

## Functional Recovery and Strength Restoration: The Role of Rehabilitative Exercise in ACL Ligament Injury Patients

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### Abstract

**Background:** Anterior cruciate ligament (ACL) injuries are common among athletes and can significantly impair knee function and quality of life. Effective rehabilitation is crucial for restoring strength and function.

**Methods:** This experimental study was conducted at the Department of Physical Medicine & Rehabilitation, BSMMU, Dhaka, over one year from July 2015 to June 2016. A total of 50 patients with ACL injuries participated in a structured rehabilitation program. Outcome measures included range of motion, muscle strength, pain score (VAS), and functional scores, assessed using the Lysholm Knee Scoring Scale and Visual Analog Scale (VAS) before and after rehabilitation. Patients underwent a structured, progressive rehabilitation program focusing on range of motion, strength training, proprioceptive exercises, and functional drills tailored to ACL recovery, supervised by certified physiotherapists.

**Results:** Significant improvement was observed post-rehabilitation. Range of motion increased from  $90^\circ \pm 10^\circ$  to  $130^\circ \pm 15^\circ$  ( $p < 0.01$ ), while the Lysholm score improved from  $45 \pm 12$  to  $85 \pm 10$  ( $p < 0.01$ ). Pain levels measured by VAS decreased from  $7.5 \pm 1.2$  to  $2.0 \pm 0.8$  ( $p < 0.01$ ). Muscle strength assessments indicated substantial gains, with quadriceps strength increasing from  $30 \pm 5$  kg to  $50 \pm 8$  kg (66%), hamstrings from  $25 \pm 4$  kg to  $45 \pm 6$  kg (80%), calf muscles from  $20 \pm 3$  kg to  $38 \pm 5$  kg (90%), and hip flexors from  $28 \pm 4$  kg to  $46 \pm 6$  kg (64%). Moreover, 70% of participants exhibited high adherence to the exercise regimen, with only 20% reporting minor complications.

**Conclusion:** The findings of this study underscore the effectiveness of a structured rehabilitative exercise program in enhancing functional recovery and muscle strength in patients with ACL injuries.

**Keywords:** ACL injury, rehabilitation, functional recovery, muscle strength, exercise program, patient adherence.

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### 1. INTRODUCTION

Anterior Cruciate Ligament (ACL) injuries are among the most common sports-related injuries, particularly in activities that involve rapid changes in direction, jumping, and sudden stops, such as football, soccer, basketball, and skiing.<sup>1</sup> The ACL plays a critical role in stabilizing the knee joint, and its injury can significantly affect an individual's mobility and athletic performance.<sup>2</sup> Rehabilitation is a crucial component of the recovery process for ACL injuries, aiming to restore knee function, improve muscle strength, and reduce the risk of reinjury.<sup>3</sup> Understanding the optimal strategies for rehabilitation is essential for achieving long-term recovery and returning to pre-injury levels of activity.<sup>4</sup>

The incidence of ACL injuries has been rising over the years, especially among younger, active populations.<sup>5</sup> Studies have shown that these injuries are more prevalent in athletes due to the biomechanical demands placed on their knees during high-intensity sports.<sup>6</sup> Gender differences also play a significant role in ACL injury rates, with female athletes being more prone to these injuries than their male counterparts.<sup>7</sup> This increased risk in women is attributed to various factors, including anatomical differences, hormonal influences, and neuromuscular control patterns.<sup>8</sup>

The management of ACL injuries often involves surgical and non-surgical interventions, with the choice of treatment depending on factors such as the severity of the injury, patient age, activity level, and overall health status.<sup>9</sup> Surgical intervention, particularly ACL reconstruction, is commonly recommended for active individuals who wish to return to high-level sports. However, post-surgical rehabilitation is equally vital to ensure successful outcomes.<sup>10</sup> Rehabilitation protocols have evolved significantly over the years, emphasizing the need for individualized exercise programs that cater to the specific needs of each patient.<sup>11</sup>

Rehabilitative exercises for ACL injuries primarily focus on restoring muscle strength, particularly in the quadriceps and hamstrings, enhancing knee stability, and improving proprioception.<sup>12</sup> Strengthening exercises are typically categorized into open kinetic chain (OKC) and closed kinetic chain (CKC) exercises, both of which have unique benefits in ACL rehabilitation.<sup>13</sup> CKC exercises, such as squats and leg presses, are often preferred in the early stages of rehabilitation due to their ability to improve functional stability while minimizing stress on the knee joint.<sup>14</sup> OKC exercises, on the other hand, are introduced gradually as the patient progresses, focusing on isolating specific muscle groups to enhance strength and control.<sup>15</sup>

Neuromuscular training is another critical component of ACL rehabilitation, aiming to improve the body's ability to stabilize and control joint movement during dynamic activities. It includes exercises that enhance balance, coordination, and agility, which are essential for preventing future injuries.<sup>3</sup> The integration of neuromuscular training with traditional strengthening exercises has been shown to reduce the risk of ACL re-injury significantly.<sup>16</sup>

Research has demonstrated that the timing and intensity of rehabilitation exercises can significantly influence recovery outcomes in ACL injury patients.<sup>11</sup> Early initiation of rehabilitation, preferably within a week of injury or surgery, has been associated with better functional outcomes and faster return to activity. High-intensity rehabilitation, when introduced appropriately, helps in the rapid restoration of muscle strength and knee stability.<sup>17</sup> However, it is crucial to tailor the rehabilitation program to the patient's tolerance level to prevent overloading the knee joint and causing further damage.<sup>9</sup>

### **1.1. Objective**

The objective of this study is to evaluate the effectiveness of rehabilitative exercise in enhancing functional recovery and restoring strength in patients who have undergone anterior cruciate ligament (ACL) reconstruction.

## **2. METHODOLOGY AND MATERIALS**

This study employed an experimental design to evaluate the role of rehabilitative exercise in ACL ligament injury patients. It was conducted at Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, from July 2015 to June 2016, with a sample size of 50 patients treated at the Department of Physical Medicine and Rehabilitation. Participants were selected based on specific inclusion criteria, which included individuals diagnosed with isolated ACL injuries and willing to participate in the rehabilitation protocol. Exclusion criteria involved patients with multiple ligament injuries, significant comorbidities, previous knee surgeries, or any condition that could impair adherence to the exercise regimen.

Data collection was facilitated using pre-designed data sheets and structured questionnaires, capturing variables like muscle strength, range of motion, functional outcomes, and duration of recovery. Standardized clinical assessments and exercise protocols were implemented, involving neuromuscular electrical stimulation, open and closed kinetic chain exercises, and progressive strength training in both supervised and home-based sessions. Measurements were taken at baseline, mid-rehabilitation, and post-rehabilitation stages to assess improvements in quadriceps and hamstring strength, knee stability, and functional performance.

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Data analysis was performed using SPSS software, focusing on descriptive and inferential statistics to compare pre-and post-rehabilitation results, evaluating significant changes in muscle strength and recovery patterns. A p-value of less than 0.05 was considered statistically significant.

### 3. RESULTS

**Table I.** Patient Demographics and Baseline Characteristics (N = 50)

Characteristic	Frequency (n)	Percentage (%)
Gender		
- Male	28	56%
- Female	22	44%
Age Group (years)		
- < 20	5	10%
- 20-29	20	40%
- 30-39	15	30%
- ≥ 40	10	20%
Body Mass Index (BMI)		
- Underweight (<18.5)	3	6%
- Normal (18.5-24.9)	25	50%
- Overweight (25-29.9)	15	30%
- Obese (≥30)	7	14%
Injury Type		
- Complete ACL Tear	35	70%
- Partial ACL Tear	15	30%
Time Since Injury		
- < 1 month	10	20%
- 1-6 months	25	50%
- > 6 months	15	30%

Table I presents the demographics and baseline characteristics of the 50 patients involved in the study evaluating the effectiveness of rehabilitative exercise for ACL injuries. The majority of participants are male (56%), with a significant representation of younger adults aged 20-29 years (40%). Most patients have a normal Body Mass Index (BMI) (50%), while 70% of the injuries were complete ACL tears, indicating a severe injury profile. The time since injury varied among participants, with half reporting injuries sustained between 1 to 6 months prior to the study, which is critical for understanding their rehabilitation stage.

**Table II.** Functional Recovery Outcomes (Pre- and Post-Rehabilitation)

Outcome Measure	Pre-Rehabilitation	Post-Rehabilitation	p-value
Range of Motion (Degrees)	90 ± 10	130 ± 15	< 0.01
Lysholm Knee Scoring Scale	45 ± 12	85 ± 10	< 0.01
Tegner Activity Level Scale	2.5 ± 1.0	5.0 ± 1.5	< 0.01
Visual Analog Scale (VAS) for Pain	7.5 ± 1.2	2.0 ± 0.8	< 0.01
Time to Return to Normal Activity (weeks)	24 ± 5	12 ± 3	< 0.01

Table II illustrates significant improvements in functional recovery outcomes for patients undergoing rehabilitative exercise post-ACL reconstruction. After rehabilitation, the range of motion increased from a mean of 90 degrees (±10) to 130 degrees (±15), demonstrating a statistically significant enhancement (p < 0.01). Similarly, the Lysholm Knee Scoring Scale, which assesses knee function, showed substantial improvement from 45 (±12) pre-rehabilitation to 85 (±10) post-rehabilitation (p < 0.01). The Tegner Activity Level Scale also indicated a notable increase in activity levels, rising from 2.5 (±1.0) to 5.0 (±1.5) (p < 0.01). Furthermore, patients experienced a marked reduction in pain, as reflected by the Visual Analog Scale (VAS) for pain, which decreased from 7.5 (±1.2) to 2.0 (±0.8) (p < 0.01). Lastly, the time to return to normal activity significantly decreased from an average of 24 weeks (±5) to 12 weeks (±3) (p < 0.01).

**Table III.** Muscle Strength Restoration (Pre- and Post-Rehabilitation)

Muscle Group	Pre-Rehabilitation Strength (kg)	Post-Rehabilitation Strength (kg)	Strength Gain (%)
Quadriceps	30 ± 5	50 ± 8	66%
Hamstrings	25 ± 4	45 ± 6	80%
Calf Muscles	20 ± 3	38 ± 5	90%
Hip Flexors	28 ± 4	46 ± 6	64%

Table III shows muscle strength restoration in patients post-ACL rehabilitation, with significant gains across all muscle groups. Quadriceps strength improved from 30 kg ( $\pm 5$ ) to 50 kg ( $\pm 8$ ) (66% gain), hamstrings from 25 kg ( $\pm 4$ ) to 45 kg ( $\pm 6$ ) (80% gain), calf muscles from 20 kg ( $\pm 3$ ) to 38 kg ( $\pm 5$ ) (90% gain), and hip flexors from 28 kg ( $\pm 4$ ) to 46 kg ( $\pm 6$ ) (64% gain). Muscle strength was measured using a handheld dynamometer, with patients performing maximal isometric contractions for each targeted muscle group—quadriceps, hamstrings, calf muscles, and hip flexors—to record peak force output in kilograms.

**Table IV.** Rehabilitation Program Adherence and Complications

Parameter	Frequency (n)	Percentage (%)
Adherence to Exercise Regimen		
- High Adherence	35	70%
- Moderate Adherence	10	20%
- Low Adherence	5	10%
Reported Complications		
- No Complications	40	80%
- Minor Complications	8	16%
- Major Complications	2	4%

Table IV summarizes adherence to the rehabilitation program and reported complications among 50 ACL reconstruction patients. High adherence was observed in 35 patients (70%), with moderate adherence in 10 patients (20%) and low adherence in 5 patients (10%). Most patients (80%) experienced no complications, while 8 patients (16%) reported minor complications, and only 2 patients (4%) encountered major complications. Adherence to the rehabilitation program was monitored through weekly check-ins and patient logs, where patients recorded completion of prescribed exercises and attendance at scheduled sessions.

#### 4. DISCUSSION

The discussion surrounding the effectiveness of rehabilitative exercise in restoring function and strength after anterior cruciate ligament (ACL) injuries is well-supported by numerous studies. Our findings, which indicated substantial improvements in functional recovery outcomes, muscle strength restoration, and high adherence rates to rehabilitation programs, align with existing literature on the subject.

In our study, patients demonstrated significant gains in range of motion, pain reduction, and return to normal activities, similar to findings reported by Logerstedt et al., who emphasized the importance of early rehabilitation in enhancing knee function post-ACL reconstruction.<sup>18</sup> Their research showed that a structured rehabilitation protocol improved range of motion and better patient-reported outcomes, which is echoed in Micheo et al.,<sup>19</sup> They highlighted the crucial role of rehabilitation and prevention strategies, emphasizing that early intervention can mitigate long-term complications.

Furthermore, our results reflected a significant increase in Lysholm Knee Scoring Scale and Tegner Activity Level Scale scores, consistent with findings from Kvist study. Kvist noted that a systematic approach to rehabilitation following ACL injuries is essential for optimal sports participation.<sup>20</sup> This aligns with our observation that post-rehabilitation scores improved significantly, reinforcing the necessity of tailored rehabilitation programs.

In terms of muscle strength restoration, our findings showed notable gains in all assessed muscle groups, particularly in the hamstrings and calf muscles. This is consistent with the work of Eitzen et al., who demonstrated that progressive exercise therapy significantly improves knee function early after ACL injury.<sup>21</sup> Their study supports our conclusion that muscle strengthening plays a vital role in recovery, as reflected in the substantial strength gains observed in our participants.

Adherence to the rehabilitation program is critical for achieving optimal outcomes, and our study found that 70% of patients exhibited high adherence. This finding parallels the research by Grindemet al., who identified a strong correlation between adherence levels and recovery outcomes in ACL rehabilitation.<sup>22</sup> Wilk et al., also emphasized the importance of patient adherence to rehabilitation protocols, which is crucial for successful recovery and reintegration into sports activities.<sup>23</sup>

Complications during rehabilitation are an important factor in evaluating the overall effectiveness of rehabilitation protocols. Our study reported that 80% of participants experienced no complications,

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aligning with findings from Lorenz et al., which indicated that well-structured rehabilitation programs are associated with low complication rates.<sup>24</sup> In addition, Mohtadi noted that effective rehabilitation strategies are linked to reduced complications and improved outcomes, reinforcing our study's findings.<sup>25</sup>

The reduction in pain as measured by the Visual Analog Scale (VAS) is another critical indicator of rehabilitation success. Our results showed a decrease in pain levels from 7.5 ( $\pm 1.2$ ) pre-rehabilitation to 2.0 ( $\pm 0.8$ ) post-rehabilitation, which aligns with the findings of Paterno et al.,<sup>26</sup> Their research emphasized that pain management strategies incorporated into rehabilitation protocols significantly improve patient satisfaction and compliance. This notion is supported by Micheo et al., who discussed the importance of addressing pain in the rehabilitation of ACL injuries.<sup>19</sup>

Moreover, our study's finding that the time to return to normal activity was significantly reduced from 24 weeks ( $\pm 5$ ) to 12 weeks ( $\pm 3$ ) post-rehabilitation is consistent with findings from studies examining the timing of rehabilitation interventions. For instance, research by Roos et al., indicated that early rehabilitation positively influences recovery timelines, leading to quicker returns to daily activities and sports.<sup>27</sup> This is echoed in Eitzen et al., which showed that early rehabilitation is crucial for a faster recovery, underscoring the need for timely interventions.<sup>21</sup>

### 5. CONCLUSION

In conclusion, this study demonstrates that a structured rehabilitative exercise program significantly improves functional recovery and muscle strength in patients with ACL injuries. The findings highlight that patients experienced substantial improvements in range of motion, pain levels, and functional scores following rehabilitation. Moreover, high adherence to the rehabilitation regimen was associated with better outcomes, underscoring the importance of patient commitment to the rehabilitation process.

### LIMITATIONS OF THE STUDY

This study has several limitations that should be acknowledged. Firstly, the sample size of 50 patients may limit the generalizability of the findings, as larger studies could provide more robust data and insights into the efficacy of rehabilitative exercises for ACL injuries. Secondly, the study was conducted at a single institution (BSMMU, Dhaka), which may introduce a selection bias and limit the diversity of the patient population, affecting the external validity of the results.

### RECOMMENDATIONS

Future research should continue to explore various rehabilitation modalities and their impacts on long-term outcomes, particularly in diverse patient populations, to further refine and optimize rehabilitation strategies for ACL injuries.

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