

The Effect of Staged Versus Usual Care Physiotherapy on Knee Function Following Anterior Cruciate Ligament Reconstruction

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Context: The long duration and high cost of anterior cruciate ligament reconstruction (ACLR) rehabilitation can pose barriers to completing rehabilitation, the latter stages of which progress to demanding sport-specific exercises critical for a safe return to sport. A staged approach shifting in-person physiotherapy sessions to later months of recovery may ensure patients undergo the sport-specific portion of ACLR rehabilitation. **Design/Objective:** To compare postoperative outcomes of knee function in patients participating in a staged ACLR physiotherapy program to patients participating in usual care physiotherapy through a randomized controlled trial. **Methods:** One hundred sixty-two patients were randomized to participate in staged (n = 80) or usual care physiotherapy (n = 82) following ACLR and assessed preoperatively and postoperatively at 2 weeks, 6 weeks, 3 months, and 6 months. The staged group completed the ACLR rehabilitation protocol at home for the first 3 months, followed by usual care in-person sessions. The usual care group completed in-person sessions for their entire rehabilitation. Outcome measures included the Lower Extremity Functional Scale, International Knee Documentation Committee Questionnaire, pain, range of motion, strength, and hop testing. **Results:** There were no statistically significant between-group differences in measures of knee function at 6 months postoperative. Patients in the usual care group reported significantly higher International Knee Documentation Committee scores at 3 months postoperative (mean difference = 5.8; 95% confidence interval, 1.3 to 10.4; $P = .01$). **Conclusion:** A staged approach to ACLR rehabilitation does not appear to impede knee function at 6 months postoperative but may result in worse patient reported outcomes at early follow-ups.

Keywords: rehabilitation, return to sport, randomized controlled trial

Young athletic patients who undergo anterior cruciate ligament (ACL) reconstruction (ACLR) have high expectations of a normally functioning knee and a successful return to their preinjury sports or activities after surgery.¹ Unfortunately, these patients experience low rates of return to their preinjury level of sport (less than 50%)^{2,3} and high rates of secondary injury (up to 30%)⁴ resulting in further declines in knee function.




Evidence-based ACLR rehabilitation protocols are instrumental in preventing secondary injury and are critical to a successful recovery and return to sport (RTS).^{5,6} ACL rehabilitation protocols commonly span 6 to 9 months and are divided into phases, beginning with early range of motion (ROM), and weight-bearing and progressing to sport-specific training.⁷⁻⁹ Participation in the sport-specific phase of rehabilitation is critical for patients to obtain the strength, endurance, coordination, and psychological readiness required to safely RTS.⁹

The extensive rehabilitation process following ACLR is not without difficulties such as cost and adherence-related issues. Although most insurance plans cover a portion of rehabilitation costs, it is not uncommon for patients to reach their coverage limits before 6 months, requiring out of pocket payment to complete the entirety of their rehabilitation program.^{10,11} Care delivery factors

can be both barriers and facilitators to ACL rehabilitation adherence and participation.¹² These factors include length of rehabilitation/commitment, cost, insurance, activity restrictions, type and progression of exercises, patient control, enjoyment, and assessment of progress.¹²

Adherence is a multifactorial concept influenced by personal schedules, income, housing location, and access to physiotherapy clinics.¹³ Moderate or full adherence to supervised rehabilitation following ACLR has been shown to improve patient-reported and functional measures of knee function, and increase patients' chances of returning to sport.¹⁴ However, patients may experience rehabilitation fatigue due to the high frequency of required appointments during early ACLR physiotherapy protocols. For these reasons, patients may not adequately adhere to their rehabilitation to return to preinjury sport or activity levels.

Some level of clinician contact is important for successful rehabilitation, but continuous supervision may not be necessary.^{15,16} We propose that a staged approach could offer a solution to issues surrounding traditional in-person and fully supervised physiotherapy. In a staged model, patients see their physiotherapists' in-person for assessment at specified milestones but complete weekly exercises and the prescribed protocol on their own, with more regular in-person sessions initiated at the sport-specific stage of rehabilitation. Shifting the frequency of in-person visits from early to late phase rehabilitation may ensure that patients undergo more advanced rehabilitation and achieve the knee function

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required to safely RTS. Previous research has evaluated the effectiveness of different home-based or semisupervised rehabilitation models and has suggested no significant differences in postoperative outcomes compared with clinic-based physiotherapy.^{10,15,17}

Therefore, the purpose of this study was to compare postoperative measures of knee function in patients participating in a staged physiotherapy program versus patients participating in usual care physiotherapy following ACLR. We hypothesized that there would be no differences between groups at 3 or 6 months postoperative in the primary outcome of knee function or secondary outcomes of knee-related quality of life, ROM, pain, strength- and performance-based measures.

Methods

Study Design and Participants

This study was a 2 group, parallel design randomized controlled trial that took place through the practices of 5 orthopedic surgeons at the Fowler Kennedy Sport Medicine Clinic. All patients between the ages of 15 and 40 who were scheduled to undergo ACLR using a hamstring autograft were invited to take part in the study. The exclusion criteria were as follows: (1) previous ACLR on either knee; (2) repair or reconstruction of the posterior cruciate ligament or medial collateral ligament was required; (3) history of metabolic bone, collagen crystalline, degenerative joint or neoplastic disease; (4) chondral defect requiring treatment; (5) femoral, tibial or patellar fracture (apart from Segond fractures); (6) bilateral ACLR required; (7) the patient did not speak, understand, or read the English language; (8) impairment or illness that precluded informed consent or rendered the patient unable to complete questionnaires; (9) no fixed address or means of contact; or (10) major medical illness where life expectancy was less than 2 years. Consenting patients were enrolled at their preoperative clinic visit by a research assistant. This study was granted ethics approval by the University of Western Ontario Research Ethics Board.

Procedures: Interventions

Patients in both groups attended their first consultation with a physiotherapist at approximately 2 weeks postoperatively. The Fowler Kennedy ACLR rehabilitation protocol⁹ was provided to all patients (Supplementary Material S1 [available online]). Both groups of patients were seen by their orthopedic surgeon postoperatively at 2 weeks, 6 weeks, and 3 months. All surgeons were blinded to group allocation. At 6 weeks and 3 months, the surgeon completed a clinical assessment to evaluate each patient's progress by answering yes or no to the following questions: does the patient demonstrate an inability to (1) bend their knee at least 80 degrees (knee flexion), (2) straighten their knee by greater than 10 degrees (knee extension), (3) contract and hold their quadriceps muscle, (4) perform a straight leg raise, and (5) displays quads avoidance gait pattern? If the surgeon answered "yes" to any of these questions the patient increased the frequency of their in-person physiotherapy appointments.

Patients randomized to the staged physiotherapy group received a copy of a 12-week home-based program at their 2-week initial consultation which included education on the home-based rehabilitation purpose, commitment, stages, and progressions in addition to detailed exercise instructions, pictures, dosage, and progressions (Supplementary Material S2 [available online]). The

therapist reviewed the first 6 weeks of the program with the patient to confirm understanding of all exercises. Patients in the staged group then only returned to the clinic at 6 weeks and 3 months to be assessed by a physiotherapist and their surgeon, and were encouraged to perform the protocol at home. At 6 weeks postoperatively, the patient was evaluated using the previously described clinical assessment. If they passed, the physiotherapist reviewed the structure of the final 6 weeks of the home-based component of the staged program. In the staged group, if a patient had not completely met the objectives of the first 6 weeks, the therapist reassigned the exercises from the first 6 weeks and demonstrated and assigned the final 6 weeks of the program. The patient was then encouraged to work on the entire program at home. Patients for whom there was a significant delay in expected progress were encouraged to attend additional supervised physiotherapy visits as dictated by clinician expertise and patient needs. This would not be considered a crossover to usual care, as the majority of the program would continue to be home based for the first 3 months. A patient would be considered a crossover if they opted to attend the same frequency of in-person physiotherapy sessions as the usual care group within the first 3-month period of the program (1–2 times per week), or if it was deemed necessary by clinicians due to delays in progress. After 3 months, patients in the staged group began to progress through the ACLR protocol with regularly scheduled in-person visits as per usual care.

Patients in the usual care group followed the same ACLR protocol but attended in-person clinic physiotherapy sessions 1 to 2 times per week. This schedule was determined through discussions between the physiotherapist and patient to schedule physiotherapy visits according to the therapist's usual practice and the patient's funding, family, school, and work situation (usual determinants of physiotherapy frequency and duration following ACL reconstruction).

Procedures: Outcome Measures

Baseline preoperative assessments were conducted 1 week before surgery, and included patient reported outcomes and functional measures. Follow-up activities were completed at 2 weeks, 6 weeks, 3 months, and 6 months postoperatively (Figure 1). The primary outcome measure was knee function at 6 months postoperatively, as measured by the Lower Extremity Functional Scale (LEFS). The LEFS is a valid self-reported measure of function for patients with lower extremity orthopedic conditions that is responsive to change, and highly reliable.¹⁸

Secondary outcome measures included knee-specific quality of life, pain, ROM, strength, and performance-based functional hop testing. Knee-specific quality of life was measured by the International Knee Documentation Committee (IKDC) Subjective Questionnaire, an 18-item knee-specific questionnaire designed to detect change in patients with a variety of knee conditions.¹⁹ The 4-Item Pain Intensity Measure (P4) was used to evaluate pain for participants over the 2 days prior to their visit.²⁰ ROM was measured through passive knee extension and active-assisted knee flexion tests using a universal goniometer. Side-to-side difference (surgical knee – contralateral knee) was calculated for active-assisted knee flexion and passive knee extension.

Hop testing was used as a performance-based outcome measure to evaluate neuromuscular control, strength, and confidence in both limbs. This involved a combination of 4 hop tests (single hop for distance, timed 6-m hop, triple hop for distance, and crossover hop for distance).²¹ All tests were performed twice per leg and the

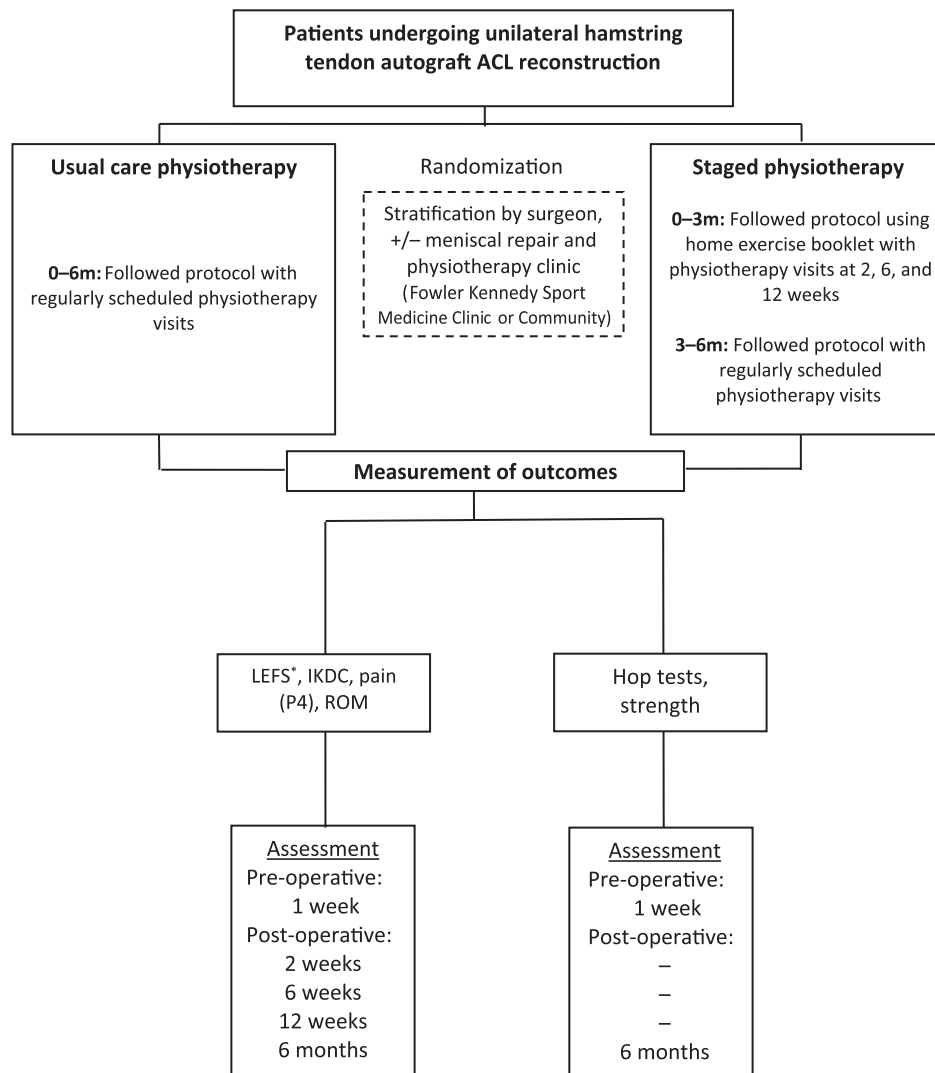


Figure 1 — Timing of outcome assessments and trial activities. *LEFS was not administered at the preoperative timepoint. ACL indicates anterior cruciate ligament; IKDC, International Knee Documentation Committee Subjective Questionnaire; LEFS, Lower Extremity Functional Scale; LSI, limb symmetry index; ROM, range of motion.

average of the 2 trials was included in the analysis. Limb Symmetry Index was calculated for all hop tests, and was performed as per Reid et al.²¹ The total Limb Symmetry Index was calculated by taking an average of the 4 scores.

Quadriceps (knee extension) and hamstring (knee flexion) strength were measured preoperatively and 6 months postoperatively using an isokinetic dynamometer. Peak torque (in newton meters), average peak torque (in newton meters), and average power (in Watts) were recorded on the surgical limb and expressed as a percentage of the contralateral limb. Assessors consisted of surgeons, kinesiologists, and physiotherapists, all of whom were trained to administer the evaluations employed within this study, in a standardized manner. All assessors were blinded to patient allocation.

Procedures: Randomization

Patients were randomized postoperatively on a 1:1 basis to either (1) usual care physiotherapy or (2) staged physiotherapy. Randomization was in permuted mixed block sizes and was stratified

by surgeon, presence of meniscal repair, and physiotherapy location (Fowler Kennedy Sport Medicine Clinic or other).

Statistical Analyses

All statistical analyses were performed using SPSS Statistics (version 26). Descriptive statistics were calculated for baseline demographics and clinical characteristics with *t* tests used to determine any significant differences between the groups.

As the primary analysis, LEFS scores were examined using an analysis of covariance to examine the difference between the usual care and staged physiotherapy groups at 3 and 6 months postoperatively while adjusting for 2-week postoperative scores. Post hoc tests were adjusted for multiple comparisons using the Bonferroni correction. Secondary outcome measures were compared at 3 and 6 months postoperatively using an analysis of covariance to adjust for preoperative scores. Assumptions of normality, linearity, homogeneity of variance, and regression slopes were confirmed using Levene test and visual inspection of Q-Q plots and scatter plots.

As a secondary exploratory analysis, the proportions of patients who reached acceptable levels for selected outcomes at 3 and 6 months were calculated for both groups and compared using Fischer Exact test. Acceptable values for the outcome measures of knee function are presented in Table 1 and are based on criteria from previous literature and clinical expertise.²²⁻²⁵ A 2-sided *P* value of <.05 marked statistical significance for all analyses.

Missing midpoint data were addressed through multiple imputation using 50 iterations. All missing data were assumed to be missing at random, as no important differences were observed between participants missing and not missing data points based on Little test performed across all variables with missing data. We followed the intention-to-treat principle for all analyses.

Sample size was calculated based on a 2-sided alpha error of (.05) and a power of 80% to detect a moderate effect size of 0.5, or 8.5 points on the LEFS.²⁶ Thus, a total of 61 participants were required for each group. The sample size was increased to 71 patients per group to allow for a 15% dropout rate, requiring 142 patients total.

Results

Participants

The flow of patients is presented in Figure 2. Of the 899 patients assessed for eligibility, 522 did not meet the inclusion criteria, 54 refused to participate, and 171 were either missed during the recruitment period or cancelled their surgery. A total of 162 patients were randomized, with 80 allocated to the staged physiotherapy group and 82 to the usual care group. Two participants were excluded postrandomization. Loss to follow-up was 16% and 12% for the staged physiotherapy and usual care groups,

respectively. No crossovers between groups were documented, and 5 participants in each group experienced delays in progress at 6 weeks (*P* = .94, insignificant difference between groups). There were 67 patients in the staged physiotherapy group and 70 patients in the usual care group remaining at 6 months. Participant baseline demographics and clinical characteristics are presented in Table 2.

Primary Analysis

Between-group differences for our primary and secondary outcome measures at 3 and 6 months postoperatively are displayed in Table 3 and Figure 3. LEFS scores did not display significant mean differences between the usual care and staged physiotherapy groups at 3 months (2.6; 95% confidence interval [CI], -0.8 to 6.1; *P* = .14), or 6 months postoperatively (0.8; 95% CI, -1.0 to 3.7; *P* = .52) after adjusting for 2-week postoperative measurements.

IKDC scores were significantly higher in the usual care group (68.3 [1.6]) when compared with the staged physiotherapy group (62.4 [1.6]) at 3 months following surgery (5.8; 95% CI, 1.3 to 10.4; *P* = .01). The remaining secondary outcome measures displayed no significant differences between groups. At 6 months following surgery, no significant differences were observed between groups for any secondary outcome including IKDC (Table 3).

Secondary Analysis

The proportion of patients that reached acceptable values for select outcome measures at 3 and 6 months postoperatively are presented in Table 1. At 6 months postoperative, less than 50% of patients in both groups showed acceptable strength values and less than 75% of patients in both groups showed acceptable ROM and hop testing

Table 1 Proportion of Acceptable Values at 3 and 6 Months

Outcome measure	Acceptable value ^a	Usual care, n (%)	Staged physiotherapy, n (%)	<i>P</i>
3 mo				
LEFS (0–80 points)	55	51 (72.9)	44 (65.7)	.46
ROM, °				
Active-assisted flexion	Within 5° contralateral leg	41 (58.6)	49 (73.1)	.11
Passive extension	Equal to contralateral leg	56 (80.0)	63 (94.0)	.02*
6 mo				
LEFS (0–80 points)	61	60 (85.7)	49 (73.1)	.09
ROM, °				
Active-assisted flexion	Equal to contralateral leg	49 (70.0)	49 (73.1)	.71
Passive extension	Equal to contralateral leg	54 (77.1)	50 (74.6)	.68
Hop testing LSI, %	>90%	45 (64.3)	47 (67.1)	.47
Strength testing, N·m or W				
Quadriceps peak torque	≥90% contralateral leg	28 (40.0)	30 (44.8)	.61
Quadriceps average power	(all strength measures)	27 (38.6)	29 (43.3)	.61
Quadriceps average peak torque		26 (37.1)	29 (43.3)	.49
Hamstring peak torque		34 (48.6)	23 (34.3)	.12
Hamstrings average power		18 (25.7)	16 (23.9)	.85
Hamstring average peak torque		26 (37.1)	24 (35.8)	1.00

Abbreviations: LEFS, Lower Extremity Functional Scale; LSI, limb symmetry index (surgical leg/contralateral leg); ROM, range of motion.

^aAcceptable outcome measure values were determined based on criteria from previous literature and clinical expertise.²²⁻²⁵

**P* < .05.

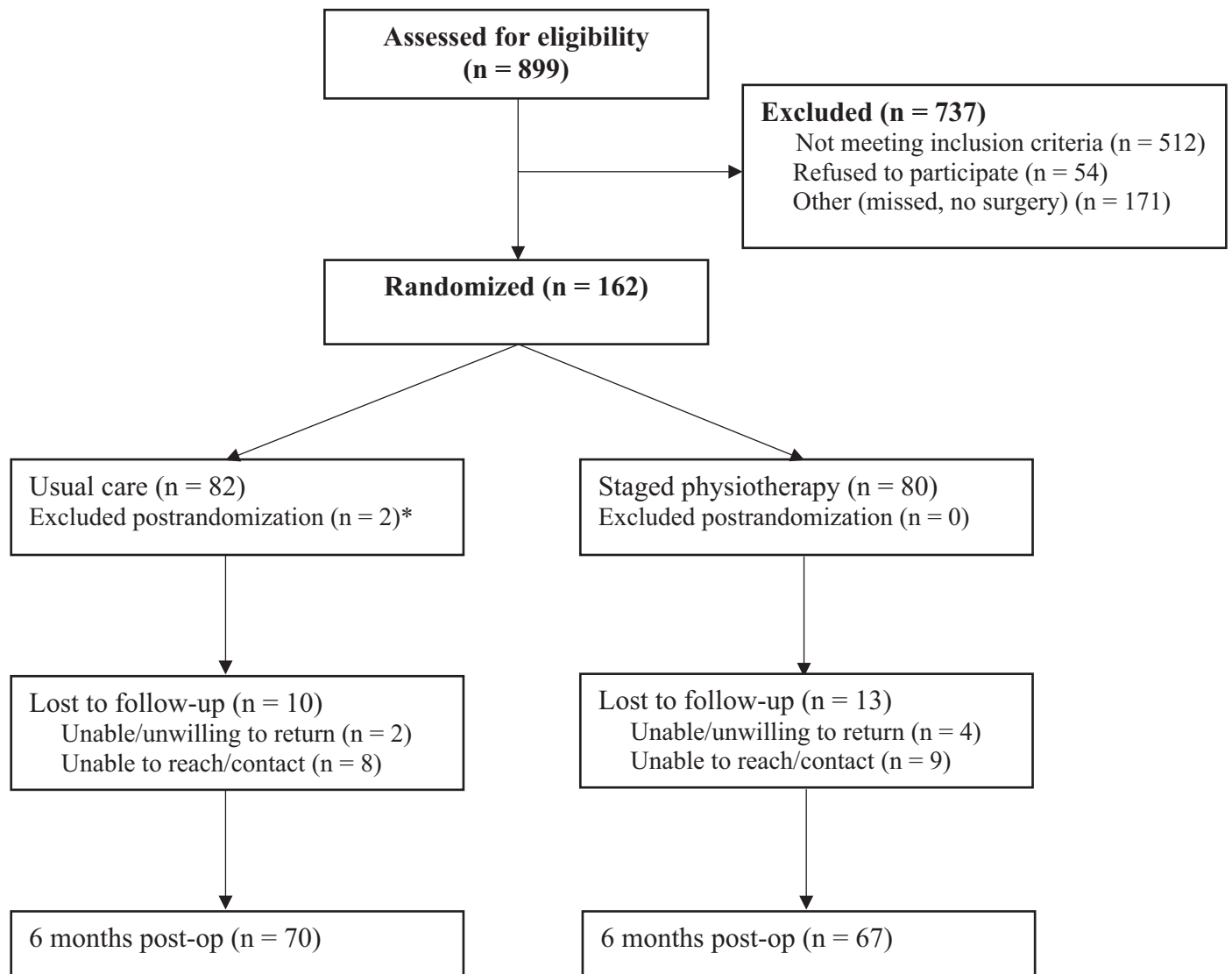


Figure 2 — Patient flow diagram. *One patient was excluded postrandomization due to a previously unreported contralateral anterior cruciate ligament tear, and one due to an additional intraarticular procedure as per surgeon direction.

values. At the 3-month timepoint, there was a significantly larger proportion of patients with acceptable passive knee extension ROM in the staged physiotherapy group (94%) than the usual care group (80%; $P = .02$). There were no other significant differences between groups.

Discussion

This study revealed that using a staged approach to ACLR rehabilitation does not appear to alter short-term knee function (ROM, hamstring and quadriceps strength or hop testing performance) up to 6 months postoperative, when compared to usual care physiotherapy rehabilitation. This could present opportunities for an individualized approach to physiotherapy following ACLR, in which patients can choose a home based or supervised in clinic model for their rehabilitation during the first 3 postoperative months of recovery based on their preferences and situational context. Ultimately, patients should be given the choice as to their preferred model. It is important to note that assessments with a physiotherapist during the acute stage are still necessary in a home-based

program to ensure appropriate progress is being made and to avoid adverse events.

Notably, the majority of patients in both groups did not have acceptable outcomes to indicate safe ability to RTS, which aligns with the recommendation to delay RTS for 9 to 12 months postoperatively.^{23,27} Flexibility in the level of supervision and location of physiotherapy may allow for optimization of late stage ACL rehabilitation and enable more patients to achieve a successful recovery and RTS.

There were no significant differences in any measures of postoperative knee function between the staged physiotherapy and usual care groups at 6 months following surgery. Overall, both groups showed significant improvements in IKDC scores from preoperative to 6 months postoperative that surpassed the minimal clinically important difference of 11.5 (staged physiotherapy: 20.3, usual care: 14.1) indicating meaningful change.²⁷ Secondary analyses showed significant differences in IKDC scores which favored usual care at the 3-month timepoint. This is notable considering the rehabilitation protocols of our 2 study groups differed for only the first 3 months (in-person vs home-based exercises). The change in

Table 2 Baseline Demographic and Clinical Characteristics

Characteristic	Usual care (N = 80)	Staged physiotherapy (N = 80)	P
Sex, n (%)			
Male	36 (52.9)	44 (61.1)	.39
Female	32 (47.1)	28 (38.9)	
Age, y, mean (SD)	22.8 (6.3)	24.0 (6.7)	.25
Height, m, mean (SD)	1.7 (0.2)	1.8 (0.1)	.61
Weight, kg, mean (SD)	76.1 (17.4)	78.9 (18.3)	.37
Leg dominance, n (%)			
Right	63 (94.0)	71 (98.6)	.20
Left	4 (6.0)	1 (1.4)	
Injured leg, n (%)			
Right	29 (43.3)	43 (60.6)	.08
Left	38 (56.7)	28 (39.4)	
Meniscal repair, n (%)			
Yes	20 (25.0)	19 (23.8)	.85
No	60 (75.0)	61 (76.3)	
IKDC (0–100), mean (SD)	62.7 (15.8)	58.6 (15.2)	.89
P4 (0–40), mean (SD)	6.2 (7.0)	8.5 (8.4)	.14
ROM, °, mean (SD)			
Active-assisted flexion			
Surgical	137.0 (8.5)	136.9 (9.4)	.67
Contralateral	140.1 (8.4)	141.0 (8.4)	.99
Side-to-side difference	–3.1 (7.3)	–4.1 (9.2)	.51
Passive extension			
Surgical	–3.5 (3.2)	–3.1 (3.0)	.55
Contralateral	–4.1 (2.6)	–3.9 (3)	.78
Side-to-side difference	0.6 (2.9)	0.9 (2.1)	.46
Hop testing (LSI), mean (SD)			
Single hop	82.6 (24.6)	70.2 (36.1)	.03*
6M hop	113.0 (47.8)	97.2 (59.0)	.04*
Triple hop	77.8 (26.0)	69.0 (38.1)	.28
Cross hop	74.6 (30.9)	68.5 (37.7)	.28
Total	87.0 (23.0)	76.2 (37.3)	.09
Strength testing, %, mean (SD)			
Quadriceps peak torque	77.8 (18.6)	79.7 (17.7)	.54
Quadriceps average power	82.0 (23.3)	82.9 (18.2)	.77
Quadriceps average peak torque	78.0 (19.0)	79.3 (19.0)	.70
Hamstring peak torque	85.5 (18.3)	87.7 (19.7)	.48
Hamstrings average power	94.1 (20.3)	86.0 (22.2)	.50
Hamstring average peak torque	85.2 (18.2)	86.9 (20.4)	.57

Abbreviations: IKDC, International Knee Documentation Committee Subjective Questionnaire; LSI, limb symmetry index (surgical leg/contralateral leg); ROM, range of motion; 6M, 6-meter.

* $P < .05$.

IKDC scores from preoperative to 3 months postoperative was similar between groups (3.8 vs 5.6, respectively), and change from 3 months to 6 months and pre-op to 6 m was higher in the staged physiotherapy group. These results may be partly due to the fact that preoperative scores were lower in the staged physiotherapy group compared with the usual care group (58.6 vs 62.7), although this difference was not statistically significant. However, the mean difference in IKDC scores between groups at 3 months (5.8),

including the upper limit of the 95% CI (10.4), and the difference in mean change scores across timepoints (pre-op to 3 m: 1.8, 3 m to 6 m: 8.0, pre-op to 6 m: 6.2), did not reach the established minimal clinically important difference (11.5), minimally important change (10.9), or minimum detectable change (11.5) of the IKDC subjective knee form.²⁷ Therefore, we cannot be confident that these results represent differences between groups beyond measurement error. It is possible that the lack of regular physiotherapy

Table 3 Three- and Six-Month Follow-Up Functional Outcome Scores for Patients in Usual Care Physiotherapy and Staged Physiotherapy Following ACL Reconstruction

Outcome measure	Usual care, mean \pm SE	Staged physiotherapy, mean \pm SE	Mean difference (95% CI)	P
3 mo				
LEFS score (0–80)	59.5 \pm 1.2	56.9 \pm 1.2	2.6 (–0.8 to 6.1)	.14
IKDC score (0–100)	68.3 \pm 1.6	62.4 \pm 1.6	5.8 (1.3 to 10.4)	.01*
P4 score (0–40)	5.9 \pm 0.7	8.1 \pm 0.7	–1.5 (–3.3 to 0.4)	.13
ROM, °				
Active-assisted flexion				
Surgical	134.0 \pm 1.0	135.7 \pm 1.1	–1.8 (–4.6 to 1.1)	.23
Contralateral	139.6 \pm 0.7	139.8 \pm 0.7	–0.3 (–2.3 to 1.8)	.79
Side-to-side difference	–5.8 \pm 0.9	–4.2 \pm 1.0	–1.6 (–4.2 to 1.1)	.24
Passive extension				
Surgical	–2.67 \pm 0.4	–3.2 \pm 0.4	0.5 (–0.6 to 1.6)	.36
Contralateral	–4.3 \pm 0.3	–5.3 \pm 0.3	1.0 (0.2 to 1.9)	.03*
Side-to-side difference	1.7 \pm 0.3	2.2 \pm 0.3	–0.5 (–1.2 to 0.2)	.19
6 mo				
LEFS score (0–80)	69.7 \pm 1.0	68.9 \pm 1.0	0.82 (–2.0 to 3.7)	.52
IKDC score (0–100)	76.8 \pm 1.5	78.9 \pm 1.6	–2.0 (–6.4 to 2.3)	.35
P4 score (0–40)	5.8 \pm 0.6	6.2 \pm 0.6	–0.4 (–2.1 to 1.3)	.66
ROM, °				
Active-assisted flexion				
Surgical	136.5 \pm 1.0	135.6 \pm 1.0	1.0 (–1.9 to 3.8)	.51
Contralateral	139.0 \pm 0.7	139.6 \pm 0.8	–0.6 (–2.7 to 1.5)	.57
Side-to-side difference	–3.5 \pm 0.8	–4.3 \pm 0.8	0.6 (–1.7 to 2.9)	.63
Passive extension				
Surgical	–3.5 \pm 0.4	–3.1 \pm 0.4	–0.4 (–1.4 to 0.7)	.52
Contralateral	–5.2 \pm 0.3	–4.6 \pm 0.3	–0.6 (–1.5 to 0.3)	.19
Side-to-side difference	1.5 \pm 0.3	1.4 \pm 0.3	0.1 (–0.8 to 1.0)	.90
Hop testing (LSI)				
Single hop	80.6 \pm 3.2	85.8 \pm 3.5	–4.2 (–11.8 to 3.4)	.27
6M hop	95.7 \pm 4.3	101.2 \pm 4.4	–5.5 (–17.7 to 6.6)	.37
Triple hop	78.5 \pm 3.3	83.0 \pm 3.3	–4.6 (–13.7 to 4.6)	.33
Cross hop	80.4 \pm 5.2	85.9 \pm 4.4	–4.1 (–15.1 to 6.9)	.46
Total	84.8 \pm 3.3	88.3 \pm 3.4	–3.5 (–12.9 to 5.9)	.47
Strength testing, %				
Quadriceps peak torque	79.0 \pm 1.9	79.7 \pm 1.9	–0.7 (–6.1 to 4.7)	.80
Quadriceps average power	77.9 \pm 1.8	78.1 \pm 1.8	–0.1 (–5.1 to 4.8)	.96
Quadriceps average peak torque	76.4 \pm 2.1	79.1 \pm 2.1	–2.7 (–8.6 to 3.2)	.38
Hamstring peak torque	81.9 \pm 1.9	79.4 \pm 2.0	2.6 (–2.9 to 8.0)	.36
Hamstrings average power	75.9 \pm 1.8	72.8 \pm 1.8	3.1 (–2.1 to 8.2)	.24
Hamstring average peak torque	80.7 \pm 1.9	78.4 \pm 1.9	2.2 (–3.1 to 7.6)	.41

Abbreviations: ACL, anterior cruciate ligament; CI, confidence interval; IKDC, International Knee Documentation Committee Subjective Questionnaire; LEFS, Lower Extremity Functional Scale; LSI, limb symmetry index (surgical leg/contralateral leg); ROM, range of motion.

* $P < .05$.

appointments contributed to the difference between groups with less support provided during the acute phases of recovery. Social support has been identified as an important factor affecting RTS following ACL injury, which can come from a variety of sources (family, friends, teammates, coaches, physiotherapists, trainers, etc).^{12,28} While it is possible that patients in the staged physiotherapy group may have continued to report worse outcomes on this

measure than those in usual care if they had not switched to regular in-person appointments at 3 months, this would not be appropriate for the individualized stage of the ACLR rehabilitation protocol and is not suggested in the staged rehabilitation approach. In the early stages of rehabilitation consisting of standard ROM and strength exercises, other sources of support are likely adequate and do not need to be physiotherapy specific. Patients involved in a

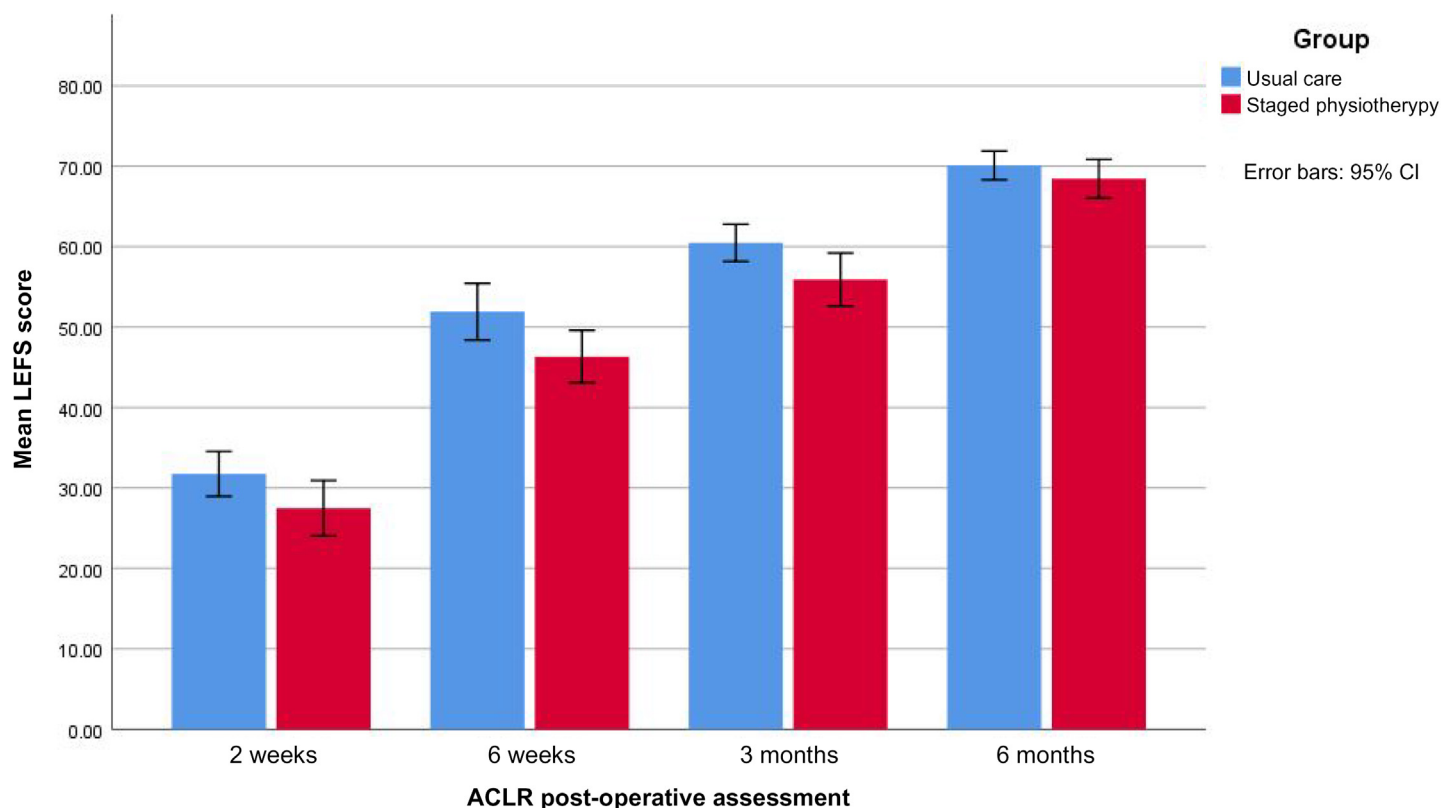


Figure 3 — Unadjusted Lower Extremity Functional Scale (LEFS) scores at ACLR postoperative assessment timepoints in the staged physiotherapy and usual care groups. ACLR indicates anterior cruciate ligament reconstruction; CI, confidence interval; LEFS, Lower Extremity Functional Scale.

staged rehabilitation program would likely benefit from education regarding utilizing these supports and active coping strategies for the early phase of recovery when physiotherapy would be less involved. In terms of safety, complication rate in this population is low and can be monitored effectively with milestone follow-up appointments with the surgeon and physiotherapist.²⁹ Although likely helpful at all stages, we hypothesize that support from a physiotherapist may be most advantageous in the sport-specific late stages of ACL rehabilitation to address psychological factors such as confidence to RTS, fear of reinjury, kinesiophobia, and self-efficacy.²⁸

Our results are consistent with previous research suggesting that there are no significant differences in outcomes between home-based and supervised approaches to ACLR rehabilitation.^{22,30–32} A 2022 systematic review and meta-analysis by Uchino et al,³¹ concluded that there were no significant differences in self-reported knee function or knee muscle strength when comparing supervised versus home-based rehabilitation following ACLR. However, this review included only 9 studies, 5 of which were included in the meta-analyses, and the body of evidence was deemed of very low quality based on the Cochrane Collaboration's Risk of Bias tool.³¹ Most studies had very small sample sizes, with only 2 studies including more than 100 patients.

Ugutmen et al³² included 104 patients randomized to a home-based (n = 52) or clinic-based rehabilitation program (n = 52) for 8 months (5 phases). Patients were assessed weekly for the first 6 weeks with ROM and strength exercise demonstrations at in-person visits and a home exercise booklet provided. Patients were then seen biweekly for the next 6 weeks and then monthly, concluding the study with a mean follow-up period of 31.1 months (range 12–66).³²

Interestingly, this model is reversed from that of the present study, with the highest frequency of physiotherapy visits in the first 6 weeks and the lowest frequency at the final stages of recovery. Despite this difference, both studies showed no significant differences between groups in patient reported or clinical outcomes. Grant et al²² conducted an adequately powered randomized controlled trial of 145 patients assigned to either home-based physiotherapy attending 4 physical therapy sessions (0, 3, 6, and 12 wk postoperative) over the first 3 months postoperative (n = 73) or to supervised physical therapy attending 17 sessions (2 sessions per week for weeks 2–7, weekly for weeks 8–12) over the first 3 months (n = 72). This is similar to the model of the present study, in which patients were seen 3 times in the first 3 months (2, 6, and 12 wk postoperative) with the potential for an extra visit(s) if not progressing as expected. In the study by Grant et al,²² all patients were provided an education booklet including information on ACL injury, surgery, and exercise instructions, pictures, progressions, and precautions. The trial outcomes including ROM, ligament laxity, and strength were categorized as clinically acceptable or unacceptable.²² At 3 months postoperative, the home-based group had a significantly higher proportion of patients with acceptable knee flexion and extension, with no other significant differences between groups.²² At long-term follow-up of 2–4 years (mean = 38 mo), there were no significant differences between groups in knee extension or flexion, ligament laxity, strength, or IKDC scores.³⁰

In the current study, the staged physiotherapy group showed a significantly larger proportion of patients with acceptable passive knee extension (surgical leg equal to the contralateral leg) at 3 months postoperative (94% vs 80%, respectively) compared with the usual care group. However, the mean difference in passive knee

extension at this timepoint was only half a degree, providing little clinical relevance. Additionally, while the staged physiotherapy group showed a significantly higher proportion of patients with acceptable passive extension at 3 months, our study was not powered to detect differences between groups for the dichotomized outcomes and this difference was not seen at 6 months.

In both the usual care and staged groups, less than half of patients had acceptable strength values (surgical leg $\geq 90\%$ contralateral leg), and less than 3 quarters had acceptable knee flexion (surgical leg equal to contralateral leg) to RTS at 6 months after surgery. A recent cohort study of 108 patients similarly reported that only 50% of patients passed RTS criteria at 6 months.²⁴ Another prospective study of 62 patients reported higher proportions (33%–80%) of patients meeting the individual criteria of Limb Symmetry Index $> 90\%$ at 6 months for various strength measures.²⁵ However, when analyzed together, only 3% of patients passed all RTS criteria at 6 months.²⁵ The low proportion of patients meeting functional performance goals and/or RTS criteria suggests that functional recovery is incomplete at 6 months and that this postoperative milestone is likely too early for RTS evaluations. In fact, the Delaware-Oslo ACL Cohort Study showed a 51% reduction in reinjury risk for every month that RTS was delayed after surgery, until 9 months.²³ A recently published ACL injury RTS consensus statement also showed unanimous agreement among experts that the time-based RTS criteria should be abandoned in clinical practice.²⁷ The length of ACLR rehabilitation protocols and timing of RTS testing should be extended beyond the length of the protocol used in this study 6 to 9, or 12 months postoperative to ensure patients meet appropriate criteria before RTS to reduce the risk of reinjury.

The current body of evidence suggests that a home-based rehabilitation program could be equally as reliable as a home-based program, with the potential to save time and money.^{30–32} However, more high-quality and rigorous research is required to increase confidence in this messaging. This study focused on rehabilitation supervision at 3 to 6 months post-ACLR, but the timing at which supervision, support, and motivation is beneficial may be different for individual patients. The willingness to be flexible in the delivery of an ACLR rehabilitation programs and alter periods of supervision and home-based care throughout one patient's care based on additional factors not addressed in this study such as self-efficacy, funding, patient goals, and recovery progression may increase the likelihood of a successful outcome.

Strengths and Limitations

This study's strengths lie in its rigorous methodology, including the randomization process and blinding procedures. To our knowledge, this trial of staged versus traditional supervised physiotherapy is the largest to date. However, despite enrolling an adequate number of participants into the study for our primary analysis, missing mid-point data required addressing through multiple imputation. Finally, our secondary analysis was underpowered for the dichotomization of select outcome measures into acceptable and unacceptable levels but was exploratory in nature. Wide confidence intervals indicate imprecise results among some outcomes which prevent us from concluding with certainty, that a stage rehabilitation protocol provides similar outcomes to in-person, supervised rehabilitation.

Psychological factors such as perceived support, self-efficacy, confidence, and motivation are often discussed as important confounding factors, which may influence how effective a home-based or supervised rehabilitation program is for an individual patient.³⁰ If such an approach is chosen, effective early education with clear

messaging is likely critical to establish buy-in from the patient and a common understanding of the program progression, goals, and expectations. These factors not being assessed is a limitation of the present study and should be included in future research. Previous research in this area emphasizes the importance of a home exercise booklet, careful selection of compliant patients, and periodic follow-up with a physiotherapist as important ingredients for a successful home program, however, the influence of these program components have not been formally assessed.^{31,32} The use of patient factors will be critical to individualize the decision for a supervised or home-based rehabilitation program.

Our study protocol included 6 months of rehabilitation, which we have concluded is too short to achieve functional outcomes. Therefore, the effects of staged physiotherapy on long term (1–5 y postoperative) functional and patient reported outcomes, RTS, and secondary injury rates remain unclear. More longitudinal research incorporating the aforementioned confounding patient factors and evaluating long-term outcomes is needed to determine if a staged format for physiotherapy following ACLR is appropriate.

Conclusion

A staged approach to rehabilitation (shifting the frequency of in-person visits from early to late phase rehabilitation) following ACLR does not appear to influence patient reported or functional outcomes within the first 6-month postsurgery when compared with usual care physiotherapy. More longitudinal and multicenter research is needed to determine if a staged format for physiotherapy following ACLR is appropriate for all patient groups and evaluate its impact on long-term functioning, including RTS.

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