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Role of Prehabilitation in Improving Outcomes after Anterior Cruciate Ligament Reconstruction

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Learning Point of the Article:

Pre-operative strengthening and neuromuscular training improve quadriceps strength and reduce pain before ACL reconstruction. Patients undergoing prehabilitation demonstrate better post-operative functional recovery and faster return to independent mobility.

Abstract

Introduction: Anterior cruciate ligament (ACL) injury is a frequent orthopedic problem which commonly leads to knee instability, loss of function, and delay in recovery. Even though ACL reconstruction (ACLR) is a common procedure, there are significant differences in the results that follow the procedure. Recent data indicate that prehabilitation, which is a rehabilitation performed before surgery, can enhance post-operative outcomes; although its use has not been widely incorporated into clinical practice yet.

Objectives: The objective of the study was to determine the efficacy of structured prehabilitation in enhancing the pain, muscle strength, functional outcomes, range of motion, and early post-operative recovery after ACLR.

Materials and Methods: A prospective comparative interventional study was done on 50 patients who had primary ACL repair in a tertiary care hospital. The participants were separated into two groups: Group A (n = 25) underwent a structured prehabilitation before surgery, and Group B (n = 25) underwent the usual care that did not involve prehabilitation. Prehabilitation involved strengthening, range-of-motion, balance, proprioception, and patient education. The two groups were subjected to the same post-operative rehabilitation program. Measures of outcomes such as strength of the quadriceps, pain level with the visual analog scale (VAS), knee range of motion, functional outcome scores, time to ambulate independently, and overall post-operative outcome were also evaluated.

Findings: The prehabilitation group had better pre-operative quadriceps strength (4.1 ± 0.6 vs. 3.5 ± 0.7) and low pre-operative pain scores (4.2 ± 0.9 vs. 5.1 ± 1.0). During the post-operative period, Group A had a significantly lower pain level at 6 weeks (2.1 ± 0.7 vs. 3.4 ± 0.8) and had a higher knee range of motion (128.5 ± 6.2 vs. 118.3 ± 7.1). The prehabilitation group had more favorable functional outcome scores at 3 months (86.4 ± 5.8 vs. 78.2 ± 6.4). Excellent overall results were more common in the prehabilitation group (72% vs. 40 percent of Group A vs. Group B).

Conclusion: Pre-operative structured prehabilitation before ACLR is an important factor in the management of pain post-operative, functional outcome, muscle strength, and early mobility. Prehabilitation can be implemented as a part of the standard ACLR care to potentially improve the outcomes of the surgery and recovery of patients.

Keywords: Anterior cruciate ligament reconstruction, knee function, prehabilitation, post-operative recovery, physiotherapy.

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Introduction

Anterior cruciate ligament (ACL) injury is a common knee injury in sports, especially among the young physically active population, and is likely to result in knee instability, functional loss, and premature osteoarthritis unless well managed [1]. ACL reconstruction (ACLR) is the current operation used to restore the knee stability and allow the patient to resume sports and everyday activities; nevertheless, the outcomes of the post-operative period differ significantly among patients despite the improved approach to surgery and rehabilitation regimen [2]. Recovery following ACLR is affected by a number of factors, among them being pre-operative knee functioning, muscle strength, range of motion, neuromuscular control, psychological preparedness, and compliance with rehabilitations programs [3]. The traditional focus has been on the post-operative rehabilitation time with little formal consideration on the pre-operative time. The idea of prehabilitation, which is considered to be purposeful physical and psychological interventions before surgery to increase post-operative recovery, has been gaining popularity in orthopedic and sports medicine within recent years [4]. Prehabilitation should be used to maximize the functional state of the patient before "ACLR", with a focus on quadriceps and hamstring strength, decreasing knee effusion, restoring full movement considerations, proprioception, and psychological issues such as fear of motion and low self-efficacy [5].

The weakness of the quadriceps has been thoroughly reported as one of the outcomes of ACL injury and is highly correlated with poor functional results after ACLR [6]. Research has revealed that patients who arrive in surgery with excellent quadriceps strength and neuromuscular control portray quicker recovery of strength after surgery and excellent functional performance [7]. Furthermore, pre-operative losses in knee extension and sustained swelling have been associated with arthrofibrosis, slow rehabilitation, and poor long term recovery after reconstruction [8]. The strength training, neuromuscular, balance training, and movement retraining have been proved to be effective in prehabilitation programs to enhance pre-operative functional scores and minimize post-operative deficits [9]. Moreover, symmetrical movement pattern restoration in the pre-operative phase can help to eliminate maladaptive motor strategies that remain after surgery [10].

In addition to physical conditioning, psychological preparation is also important in post-ACLR recovery. Kinesiophobia, fear of reinjury, and lack of confidence have been found out to be significant impediments to return to sport (RTS) even with patients who have good physical recovery [11]. Prehabilitation offers a chance to teach patients about their surgery, the post-operative experience, and the milestones of rehabilitation, and decrease anxiety and enhance motivation and compliance to the post-operative rules [12]. There is evidence to indicate that patients undergoing organized pre-operative programs achieve better patient-reported outcome measures, an increased rate of RTSs, as well as overall patient satisfaction following ACLR [13].

Although more and more evidence is pointing towards prehabilitation, it is still not fully adopted in clinical practice because of time-constrains, limited resources, and poorly standardized protocols [14]. In addition, the difference in the program length, exercise elements, and results of the studies has led to the heterogeneity of the results, and it is hard to conclude about the effectiveness of the program in general. In underdeveloped countries such as India may have shortage of monitored pre-operative rehabilitation, and the role of prehabilitation in enhancing surgical outcomes is not well studied. To come up with cost-effective evidence-based care pathways, it is important to understand how prehabilitation affects post-operative pain, functional recovery, muscle strength, and return-to-activity. Hence, the present research should be a comparative assessment of the benefits of structured prehabilitation in enhancing post-operative outcomes after ACLR, aimed at maximizing the recovery, increasing the functional performance, and quality of life of ACLR patients.

Materials and Methods

Study design

This study was conducted as a multicentric, prospective, comparative, interventional study across the Departments of Orthopedics and Physiotherapy at multiple tertiary care teaching hospitals. The study protocol was approved by the Institutional Ethics Committees of all participating centers, and written informed consent was obtained from all patients before inclusion in the study.

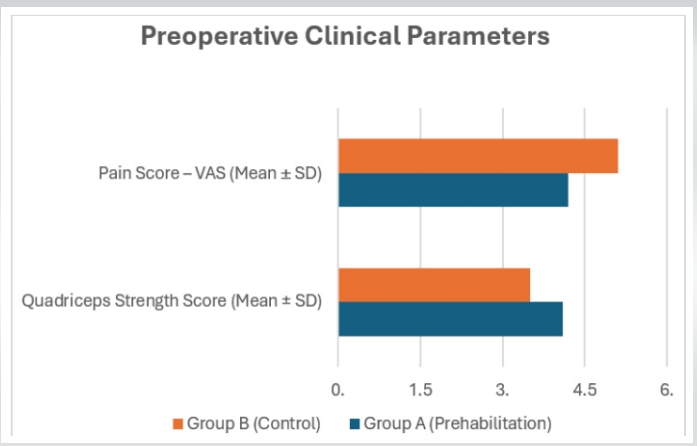

Figure 1: Preoperative Clinical Parameters

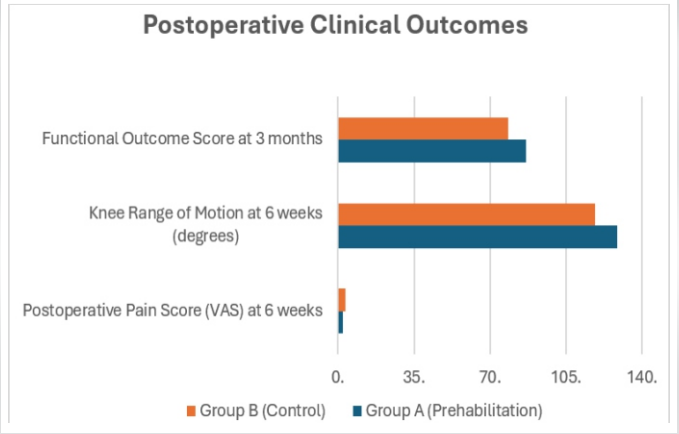

Figure 2: Postoperative Clinical Outcomes

Study setting

The study was carried out in collaboration between the Departments of Orthopaedics and Physiotherapy at participating tertiary care teaching hospitals. All surgical procedures were performed by experienced orthopedic surgeons at their respective centers, and rehabilitation sessions were supervised by qualified physiotherapists following standardized protocols to ensure uniformity of treatment across all study sites.

Study duration

The total duration of the study was 12 months. This period included patient recruitment, implementation of the prehabilitation protocol, surgical intervention, post-operative rehabilitation, and follow-up assessments. Each participant was followed from the pre-operative period until completion of the early post-operative rehabilitation phase.

Participants

Patients diagnosed with ACL injury and planned for ACLR were screened for eligibility.

Inclusion criteria

- Patients aged between 18 and 45 years
- Clinically and radiologically confirmed ACL tear
- Patients planned for primary ACLR
- Patients willing to participate and provide informed consent
- Patients able to follow rehabilitation instructions.

Exclusion criteria

- Multiligament knee injuries
- Associated fractures around the knee
- Previous surgery on the affected knee
- Advanced osteoarthritis of the knee joint
- Neurological disorders affecting lower limb function
- Patients medically unfit for surgery or exercise therapy.

Study sampling

A non-probability purposive sampling technique was used to select participants who met the inclusion criteria. Eligible patients presenting to the orthopedic outpatient department during the study period were approached consecutively and enrolled after obtaining informed consent.

Study sample size

The total sample size for the study was 50 participants. The sample size was determined based on feasibility, availability of eligible patients during the study period, and institutional constraints. All enrolled participants completed the study protocol.

Study groups

Participants were divided into two equal groups, with 25 patients in each group.

- Group A (Prehabilitation Group): Patients received a structured prehabilitation program before ACLR in addition to standard post-operative rehabilitation.
- Group B (Control Group): Patients received standard care without structured prehabilitation and underwent routine post-operative rehabilitation only.

Study parameters

The following parameters were assessed to evaluate outcomes:

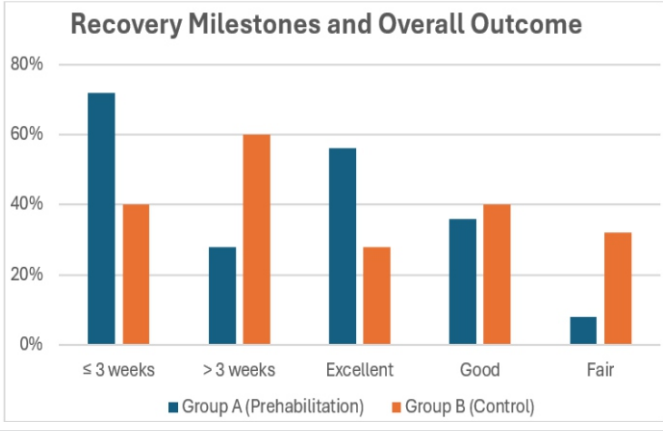

Figure 3: Recovery Milestones and Overall Outcome

Table 1: Demographic and clinical characteristics of participants			
Variable	Group A (Prehabilitation) n=25 (%)	Group B (Control) n=25 (%)	Total (%)
Age group (years)			
18–25	9 (36)	8 (32)	17 (34)
26–35	11 (44)	12 (48)	23 (46)
36–45	5 (20)	5 (20)	10 (20)
Gender			
Male	19 (76)	18 (72)	37 (74)
Female	6 (24)	7 (28)	13 (26)
Side of ACL injury			
Right knee	14 (56)	15 (60)	29 (58)
Left knee	11 (44)	10 (40)	21 (42)
ACL: Anterior cruciate ligament			

- Quadriceps and hamstring muscle strength
- Knee range of motion
- Pain intensity using VAS
- Functional outcome using standardized knee scoring systems
- Time to achieve post-operative rehabilitation milestones
- Patient-reported functional recovery

These parameters were assessed preoperatively and during the post-operative follow-up period.

Study procedure

On recruitment, a baseline of demographic and clinical information was collected among all the participants. Group A patients went through a formal pre-operative course of a specified time before surgery. The program involved strengthening exercises of the quadriceps and hamstrings, range-of-motion exercises, balance and proprioceptive training, and patient education as per post-operative expectations. Group B patients were not given structured prehabilitation and took standard pre-operative advice. The participants were then all subjected to arthroscopic ACLR done in the normal surgical procedures. Both groups also received the same standardized rehabilitation protocol to ensure a reduction in treatment bias in the post-operative period.

Study data collection

Data were collected using a structured data collection form. Baseline assessments were performed before surgery, including pain scores, range of motion, and functional status. Post-operative assessments were conducted at scheduled follow-up visits. All measurements were recorded by trained assessors using standardized assessment tools to ensure consistency and reliability of data.

Data analysis

Collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences software. Descriptive statistics such as mean, standard deviation, frequency, and percentage were used to summarize demographic and clinical variables. Inferential statistics were applied to compare outcomes between the two groups. Appropriate statistical tests were used based on data distribution, and a $P < 0.05$ was considered statistically significant.

Ethical considerations

Ethical permission to conduct the study was granted by the Institutional Ethics Committee before the study began. All participants gave informed consent in writing after being informed about the objectives of the study, the procedures, the risks, and benefits. The privacy of the information of the participants was granted during the study, and they were assured of their right to leave the study any time without interfering with their medical services. The research was carried out in line with the ethical principles contained in the Declaration of Helsinki.

Results

Demographic and clinical characteristics of participants

The majority of participants were aged 26–35 years (46%), and male patients predominated (74%), which reflects the typical epidemiology of ACL injuries among young active individuals. Both groups were comparable in age, gender distribution, and side of injury, indicating baseline similarity between groups (Table 1).

Pre-operative clinical parameters

Participants who underwent prehabilitation demonstrated

Table 2: Pre-operative clinical parameters		
Parameter	Group A (Prehabilitation)	Group B (Control)
Quadriceps strength score (Mean±SD)	4.1±0.6	3.5±0.7
Pain Score–VAS (Mean±SD)	4.2±0.9	5.1±1.0
VAS: Visual analog scale, SD: Standard deviation		

Table 3: Post-operative clinical outcomes		
Parameter	**Group A (Prehabilitation)**	**Group B (Control)**
Post-operative pain score (VAS) at 6 weeks	2.1±0.7	3.4±0.8
Knee range of motion at 6 weeks (degrees)	128.5±6.2	118.3±7.1
Functional outcome score at 3 months	86.4±5.8	78.2±6.4
VAS: Visual Analog Scale		

higher quadriceps strength and lower pain scores before surgery compared to the control group, suggesting that structured pre-operative exercises improve muscle conditioning and reduce symptoms before ACLR (Table 2 and Fig. 1).

Post-operative clinical outcomes

Patients in the prehabilitation group showed lower post-operative pain, better knee range of motion, and higher functional outcome scores, indicating that prehabilitation enhances early post-operative recovery and functional performance after ACLR (Table 3 and Fig. 2).

Recovery milestones and overall outcome

A significantly higher proportion of patients in the prehabilitation group achieved early independent walking and excellent post-operative outcomes, highlighting the positive role of pre-operative rehabilitation in accelerating recovery and improving surgical outcomes (Table 4 and Fig. 3).

Discussion

The given research examined the value of the structured prehabilitation in enhancing post-operative results after ACLR and showed that the patients with pre-operative rehabilitation recorded consistently better outcomes in a variety of clinical and functional measures as compared to the patients treated with a standard care only. The study population is characterized by the demographic distribution of the participants (mostly young adults aged 2635 years, 46%, and a larger number of male participants, 74%), which is consistent with the normal epidemiology of ACL injuries, which has been reported in the literature. The comparability of the baseline between the prehabilitation and the control group, considering age, sex distribution, and side of injury, meant that the observed post-operative differences could be due to the influence of prehabilitation and not the intervening factors. Among the most significant results of the given study was the fact that the pre-operative quadriceps strength was clearly more advanced in the prehabilitation group (4.1 ± 0.6) as opposed to the control group (3.5 ± 0.7). This result is similar to the systematic review conducted by Giesche et al. (2020) [15], who showed greater increases in maximal quadriceps torque between baseline and pre-reconstruction in prehabilitation groups and limb symmetry index improvements over controls. This capacity to increase the quadriceps strength before surgery is a clinically significant factor since, the quadriceps weakness is a significant predictor of slow functional recovery and long-term functional deficiency after ACLR.

The current study also found the pre-operative level of pain was less in the prehabilitation group, with the mean VAS scores of 4.2 ± 0.9 as compared to the control group of 5.1 ± 1.0. Although the study of Carter et al. (2020) [16] found no consistent results about the pain reduction after prehabilitation, as one randomized controlled study reported no essential difference in the pain outcomes, the positive result obtained in the given study provides evidence that the targeted exercise and neuromuscular training can help change the perception of pain and decrease the level of joint irritability before surgery. Notably, pain after surgery decreased more, with higher VAS scores recorded at six weeks after the surgery at a significantly lower level in the prehabilitation group (2.1 ± 0.7) than the controls (3.4 ± 0.8). These results indicate the idea suggested by Fu et al. (2025), [17] when the 12-month pain control is better in the group where prehabilitation was performed, as the scores of pain in the prehabilitation group were 0.0 and 1.0 in the non-prehabilitation group.

The prehabilitation group was significantly more improved on functional recovery after ACLR. In the current research, the knee range of motion was significantly higher in patients who received prehabilitation at 6 weeks after operation (128.5 ± 6.2) than it was in controls (118.3 ± 7.1). Knee range of motion restoration is of utmost importance in the prevention of stiffness and arthrofibrosis, and these results correspond to the

Table 4: Recovery milestones and overall outcome		
Parameter	**Group A (Prehabilitation) (%)**	**Group B (Control) (%)**
Time to independent walking		
≤3 weeks	18 (72)	10 (40)
>3 weeks	7 (28)	15 (60)
Overall post-operative outcome		
Excellent	14 (56)	7 (28)
Good	9 (36)	10 (40)
Fair	2 (8)	8 (32)

conclusions of Zakharia et al. (2025), [18] documented that modern prehabilitation activities focus on impairment resolution and the restoration of the range of motion, as well as that patients following prehabilitation achieved and exceeded patient acceptable symptom state thresholds. There was also a higher functional outcome score at 3 months of post-operative period in the prehabilitation group (86.4 ± 5.8) than in the control group (78.2 ± 6.4), which indicated better recovery of knee functions. Giesche et al. (2020) [15] reported clinically significant better results of self-report knee functioning before reconstruction and at 2-year follow-up of patients receiving prehabilitation.

The positive impact of prehabilitation is further brought out by the rapid attainment of functional milestones. In the current study, 72% of patients in prehabilitation group were able to walk on their own within 3 weeks after surgery as opposed to 40% of the control group. Such a quicker recovery course resembles results by Fu et al. (2025), [17] shown that prehabilitation shortened recovery time by 2.6 weeks (7.2 weeks vs. 9.8 weeks) and was the most powerful predictor of enhanced knee functioning. On the same note, Giesche et al. (2020) [15] showed that there was a tendency to have faster RTS in prehabilitation groups, and more RTS was reported in one of the included studies at 2 years post-intervention. Even though RTS was not directly measured in the present study, the increased early functional outcomes and accelerated ambulation seen indicate a possible positive effect on the longer-term return-to-activity outcomes.

The general distribution of the post-operative outcome in the current study also supports the clinical importance of prehabilitation. There were significant improvements in 56% of the patients who took prehabilitation and fair improvement in control group (32 vs. 8) and excellent outcomes were more prevalent in prehabilitation group (56 vs. 28). Such data can be explained by the findings of Shaarani et al. (2013), [19] who showed sustained changes in single-leg hop performance and modified Cincinnati Knee Rating System over 12 weeks of post-operative in patients who received a 6-week progressive prehabilitation course. Interestingly, Shaarani et al. also reported mechanistic information, and as they noted, prehabilitation led to increased expression of hypertrophic IGF-1 genes and favorable changes in muscle fiber composition, a fact that could be partially responsible of the better functional recovery in their study and the current one.

Although Carter et al. (2020) [16] found extremely low-quality evidence and emphasize the variability of prehabilitation program content, frequency, and duration, they still found statistically significant change in quadriceps strength and single-leg hop performance at 3 months follow-up after ACLR in favor of prehabilitation. These reported benefits are thus consistent with the findings of the present study of improved quadriceps strength, functional scores, and early mobility even though the programs were designed differently and the outcome measures varied. Notably, Zakharia et al. (2025) [18] systematic review further confirms the safety and efficacy of prehabilitation with no pre-operative complications and similar post-operative complication rates as standard care, and retain functional improvements up to 10 years after operation". Even though the present study did not measure long-term outcomes, it is evident that the observed consistent early benefits indicate a positive course towards long-term recovery.

Nevertheless, in spite of its advantages, the current study has been limited in several aspects, such as the size of the sample and the duration of the follow-up recruited, which did not allow the researcher to evaluate further results of the intervention, such as returning to sport and graft survival. However, the uniformity of the gains in pain, strength, range of motion, functional scores, and recovery milestones is a compelling point that can be used to support the idea of introducing structured prehabilitation into the regular treatment of ACLR. The findings, when interpreted in conjunction with available literature, support the rising literature that prehabilitation is a safe, effective, and clinically meaningful intervention that maximizes neuromuscular preparedness, improves post-operative recovery, and patient-reported outcome after ACLR.

Conclusion

The current research finds out that prehabilitation before ACLR is an important process that helps in improving the post-surgery outcomes. Pre-operative rehabilitation patients boasted of superior quadriceps strength, pain levels, knee range of motion, faster functional milestones attained, and better overall functional outcomes than those who were only subjected to standard care. Prehabilitation established an advantageous pre-operative conditioning and neuromuscular control that developed a positive post-operative recovery in terms of patient-reported ability and earlier mobility. These conclusions uphold the importance of structured prehabilitation programs as a part and parcel of an overall ACLR management to enhance recovery and functional performance.

Clinical Message

Structured prehabilitation before ACL reconstruction significantly improves post-operative recovery, functional outcomes, and early mobility. Incorporating prehabilitation into routine ACL management may enhance surgical success and patient quality of life.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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