Anterolateral Ligament Reconstruction Does Not Delay Functional Recovery, Rehabilitation, and Return to Sport After Anterior Cruciate Ligament Reconstruction: A Matched-Pair Analysis From the SANTI (Scientific ACL Network International) Study Group

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Purpose: To determine whether the addition of an anterolateral ligament reconstruction (ALLR) resulted in delayed functional recovery (based on the Knee Santy Athletic Return to Sport [K-STARTS] score) at 6 months after anterior cruciate ligament reconstruction (ACLR). **Methods:** A retrospective analysis of prospectively collected data from consecutive patients who underwent an ACLR between September 2017 and December 2020 was conducted. Patients who received an isolated hamstring autograft (isolated ACLR group) were propensity matched in a 1:1 ratio to patients who received a hamstring autograft ACLR combined with an ALLR (ACLR-ALLR group). Outcome measures included the Tegner Activity Scale and the K-STARTS test—a validated composite return-to-sports test (including the Anterior Cruciate Ligament–Return to Sport After Injury scale, Qualitative Assessment of Single-Leg Landing tool, limb symmetry index, and ability to change direction using the Modified Illinois Change of Direction Test). **Results:** The study included 111 matched pairs. At 6 months postoperatively, there were no significant differences between groups in the overall K-STARTS score (65.4 for isolated ACLR vs 61.2 for ACLR-ALLR, $P = .087$) or the Tegner Activity Scale score (3.7 for isolated ACLR vs 3.8 for ACLR-ALLR, $P = .45$). In addition, an evaluation of the subscales of the K-STARTS score revealed no disadvantage across the domains of neuromuscular control, limb symmetry index, agility, or psychological readiness to return to sport when an ALLR was performed. **Conclusions:** The addition of ALLR at the time of ACLR does not delay functional recovery. Specifically, at 6 months postoperatively, there was no disadvantage in patients undergoing ALLR-ACLR, when compared with those undergoing isolated ACLR, with respect to neuromuscular control, limb symmetry indices (hop tests), agility, or psychological readiness to return to sport. **Level of Evidence:** Level III, retrospective comparative study.

Lateral extra-articular procedures (LEAPs) performed at the time of anterior cruciate ligament reconstruction (ACLR) are popular in contemporary practice. However, it is important to note that LEAPs were previously widely abandoned in the 1980s. The reasons for this were multifactorial but included the failure to show clinical efficacy (likely owing to underpowered studies), concerns about complications and reoperation rates, and the advent of arthroscopic ACLR resulting in a move away from open procedures. The current renaissance of LEAPs has been facilitated by addressing many of these issues. The recent literature

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shows efficacy, safety, and low reoperation rates for both revision ACLR and non—graft rupture—related reoperations in both large study populations and comparative studies including randomized controlled trials. The reported benefits of combined procedures include lower graft rupture rates, better knee stability, improved rates of return to sport, better patient-reported outcome measures, better anterior cruciate ligament (ACL) graft incorporation, and lower rates of secondary meniscectomy after meniscal repair.[1-6] A logical basis for these clinical findings is shown by biomechanical studies reporting that combined procedures more reliably restore normal knee kinematics when compared with isolated ACLR and that LEAPs confer a protective effect on ACL grafts by load sharing with them.[7-10]

Despite compelling data supporting the use of LEAPs, one of the currently unanswered questions is whether adding an extra procedure delays early functional recovery when compared with isolated ACLR. In addition, the impact of the choice of LEAP on functional recovery is incompletely understood. Getgood et al.[11] recently reported that patients undergoing ACLR plus the modified Lemaire procedure had significantly more pain in the early postoperative period and had inferior lower-extremity functional scores and quadriceps strength at 6 months postoperatively. Although these differences resolved by 12 months, these findings are clearly important because many patients expect to return to sport well before 12 months postoperatively.[12] Consequently, there is an important need to evaluate whether anterolateral ligament reconstruction (ALLR) and other types of LEAPs are also associated with delayed functional recovery when compared with isolated ACLR.

Several tools have been developed for a broad assessment of functional outcomes and athletic progression after knee surgery. In 2018, validation of the Knee Santy Athletic Return to Sport (K-STARTS) composite test was reported.[13] On the basis of its high completion rate, high reproducibility, and high sensitivity to change, the K-STARTS test has been considered an appropriate and objective outcome measure for functional improvement after ACLR.[13,14] This battery of tests evaluates psychological readiness to return to sport, the limb symmetry index, neuromuscular control, and the ability to change direction.

The purpose of this study was to determine whether the addition of an ALLR resulted in delayed functional recovery (based on the K-STARTS score) at 6 months after ACLR. The hypothesis was that there would be no difference in functional recovery between patients undergoing combined ACLR and ALLR and their matched counterparts undergoing isolated ACLR.

Methods

Study Design and Participants

Institutional review board approval was granted for this study (institutional review board number COS-RGDS-2021-07-005). All participants gave valid consent to participate. We conducted a retrospective analysis of prospectively collected data from consecutive patients who underwent ACLR performed by the senior author between September 1, 2017, and December 31, 2020.

Patients were considered for study eligibility if they had experienced symptomatic instability after ACL injury and subsequently underwent ACLR with hamstring tendon autograft either with or without a concomitant ALLR. The decision to perform ALLR in addition to isolated ACLR was based on published indications[15] and patient and/or surgeon preference. Patients were excluded if they had a history of ipsilateral knee surgery, if they underwent other concomitant procedures at the time of ACLR (e.g., multiligament reconstruction, LEAP other than ALLR, osteotomy, or cartilage restoration procedure), or if they did not undergo the K-STARTS test at 6 months postoperatively.

Surgical Techniques

All procedures were performed in accordance with previously published techniques, as summarized in this section (Figs 1 and 2). Outside-in drilling was used to create all tunnels.

ACLR With Hamstring Tendon Graft. Both the semitendinosus (ST) and gracilis tendons were harvested using an open-ended tendon stripper (Fig 1). The tibial insertion was preserved to achieve a “double tibial fixation” and to maintain an amount of graft vascularity.[16] Tendons were quadrupled and then, with the knee flexed at 30°, fixed on the tibial side with an interference screw (Bio-Interference screw; Arthrex) and fixed on the femoral side with an adjustable—loop length implant (TightRope; Arthrex).

Combined ACLR With Hamstring Tendon and ALLR. The ST and gracilis tendons were harvested as described earlier. A single graft construct (comprising a tripled ST and additional strand of gracilis) and a single femoral tunnel were used for both the ACLR and ALLR (Fig 2).[17] The femoral tunnel was drilled in an anatomic position intra-articularly, commencing from a point just proximal and posterior to the lateral epicondyle, corresponding to the femoral origin of the anterolateral ligament (ALL). The intra-articular portion of the graft was fixed, with the knee flexed at 30°, on both the tibial and femoral sides using bioabsorbable screws (Bio-Interference screws). The free end of the gracilis

Fig 1. ACLR with hamstring tendon graft.

was used as the ALL portion of the graft. After the graft was passed underneath the iliotibial band (ITB), it was passed through a tibial tunnel and then returned to the femoral-sided ALL origin, where it was fixed with the knee in full extension.

Postoperative Rehabilitation Protocol

All patients underwent the same rehabilitation protocol regardless of whether they received an isolated ACLR or a combined procedure. This included immediate brace-free, full weight bearing using crutches, cold pneumatic compression therapy, and progressive range-of-motion exercises. Only patients who underwent a meniscal repair were recommended to restrict range of motion from 0° to 90° for 6 weeks postoperatively. Return to sport was allowed at 4 months for non-pivoting sports, at 6 months for pivoting non-contact sports, and at 9 months for pivoting contact sports if patients achieved satisfactory results on the K-STARTS test.

Clinical Evaluation and K-STARTS Test

Patients were reviewed at 2 weeks, 6 weeks, 3 months, and 6 months postoperatively. At 6 months postoperatively, all patients underwent the K-STARTS test at Reathletic, Lyon, France provided that they were able to show a less than 40% deficit in isokinetic strength testing compared with the contralateral limb.

The K-STARTS test aims to evaluate the functional and psychological status of patients after ACLR. It is composed of 4 domains: The first section of the K-STARTS test appraises the psychological readiness to return to sport and is determined by the outcome of the Anterior Cruciate Ligament—Return to Sport After Injury (ACL-RSI) questionnaire. On this K-STARTS assessment, 3 points are given for ACL-RSI scores of 76% or more; 2 points, scores between 64% and 75%; 1 point, scores between 56% and 63%; and 0 points, scores of 55% or less.

The second section of the K-STARTS test evaluates neuromuscular control, determined by the outcome of the Qualitative Assessment of Single-Leg Landing (QASLS) tool. This tool provides an analysis of movement occurring in the arms, trunk, pelvis, thighs, knees, and feet during single-leg loading tasks.[18] The QASLS score ranges between 0 points (best) and 10 points (worst), with the number of points increasing for

Fig 2. Combined ACLR with hamstring tendon and ALLR.

inappropriate movement strategies. Patients with QASLS scores of 0 points, 1 points, 2 points, and 3 or more points receive scores of 3 points, 2 points, 1 point, and 0 points, respectively, on the K-STARTS test. Furthermore, 3 points are deducted if a patient is judged to have dynamic valgus of the limb during the single-leg loading task.

The third section of the K-STARTS test is an estimation of the limb symmetry index. Four categories of hop test (single, triple, side, and crossover) are carried out, and the percentage deficit of the distance hopped on the involved leg compared with the uninvolved, contralateral leg is computed.[14,19,20] For each of the hop tests, a limb symmetry index of 90% or more corresponds to 3 points on the K-STARTS test, between 80% and 89% corresponds to 2 points, and 79% or less corresponds to 1 point, and if pain occurs during the test, no points are attributed.

The fourth section of the K-STARTS test evaluates the ability to change direction using the Modified Illinois Change of Direction Test (MICODT).[21] An average MICODT time of 12.5 seconds or less scores 3 points on the K-STARTS test. If the time ranges from 12.51 to 13.5 seconds, it scores 2 points, and if the time is greater than 13.5 seconds, it scores 1 point. Moreover, if pain prevents the test, no points are given.

The final score was calculated as a percentage of the maximum available points. If the final score was less than 50 points, return to sport was discouraged. If the score ranged between 66 and 80 points, pivoting non-contact sports were allowed. If the score ranged between 65 and 80 points, pivoting non-contact sports were allowed. If the score was higher than 80 points, the patient was allowed to return to contact sports. A review of medical notes was used to extract data regarding patient characteristics and technical details of surgery.

Propensity Matching

A matched-pair analysis was conducted to minimize the impact of extraneous factors and any potential treatment selection bias. A propensity score was calculated for each patient using the following parameters: age at the time of surgery (<30 years or ≥30 years), time interval between injury and reconstruction (<12 weeks or ≥12 weeks), body mass index (World Health Organization categories),[22] sex (male or female), and preoperative Tegner Activity Scale score (<7 or ≥7). Then, each patient who received isolated ACLR was matched with a patient who underwent ACLR-ALLR, according to the nearest corresponding propensity score.[23] In the evaluation of covariates, a threshold of absolute standardized differences lower than 0.25 was defined a priori to reach enough similarity between groups to allow for comparisons to be drawn.[24]

Statistical Analyses

Statistical analyses were conducted using SPSS software (version 27.0; IBM) for MacOS (Apple); the level of significance was set at $P < .05$. For the evaluation of the K-STARTS scores and subscales, nonparametric rank-based statistical methods were used: the Wilcoxon signed rank test for continuous data and the McNemar test for binary outcomes. Multivariate logistic regression was performed to identify factors influencing any variables that were significantly different between groups.

Results

Patients

Overall, 1,681 patients underwent ACLR during the study period; of these, 1,067 fulfilled the inclusion criteria. The study flow is presented in Figure 3.

A total of 767 patients were identified as potentially eligible for the matching process and final inclusion: 656 patients who underwent ACLR-ALLR and 111 who underwent isolated ACLR. Each patient in the isolated ACLR group was matched to a patient in the ACLR-ALLR group by use of the propensity score. The final population comprised 111 propensity-matched pairs (Table 1). The demographic characteristics of the study population are summarized in Table 2.

Clinical Outcomes

At 6 months postoperatively, there were no significant differences between groups in the overall K-STARTS score (65.4 for isolated ACLR vs 61.2 for ACLR-ALLR, $P = .087$) or the Tegner Activity Scale score (3.7 for isolated ACLR vs 3.8 for ACLR-ALLR, $P = .45$). In addition, an evaluation of the subscales of the K-STARTS score revealed no differences between groups across the domains of psychological readiness to return to sport, limb symmetry index, or neuromuscular control (Table 3). However, there was a significant difference between groups with respect to the MICODT time, favoring the ACLR-ALLR group (13.77 seconds for isolated ACLR vs 13.39 seconds for ACLR-ALLR; mean difference, 0.38 seconds; $P = .007$).

Multivariate regression analyses were performed to identify factors influencing the MICODT time. Sex, age, body mass index, preoperative and postoperative Tegner Activity Scale scores, presence of meniscal lesions at the time of surgery, addition of ALLR to ACLR, time between injury and surgery, dominant limb, and injured limb were all included in the analysis. Variables that were significantly associated with a MICODT time of less than 13.5 seconds included the addition of an ALLR (when compared with isolated ACLR), younger age, higher preoperative Tegner score, and male sex (Table 4). The combined ACLR-ALLR procedure, an age younger than 30 years at the time of surgery, a Tegner Activity Scale score of 7 or more prior to surgery, and

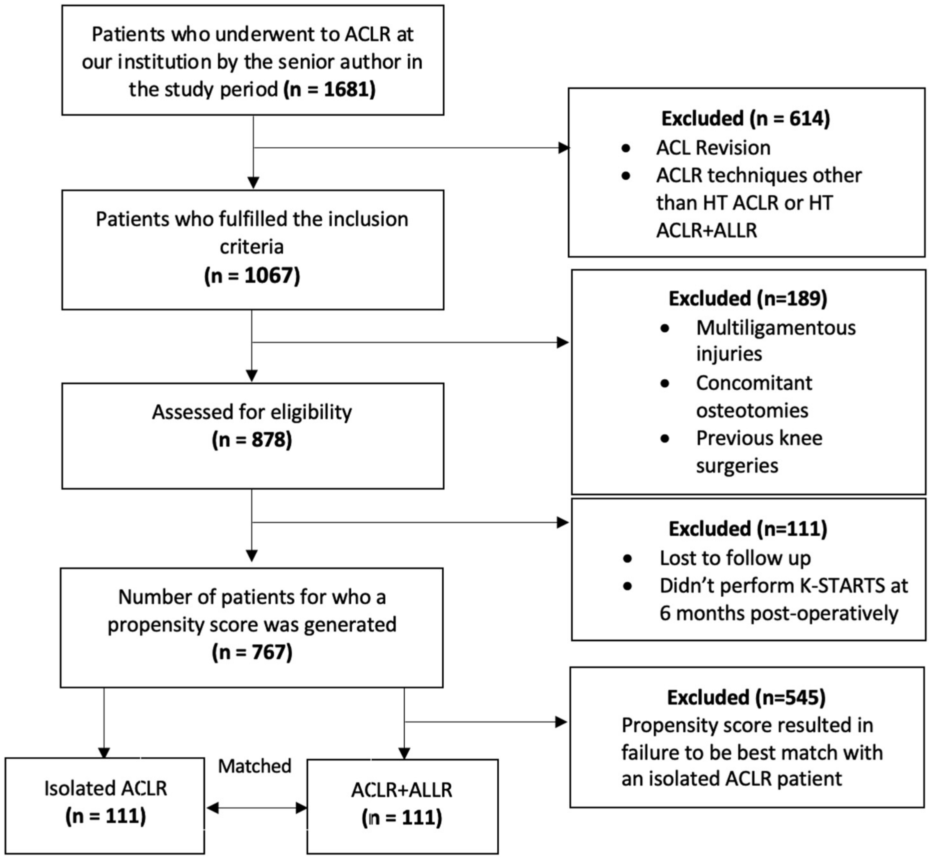

Fig 3. Study flowchart in line with STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement (http://www.strobe-statement.org). (ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; ALLR, anterolateral ligament reconstruction; HT, hamstring tendon; K-STARTS, Knee Santy Athletic Return to Sport.)

male sex were the most successful categories in terms of obtaining an MICODT time of less than 13.5 seconds.

Discussion

The main findings of this study were that, at 6 months postoperatively, there were no significant differences in the overall K-STARTS score or the postoperative Tegner score between the isolated ACLR group and combined ACLR-ALLR group. More specifically, there were no differences between groups with respect to the ACL-RSI score, limb symmetry index, or neuromuscular control domains of the K-STARTS test. These findings show that the addition of an ALLR does not delay functional recovery or psychological readiness to return to sport at 6 months postoperatively when compared with isolated ACLR.

A further interesting finding was that patients who underwent combined ACLR-ALLR performed significantly better on the MICODT (13.77 ± 1.29 seconds for isolated ACLR vs 13.39 ± 1.23 seconds for ACLR-ALLR; mean difference, 0.38 seconds; P = .007). To our knowledge, the minimal clinically important difference for the MICODT has not been defined but the minimal detectable change has been reported to be 0.28 seconds (in an adolescent population and not specifically in adults).[21] Although the test is popular in assessing agility, a particular criticism is that the test is asymmetrical, with unequal numbers of turns performed to the left and to the right. Rouissi et al.[25] reported that inverting the test resulted in significantly different results and cautioned that the MICODT could underestimate ability in more than half of participants. Furthermore, owing to the retrospective nature of this study, data on preinjury baseline differences between groups with respect to the MICODT were unknown. For these reasons, the clinical importance of this statistically significant advantage cannot be clearly defined. Despite these

Table 1. Absolute Standardized Differences for Each Variable Used in Propensity Matching

Variable	Standardized Difference
Age	0.080
BMI	0.073
Time between injury and ACLR	0.049
Preoperative Tegner Activity Scale score	0.076
Sex	0.036

NOTE. The predetermined threshold of 0.25 was met for all variables, showing that the matching was successful in generating 2 study groups that were similar enough to allow reliable comparisons to be drawn between them.

ACLR, anterior cruciate ligament reconstruction; BMI, body mass index.

Table 2. Patient Demographic Characteristics

	Isolated ACLR (n = 111)	ACLR-ALLR (n = 111)
Age, yr	37.57 ± 10.05 (15.3-65.0)	37.67 ± 8.87 (16.5-60.1)
Sex, n (%)		
Male	61 (54.95)	64 (57.66)
Female	50 (45.05)	47 (42.33)
BMI	24.32 ± 3.57 (16.82-35.6)	24.6 ± 3.43 (17.15-37.55)
Time from injury to surgery, d	124.9 ± 144 (2-1,437)	125.4 ± 132.3 (2-1,567)
Preoperative Tegner Activity Scale score	6.14 ± 1.69 (3-10)	6.49 ± 1.72 (3-9)

NOTE. Data are presented as mean ± standard deviation (range) unless otherwise indicated. Statistical analyses of mean differences between groups—and the resulting *P* values—are not required after propensity matching. The absolute standardized differences presented in Table 1 show that the groups are similar enough for consistent comparison.

ACLR, anterior cruciate ligament reconstruction; ALLR, Anterolateral Ligament Reconstruction; BMI, body mass index.

concerns, it remains of interest that the addition of ALLR was found to remain an important predictor of an improved MICODT time even when other important predictors such as age, sex, and preoperative Tegner score were included in multivariate analysis. Previous in vivo evaluations of knee kinematics after combined ACLR and lateral extra-articular tenodesis procedures have not shown any significant advantage with respect to anterior tibial translation or tibial rotation during downhill running (lateral extra-articular tenodesis)[26] or with respect to peak knee abduction moments during drop vertical jump landing tests.[27] To our knowledge, the influence on change in direction ability has not previously been reported, but the findings of this study warrant further evaluation. Regardless, and perhaps more important, it is clear that the addition of ALLR did not have a deleterious effect on the MICODT time or any of the other outcomes measured at 6 months postoperatively. The overall main finding of this study, that the addition of ALLR does not impair functional recovery, is also supported by the work of Gillet et al.,[28] who reported that the addition of an ALLR does not alter recovery of isokinetic muscle strength measured at 6 months after ACLR. In fact, despite the fact that combined ACLR-ALLR required the additional harvesting of the gracilis tendon (in addition to the ST tendon), the postoperative strength recovery was not significantly different from that of isolated ACLR.

In some contrast to the aforementioned findings with ALLR, Getgood et al.[11] recently reported that patients undergoing ACLR plus the modified Lemaire procedure had inferior knee function when compared with those undergoing isolated ACLR at 6 months postoperatively (including lower self-reported knee function [lower-extremity functional score], as well as lower quadriceps peak torque and average power), although the differences between groups had resolved by 12 months. The authors suggested that the association of the modified Lemaire procedure with a greater degree of pain and reduced subjective function was likely because of the additional incision, ITB harvest, and vastus lateralis muscle damage through retraction. A further possible explanation for the delay in functional recovery could be the high rate of ITB irritation from the staple fixation used, which also results in a high rate of reoperation for removal.[2] In contrast to the modified Lemaire procedure, ALLR avoids most of these issues because it is percutaneously performed, preserves the ITB, does not require vastus lateralis retraction, and does not use any additional hardware. This could

Table 3. K-STARTS Scores and Clinical Outcomes

	Isolated ACLR (n = 111)	ACLR-ALLR (n = 111)	*P* Value
Total score	65.4 ± 18.49 (19 to 100)	61.2 ± 18.24 (19 to 100)	.087
ACL-RSI score	67.47 ± 17.79 (12 to 100)	67.60 ± 16.11 (21 to 100)	.795
Difference in single-leg landing	0.126 ± 0.589 (−1 to 3)	0.207 ± 0.507 (−1 to 2)	.263
Single-hop ratio, %	89.89 ± 10.95 (61.83 to 123.53)	89.56 ± 10.26 (50 to 116.24)	.852
Triple-hop ratio, %	91.48 ± 9.11 (67.21 to 122.9)	90.84 ± 8.43 (66 to 114.7)	.617
Ratio of single hop for 15 s, %	88.07 ± 16.21 (10 to 128.6)	88.31 ± 17.73 (30.77 to 125)	.995
Ratio of single hop for 30 s, %	88.78 ± 17.41 (11 to 145)	87.61 ± 17.83 (40 to 140.5)	.613
Crossover hop ratio, %	91.36 ± 9.86 (67.14 to 125)	91.18 ± 9.48 (55.22 to 115.33)	.899
MICODT time, s	13.77 ± 1.29 (11.2 to 16.9)	13.39 ± 1.23 (10.96 to 17.68)	.007*
Postoperative Tegner Activity Scale score	3.7 ± 0.85 (3 to 7)	3.8 ± 0.84 (3 to 7)	.455

NOTE. Data are presented as mean ± standard deviation (range).

ACLR, anterior cruciate ligament reconstruction; ACL-RSI, Anterior Cruciate Ligament−Return to Sport After Injury; ALLR, Anterolateral Ligament Reconstruction; K-STARTS, Knee Santy Athletic Return to Sport; MICODT, Modified Illinois Change of Direction Test.

*Statistically significant ($P < .05$).

Table 4. Multivariate Regression Analysis of Factors Associated With Better (<13.5 Seconds) MICODT Results

Risk Factor	Comparison	OR	95% CI	*P* Value
Group	ACLR-ALLR vs isolated ACLR	1.98	1.004-3.906	.049*
Age at time of surgery	<30 yr vs ≥30 yr	4.259	1.526-11.887	.006*
Preoperative Tegner Activity Scale score	<7 vs ≥7	0.311	0.157-0.615	.001*
Sex	Male vs female	14.92	6.329-35.714	.001*

ACLR, anterior cruciate ligament reconstruction; ALLR, anterolateral ligament reconstruction; CI, confidence interval; MICODT, Modified Illinois Change of Direction Test; OR, odds ratio.
*Statistically significant ($P < .05$).

potentially explain why no significant functional deficits were seen in our study (when compared with isolated ACLR), but it must also be noted that the studies are not directly comparable because of heterogeneity—and not least because of differences in the choice of outcome measures used. However, these apparent differences between procedures are clearly of clinical relevance because functional outcomes at 6 months postoperatively have been shown to positively correlate with superior knee function and higher activity levels at mid-term follow-up,[29] as well as being predictive of the ability to return to sport at 12 and 24 months postoperatively.[30]

Limitations

The main limitations of this study include its retrospective nature and the inherent weaknesses of this design including the potential for treatment selection bias. However, the effects of this were minimized by using propensity matching. Other limitations were the single-center design and the lack of correlation between outcomes at 6 months postoperatively and longer-term outcomes such as return to the preinjury level of sport. Furthermore, no blinding was possible in this study because the patient (and the K-STARTS assessor) could see if the patient had undergone a combined or isolated procedure based on the presence of additional percutaneous stab incisions on the lateral aspect of the knee with ALLR. Additionally, a sample size calculation was not performed because all eligible patients were included. Finally, owing to the retrospective nature of the study, we were unable to evaluate whether postoperative pain scores were different between the groups.

Conclusions

The addition of ALLR at the time of ACLR does not delay functional recovery. Specifically, at 6 months postoperatively, there was no disadvantage in patients undergoing ALLR-ACLR, when compared with those undergoing isolated ACLR, with respect to neuromuscular control, limb symmetry indices (hop tests), agility, or psychological readiness to return to sport.

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