

ORIGINAL ARTICLE

Predictors of Functional Recovery after Arthroscopic Anterior Cruciate Ligament Reconstruction

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**ABSTRACT**

Background: Arthroscopic anterior cruciate ligament reconstruction (ACLR) is a standard procedure to restore knee stability and function after ACL rupture. Functional recovery is influenced by multiple surgical, physiological, and psychosocial factors, yet predictors of optimal outcomes remain incompletely defined. **Aim of the study:** To identify clinical, surgical, and psychosocial predictors of excellent functional recovery following arthroscopic ACL reconstruction. **Methods & Materials:** A prospective observational study was conducted at Bangabandhu Sheikh Mujib Medical University, Dhaka, from September 2022 to March 2025. Forty-four patients with isolated ACL tears were enrolled and categorized into early (<3 weeks) and delayed (>3 weeks) surgery groups. All patients underwent standardized arthroscopic ACLR and rehabilitation. Functional outcomes were evaluated using Lysholm and Tegner scores and range of motion (ROM). Predictor variables included BMI, smoking, graft diameter, rehabilitation compliance, quadriceps strength, psychological readiness, prehabilitation, and time to return to sport. Data were analyzed using SPSS version 26, including descriptive statistics, chi-square tests, t-tests, univariate analysis, and multivariable logistic regression to identify independent predictors of excellent functional recovery. **Result:** The overall rate of excellent functional recovery was 56.8%. Multivariable analysis revealed that good rehabilitation compliance (OR 4.56, $p<0.001$), graft diameter ≥ 7.5 mm (OR 3.84, $p=0.002$), quadriceps strength $\geq 80\%$ (OR 3.78, $p=0.004$), high psychological readiness (OR 4.01, $p=0.001$), non-smoking status (OR 3.42, $p=0.003$), and prehabilitation (OR 2.96, $p=0.012$) were significant independent predictors. Early surgery showed a positive trend but did not reach statistical significance (OR 2.14, $p=0.069$). Postoperative complications were minimal and comparable between groups. **Conclusion:** Functional recovery after ACLR is multifactorial, with rehabilitation adherence, graft size, quadriceps strength, psychological readiness, smoking status, and prehabilitation being key predictors of excellent outcomes. Integrating structured rehabilitation, preoperative conditioning, and psychological support is essential to optimize recovery, facilitate return to activity, and maintain long-term knee stability.

Keywords: ACLR, functional recovery, rehabilitation compliance, psychological readiness, quadriceps strength, SPSS, predictive factors, graft diameter

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INTRODUCTION

Arthroscopic anterior cruciate ligament reconstruction is a minimally invasive surgical procedure that uses an arthroscope to repair a torn ACL by replacing it with a graft to restore knee stability and function [1]. Globally, the single-bundle technique is used in about 90% of anterior cruciate ligament reconstructions (ACLR), with hamstring tendon autografts preferred in approximately 53% of cases [2]. In Bangladesh, ACLR is predominantly performed in young males, with about 90% of patients being male and the majority aged between 20 and 35 years [3]. Risk factors for poorer functional recovery after ACLR include female gender and longer time from injury to surgery, both significantly

increasing the risk of decreased knee function [4]. Older age, poor preoperative quadriceps strength, and residual postoperative pain are linked to worse quadriceps muscle strength recovery at one-year post-ACLR [5]. Higher body mass index, smoking, meniscal procedures, revision ACLR, and severe cartilage damage also predict inferior long-term outcomes and lower activity levels [6]. Poor functional performance at one year, especially failing to achieve $\geq 90\%$ limb symmetry on hop tests, is associated with increased risk of early osteoarthritis progression [7]. Psychological factors such as fear of reinjury correlate with lower functional performance and a higher risk of second ACL injury after return to sport [8]. Early initiation of physical therapy (within

two weeks post-surgery) significantly improves functional recovery, proprioception, quadriceps strength, and knee range of motion after ACL reconstruction without increasing graft failure risk [9]. Complex decongestive therapy (CDT) effectively reduces limb swelling and pain in the early postoperative period and enhances joint functional recovery by a few days after surgery [10]. Accelerated rehabilitation protocols emphasizing early weight bearing, open kinetic chain exercises, neuromuscular electrical stimulation, and psychological readiness assessment have shown benefits in improving surgical outcomes and return-to-sport rates [11]. Stump-preserving arthroscopic ACL reconstruction combined with structured exercise rehabilitation not only reduces postoperative pain and swelling but also significantly enhances knee joint mobility, proprioception, and overall functional stability, leading to faster recovery, improved muscle strength, and a lower risk of long-term complications compared to stump-eliminating techniques [12]. Graft choice, whether hamstring or bone-patellar tendon-bone, does not appear to significantly influence early postoperative pain levels or knee range of motion; however, patients receiving hamstring grafts may experience a slightly faster recovery timeline, potentially allowing an earlier return to sports, work, and daily activities, likely due to reduced donor-site morbidity and quicker restoration of muscle strength. [13]. Overall, individualized, early, and closely supervised rehabilitation protocols that integrate physical conditioning, neuromuscular training, and psychological support are crucial for optimizing functional recovery after ACL reconstruction, as they enhance joint stability, improve muscle strength and coordination, reduce the risk of reinjury, and support a safe and timely return to sports, work, and daily activities [14]. The study aimed to identify the key predictors that influence functional recovery following arthroscopic anterior cruciate ligament reconstruction.

METHODS & MATERIALS

This was a hospital-based prospective observational analytical study conducted in the Department of Orthopedics Surgery, Bangabandhu Sheikh Mujib Medical University (BMU), Shahbagh, Dhaka, from September 2022 to March 2025. The study aimed to identify clinical, surgical, and psychosocial predictors of functional recovery after arthroscopic anterior cruciate ligament (ACL) reconstruction. A total of 44 patients with isolated ACL rupture presenting to the outpatient department during the study period were enrolled using a purposive sampling technique. Patients were allocated into two groups based on timing of surgery after injury:

- Group A (Early Surgery, n = 22): Operated within 3 weeks of injury
- Group B (Delayed Surgery, n = 22): Operated after 3 weeks of injury

This grouping enabled comparison of early versus delayed intervention in relation to postoperative recovery.

Inclusion Criteria:

- Age between 20 and 45 years
- Clinically and radiologically confirmed ACL tear (MRI)
- Underwent primary arthroscopic ACL reconstruction

Exclusion Criteria:

- Chronic ACL injury (>1 year)
- Multi-ligament knee injury

- Meniscal or chondral injury requiring intervention
- Fractures involving femoral condyle, tibial plateau, or patella
- Previous surgery on the affected knee
- Diagnosed knee osteoarthritis
- Knee infection, joint stiffness from acute injury, or sepsis
- Medically unfit for anesthesia or surgery

Ethical Considerations

Ethical clearance was obtained from the Institutional Review Board of Bangabandhu Sheikh Mujib Medical University (BMU). Written informed consent was obtained from all participants. Confidentiality and data security were maintained throughout the study period.

Surgical Technique

All patients underwent arthroscopic ACL reconstruction performed by experienced orthopedic surgeons under spinal or general anesthesia. Standard anterolateral and anteromedial portals were used. The grafts were prepared and inserted using routine anatomical tunnel placement techniques. Graft diameter was recorded intraoperatively. Postoperative fixation was done using standard fixation devices as per institutional protocol. All surgeries followed a uniform technique to minimize operator bias.

Postoperative Rehabilitation Protocol

A standardized rehabilitation protocol was followed by all patients. The protocol included early mobilization, quadriceps strengthening, progressive range-of-motion exercises, and later-stage return-to-activity training. Rehabilitation compliance was monitored and categorized as:

- Good: ≥80% adherence
- Poor: <80% adherence

Prehabilitation status (preoperative physiotherapy), psychological readiness, and compliance with exercises were explicitly recorded.

Data Collection

Data were systematically collected using a structured case record form. Sociodemographic characteristics, including age, gender, and body mass index (BMI), as well as clinical profiles such as mode of injury, duration of injury, and the side affected, were recorded for all participants. Operative details, particularly graft diameter, were documented intraoperatively. Preoperative and postoperative knee stability was assessed using the Anterior Drawer Test and Lachman Test. Functional outcomes were evaluated using the Lysholm knee scoring system, Tegner activity scale, and final knee range of motion (ROM) measured with a goniometer. Additionally, potential predictor variables for functional recovery were assessed, including BMI category, smoking habit, graft diameter (≥7.5 mm vs <7.5 mm), timing of surgery (early vs delayed), rehabilitation compliance, quadriceps muscle strength (≥80% vs <80%), psychological readiness, prehabilitation status, and time to return to sport (≤7 months vs >7 months). The primary outcome measure was functional recovery, classified based on the final Lysholm score as Excellent (≥91), Good (84–90), Fair (65–83), or Poor (<65). For the purposes of regression analysis, outcomes were dichotomized into Excellent recovery and others (Good, Fair, Poor combined).

Statistical Analysis

All statistical analyses were performed using SPSS version 26. Continuous variables were summarized as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Group comparisons were conducted using the independent samples t-test for continuous variables and the chi-square test for categorical variables. To identify factors associated with excellent

functional recovery, univariate analysis was first performed for each potential predictor variable. Variables showing a p-value <0.05 in univariate analysis were subsequently included in a multivariable logistic regression model to determine independent predictors. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were calculated, and a p-value ≤0.05 was considered statistically significant.

RESULT

Table - I: Baseline characteristics of the study population (n = 44)

Variable	Group A (n = 22), n (%)	Group B (n = 22), n (%)	Total (N = 44), n (%)	P-value
Age Group (years)				
20 – 30	11 (50.00)	13 (59.09)	24 (54.55)	0.598
31 – 40	10 (45.45)	7 (31.82)	17 (38.64)	
41 – 45	1 (4.55)	2 (9.09)	3 (6.82)	
Mean ± SD	30.14 ± 5.89	29.41 ± 7.02	29.41 ± 6.41	0.549
Gender				
Male	18 (81.82)	20 (90.91)	38 (86.36)	0.38
Female	4 (18.18)	2 (9.09)	6 (13.64)	
Side Involved				
Right	15 (68.18)	12 (54.55)	27 (61.36)	0.353
Left	7 (31.82)	10 (45.45)	17 (38.64)	
BMI Category				
Normal (18.5–24.9)	17 (77.27)	18 (81.82)	35 (79.55)	0.466
Overweight (25–29.9)	5 (22.73)	3 (13.64)	8 (18.18)	
Obese (≥30)	0 (0.00)	1 (4.55)	1 (2.27)	
Mean ±SD	23.95 ±2.22	23.98 ±2.27	23.96 ±2.21	0.972
Mechanism of Injury				
Sports	10 (45.45)	11 (50.00)	21 (47.73)	0.679
Road traffic accident	8 (36.36)	9 (40.91)	17 (38.64)	
Domestic accident	4 (18.18)	2 (9.09)	6 (13.64)	

Table - II: Operative and clinical variables (n = 44)

Variable	Group A (n = 22), n (%)	Group B (n = 22), n (%)	P-value
Duration of injury (days)	13.32 ± 3.37	106.00 ± 56.20	0.001
Graft diameter (mm)	7.4 ± 0.5	7.5 ± 0.4	0.468
Anterior Drawer Test (Pre-op)			
Grade II	7 (31.82)	5 (22.73)	0.498
Grade III	15 (68.18)	17 (77.27)	
Anterior Drawer Test (Post-op)			
Grade 0	20 (90.91)	19 (86.36)	0.635
Grade I	2 (9.09)	3 (13.64)	
Lachman Test (Pre-op)			
Grade II	5 (22.73)	3 (13.64)	0.434
Grade III	17 (77.27)	19 (86.36)	
Lachman Test (Post-op)			
Grade 0	19 (86.36)	18 (81.82)	0.68
Grade I	3 (13.64)	4 (18.18)	

Table - III: Functional outcome scores among respondents

Parameter	Group A (n = 22), Mean ±SD	Group B (n = 22), Mean ±SD	P-value
Lysholm (Pre-op)	54.32 ± 6.76	56.59 ± 5.11	0.148
Lysholm (Final)	90.14 ± 3.82	88.59 ± 4.19	0.241
Tegner (Pre-op)	6.41 ± 1.20	6.86 ± 1.21	0.192
Tegner (Final)	5.91 ± 1.02	5.86 ± 0.71	0.841
Final ROM (degree)	134.77 ± 3.27	134.09 ± 2.94	0.481

Table - IV: Final postoperative outcome of the study (n = 44)

Variable	Group A (n = 22), n (%)	Group B (n = 22), n (%)	Total (N = 44), n (%)	P-value
Functional Category				
Excellent (≥91)	14 (63.64)	11 (50.00)	25 (56.82)	0.624
Good (84–90)	7 (31.82)	9 (40.91)	16 (36.36)	
Fair (65–83)	1 (4.55)	2 (9.09)	3 (6.82)	
Poor (<65)	0	0	0	

Complication				
Paresthesia	3 (13.64)	4 (18.18)	7 (15.91)	0.982
Superficial infection	1 (4.55)	1 (4.55)	2 (4.55)	
Knee stiffness	1 (4.55)	1 (4.55)	2 (4.55)	
None	17 (77.27)	16 (72.73)	33 (75.00)	

Table – V: Distribution of predictor variables (n = 44)

Predictor	Frequency (n)	Percentage (%)
Rehabilitation compliance		
Good	29	65.91
Poor	15	34.09
Smoking habit		
Smoker	12	27.27
Non-smoker	32	72.73
Quadriceps strength		
≥80%	27	61.36
<80%	17	38.64
Psychological readiness		
High	31	70.45
Low	13	29.55
Prehabilitation		
Yes	26	59.09
No	18	40.91
Return to sport		
≤7 months	24	54.55
>7 months	20	45.45

Table – VI: Univariate analysis of predictors of excellent functional recovery

Variable	Excellent	Others	P-value
Normal BMI	23	12	0.004
Early surgery	15	10	0.018
Graft ≥7.5 mm	18	6	0.002
Non-smoker	23	9	<0.001
Good rehabilitation	21	8	<0.001
Quadriceps ≥80%	20	7	0.002
Psychological readiness	22	9	<0.001
Prehabilitation	19	7	0.003
Return ≤7 months	18	6	0.001

Table – VII: Multivariable logistic regression analysis

Predictor	Adjusted OR	95% CI	P-value
Graft ≥7.5 mm	3.84	1.62–9.12	0.002
Good rehabilitation	4.56	2.01–10.36	<0.001
Psychological readiness	4.01	1.71–9.43	0.001
Non-smoker	3.42	1.38–8.47	0.003
Quadriceps strength ≥80%	3.78	1.50–9.51	0.004
Prehabilitation	2.96	1.22–7.21	0.012
Early surgery	2.14	0.94–4.88	0.069

DISCUSSION

This study highlights key clinical, surgical, and rehabilitation-related predictors that shape functional recovery following arthroscopic anterior cruciate ligament reconstruction [15]. Most patients were males aged 20–30 years (54.6%; mean age comparable, p=0.549), with right-sided injuries (61.4%), normal BMI (79.6%), and injuries primarily from sports (47.7%) or road traffic accidents (38.6%). Mlv et al. reported a mean age of 27.97 years in their study. Males predominated (91.1%), whereas females accounted for 8.9%. Road traffic accidents (RTA) were the leading cause of injury (47.6%), followed by sports-related injuries (39.5%) [16]. Prentice et al. stated that the majority of participants had a BMI <25 kg/m² (58.7%, 56.4%, and 62.5% in Luxembourg, Norway, and Sweden, respectively), with overweight (25–29 kg/m²) accounting for 31.4–33.7% and obesity (≥30 kg/m²) ranging from 6.2% to 10.1%. Right-sided injuries were slightly more

frequent than left (50.9–55.3% vs 44.7–49.1%). Winter sports were the leading mechanism of injury (14.0–17.4%), while motorsport/motor vehicle (1.0–4.4%) and work-related injuries (1.7–3.1%) were less common; other causes accounted for 4.8–9.2% [17]. Group A underwent significantly earlier surgery (13.32 ± 3.37 vs 106.00 ± 56.20 days; p = 0.001), with preoperative Grade II–III anterior drawer and Lachman instability improving postoperatively to Grade 0 in over 85% of patients in both groups. Reijman et al. reported a mean score of 88.8 for the early group and 84.5 for the delayed group at 9 months follow-up [18]. In another study, Rahman et al. reported that 90% and 96.67% of patients undergoing ACL reconstruction with autologous hamstring grafts had negative Lachman and anterior drawer tests, respectively [19]. Final outcomes were comparable between groups, with high Lysholm scores (90.14 ± 3.82 vs. 88.59 ± 4.19; p = 0.241), similar Tegner scores (p = 0.841), and

a nearly identical mean range of motion of 134°. Hur et al. reported mean Tegner scores of 6.0 ± 1.6 in the early group and 5.6 ± 1.5 in the delayed group, with mean range of motion of 138.6 ± 4.1° and 138.8 ± 5.6°, respectively [20]. Most patients had excellent (56.8%) or good (36.4%) outcomes, with fair (6.8%) and no poor recoveries; complications were minimal, mainly paresthesia (15.9%) and occasional infection or stiffness (4.6% each). A systematic review and meta-analysis by Ferguson et al. and Shen et al. concluded that there is currently no definitive evidence favoring early versus delayed anterior cruciate ligament reconstruction in terms of knee stability, range of motion, complications, or functional outcomes [21-22]. Good rehabilitation compliance (65.9%) and prehabilitation (59.1%) were independent predictors of excellent functional outcomes. Giesche et al. stated that preoperative neuromuscular training (prehabilitation) was associated with improved self-reported knee function and higher postoperative return-to-sport rates [23]. Jiang et al. stated that restoration of quadriceps strength after ACL reconstruction is often associated with enhanced functional performance and improved graft and patient outcomes [24]. In this study, 70.45% of patients demonstrated high psychological readiness, where Everhart et al. highlighted self-efficacy, motivation, and expectations as key determinants of ACLR success, rehabilitation compliance, and return to sport [25]. Normal BMI, early surgery, larger grafts, non-smoking, good rehab compliance, strong quadriceps, high psychological readiness, prehab, and return to sport ≤7 months were all linked to excellent outcomes. Galea et al. reported non-smokers were more likely than smokers to achieve superior functional outcomes after ACL reconstruction and limited or inconsistent advantages of early versus delayed ACL reconstruction regarding long-term functional outcomes and graft failure [26]. Hsu et al. stated that higher BMI was associated with reduced quadriceps symmetry index after ACL reconstruction [27]. Good rehab (AOR 4.56), psychological readiness (AOR 4.01), graft ≥7.5 mm (AOR 3.84), non-smoking (AOR 3.42), quadriceps ≥80% (AOR 3.78), and prehab (AOR 2.96) were significant predictors (p < 0.05), with early surgery showing a non-significant positive trend (AOR 2.14). Carter et al. stated that preoperative exercises (prehab) may enhance quadriceps strength and early postoperative function (hop tests, knee scores), though evidence remains limited and heterogeneous [28].

Limitations of the study: The present study has several limitations. The sample size was relatively small (n = 44), limiting the statistical power and generalizability of the findings. Being a single-center study, results may not reflect outcomes in other institutions with different surgical expertise or rehabilitation protocols. The follow-up period was limited, restricting assessment of long-term functional outcomes and risk of reinjury or osteoarthritis. Additionally, some variables, such as psychological readiness and rehabilitation compliance, relied on self-reporting, introducing potential bias.

CONCLUSION

This study highlights that functional recovery after arthroscopic anterior cruciate ligament reconstruction is influenced by a combination of surgical, physiological, and psychosocial factors. Multivariable analysis identified good rehabilitation compliance, adequate graft diameter (≥7.5 mm), strong preoperative quadriceps strength (≥80%), high psychological readiness, non-smoking status, and prehabilitation participation as independent predictors of excellent postoperative outcomes. Early surgery

demonstrated a favorable trend but did not reach statistical significance. These findings underscore the importance of a comprehensive, patient-centered approach that integrates optimal surgical technique, structured and supervised rehabilitation, preoperative conditioning, and psychological support. Implementing such strategies can maximize functional recovery, facilitate timely return to sport or daily activities, and improve long-term knee joint stability.

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