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Original Article

Determining Factors Affecting Reconstruction and Rehabilitation Outcomes of Anterior Cruciate Ligament (ACL)

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Background: Clinical recovery after anterior cruciate ligament (ACL) surgery may be influenced by patient characteristics, associated intra-articular injuries, surgical factors, and rehabilitation. This study aimed to evaluate early postoperative outcomes and factors associated with unfavorable outcomes after ACL repair or reconstruction.

Methods: This prospective cohort study included adults undergoing surgical treatment for unilateral ACL rupture at Shahid Beheshti Hospital, Babol, Iran, in 2023. Patients were followed for 3 months. Demographic characteristics, body mass index, pre-injury physical activity, concomitant meniscal and articular cartilage injuries, patellar tendon autograft use, physiotherapy exposure, knee range of motion, and clinical knee stability were recorded. Overall early surgical outcome was classified as good or poor according to the original study assessment, and associated factors were explored using univariable analyses.

Results: A total of 112 patients were analyzed; the mean age was 31.75±7.61 years and 75.9% were male. Full knee range of motion was observed in 94.6% and clinical knee stability in 91.1%. Overall, 106 patients (94.6%) had a good early outcome and 6 (5.4%) had a poor outcome. Meniscal injury, articular cartilage damage, and patellar tendon autograft use were significantly more frequent among patients with poor outcomes (all $P<0.001$). Age, sex, body mass index, pre-injury physical activity, and physiotherapy duration were not significantly associated with outcome.

Conclusion: Most patients demonstrated favorable early outcomes after ACL surgery. Meniscal injury, cartilage damage, and graft-related factors were associated with poorer 3-month outcomes; however, the small number of poor outcomes limits definitive prognostic inference.

Keywords: anterior cruciate ligament; ACL repair; ACL reconstruction; early outcome; knee stability; range of motion; prospective cohort study

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Introduction

The anterior cruciate ligament (ACL) is an extrasynovial structure, with fibroblasts playing a role in its continuous remodeling and maintenance. This ligament also contributes to preventing excessive tibial rotation and varus/valgus angulation. Anterior cruciate ligament rupture is a common sports-related injury and one of the most frequent causes of requiring knee treatment in young individuals (1).

ACL injury is highly prevalent among patients and leads to knee dysfunction. In fact, the exact mechanism of ACL injury has not been clearly determined (2). Numerous studies have been conducted to identify risk factors associated with ACL rupture (3). The most common knee injury is ACL rupture (4), which is one of the most significant injuries among active individuals, with its mechanism being approximately 70% non-contact and 30% contact (5). ACL rupture reduces knee stability; furthermore, this condition can lead to problems in the athletic performance of the patient, increase the risk of subsequent meniscal injuries, and elevate the risk of premature knee joint degeneration (5).

It has been established that ACL rupture is associated with individuals' anatomy, hormones, genetics, and biomechanics. Anatomical factors are considered intrinsic factors in ACL rupture among athletes. Among these intrinsic factors, a narrow intercondylar notch and increased tibial plateau slope have been reported as risk factors for ACL injury (6).

Risk factors for ACL injuries include gender, the intercondylar notch width, ACL size, and joint laxity. Magnetic resonance imaging (MRI) is the most efficient and non-invasive method for diagnosing ACL injuries and observing knee morphology. Recently, an increasing number of studies have utilized MRI technology to evaluate various anatomical aspects of the knee joint, such as an increased tibial plateau slope and the type of intercondylar notch (7, 8). The ACL has a dual sensory and motor role, such that anterior cruciate ligament injury leads to a reduced functional level, which is not only due to the absence of the "mechanical" role of the ACL in providing knee joint stability but also due to the loss of its sensory role (9).

The incidence of anterior cruciate ligament injuries is increasing due to greater involvement in sports-related activities (10). ACL injury alters tibiofemoral kinematics, which is evidenced by an increased incidence of meniscal tears and loss of articular cartilage. Damage to this ligament leads to a loss of tibiofemoral motion balance and abnormal biomechanical behavior, placing the patellofemoral joint at risk for secondary injuries (11). Knees with anterior cruciate ligament deficiency are often observed to develop patellofemoral cartilage degeneration, accompanied by quadriceps muscle atrophy and weakness. Anterior knee pain remains one of the main complaints of these patients. Altered motion in the tibiofemoral joint creates changes in the patellofemoral joint to which it is connected (11, 12).

ACL injuries can occur as a result of excessive valgus stress and excessive external rotation of the femur on the tibia. ACL injury leads to interruption in an athletic career, and in some cases, even after successful reconstruction, prior athletic performance cannot be achieved. Therefore, evidence-based preventive interventions should be offered at least as advanced therapeutic approaches. Evaluation of ACL injury risk factors is the first step in preventive measures (13). Although the cause of ACL injuries remains unclear, many risk factors have been proposed. In addition to individual biomechanical, anatomical, and hormonal factors, environmental factors may also increase the risk of injury (14).

Patients with anterior cruciate ligament rupture experience pain, swelling, and hemarthrosis in the knee, requiring a period of initial supportive treatment including immobilization, use of anti-inflammatory drugs, followed by a period of physiotherapy (15). Since spontaneous ligament repair does not occur despite all these measures, the athlete develops knee laxity and is therefore unable to continue sports activities; moreover, due to the

complications of the rupture, they experience knee pain, weakness of the affected limb, and knee giving way even during daily activities. Consequently, in most patients with ACL rupture, surgical reconstruction using a graft procedure is necessary. Due to the surgery and its rehabilitation, the athlete must refrain from their main sport activity for at least 6 months (15). Given that direct ACL repair is not particularly successful and non-surgical conservative treatments are unsatisfactory in active individuals, factors influencing the success of surgical treatment for ACL rupture have been increasingly studied (16, 17). Identifying risk factors affecting surgical success has been investigated to minimize strategies for preventing unpleasant post-operative complications. Considering the geographical conditions and individual characteristics in each region of the country, ACL treatment outcomes may vary, and this study has not been conducted in the northern region. Therefore, the aim of this study is to determine the factors influencing the outcomes of ACL repair and reconstruction surgery.

Materials and Methods

This prospective cohort study was conducted at Shahid Beheshti Hospital, Babol, Iran, during 2023. Adult patients undergoing surgical treatment for unilateral ACL rupture were enrolled using convenience sampling and followed for 3 months after surgery. Patients were eligible if they were 18–60 years of age, had a unilateral ACL tear requiring surgical treatment, and provided informed consent to participate. Exclusion criteria included a history of previous knee surgery other than surgery for the current ACL injury, inability to complete postoperative follow-up because of relocation or loss of contact, and the need for reoperation during the follow-up period. Both ACL repair and reconstruction procedures were represented in the cohort. Of the 112 patients included in the final analysis, 102 (91.1%) underwent ACL repair without graft reconstruction, whereas 10 (8.9%) underwent ACL reconstruction using a patellar tendon autograft; no patient underwent hamstring autograft reconstruction.

The required sample size was calculated based on data from the study by Rosso et al. The calculation assumed a complete postoperative improvement rate of 57.6%, an odds ratio of 1.13 for the effect of physiotherapy on surgical outcome, a two-sided significance level of 0.05, and 80% statistical power. The minimum required sample size was estimated to be 97 patients; allowing for an anticipated 10% loss to follow-up, at least 110 participants were planned for enrollment.

At the 3-month postoperative follow-up, patients underwent clinical examination to assess knee range of motion and anteroposterior knee stability. Knee stability was evaluated using the Lachman and anterior drawer tests. Anterior tibial translation of <5 mm was considered indicative of a stable knee, whereas translation of ≥5 mm was classified as instability. The clinical examinations were performed by a resident using standard examination techniques. The examiner was not formally blinded to the type of surgical procedure, and no formal inter-rater or intra-rater reliability assessment was performed. Knee range of motion was assessed using a standard goniometric examination. Full range of motion was defined as 0–140°, and postoperative restriction of motion was recorded as limited range of motion.

Postoperative physiotherapy was provided according to the routine rehabilitation program of Shahid Beheshti Hospital. The program included progressive exercises aimed at restoring knee range of motion, reducing postoperative stiffness, improving quadriceps strength, and gradually restoring knee function. Physiotherapy exposure during the 3-month postoperative period was recorded at follow-up. Revised 06.17-2 Pre-injury physical activity was assessed using the validated Persian short form of the International Physical Activity Questionnaire (IPAQ-SF). Physical activity was expressed as metabolic equivalent minutes per week (MET-min/week), using weighting factors of 8.0 METs for vigorous activity, 4.0 METs for moderate activity, and 3.3 METs for walking. Participants were categorized as having low, moderate, or high physical activity according

to the standard IPAQ scoring criteria. Demographic and clinical variables included age, sex, body mass index (BMI), concomitant meniscal injury, associated articular cartilage damage, use of a patellar tendon autograft, pre-injury physical activity level, physiotherapy exposure, knee range of motion, and knee stability.

At the end of the 3-month follow-up, patients were categorized into good and poor early surgical outcome groups according to the classification used in the original study protocol, and demographic, clinical, surgical, and rehabilitation-related characteristics were compared between the two groups. The original thesis confirms that this good/poor classification formed part of the prespecified analysis, although it does not provide a sufficiently explicit independent operational definition of the classification; therefore, no new retrospective definition was introduced in the present manuscript.

Data were entered into Microsoft Excel and analyzed using SPSS software, version 25. Continuous variables were summarized using mean and standard deviation and, where appropriate, median and range, while categorical variables were presented as frequencies and percentages. Associations between categorical variables and surgical outcome were evaluated using Pearson's chi-square test or Fisher's exact test, as appropriate, with Fisher's exact test preferred when expected cell counts were small.

Comparisons of physiotherapy exposure between outcome groups were performed using a non-parametric test because of the small number of poor-outcome cases. All statistical tests were two-sided, and a *P*value <0.05 was considered statistically significant. The study protocol was approved by the Institutional Ethics Committee of Babol University of Medical Sciences (approval code: IR.MUBABOL. HRI.REC. 1402.121**).**

Written informed consent was obtained from all participants before enrollment.

Results

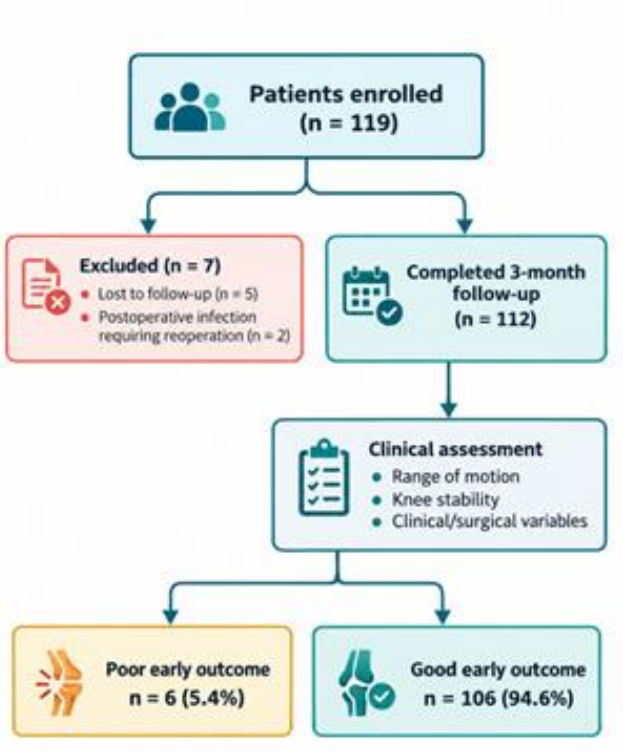


Fig 1. Patient flow through enrollment and 3-month follow-up. Of 119 initially enrolled patients, five were lost to follow-up and two were excluded after postoperative infection requiring reoperation. A total of 112 patients were included in the final analysis, of whom 106 had a good early surgical outcome and 6 had a poor early surgical outcome.

A total of 119 patients who underwent surgical treatment for anterior cruciate ligament (ACL) injury at Shahid Beheshti Hospital, Babol, Iran, during 2023 were initially enrolled. Five patients were lost to follow-up, and two were excluded after developing postoperative infection requiring reoperation approximately 1 month after the index procedure, in accordance with the predefined exclusion criteria. Therefore, 112 patients completed the 3-month follow-up and were included in the final analysis (Figure 1). The mean age of the participants was 31.75 ± 7.61 years, with a median of 30.50 years and a range of 18–49 years. Eighty-five patients (75.9%) were male and 27 (24.1%) were female. The mean body mass index (BMI) was 25.59 ± 3.73 kg/m², with a median of 25.20 kg/m² (range, 19.30–32.20 kg/m²). The mean recorded duration of physiotherapy was 8.80 ± 1.45 days, with a median of 8.75 days (range, 5–12 days) (Table 1).

Regarding pre-injury physical activity, 51 patients (45.5%) were classified as having a low activity level, 34 (30.4%) as moderate, and 27 (24.1%) as high. Concomitant meniscal injury was documented in 7 patients (6.3%), articular cartilage damage in 6 (5.4%), and patellar tendon autograft use in 10 (8.9%).

At the 3-month follow-up, 106 patients (94.6%) had full knee range of motion, whereas 6 (5.4%) had limited range of motion. Knee stability was observed in 102 patients (91.1%), while 10 (8.9%) demonstrated clinical instability (Table 2).

Table 1. Continuous Characteristics of the Study Population

Variable	Mean ± SD	Median	Range
Age, years	31.75 ± 7.61	30.50	18–49
Body mass index, kg/m²	25.59 ± 3.73	25.20	19.30–32.20
Physiotherapy duration, days	8.80 ± 1.45	8.75	5–12

Table 2. Clinical and Early Postoperative Characteristics of the Study Population

Variable	n (%)
Sex	
Male	85 (75.9)
Female	27 (24.1)
Pre-injury physical activity level	
Low	51 (45.5)
Moderate	34 (30.4)
High	27 (24.1)
Concomitant meniscal injury	
No	105 (93.8)
Yes	7 (6.3)
Articular cartilage damage	
No	106 (94.6)
Yes	6 (5.4)
Patellar tendon autograft use	
No	102 (91.1)
Yes	10 (8.9)
Knee range of motion at 3 months	
Full	106 (94.6)
Limited	6 (5.4)
Knee stability at 3 months	
Stable	102 (91.1)
Unstable	10 (8.9)
Early surgical outcome	
Good	106 (94.6)
Poor	6 (5.4)

Overall, 106 patients (94.6%) were classified as having a good early surgical outcome and 6 patients (5.4%) as having a poor early surgical outcome. For exploratory comparisons, age was categorized according to the sample median into <31 and ≥31 years. Among patients with poor outcomes, 4 of 6 (66.7%) were aged ≥31 years, compared with 52 of 106 (49.1%) patients with good outcomes. No statistically significant association was observed between age category and early surgical outcome (*P*=0.679).

Similarly, 5 of the 6 patients (83.3%) with poor outcomes were male, compared with 80 of 106 patients (75.5%) with good outcomes; this difference was not statistically significant (*P*=1.000). BMI category was also not significantly associated with surgical outcome (*P*=0.855) (Table 3).

Table 3. Association of Demographic Characteristics With Early Surgical Outcome

Variable	Poor outcome, n (%)	Good outcome, n (%)	P value
Age, years	-	-	**0.679**
<31	2 (33.3)	54 (50.9)	
≥31	4 (66.7)	52 (49.1)	
Sex	-	-	**1.000**
Male	5 (83.3)	80 (75.5)	
Female	1 (16.7)	26 (24.5)	
BMI category	-	-	**0.855**
Normal	2 (33.3)	51 (48.1)	
Overweight	3 (50.0)	38 (35.8)	
Obesity	1 (16.7)	17 (16.0)	

Data are presented as n (% within outcome group). Pearson's chi-square test or Fisher's exact test was used as appropriate.

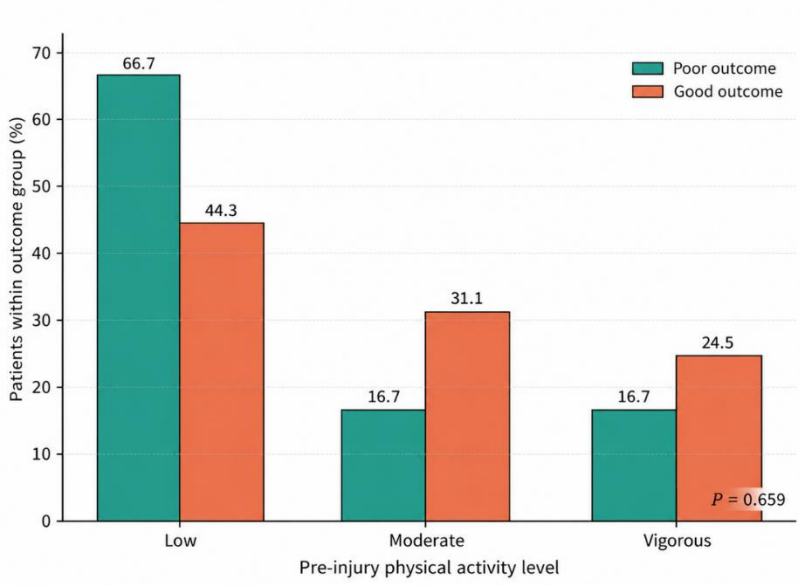


Fig 2. Distribution of pre-injury physical activity level according to early surgical outcome. Among patients with poor outcomes, 66.7%, 16.7%, and 16.7% had low, moderate, and high pre-injury physical activity, respectively. Corresponding proportions in the good-outcome group were 44.3%, 31.1%, and 24.5%. The association was not statistically significant (*P*=0.659).

Pre-injury physical activity level was not significantly associated with early surgical outcome (*P*=0.659). Among patients with poor outcomes, 4 of 6 (66.7%) had a low pre-injury activity level, whereas 1 (16.7%) had moderate and 1 (16.7%) had high activity. Among patients with good outcomes, 47 of 106 (44.3%) had low, 33 (31.1%) had moderate, and 26 (24.5%) had high pre-injury physical activity (Figure 2).

Several clinical characteristics demonstrated significant univariable associations with early surgical outcome. Concomitant meniscal injury was present in 4 of 6 patients (66.7%) with poor outcomes compared with 3 of 106 patients (2.8%) with good outcomes (OR, 68.67; 95% CI, 8.85–500.00; *P*<0.001). Articular cartilage damage was present in 4 patients (66.7%) with poor outcomes and 2 patients (1.9%) with good outcomes (OR, 104.00; 95% CI, 11.49–1000.00; *P*<0.001). Patellar tendon autograft use was recorded in 4 of 6 patients (66.7%) with poor outcomes compared with 6 of 106 patients (5.7%) with good outcomes (OR, 33.33; 95% CI, 5.05–200.00; *P*<0.001). Limited knee range of motion was observed in 3 patients (50.0%) with poor outcomes and 3 patients (2.8%) with good outcomes (OR, 34.33; 95% CI, 4.79–246.06; *P*=0.002). Knee instability showed the strongest crude association with early surgical outcome. All 6 patients (100%) with poor outcomes had an unstable knee compared with 4 of 106 patients (3.8%) with good outcomes (*P*<0.001). Because none of the patients with a poor outcome had a stable knee, the corresponding odds ratio could not be estimated because of complete separation and the resulting zero cell (Table 4). The mean physiotherapy duration was 9.55 ± 1.22 days in patients with poor outcomes and 8.76 ± 1.46 days in those with good outcomes. The between-group difference was not statistically significant (independent-samples *t* test, *P*= 0.198).

Table 4. Univariable Associations Between Clinical Characteristics and Poor Early Surgical Outcome

Clinical characteristic	Poor outcome, n (%)	Good outcome, n (%)	OR	95% CI	P value
Meniscal injury	4 (66.7)	3 (2.8)	68.67	8.85–500.00	<0.001
Articular cartilage damage	4 (66.7)	2 (1.9)	104.00	11.49–1000.00	<0.001
Patellar tendon autograft use	4 (66.7)	6 (5.7)	33.33	5.05–200.00	<0.001
Limited knee range of motion	3 (50.0)	3 (2.8)	34.33	4.79–246.06	0.002
Knee instability	6 (100.0)	4 (3.8)	NE	NE	<0.001

Values are unadjusted estimates. Percentages represent the proportion of patients within each outcome group. OR, odds ratio; CI, confidence interval; NE, not estimable because of a zero cell. Fisher's exact test was used when expected cell counts were small.

Discussion

In this prospective cohort study, most patients demonstrated favorable early clinical outcomes 3 months after ACL surgery. Overall, 94.6% of patients were classified as having a good early surgical outcome, while full knee range of motion and clinical knee stability were observed in 94.6% and 91.1% of patients, respectively. In univariable analyses, concomitant meniscal injury, articular cartilage damage, and patellar tendon autograft use were significantly more frequent among patients with poor early outcomes. In contrast, age, sex, BMI, pre-injury physical activity level, and physiotherapy duration were not significantly associated with early surgical outcome. Because only six patients experienced a poor outcome, these associations should be interpreted as exploratory and should not be considered evidence of independent prognostic effects.

The high proportion of favorable early outcomes observed in the present cohort is broadly consistent with previous reports. Khorami et al. reported favorable functional outcomes in most patients undergoing arthroscopic ACL reconstruction and demonstrated

substantial restoration of knee function and stability after surgery (19). Similarly, Shahrezaee et al. reported high rates of postoperative knee stability and restoration of range of motion following ACL reconstruction (20). Although differences in surgical technique, graft selection, follow-up duration, and outcome definitions limit direct comparison across studies, these observations support the finding that satisfactory early clinical recovery can be achieved in a substantial proportion of appropriately selected patients.

Nevertheless, favorable early range of motion and stability should not be equated with complete functional recovery. In their meta-analysis comparing bone–patellar tendon–bone and hamstring autografts, Biau et al. demonstrated that residual functional abnormalities and clinical instability may persist in a proportion of patients after ACL reconstruction (21). Similarly, Freedman et al. reported differences in clinical outcomes between patellar tendon and hamstring autografts, emphasizing that postoperative success after ACL reconstruction is multidimensional and cannot be characterized by a single clinical measure (22). Furthermore, Lohmander et al. demonstrated that ACL and meniscal injuries are associated with an increased long-term risk of knee osteoarthritis despite surgical treatment (23). Therefore, the favorable 3-month findings in the present study should be interpreted as indicators of early postoperative recovery rather than evidence of long-term restoration of knee health.

Associated intra-articular pathology appeared to be particularly relevant in the present cohort. Meniscal injury and articular cartilage damage were substantially more frequent among patients with poor early outcomes. These findings are biologically plausible because concomitant meniscal and chondral lesions may reflect greater initial injury severity and may adversely affect postoperative symptoms, joint mechanics, and rehabilitation. However, the very small number of poor outcomes resulted in wide confidence intervals, and the present data do not allow these variables to be regarded as independent predictors. Ueki et al. identified factors associated with residual pivot shift following ACL reconstruction, highlighting the importance of residual rotational instability and accompanying structural characteristics in postoperative knee function (24). Future studies incorporating detailed characterization of meniscal injury, cartilage damage, lower-limb alignment, and pre-existing degenerative changes may better define their independent contribution to postoperative outcomes.

Patellar tendon autograft use was also more frequent among patients with poor outcomes in the present study. This finding requires particularly cautious interpretation. In this cohort, patellar tendon autograft use was closely linked to the reconstruction subgroup, whereas most patients underwent ACL repair without graft reconstruction. Consequently, the observed unadjusted association cannot distinguish a graft-specific effect from differences in surgical procedure, injury severity, patient selection, or other unmeasured characteristics. The present results therefore should not be interpreted as evidence that patellar tendon autografting itself causes poorer outcomes.

Patient-related characteristics, particularly BMI, have also been investigated as potential determinants of outcome after ACL reconstruction. Kowalchuk et al., Abd Razak et al., and Naderi et al. reported associations between patient characteristics including body weight or BMI and postoperative knee function following ACL reconstruction (25–27). A systematic review of Scandinavian knee ligament registry studies similarly demonstrated that patient-related and clinical characteristics can influence patient-reported outcomes after ACL reconstruction (28). In the present study, however, BMI category was not significantly associated with early surgical outcome. This discrepancy may partly reflect the relatively small number of poor outcomes, the short follow-up period, and differences in the outcome measures used.

Harput et al. reported that higher BMI was associated with reduced quadriceps strength, lower functional capacity, and poorer functional scores following ACL

reconstruction (29). In contrast, Boyle et al., in their evaluation of long-term outcomes and influencing factors after revision ACL reconstruction, further illustrated that postoperative outcome is multifactorial and cannot be attributed to a single demographic characteristic such as BMI (30). Taken together, these findings suggest that any influence of BMI may depend on follow-up duration, rehabilitation status, associated pathology, and the specific outcome being evaluated.

Age may similarly influence recovery through biological, behavioral, and activity-related pathways. Spindler et al. demonstrated that long-term sports function following ACL reconstruction is influenced by several baseline and patient-related characteristics, whereas Corona et al. reported comparable clinical and functional outcomes in appropriately selected patients above and below 40 years of age (31,32). These findings suggest that chronological age alone may be less important than the combination of activity level, tissue quality, associated injuries, rehabilitation adherence, and patient expectations. Consistent with this interpretation, age was not significantly associated with early surgical outcome in the present cohort.

Long-term cohort data from the MOON Knee Group have further demonstrated that outcomes after ACL reconstruction are influenced by multiple patient, injury, and treatment-related factors rather than by age or activity level alone (33). Villa et al., although studying highly competitive athletes undergoing arthroscopic autologous chondrocyte implantation rather than ACL reconstruction, demonstrated that intensive rehabilitation may facilitate earlier return to sport without necessarily compromising clinical outcome (34). Because the latter study involved cartilage restoration rather than ACL reconstruction, its findings cannot be directly extrapolated to the present population, but they highlight the broader importance of rehabilitation exposure when evaluating recovery after knee surgery.

Pre-injury physical activity was not significantly associated with early outcome in the present study, although 66.7% of patients with poor outcomes belonged to the low-activity group. Naderi et al. similarly reported that sports activity level was not significantly associated with postoperative knee outcomes after ACL reconstruction (27). In contrast, long-term data from the MOON cohort suggest that baseline activity and other patient characteristics may contribute to subsequent functional outcomes and activity levels (33). The lack of statistical significance in the present study may therefore reflect limited statistical power rather than absence of a clinically relevant relationship.

Postoperative physiotherapy duration also did not differ significantly between patients with good and poor outcomes. This finding should be interpreted cautiously because the recorded measure reflects the quantity of physiotherapy exposure rather than rehabilitation quality, adherence, exercise intensity, progression, or achievement of rehabilitation milestones. Future studies should therefore evaluate structured rehabilitation parameters rather than duration or number of sessions alone.

Overall, the findings indicate that most patients in this cohort achieved favorable early postoperative status after ACL surgery. However, the marked associations observed for concomitant meniscal injury, cartilage damage, and the reconstruction/autograft subgroup require confirmation in substantially larger cohorts. Adequately powered multivariable analyses will be necessary to distinguish true independent prognostic factors from confounding by injury severity, surgical selection, and other patient characteristics.

Limitations

This study has several limitations. First, although the overall sample size met the prespecified sample-size target, only six patients (5.4%) experienced a poor early outcome. This small number of events substantially limits statistical power, produces very wide confidence intervals for several effect estimates, and precludes reliable multivariable modeling. Accordingly, the reported associations should be considered exploratory rather than confirmatory.

Second, follow-up was limited to 3 months after surgery. The findings therefore characterize early postoperative recovery and cannot be extrapolated to longer-term outcomes such as recurrent instability, graft or repair failure, return to sport, patient-reported function, or development of osteoarthritis. Third, the study was conducted at a single center, which may limit generalizability to other populations and surgical practices.

Fourth, two patients who developed postoperative infection and required reoperation were excluded according to the predefined study criteria. Because reoperation represents an unfavorable postoperative event, their exclusion may have resulted in some overestimation of the proportion of favorable outcomes among the analyzed patients. Fifth, standardized patient-reported outcome measures such as the IKDC, KOOS, or Lysholm score were not collected, limiting comparison with contemporary ACL outcome studies.

Sixth, knee stability was assessed clinically using the Lachman and anterior drawer tests rather than an instrumented arthrometer, and no formal assessment of intra-rater or inter-rater reliability was performed. Pre-injury physical activity was assessed retrospectively, which may also have introduced recall bias. In addition, the relatively small reconstruction subgroup and close correspondence between patellar tendon autograft use and procedure type prevent separation of the effects of graft choice from those of surgical strategy or case selection.

Future prospective multicenter studies should incorporate larger numbers of unfavorable outcomes, longer follow-up, standardized patient-reported outcome measures, objective instrumented stability assessment, detailed rehabilitation metrics, and adequately powered multivariable analyses.

Conclusion

In this prospective cohort study, most analyzed patients demonstrated favorable early clinical outcomes 3 months after ACL surgery, with high rates of full knee range of motion and clinical stability. Concomitant meniscal injury, articular cartilage damage, and membership in the patellar tendon autograft/ reconstruction subgroup showed strong unadjusted associations with poor early outcome, whereas age, sex, BMI, pre-injury physical activity, and physiotherapy duration were not significantly associated with outcome. Given the small number of poor outcomes, these findings should be regarded as exploratory and do not establish independent prognostic effects. Larger multicenter studies with longer follow-up and standardized functional outcome assessment are needed to determine predictors of long-term recovery after ACL surgery.

Declaration

Availability of data and materials

All data generated or analysed during this study are included in this published article. Further information is available from the corresponding author on reasonable request.

Conflict of Interest

The author declares no conflict of interest.

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Authors' contribution

(All authors) contributed to the clinical management of the patient, conception of the case report, data collection, and drafting and critical revision of the manuscript. All authors read and approved the final manuscript.

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Ethics approval and consent to participate

This article was IR.MUBABOL.HRI.REC.1402.121 reviewed and approved by the institutional ethics committee (approval details provided on the separate title

page to preserve blinding). Written informed consent was obtained from the patient for participation in this study.

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