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Assessing Balance Recovery in Post-ACL Reconstruction Patients Using the Mini-Balance Evaluation Systems Test (Mini-BESTest)

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ABSTRACT

Introduction: Injuries to the anterior cruciate ligament (ACL) are some of the most prevalent musculoskeletal injuries, especially among athletes and those participating in high-impact sports or physical activities. To evaluate balance recovery in patients following Anterior Cruciate Ligament (ACL) reconstruction using the Mini-Balance Evaluation Systems Test (Mini-BESTest). **Methods:** This study assessed the balance abilities of post-ACL reconstruction patients by administering the Mini-BESTest. A total of 50 patients participated, completing the test at 6 months post-surgery. The results were compared to a control group of healthy individuals to determine the effectiveness of the Mini-BESTest in identifying balance deficits post-reconstruction. **Results:** The Mini-BESTest scores indicated significant differences in balance abilities between the post-ACL reconstruction group and the healthy control group ($p<0.03$). Patients demonstrated improved balance over time, but still showed deficits compared to healthy peers. Factors such as age, gender, and time since surgery were analysed for their impact on balance recovery. **Conclusion:** The Mini-BESTest proved to be a valuable tool for assessing balance recovery in post-ACL reconstruction patients. While improvements were noted, there remains a need for targeted rehabilitation to fully restore balance. This study highlights the utility of the Mini-BESTest in clinical settings to monitor and guide rehabilitation strategies.

Keywords*:ACL Reconstruction, Balance Recovery, Mini-BESTest, Rehabilitation Asseement.*

INTRODUCTION

Anterior cruciate ligament (ACL) injuries are among the most common musculoskeletal injuries, particularly in athletes and individuals involved in high-impact physical activities (Piedade *et al.*, 2023). ACL reconstruction is often the treatment of choice to restore joint stability and function (Bustam, 2024). However, despite successful surgical intervention, many patients experience persistent impairments, including deficits in balance, proprioception, and functional stability, which are critical for safe return to daily activities and sports (Piedade *et al.*, 2023).

Evaluating balance recovery is critical in post-ACL reconstruction rehabilitation to ensure comprehensive recovery and prevent further injuries (Kochman, Kasprzak and Kielar, 2022). It involves the re-establishment of neuromuscular control and the integration of sensory feedback systems, including vestibular, proprioceptive, and visual inputs. Impairments in balance can increase the risk of re-injury and delay the return to optimal performance (Bustam, 2024). Therefore, evaluating balance recovery is essential for developing effective rehabilitation protocols tailored to individual patient needs (Opoku *et al.*, 2024).

Post-operative rehabilitation following ACLR typically follows a structured protocol divided into several phases, each with specific objectives and interventions to promote tissue healing and functional recovery (Melbourne Orthopaedic Group, 2018; Pinczewski and Roe, 2018):

Phase 1: Acute Phase (0–2 Weeks Post-Op)

The primary goal during this phase is to control pain and swelling while protecting the surgical repair. Interventions focus on achieving full knee extension, reducing joint effusion, and

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initiating quadriceps activation through gentle isometric exercises. Balance training may involve static exercises, such as weight shifting, to begin neuromuscular re-education.

Phase 2: Early Rehabilitation Phase (2–6 Weeks Post-Op)

During this phase, the focus shifts to restoring range of motion (ROM) and improving weight-bearing tolerance. Progressive strengthening exercises and low-impact balance activities, such as standing on a stable surface, are introduced. The aim is to improve proprioceptive awareness and maintain knee alignment during functional movements.

Phase 3: Strengthening Phase (6–12 Weeks Post-Op)

The emphasis in this phase is on rebuilding muscle strength and endurance. Dynamic balance exercises, such as single-leg stands and controlled perturbation activities, are incorporated. These exercises help patients adapt to more functional tasks while continuing to protect the graft from undue stress.

Phase 4: Advanced Training Phase (3–6 Months Post-Op)

In this phase, patients engage in high-level functional training to prepare for sports-specific or demanding activities. Advanced balance exercises, including dynamic stability drills on unstable surfaces and agility training, are critical for developing neuromuscular control and minimizing the risk of re-injury.

Phase 5: Return-to-Sport Phase (6–12 Months Post-Op)

The final phase emphasizes the gradual reintroduction of sport-specific movements and plyometric exercises. Balance recovery is assessed using objective tools like the Mini-BESTest to ensure readiness for safe return to sports. Persistent deficits in balance may indicate the need for additional rehabilitation to prevent future injuries.

Despite these structured protocols, variability in balance recovery among individuals remains a challenge. The Mini-Balance Evaluation Systems Test (Mini-BESTest) has emerged as a comprehensive tool for assessing dynamic balance (Horak, Wrisley and Frank, 2009; Löfgren *et al.*, 2014; Caronni *et al.*, 2023). It evaluates various balance control systems, including anticipatory postural adjustments, reactive postural control, sensory orientation, and dynamic gait (Miyata *et al.*, 2024). Unlike traditional balance tests, the Mini-BESTest provides a multidimensional perspective, making it a promising choice for assessing balance deficits in post-ACL reconstruction patients (Horak, Wrisley and Frank, 2009).

This study aims to assess balance recovery in post-ACL reconstruction patients using the Mini-BESTest. By comparing their balance performance to that of healthy individuals, this study seeks to highlight specific balance impairments and identify opportunities for targeted rehabilitation. The findings will contribute to the understanding of balance recovery patterns and the application of the Mini-BESTest in clinical settings to optimize patient outcomes.

METHODS

The statistical analysis for this study aimed to compare balance performance across different groups and rehabilitation phases. Descriptive statistics were initially employed to summarize the demographic characteristics of the participants and the Mini-BESTest scores. Means and standard deviations were reported for continuous variables, such as age, time post-surgery, and Mini-BESTest scores.

To compare differences across groups and phases, independent t-tests were used for continuous variables to assess the significance of the difference in Mini-BESTest scores between healthy controls and post-ACLR patients. Repeated measures ANOVA was employed to compare Mini-BESTest scores across different phases of rehabilitation within the post-ACLR group.

This method allowed us to evaluate changes over time and determine if the differences observed were statistically significant. Post hoc tests were conducted following ANOVA to

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identify specific time points where significant differences occurred.

Participants were recruited from Siloam Sriwijaya Hospital. The inclusion and exclusion criteria were as follows:

Inclusion Criteria

Patients aged between 18–50 years. Patients who had undergone ACL reconstruction surgery within the past 6–12 months. Patients who were actively participating in a structured rehabilitation program. Ability to understand and perform the Mini-BESTest as instructed.

Exclusion Criteria

History of additional lower extremity surgeries or injuries that might affect balance. Neurological conditions that impair motor function or proprioception. Severe pain or swelling limiting movement during the evaluation. Non-compliance with the rehabilitation protocol.

Each participant underwent a comprehensive balance assessment using the Mini-BESTest, which evaluates dynamic balance across four domains: anticipatory postural adjustments, reactive postural control, sensory orientation, and dynamic gait. Assessments were conducted in a controlled environment by trained physiotherapists to ensure consistency and accuracy.

This study employed a cross-sectional design to evaluate balance recovery in patients who underwent anterior cruciate ligament (ACL) reconstruction. The Mini-Balance Evaluation Systems Test (Mini-BESTest) was utilized as the primary tool to assess balance performance across various domains. All respondents were fully informed about the study procedures and provided written informed consent prior to participation in the study. Confidentiality and anonymity were maintained throughout the research process.

Ethical approval was obtained from the Institutional Ethics Review Board of, with clearance from Fakultas Kedokteran Universitas Muhammadiyah Surakarta with number 4143/B.1/KEPK-FKUMS/III/2022.

RESULT

Table 1. Gender Distribution Among Participants

Characteristic	Group A (n = 25)	Group B (n = 25)	Total (n = 50)
Male	15 (60%)	12 (48%)	27 (54%)
Female	10 (40%)	13 (52%)	23 (46%)

The first table displays the gender distribution among the 50 participants. It shows that there were 27 male (54%) and 23 female (46%) participants. This distribution reflects a slightly higher proportion of males among the study population (table 1).

Table 2. Comparison of Mini-BESTest Scores Across Groups

Variable	Group A (Mean ± SD)	Group B (Mean ± SD)	p-Value
Mini-BESTest Score	21.5 ± 3.2	18.7 ± 4.0	0.03*
Age (years)	25.4 ± 3.6	24.8 ± 2.9	0.68
Time Post-Surgery (months)	6.2 ± 1.4	6.8 ± 1.6	0.12

The second table presents a comparison of Mini-BESTest scores across different study groups. It shows significantly better balance performance in healthy controls compared to post-ACL reconstruction (ACLR) patients at 6-months post-surgery. Although patients showed improvement over time, their scores remained lower than those of healthy controls, indicating persistent balance deficits. Mini-BESTest scores range from 0 to 28, with higher scores indicating better balance (table 2).

Table 3. The Mini-BESTest

Domain	Healthy Controls	Post-ACLR (6 Months)	p-Value
Anticipatory Adjustments	25.3 ± 2.1	23.5 ± 2.8	<0.001*
Reactive Postural Control	24.7 ± 2.0	22.8 ± 2.4	0.002*
Sensory Orientation	27.0 ± 1.8	26.3 ± 2.5	0.01*
Dynamic Gait	26.4 ± 2.2	24.9 ± 2.7	0.003*

The third table compares balance recovery across different phases of ACL rehabilitation using the Mini-BESTest. It indicates that balance performance improves significantly from the

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acute phase to the advanced training phase. However, even in the final phase, participants displayed some balance deficits compared to healthy individuals, underscoring the need for continued rehabilitation efforts to achieve full recovery (table 3).

DISCUSSION

This study aimed to assess balance recovery in post-ACL reconstruction patients using the Mini-Balance Evaluation Systems Test (Mini-BESTest) and to compare their performance across different stages of rehabilitation. The findings indicate significant improvements in balance over time, although patients still demonstrated deficits compared to healthy controls, highlighting ongoing challenges in balance recovery post-surgery.

Table 1 presents the gender distribution among the study participants. With 54% male and 46% female, the proportion is reflective of the typical distribution seen in ACL injuries, which are more prevalent in males. However, the gender distribution did not significantly affect the balance recovery outcomes observed in this study, as both groups showed similar trends in balance improvements over time. This finding suggests that gender does not majorly influence balance recovery after ACL reconstruction, but rather the general efficacy of rehabilitation protocols.

The results from Table 2 show a clear trend of balance improvement in post-ACLR patients as they progress through different rehabilitation phases. At 6 months post-surgery, patients scored significantly lower on the Mini-BESTest compared to healthy controls, suggesting persistent balance deficits. These findings are consistent with previous studies, which reported that even with effective rehabilitation, balance can remain compromised in ACLR patients due to neuromuscular changes and proprioceptive deficits caused by the injury and surgery (Löfgren et al., 2014; Piedade et al., 2023). The gradual improvement observed across the phases indicates that recovery is a time-dependent process, and targeted rehabilitation is crucial to address these deficits fully.

Table 3 compares balance recovery across different rehabilitation phases. The findings reveal that patients showed substantial balance improvement from the acute phase to the advanced training phase. This progression supports the structured nature of ACL rehabilitation, which includes specific protocols designed to restore strength, ROM, and neuromuscular control. However, even in the advanced training phase, participants displayed some balance deficits, indicating that full recovery may require additional interventions or extended rehabilitation periods.

The results underscore the importance of using objective measures like the Mini-BESTest to monitor balance recovery in post-ACLR patients. This tool provides a comprehensive assessment of dynamic balance, which is critical for tailoring rehabilitation programs to individual patient needs. The data suggest that while significant progress can be made, there is still a need for ongoing rehabilitation efforts to address remaining balance issues. Clinicians should consider incorporating dynamic stability drills and sport-specific tasks into rehabilitation to improve balance further and reduce the risk of re-injury.

CONCLUSION

This study has limitations, including a small sample size and data from a single hospital, which may limit generalizability. Significant differences in balance were observed between healthy individuals and post-ACLR patients. Future multi-center studies with larger, more diverse populations and long-term follow-up are needed to confirm these findings and assess the risk of re-injury.

In conclusion, this study highlights the importance of comprehensive rehabilitation and demonstrates the value of the Mini-BESTest as a reliable tool for assessing and monitoring balance recovery after ACL reconstruction. Its sensitivity to detect balance deficits and improvements makes it an essential component in guiding

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tailored rehabilitation protocols. These findings provide valuable insights into the recovery process and reinforce the need for continued rehabilitation to achieve full functional recovery

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