Mobile-Based Telerehabilitation During the First Six Weeks Following ACL Reconstruction: A Case Series of Six Patients

Abstract

Background: Early rehabilitation following anterior cruciate ligament reconstruction (ACLR) is critical for preventing quadriceps atrophy, joint stiffness, and functional decline. However, high clinical caseloads frequently delay patients' access to formal physiotherapy, creating a rehabilitation gap in the first postoperative weeks. Mobile-based tele-rehabilitation has emerged as a promising strategy to bridge this gap, yet its application specifically in the early post-ACLR period remains underreported. Emerging evidence suggests that less supervised, home-based rehabilitation can achieve outcomes comparable to intensive clinic-based programs (Gamble et al., 2021), supporting the rationale for structured remote follow-up as an adjunct to standard care.

Case Presentation: Six male patients (mean age 26.7 years, range 24–31) who had undergone ACLR were identified at their postoperative Day 2 screening appointment. All patients faced a one-month delay before their first formal physiotherapy session due to high departmental caseload. Ultrasound assessments on the day of screening confirmed suprapatellar effusion (range 0.47–0.77 cm) and bilateral quadriceps thickness asymmetry, with affected-limb muscle thickness at rest ranging from 1.40 to 2.72 cm compared to 1.83 to 3.00 cm in the unaffected limb.

Intervention: Following in-clinic ultrasound assessment, compression therapy, and ice application, each patient was enrolled in a structured home exercise program targeting quadriceps, hip, and ankle musculature. A mobile-based follow-

up protocol was implemented in which patients submitted daily exercise videos for therapist review, received individualised feedback, and participated in weekly virtual check-ins with both their physical therapist and orthopaedic consultant. Exercise progression was guided by video-assessed movement quality, pain levels, and swelling response.

Outcomes: At six weeks, all six patients achieved full knee extension and knee flexion of 110–120 degrees. Patients demonstrated single-leg standing with good balance and control, and were able to perform functional activities including walking and cycling. All patients reported high satisfaction with the remote approach, citing reduced travel burden and the value of continuous therapist feedback as key drivers.

Conclusion: Mobile-based tele-rehabilitation is a feasible and effective strategy for managing the early post-ACLR rehabilitation gap. This case series supports growing evidence that structured, less-supervised remote programs can complement in-person care, particularly in high-demand clinical settings where timely access to formal physiotherapy is limited.

Keywords: ACL reconstruction; tele-rehabilitation; mobile-based follow-up; early postoperative rehabilitation; quadriceps activation; case series

Introduction

Early rehabilitation following anterior cruciate ligament reconstruction (ACLR) is crucial for optimizing functional recovery and preventing complications. The first six weeks after surgery represent a critical period during which quadriceps muscle activation, knee joint mobility, and pain management must be prioritized to ensure a successful return to daily activities and sports. Delayed or inconsistent

rehabilitation during this period can lead to significant setbacks, including muscle weakness, joint stiffness, swelling, prolonged use of assistive devices, and impaired functional stability. Research has consistently demonstrated that early rehabilitation interventions contribute to better long-term outcomes, reducing the risk of complications and improving overall knee function (Van Melick et al., 2016; Wilk et al., 2012; Wright et al., 2015). Restoring full knee extension in the early postoperative phase and initiating progressive quadriceps strengthening are considered essential milestones, as quadriceps strength deficits of 6–18% have been documented to persist for up to six years following surgery when early rehabilitation is suboptimal (Wilk et al., 2012). However, logistical challenges such as high patient volumes and limited availability of physical therapy appointments can hinder timely rehabilitation, necessitating alternative solutions to bridge the gap in care (Dunphy & Gardner, 2020).

In a clinical setting where scheduling constraints limited early access to rehabilitation services, a new approach was implemented to ensure that patients continued to receive the necessary interventions despite delays in formal physical therapy appointments. Typically, patients referred to physical therapy on postoperative Day 2 were evaluated in the screening clinic, after which they were given an appointment for rehabilitation one month later due to the department's high caseload. This delay posed a significant risk to recovery, as patients who did not receive regular treatment during the early postoperative phase were more likely to develop quadriceps atrophy, knee range of motion limitations, persistent swelling, and increased pain. Furthermore, the prolonged reliance on crutches could delay functional recovery, preventing patients from achieving normal gait patterns and stable single-leg standing, which are essential milestones in rehabilitation. Ultrasound-based assessment of quadriceps muscle thickness and

joint swelling has been shown to provide objective, real-time data on postoperative muscle morphology and inflammation, enabling individualized and timely rehabilitation decision-making (Garcia et al., 2020). Given these concerns, an alternative approach was implemented to mitigate the risks associated with delayed rehabilitation and improve patient outcomes (Adams et al., 2012; Greenberg et al., 2018).

Case Presentation

On the day of screening, patients first underwent ultrasound diagnostic assessments to evaluate knee swelling, as shown in Figure 1. These assessments provided crucial insights into postoperative inflammation and guided individualized rehabilitation strategies. Figure 2 illustrates the measurement of quadriceps muscle thickness, offering objective data to ensure proper muscle recovery. Following these assessments, patients received immediate interventions to address early postoperative concerns. Figure 3 highlights the use of compression therapy and ice application to manage swelling and pain, helping to reduce discomfort and inflammation. To promote early activation and strength retention, a structured exercise program targeting the quadriceps, hips, and ankle muscles was introduced. Additionally, to ensure continuous monitoring and adherence to the prescribed rehabilitation program, a mobile-based follow-up was implemented.

Table 1 presents key clinical parameters assessed through ultrasound diagnostics in a sample of ACLR patients. It includes swelling measurements, quadriceps muscle thickness at rest and during activation, and comparisons between affected and sound knees under different conditions.

Patient No	Gender	Age	Diagnosis	Swelling – Suprapatellar Recess Depth (cm, Ultrasound)	Affected Leg Quad Thickness at Rest (cm)	Affected Leg Quad Thickness During Activation (cm)	Affected Leg Quad Thickness with Biofeedback (cm)	Sound Knee Quad Thickness at Rest (cm)	Sound Knee Quad Thickness During Activation (cm)
1	M	25	right knee ACLR	0.48	2.72	3.92	4	3	4
2	M	24	right knee ACLR	0.52	2.38	3.16	4.16	2.76	4.25
3	M	31	left knee ACLR	0.47	1.55	2.87	2.97	2.09	3.2
4	M	26	left knee ACLR and meniscus repair	0.51	1.4	2.3	2.74	1.83	3.26
5	M	24	right knee ACLR	0.65	1.88	2.4	3.01	2.51	3.38
6	M	30	right knee ACLR	0.77	2.03	2.88	3.26	2.94	7.45

Table 1: Ultrasound Assessment of Quadriceps Muscle Thickness and Swelling in ACLR Patients

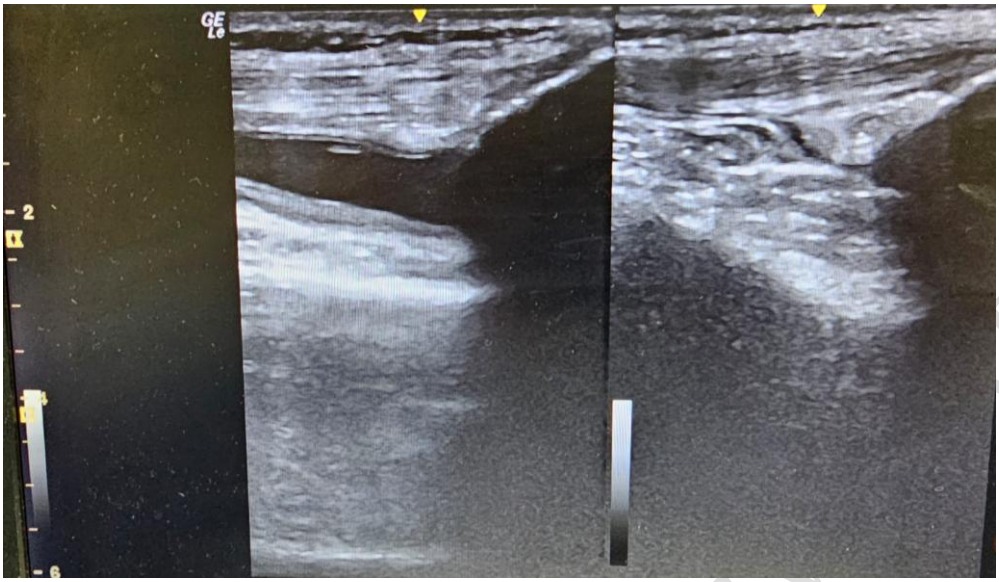
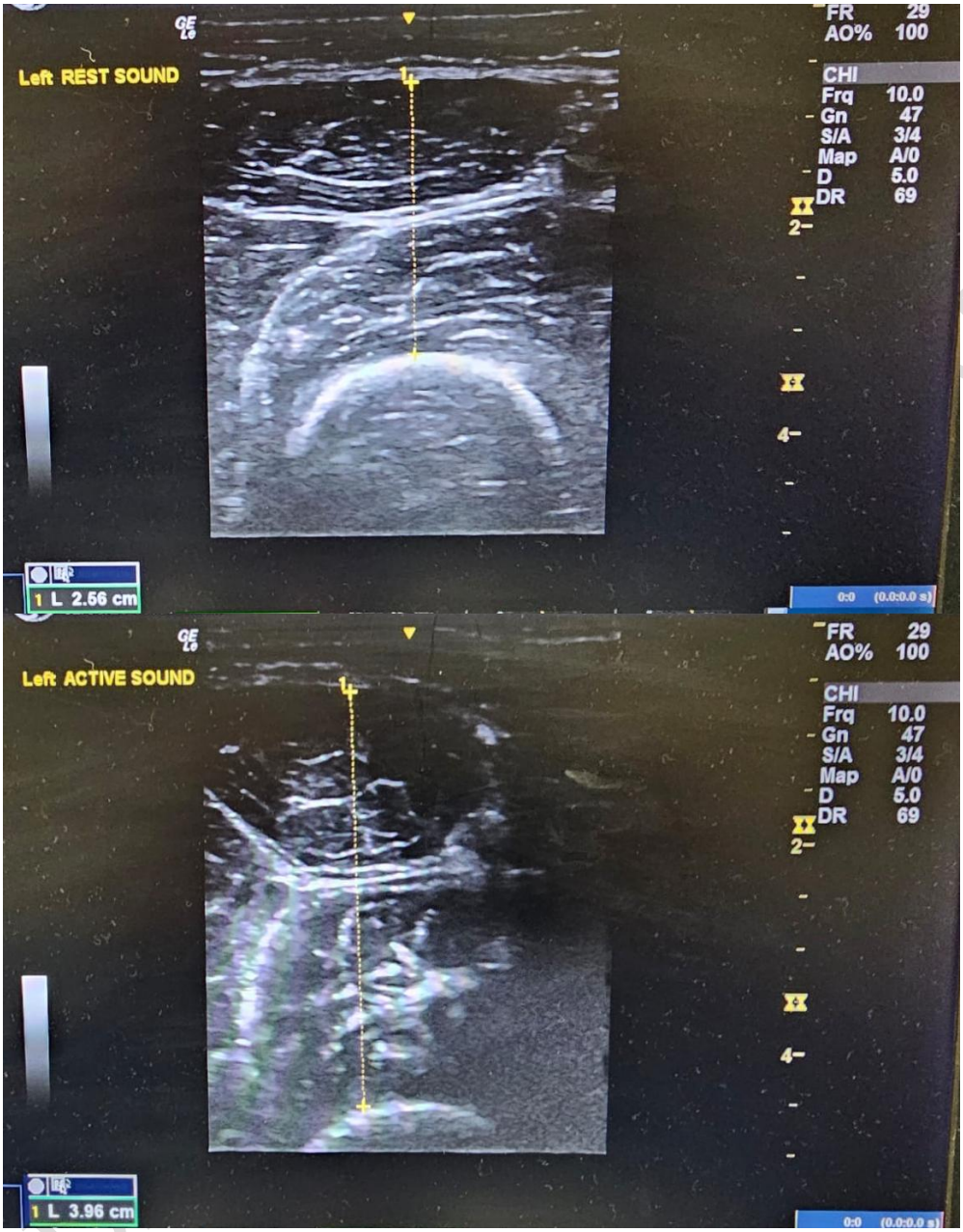


Figure 1: Detecting swelling in the suprapatellar recess: the image on the right shows the normal condition, while the left displays the affected area.



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106 Figure 2: Measuring quadriceps at rest (top) and during activation (bottom).

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Figure 3: Apply compression therapy combined with ice for a duration of 10 minutes.

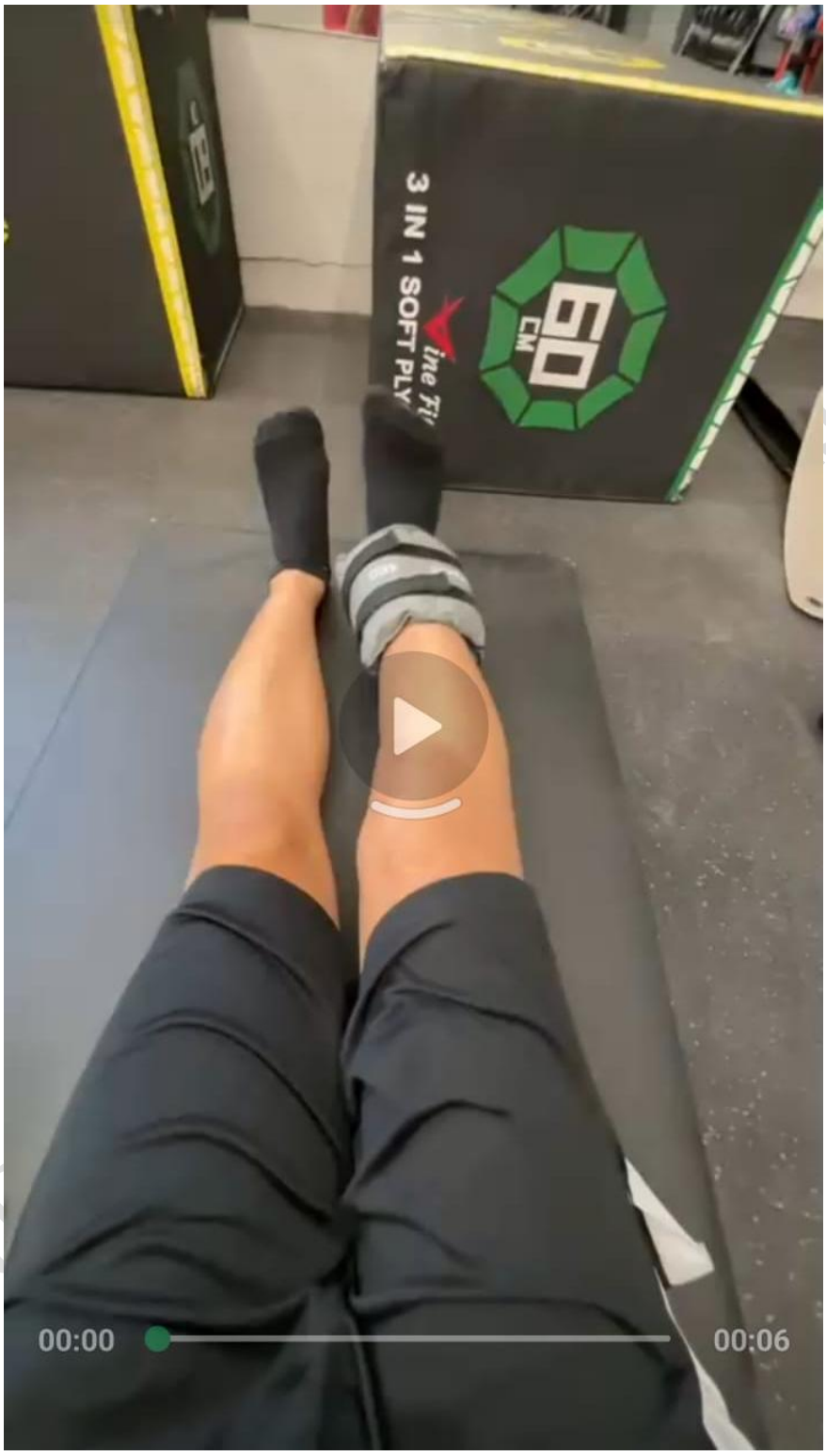

Figure 1: Example of a patient submitting an exercise video to the therapist for follow-up.

This data highlights variations in postoperative swelling and quadriceps activation between affected and unaffected legs. The measurements indicate the extent of quadriceps inhibition following surgery, with lower values in the affected leg compared to the sound knee. Biofeedback-supported activation generally showed improved muscle engagement, reinforcing the importance of guided rehabilitation techniques. These findings underscore the necessity of continuous monitoring to facilitate early detection of muscle deficits and optimize rehabilitation interventions.

Patients were instructed to record and submit daily videos of their prescribed rehabilitation exercises, allowing physical therapists to remotely monitor progress on treatment refer, as shown in Figure 4. This approach provided continuous oversight, enabling therapists to assess movement quality, adherence, and potential complications. By reviewing the videos, therapists could refine posture, range of motion, and strength, while consultants evaluated joint health and overall musculoskeletal recovery. If a patient showed proficiency, exercises were progressed, but if persistent pain, swelling, or instability was observed, therapists consulted orthopedic specialists to determine whether adjustments or medical intervention were necessary, ensuring a safe and effective rehabilitation process.

Weekly virtual check-ins further supported this approach by providing real-time discussions on patient progress, concerns, and motivation. Physical therapists guided exercise execution, while orthopedic consultants offered insights on post-surgical healing, medication adjustments, or the need for further medical evaluations. This interdisciplinary collaboration allowed for early detection of complications such as delayed healing or joint stiffness, enabling timely interventions to prevent setbacks. By leveraging technology, this integrated model ensured a seamless transition between medical and rehabilitative care, with

therapists focusing on functional progress and consultants overseeing overall musculoskeletal health. This comprehensive approach optimized recovery, ensuring patients met their rehabilitation goals safely and efficiently.

At the end of six weeks, all six patients successfully maintained full knee extension. Knee flexion ranged between 110 to 120 degrees, indicating good joint mobility. This level of recovery allowed patients to perform activities such as cycling and walking with stability. Additionally, they demonstrated the ability to stand on a single leg with good balance and control, reflecting significant functional improvement.

Patients reported excellent satisfaction with this approach for several reasons. Firstly, the intervention allowed them to adhere closely to the prescribed plan without the burden of traveling long distances to a rehabilitation center, which was particularly important for those without easy access to one nearby. The daily feedback from their therapist was another key factor, as it made patients feel more engaged in their recovery and provided reassurance that their efforts were leading to positive outcomes. This constant communication helped patients recognize the improvements in their condition, which translated into noticeable gains in muscle activation, joint mobility, and stability. These combined factors contributed significantly to their overall satisfaction.

Discussion:

The implementation of this mobile-based follow-up proved to be highly effective, as evidenced by its application in six similar cases. Patients who participated in daily remote monitoring demonstrated higher adherence to their rehabilitation

programs, which is consistent with research findings indicating that tele-rehabilitation interventions enhance patient compliance through increased accountability and engagement (Cottrell et al., 2017; Zhang et al., 2022). A systematic review with meta-analysis further confirmed that digital rehabilitation programs significantly improve therapeutic exercise adherence in musculoskeletal populations compared to non-digital approaches (Zhang et al., 2022). Maintaining quadriceps activation in the early postoperative phase is critical for preventing muscle atrophy, and this approach allowed patients to sustain muscle function, reducing the risk of postoperative quadriceps inhibition (Lepley et al., 2015; Rice & McNair, 2010; Sonnery-Cottet et al., 2019).

Early range of motion exercises facilitated by remote monitoring contributed to better knee mobility, minimizing the likelihood of stiffness and contracture formation (Kruse et al., 2012; Shelbourne & Nitz, 1990). The landmark work by Shelbourne and Nitz (1990) demonstrated that accelerated protocols incorporating immediate full extension and early weight bearing reduced arthrofibrosis rates from 12% to 4%, establishing the evidence base for early mobilization that this mobile-based intervention sought to replicate remotely. Evidence from systematic reviews further supports that tele-rehabilitation after orthopedic surgery produces outcomes comparable to conventional in-person rehabilitation (Pastora-Bernal et al., 2017). Importantly, a systematic review and meta-analysis by Gamble et al. (2021) found that intensive supervised rehabilitation was not superior to less supervised rehabilitation following ACLR across all key outcomes including self-reported function, sports participation, knee strength, range of motion, and quality of life. This supports the rationale for the mobile-based, less-supervised approach adopted in the present case series, suggesting that structured home exercise with periodic remote oversight may be sufficient to maintain early rehabilitation gains

while formal physiotherapy access is delayed. Effective pain and swelling management through structured self-care strategies also played a significant role in promoting a smoother recovery, reducing reliance on pain medications, and improving overall comfort.

Another notable advantage of this intervention was its impact on functional recovery, particularly in terms of gait training and single-leg stability. By ensuring early weight-bearing exercises and progressive strengthening activities, patients were able to transition away from crutches more efficiently and develop greater stability, aligning with evidence supporting the role of early functional training in ACLR rehabilitation (Trojian et al., 2017; Shelbourne & Nitz, 1990). Patients also reported high satisfaction with the mobile-based approach, consistent with findings from randomized controlled trials demonstrating that tele-rehabilitation produces comparable satisfaction to face-to-face rehabilitation following knee surgery (Moffet et al., 2017). The ability to provide remote guidance and progression adjustments allowed therapists to individualize treatment plans based on each patient's progress, ensuring that they arrived at their first in-person rehabilitation appointment with a solid foundation in strength and mobility. This interdisciplinary model of care—where physical therapists and orthopedic consultants collaborated through the digital platform—reflects established best practice, with research indicating that activity progression after ACLR is most effective when it involves shared decision-making between surgeons and physical therapists (Greenberg et al., 2018). This proactive approach ultimately facilitated a smoother transition into more advanced rehabilitation phases, enhancing overall recovery outcomes.

Limitations

Several limitations of this case series must be acknowledged when interpreting its findings. First, the small sample size of six patients restricts statistical generalizability and precludes conclusions about the broader efficacy of mobile-based telerehabilitation across diverse ACLR populations. All six patients were male, which limits applicability given that females are 2–10 times more likely to sustain ACL injuries during pivoting and cutting sports and may respond differently to rehabilitation protocols (Gamble et al., 2021). Second, the absence of a control group means that the functional outcomes observed—full knee extension, 110–120 degrees of flexion, and single-leg stability at six weeks—cannot be causally attributed to the mobile-based intervention alone. Comparable outcomes may have been achieved without remote monitoring, as Gamble et al. (2021) found no significant difference in self-reported function between intensively supervised and less supervised rehabilitation programs.

Third, potential selection bias cannot be excluded. Patients willing to submit daily videos and engage in weekly virtual check-ins likely represent a more motivated and digitally capable subgroup, and their outcomes may not reflect those of patients with lower adherence or technological confidence. The digital divide—encompassing disparities in smartphone access, internet connectivity, and digital literacy—was not formally assessed and could represent a significant barrier to implementing this model equitably across different socioeconomic and demographic groups. Fourth, cost-effectiveness was not evaluated. While the remote model reduced patient travel burden, the therapist time required for daily video review and written feedback was not quantified, and a formal economic analysis comparing this approach to standard in-person care would be required before broader implementation recommendations can be made. Finally, long-term outcomes beyond the six-week observation period were not assessed. Follow-up

data on quadriceps strength symmetry, return-to-sport readiness, re-injury rates, and patient-reported outcomes at three, six, and twelve months would be necessary to determine whether the early gains facilitated by mobile monitoring translate into durable rehabilitation success. Future prospective studies with larger, more diverse samples, control conditions, and standardized objective outcome measures are needed to confirm and extend these preliminary findings.

Conclusion

The mobile-based follow-up effectively addressed delays in post-ACLR rehabilitation by combining immediate in-clinic care with structured remote monitoring. This approach helped patients maintain muscle strength, joint mobility, and functional stability during early recovery. The positive outcomes in six cases highlight tele-rehabilitation's potential as a valuable supplement in high-demand clinical settings. As healthcare evolves, remote monitoring may play a greater role in optimizing rehabilitation, warranting further research to enhance its long-term effectiveness.

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