly                                                                                     | Team clearance; no symptoms or instability; full ROM; strength LSI ≥ 90%, preferably approaching 95% for pivoting sport; hop LSI ≥ 90%; sport-specific testing under fatigue |

TABLE 8: Phase-wise criterion-based rehabilitation protocol after ACL reconstruction.

The rehabilitation protocol was adapted from published peroneus longus rehabilitation protocols and contemporary criterion-based ACL reconstruction rehabilitation guidelines [29,30]. Time points are approximate, and progression was based on clinical and functional criteria.

ACL, anterior cruciate ligament; LSI, limb symmetry index; ROM, range of motion

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Ritesh Kumar, Jayanta K. Laik

Acquisition, analysis, or interpretation of data: Ritesh Kumar, Jayanta K. Laik, Ashutosh Mishra, Rajesh Thakur, Sameer Wooly

Drafting of the manuscript: Ritesh Kumar, Ashutosh Mishra

Critical review of the manuscript for important intellectual content: Ritesh Kumar, Jayanta K. Laik, Rajesh Thakur, Sameer Wooly

Supervision: Jayanta K. Laik

## Disclosures

**Human subjects:** Informed consent for treatment and open access publication was obtained or waived by all participants in this study. The Institutional Ethics Committee (IEC) of Tata Main Hospital (TMH), Jamshedpur, issued approval TMH/IEC/176/2023. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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