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Comparison of Early Versus Delayed Rehabilitation Following ACL Reconstruction

Dr. Md. Imamur Rashid[1]*, Prof. Dr. M.A. Shakoor[2], Dr. Nadia Rahman[3], Dr. Mohammad Golam Nobi[4], Dr. Mohammadullah[5]

[1]Department of Physical Medicine and Rehabilitation, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh
[2]Department of Physical Medicine and Rehabilitation, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh.
[3]Department of Physical Medicine and Rehabilitation, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh.
[4]Department of Physical Medicine and Rehabilitation, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh.
[5]Department of Prosthodontics, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh

ABSTRACT

Background: Anterior cruciate ligament (ACL) injury is a common orthopedic condition affecting physically active individuals and often results in knee instability, reduced functional capacity and impaired quality of life. Postoperative rehabilitation plays a crucial role in recovery following ACL reconstruction. However, the optimal timing of rehabilitation initiation remains controversial, particularly in resource-limited settings such as Bangladesh. This study aimed to compare the functional outcomes and postoperative complications between early and delayed rehabilitation following ACL reconstruction.

Methods: This comparative observational study was conducted in the Department of Physical Medicine and Rehabilitation, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh, from January to December 2021. A total of 60 patients undergoing primary unilateral arthroscopic ACL reconstruction were enrolled and divided equally into early rehabilitation (n=30) and delayed rehabilitation (n=30) groups. Functional outcomes were assessed using IKDC, Lysholm, Tegner activity, VAS pain scores, knee range of motion and postoperative stability tests. Statistical analysis was performed using SPSS version 25.0.

Results: Baseline characteristics were comparable between the groups. At six months, the early rehabilitation group demonstrated significantly higher IKDC scores (84.6±6.8 vs 78.2±7.5; p=0.001), Lysholm scores (89.1±5.9 vs 82.7±6.7; p<0.001), Tegner activity scores (6.2±1.1 vs 5.4±1.0; p=0.006) and greater knee flexion range of motion (132.4±7.1° vs 125.8±8.3°; p=0.002). Lower VAS pain scores and fewer postoperative complications were also observed in the early rehabilitation group.

Conclusion: Early rehabilitation following ACL reconstruction resulted in better functional recovery and lower complication rates than delayed rehabilitation.

KEYWORDS: ACL reconstruction, rehabilitation, early mobilization, knee function.

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INTRODUCTION

Anterior cruciate ligament (ACL) injury is one of the most common and debilitating ligamentous injuries affecting the knee joint, particularly among young active individuals and athletes participating in pivoting sports activities [1]. ACL rupture frequently results in knee instability, reduced functional performance, recurrent giving-way episodes and long-term risk of meniscal injury and osteoarthritis if not managed appropriately [2,3]. The incidence of ACL reconstruction has increased substantially worldwide over recent decades due to rising sports participation and greater awareness regarding functional restoration after injury [4,5].

Arthroscopic ACL reconstruction is currently considered the standard treatment for symptomatic ACL-deficient knees, particularly in physically active patients seeking return to sports and demanding activities [6]. Although surgical techniques and graft fixation methods have evolved considerably, postoperative rehabilitation remains a critical determinant of successful functional recovery [7]. Rehabilitation protocols following ACL reconstruction aim to restore knee stability, range of motion, muscle strength, proprioception and return-to-activity while minimizing complications such as stiffness, persistent pain, graft failure and re-injury [8].

The timing of postoperative rehabilitation following ACL reconstruction has remained a subject of ongoing debate. Early rehabilitation protocols emphasize immediate mobilization, early weight-bearing, rapid restoration of knee motion and accelerated muscle strengthening exercises [9]. Proponents of early rehabilitation suggest that early mobilization may reduce arthrofibrosis, improve quadriceps activation, facilitate faster recovery and promote earlier return to daily activities and sports participation [10,11]. Shelbourne and Nitz demonstrated favorable functional outcomes with accelerated rehabilitation strategies after ACL reconstruction [12]. Similarly, Wilk et al. reported that structured early rehabilitation may improve muscle recovery and functional performance without increasing graft laxity [13].

Conversely, delayed rehabilitation protocols advocate a more conservative postoperative approach to protect graft healing and reduce mechanical stress during the early postoperative period [14]. Several authors have raised concerns that overly aggressive

rehabilitation may increase graft elongation, tunnel widening, recurrent instability, or risk of revision surgery [15]. Beynnon et al. observed that accelerated rehabilitation protocols required careful monitoring to avoid excessive strain on the reconstructed ligament [14]. Fan et al. further highlighted that accelerated weight-bearing rehabilitation may influence graft-related outcomes and postoperative knee stability [16].

Previous studies comparing early and delayed rehabilitation have produced inconsistent findings regarding postoperative pain, functional scores, range of motion, return-to-sport outcomes and complication rates [17,18]. Some investigations reported superior short-term functional outcomes with early rehabilitation, whereas others found no significant long-term differences between protocols [19,20]. Moreover, most available studies were conducted in Western populations with limited representation from South Asian countries, including Bangladesh, where differences in healthcare access, physiotherapy resources, socioeconomic conditions and patient adherence may influence rehabilitation outcomes [21].

In Bangladesh, data regarding postoperative rehabilitation timing following ACL reconstruction remain scarce. Most tertiary-care orthopedic centers follow individualized rehabilitation approaches based on surgeon preference, patient compliance and resource availability. Consequently, there is limited local evidence to guide clinicians regarding the optimal timing of rehabilitation after ACL reconstruction in Bangladeshi patients.

Therefore, the present study was conducted to compare the functional outcomes, knee stability, return-to-activity status and postoperative complications between early and delayed rehabilitation following ACL reconstruction in a tertiary-level hospital in Bangladesh. The findings of this study may contribute to evidence-based rehabilitation planning and help optimize postoperative recovery strategies in resource-limited clinical settings.

MATERIALS & METHODS

This comparative observational study was conducted in the Department of Physical Medicine and Rehabilitation, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh, from January to December 2021. The study aimed to compare the clinical and functional outcomes of early versus delayed rehabilitation following arthroscopic anterior cruciate ligament (ACL) reconstruction. The study population consisted of patients aged 18 to 50 years who underwent primary unilateral ACL reconstruction in the study center during the study period. A total of 60 participants were enrolled consecutively and divided equally into two groups: early rehabilitation group (n=30) and delayed rehabilitation group (n=30).

Selection Criteria:

Inclusion Criteria

- Patients aged between 18 and 50 years
- Patients undergoing primary unilateral arthroscopic ACL reconstruction
- Patients willing to participate in the study and provide informed written consent
- Patients available for regular postoperative follow-up
- Patients undergoing rehabilitation according to the institutional rehabilitation protocol

Exclusion Criteria

- Previous ACL reconstruction or revision surgery
- Bilateral ACL injury
- Multi-ligament knee injury
- Advanced osteoarthritis of the knee joint
- Associated fracture around the knee joint
- Neuromuscular disorders affecting lower limb function
- Severe systemic illness interfering with rehabilitation
- Incomplete follow-up or noncompliance with rehabilitation protocol

DATA COLLECTION PROCEDURE

Data were collected using a structured case record form designed specifically for the study. Eligible patients were identified from the orthopedic outpatient department and inpatient ward following arthroscopic ACL reconstruction. After obtaining informed written consent, baseline demographic and clinical information including age, sex, body mass index, mechanism of injury, associated meniscal injury and duration from injury to surgery were recorded. Patients were then categorized into two groups according to the timing of initiation of postoperative rehabilitation. The early rehabilitation group started supervised rehabilitation within one week after surgery, whereas the delayed rehabilitation group-initiated rehabilitation after three weeks. Both groups underwent standardized rehabilitation protocols under the supervision of trained physiotherapists and orthopedic surgeons.

Functional outcomes were assessed using validated scoring systems including the International Knee Documentation Committee (IKDC) subjective knee score, Lysholm knee score, Tegner activity score, Visual Analog Scale (VAS) for pain assessment and knee range of motion measurements using a standard goniometer. Postoperative knee stability was evaluated clinically using Lachman and Pivot Shift tests. Muscle strength and functional performance were assessed through quadriceps strength testing and single-leg hop symmetry evaluation during follow-up visits. Data were collected during scheduled postoperative follow-up visits at six and nine months after surgery.

All clinical assessments were performed using uniform methods to maintain consistency and reduce observer bias. Patient confidentiality and privacy were maintained throughout the study by coding participant information and restricting data access only to the research team. All collected data were verified, cross-checked and entered carefully into a secured database to ensure reliability and accuracy.

Statistical Analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 25.0. Continuous variables were expressed as mean ± standard deviation and compared using the independent sample t-test. Categorical variables were presented as frequency and percentage and analyzed using the Chi-square test or Fisher's exact test where appropriate. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1. Baseline demographic and clinical characteristics of the study participants (N=60)

Variables	Early Rehabilitation (n=30)	Delayed Rehabilitation (n=30)	p-value
Age (years), mean ± SD	27.8 ± 5.6	28.9 ± 6.1	0.468
Male, n (%)	24 (80.0)	23 (76.7)	0.754
BMI (kg/m²), mean ± SD	24.3 ± 2.7	24.8 ± 2.9	0.492
Time from injury to surgery (weeks), mean ± SD	5.8 ± 1.9	6.2 ± 2.1	0.438
Sports-related injury, n (%)	21 (70.0)	19 (63.3)	0.584
Associated meniscal injury, n (%)	11 (36.7)	13 (43.3)	0.598
Preoperative IKDC score, mean ± SD	46.9 ± 7.5	45.8 ± 8.1	0.589
Preoperative Lysholm score, mean ± SD	48.7 ± 8.4	47.9 ± 7.8	0.703
Preoperative VAS pain score, mean ± SD	7.1 ± 1.0	7.3 ± 0.9	0.412

Table 1 presents the baseline demographic and clinical characteristics of the study participants. The mean age was comparable between the early rehabilitation group (27.8±5.6 years) and the delayed rehabilitation group (28.9±6.1 years). Male patients predominated in both groups, accounting for 80.0% and 76.7%, respectively. Mean BMI, duration from injury to surgery, frequency of sports-related injury and associated meniscal injury were also similar between the groups. Preoperative IKDC, Lysholm and VAS pain scores showed no statistically significant differences, indicating comparable baseline clinical status.

Table 2. Comparison of functional outcomes at 6 months following ACL reconstruction

Functional outcome measures	Early Rehabilitation (n=30)	Delayed Rehabilitation (n=30)	Mean Difference	p-value
IKDC score, mean ± SD	84.6 ± 6.8	78.2 ± 7.5	6.4	0.001
Lysholm knee score, mean ± SD	89.1 ± 5.9	82.7 ± 6.7	6.4	<0.001
Tegner activity score, mean ± SD	6.2 ± 1.1	5.4 ± 1.0	0.8	0.006
Knee flexion ROM (degrees), mean ± SD	132.4 ± 7.1	125.8 ± 8.3	6.6	0.002
Extension lag >5°, n (%)	2 (6.7)	7 (23.3)	—	0.072
VAS pain score, mean ± SD	1.8 ± 0.8	2.6 ± 1.0	-0.8	0.001

Table 2 describes the comparison of functional outcomes at six months following ACL reconstruction. The early rehabilitation group demonstrated higher mean IKDC scores (84.6±6.8 vs 78.2±7.5), Lysholm knee scores (89.1±5.9 vs 82.7±6.7) and Tegner activity scores (6.2±1.1 vs 5.4±1.0) compared to the delayed rehabilitation group. Mean knee flexion range of motion was greater in the early rehabilitation group (132.4±7.1 degrees) than in the delayed rehabilitation group (125.8±8.3 degrees). The delayed rehabilitation group showed a higher proportion of extension lag greater than 5°. The mean postoperative VAS pain score was lower in the early rehabilitation group.

Table 3. Comparison of postoperative knee stability and return-to-activity outcomes at 9 months

Variables	Early Rehabilitation (n=30), n (%)	Delayed Rehabilitation (n=30), n (%)	p-value
Negative Lachman test	26 (86.7)	22 (73.3)	0.197
Negative Pivot Shift test	25 (83.3)	20 (66.7)	0.136
Single-leg hop symmetry >90%	22 (73.3)	15 (50.0)	0.048
Return to pre-injury activity level	21 (70.0)	14 (46.7)	0.067
Quadriceps strength deficit <15%	24 (80.0)	17 (56.7)	0.049
Subjective satisfaction ("good/excellent")	27 (90.0)	21 (70.0)	0.053

Table 3 shows postoperative knee stability and return-to-activity outcomes at nine months. Negative Lachman and Pivot Shift

test findings were more frequent in the early rehabilitation group. A higher proportion of patients in the early rehabilitation group achieved single-leg hop symmetry greater than 90%, demonstrated quadriceps strength deficit below 15% and returned to their pre-injury activity level. Subjective satisfaction rated as “good” or “excellent” was also higher among patients receiving early rehabilitation.

Table 4. Postoperative complications and adverse outcomes during follow-up

Complications	Early Rehabilitation (n=30), n (%)	Delayed Rehabilitation (n=30), n (%)	p-value
Knee stiffness/arthrofibrosis	2 (6.7)	6 (20.0)	0.129
Persistent knee swelling	3 (10.0)	8 (26.7)	0.095
Recurrent instability episodes	2 (6.7)	5 (16.7)	0.228
Superficial wound infection	1 (3.3)	1 (3.3)	
Re-hospitalization for knee-related symptoms	1 (3.3)	4 (13.3)	0.161
Overall complication rate	5 (16.7)	12 (40.0)	0.044

Table 4 presents postoperative complications and adverse outcomes during follow-up. Knee stiffness, persistent swelling, recurrent instability episodes and re-hospitalization for knee-related symptoms were more common in the delayed rehabilitation group. Superficial wound infection occurred equally in both groups. The overall complication rate was higher among patients receiving delayed rehabilitation compared with those undergoing early rehabilitation.

DISCUSSION

The present comparative observational study evaluated the outcomes of early versus delayed rehabilitation following arthroscopic ACL reconstruction among Bangladeshi patients treated at a tertiary-level hospital. The findings demonstrated that patients who underwent early rehabilitation achieved significantly better functional outcomes, improved range of motion, lower postoperative pain scores, superior muscle recovery and fewer overall complications compared with those who underwent delayed rehabilitation.

In the current study, the mean age of the participants was 27.8±5.6 years in the early rehabilitation group and 28.9±6.1 years in the delayed rehabilitation group. Male predominance was observed in both groups. These findings are consistent with the epidemiological trends reported by Sanders et al., who observed that ACL injuries predominantly affect young active adults and males involved in sports-related activities [1]. Similar demographic distributions were also reported by Herzog et al. and Zhang et al., who demonstrated increasing incidence of ACL reconstruction among physically active younger populations [4,5].

Baseline preoperative IKDC, Lysholm and VAS pain scores were comparable between the two groups in the present study, indicating homogeneity before rehabilitation initiation. Similar baseline comparability was maintained in the randomized trial conducted by Frobell et al., which evaluated outcomes after ACL injury management and emphasized the importance of balanced baseline characteristics for reliable comparison [6].

A major finding of this study was the significantly higher postoperative functional scores among patients receiving early rehabilitation. At six months, the early rehabilitation group achieved significantly better IKDC scores (84.6±6.8 vs 78.2±7.5), Lysholm scores (89.1±5.9 vs 82.7±6.7) and Tegner activity scores (6.2±1.1 vs 5.4±1.0). These results are comparable with the findings of Heijne and Werner, who reported that early initiation of quadriceps strengthening exercises improved functional recovery after ACL reconstruction [22]. Similarly, Wilk et al. emphasized that accelerated rehabilitation protocols may facilitate earlier restoration of muscle function, proprioception and knee mechanics without adversely affecting graft integrity [13].

The present study also demonstrated superior postoperative knee flexion range of motion in the early rehabilitation group. Mean knee flexion was 132.4±7.1 degrees in the early rehabilitation group compared with 125.8±8.3 degrees in the delayed rehabilitation group. Furthermore, extension lag greater than 5 degrees was less frequent among patients undergoing early rehabilitation. These findings are supported by Bottoni et al., who observed improved postoperative range of motion and lower incidence of stiffness with earlier mobilization protocols after ACL reconstruction [23]. van Grinsven et al. also highlighted that controlled early mobilization contributes to the prevention of arthrofibrosis and enhances the restoration of normal joint movement [8].

Pain reduction was another important finding in the current study. Patients in the early rehabilitation group had significantly lower VAS pain scores at follow-up than those in the delayed rehabilitation group. Similar observations were reported by Shelbourne and Nitz, who demonstrated that accelerated rehabilitation combined with early weight-bearing reduced postoperative discomfort and improved patient confidence during recovery [12]. Tyler et al. also found that immediate weight-bearing after ACL reconstruction improved patient comfort without increasing complications [24].

Regarding postoperative knee stability, the current study found higher rates of negative Lachman and Pivot Shift tests among patients receiving early rehabilitation, although statistical significance was not reached. However, functional performance outcomes such as single-leg hop symmetry and quadriceps strength recovery were significantly better in the early rehabilitation group. These findings correspond with the study by Grindem et al., who emphasized the importance of neuromuscular recovery

and functional performance in successful rehabilitation after ACL reconstruction [25]. Kaplan and Witvrouw further noted that adequate restoration of strength and functional symmetry is essential before return to sports participation [26].

Return to pre-injury activity level was achieved in 70.0% of patients undergoing early rehabilitation compared with 46.7% in the delayed rehabilitation group. Although the difference did not reach statistical significance, the trend favored earlier rehabilitation. Similar findings were observed by Ardern et al., whose systematic review demonstrated that rehabilitation quality and timing significantly influence return-to-sport outcomes after ACL reconstruction [27]. Battaglia et al. also reported that accelerated rehabilitation and earlier return-to-play protocols may positively affect functional recovery and sports participation when appropriately supervised [28].

The present study additionally demonstrated a lower overall complication rate in the early rehabilitation group. Knee stiffness, persistent swelling, recurrent instability and re-hospitalization were more common among patients undergoing delayed rehabilitation. The overall complication rate was significantly higher in the delayed rehabilitation group (40.0% vs 16.7%). These findings align with the work of Kruse et al., who reported that delayed restoration of motion may predispose patients to postoperative stiffness and prolonged recovery [7]. Similarly, van Melick et al. recommended evidence-based early rehabilitation strategies to reduce postoperative morbidity and improve overall clinical outcomes [11].

Concerns regarding graft laxity and graft-related complications with accelerated rehabilitation have been raised in some previous studies. Beynnon et al. reported that aggressive rehabilitation protocols require careful monitoring to prevent excessive strain on the reconstructed graft [14]. However, the current study did not observe increased instability or complication rates in the early rehabilitation group, suggesting that structured and supervised early rehabilitation may be safe and beneficial when applied appropriately.

The findings of the present study are particularly relevant in the Bangladeshi context, where rehabilitation practices after ACL reconstruction vary considerably between institutions and are often influenced by resource limitations, patient adherence and accessibility to physiotherapy services. The study provides local evidence supporting structured early rehabilitation as an effective strategy for improving postoperative recovery and functional outcomes in patients undergoing ACL reconstruction.

LIMITATIONS AND RECOMMENDATIONS

The study was conducted at a single tertiary-care center with a relatively small sample size and short follow-up duration. Larger multicenter longitudinal studies are recommended to evaluate long-term functional outcomes, graft integrity and return-to-sport performance following different rehabilitation protocols.

CONCLUSION

Early rehabilitation following arthroscopic ACL reconstruction was associated with superior functional recovery, improved range of motion, reduced postoperative pain, enhanced muscle strength and lower overall complication rates compared with delayed rehabilitation. Patients undergoing early rehabilitation also demonstrated better return-to-activity outcomes and higher subjective satisfaction. These findings support the effectiveness and safety of structured early rehabilitation protocols following ACL reconstruction in a Bangladeshi tertiary-care setting and highlight the importance of timely postoperative physiotherapy for optimal clinical recovery.

Conflicts of interest: There are no conflicts of interest.

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