COMPARATIVE EFFECTIVENESS OF SUPERVISED AND HOME-BASED REHABILITATION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN COMPETITIVE ATHLETES

PhD thesis

Syed Rehan Iftikhar Bukhari

Károly Rácz Doctoral School of Clinical Medicine

Semmelweis University

Supervisor: István Berkes, M.D., Ph.D.

Official reviewers: Zoltán Bejek, M.D., Ph.D.

Tibor Mintál, M.D., Ph.D.

Head of the Complex Examination Committee: Miklós Szendrői, M.D., D.Sc.

Members of Complex Examination Committee: Zoltán Bejek, M.D., Ph.D.
Gábor Fazekas, M.D., Ph.D.

Budapest
2024

1. Introduction

Anterior cruciate ligament (ACL) injuries are prevalent in competitive sports, leading to significant impairments in athlete's mobility and performance. ACL reconstruction (ACLR) is the standard treatment, but surgical success depends on effective rehabilitation. Athletes can choose between supervised rehabilitation (SVR) in clinical settings and home-based rehabilitation (HBR), with both approaches aiming to rebuild strength, flexibility, and function for a safe return to sports (RTS). The effectiveness of SVR versus HBR has been a subject of debate. While HBR offers convenience and personalized routines, SVR often provides better guidance and access to specialized equipment. Despite some positive outcomes with both approaches, the re-injury rate remains a concern, with fewer than half of competitive athletes returning to their pre-injury level. Key risk factors for re-injury include muscle strength deficits, an abnormal hamstring-quadriceps ratio, and a lack of motivation. Our study assessed the effectiveness of SVR versus HBR after ACLR among competitive athletes, considering both biomechanical and psychological outcomes.

2. Objectives

Our study aimed to compare the effectiveness of SVR and HBR among competitive athletes after ACLR. We assessed biomechanical outcomes, such as muscle strength in quadriceps, hamstrings, abductors, and adductors, along with squat analysis and stance evaluation. Psychological readiness for RTS was also evaluated. We hypothesized that SVR could yield better outcomes in terms of re-injury prevention and successful RTS due to its structured environment and professional guidance. Additionally, we aimed to identify why re-injury might occur post-ACLR, despite advancements in surgery and rehabilitation. Our goal was to inform better rehabilitation practices and provide insights that guide sports medicine professionals, physiotherapists, coaches, and athletes toward effective strategies for optimal recovery and safe RTS after ACLR.

3. Methods

3.1 Design

This clinical study was conducted at Castle Park Surgical Hospital in Tata, Hungary, and the TSO Biomechanics Lab in Budapest, Hungary, from January 2020 to February 2023. It received ethical approval from the Regional and Institutional Science and Research Ethic Committee of Semmelweis University. The study was non-randomized and observational, with informed consent obtained from all patients.

3.2 Patient Enrollment

Participants were competitive athletes involved in high-risk pivoting sports (Figure 1), diagnosed with isolated ACL injuries, and aged 15 to 50. Surgeries were performed by a single surgeon at Castle Park Surgical Hospital from January 2020 to March 2021. Selection criteria included athletes with no other major injuries. Out of 74 patients screened, 14 were excluded due to medical complications or lack of consent, resulting in a final sample of 60 participants, divided into two groups of 30 each. The SVR group underwent supervised rehabilitation, and the HBR group followed home-based rehabilitation.

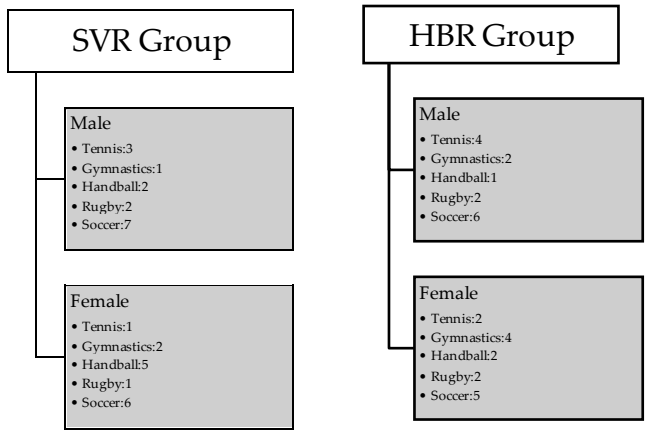

Figure 1. Type of Sports; A gender-differentiated breakdown of sports participation among athletes in SVR and HBR groups.

3.3 Surgical Technique

ACLR was performed using an arthroscopic transtibial technique. Patients were positioned supine, with a thigh tourniquet applied. The procedure started with an anterolateral portal, followed by diagnostic arthroscopy to assess ACL damage. Graft harvesting involved semitendinosus and gracilis tendons, with the femoral tunnel created using a guide pin and careful reaming. Meniscus tears were repaired when possible; otherwise, partial meniscectomy was done for stability. The graft was

fixed with an endobutton on the femoral side and absorbable screws on the tibial side, ensuring proper graft tensioning.

3.4 Rehabilitation Protocols

After ACLR, a structured rehabilitation program was implemented to optimize recovery and ensure a safe RTS. This program consisted of five phases, focusing initially on pain management, mobility, and range of motion, and later transitioning to strength, power, endurance, and stability. During the first eight months after surgery, participants in the SVR group attended supervised physical therapy twice a week, while the HBR group performed exercises at home with periodic clinic visits for monitoring. The frequency of visits ranged from 40-64 for SVR and 5-12 for HBR. Supervision and communication through follow-up appointments and remote consultations helped ensure adherence to the program.

Five mandatory follow-up examinations were conducted, including at 14 days, 6 weeks, 3 months, 6 months, and 8 months. The final assessment allowed patients to gradually return to their sports based on set criteria. Both groups typically returned to sports about nine months after

surgery. Throughout the rehabilitation, adjustments were made to meet individual needs, and smartphone apps for monitoring were considered for future research.

3.5 Outcome Measures

The Tegner Activity Scale (TAS) was used to assess participants' level of sports activity, with a scale from 0 (knee-related disability) to 10 (highest level of competitive sport).

The International Knee Documentation Committee subjective knee form (IKDC-SKF) evaluated knee function with scores ranging from 0 to 100, including questions on knee symptoms, function, and sports activities.

The ACL Return to Sport after Injury (ACL- RSI) questionnaire assessed psychological readiness with 12 questions covering emotional well-being, confidence in sport, and risk appraisal. The final score was reported as a percentage, indicating the athlete's psychological readiness to return to sports.

3.6 Muscle Strength and Neuromuscular Control

We measured isometric strength in the quadriceps and hamstrings at knee flexion angles of 30°, 45°, and 90° using Kinvent Isometric Dynamometers. Strength deficits and hamstring-to-quadriceps ratios were calculated. Quadriceps concentric contractions were assessed at angular velocities of 120°/s and 240°/s with the Kineoglobus system. Balance tests were conducted on KINVENT Force Plates, measuring the average Center of Pressure (COP) and foot pressure differences between sides. Hip adductor and abductor strength was measured using the Vald Performance Force Frame at a 60-degree knee angle.

Re-injury was identified through clinical and MRI examinations. RTS was tracked based on athletes' reported sports participation.

3.7 Statistical Analysis

We used a post hoc power analysis with GPower software to ensure our sample size was sufficient to detect significant differences. Data was analyzed with averages and standard deviations. The Shapiro-Wilk W test checked

for normality. For within-group comparisons, we used paired sample t-tests or Wilcoxon tests; for between-group comparisons, independent sample t-tests or Mann-Whitney U tests. Chi-Square tests were applied to discrete data. We set the significance level at $p < 0.05$, using JASP and Statistica software for analysis. Effect Size (Cohen's d) and post hoc power values were calculated to ensure robust and reliable results. These additional metrics helped confirm the validity of our statistical findings.

4. Results

4.1. Baseline Characteristics

The study included 60 participants, with an equal allocation of 15 males and 15 females in both the SVR and HBR groups to avoid gender-related biases. The average age in the SVR group was 22.43 ± 6.34 years, while in the HBR group, it was 24.96 ± 7.93 years, a difference that wasn't statistically significant (p = 0.1991). Additionally, height and weight were similar across groups, with no significant differences (p = 0.3022 for height, p = 0.1960 for weight). The mean follow-up time was also comparable between the groups (p = 0.9501) (Table 1).

Table 1. Demographic data of participants in the SVR and HBR Groups. Values are expressed as mean ± standard deviation.

Baseline Characteristics	**SVR (n = 30)**	**HBR (n = 30)**	**p**
Gender (male/female)	15/15	15/15	
Age (years)	22.43±6.34	24.96±7.93	0.199

Height (cm)	174.78±9.59	172±9.81	0.302
Weight (kg)	71.11±12.90	77.23±20.41	0.196
Follow-up time(months)	8.62±7.32	8.48±7.68	0.950
BMI (Male)	22.19±2.02	23.93±2.75	0.070
BMI (Female)	24.23±2.52	25.53±3.66	0.327

4.2. Patient-Reported Questionnaires

The TAS scores for male athletes in the SVR group dropped from 8 preoperatively to 7 by postoperative day (POD) 240, while in the HBR group, they fell from 7 to 5. For female athletes, the scores decreased from 7 to 6 in the SVR group and from 8 to 6 in the HBR group. The IKDC-SKF scores showed a significant difference at POD 240. The SVR group improved from 49 to 81.82, while the HBR group rose from 45 to 68.43 (p=0.0021). HBR group showed better psychological readiness to RTS, with ACL-RSI scores of 55.25±9.72 as compared to 49.46±8.14 in the SVR group (p=0.0194) at POD 240.

4.3. Muscle Strength and Neuromuscular Control

Quadriceps isometric strength deficits at 30 degrees were 26.1% for the SVR group and 27.9% for the HBR group, while hamstring deficits were 14.1% for SVR and 32.2% for HBR. At 45 degrees, the hamstring deficit was 12.8% for SVR and 47.8% for HBR. H/Q asymmetry at this angle was significant in the HBR group (16.6%, $p < 0.05$), but not in the SVR group.

At 90 degrees, hamstring deficits were significantly higher in both groups—69.7% for SVR and 84.9% for HBR. The H/Q asymmetry was 37.9% for SVR and 30.5% for HBR (both $p < 0.05$). No significant differences were observed in weight distribution during stance and squat analysis, suggesting that both rehabilitation approaches led to similar outcomes in those aspects.

4.4. Return to Sport

In the SVR group, 76.6% of participants returned to their previous level of sport following ACL rehabilitation. Another 16.6% returned to a lower level of sport, and 6.6% did not resume any sport activities. In the HBR group, only 53.3% returned to the same level, 30% to a lower level,

and 16.6% did not return to sport at all. The differences in these outcomes were statistically significant ($p = 0.036$), indicating a notable disparity in sport participation after rehabilitation between SVR and HBR groups (Table 2).

Table 2. Number of individuals returning to sport for the SVR and HBR groups respectively. The table describes numbers and percentages of RTS to difference levels as reported in both the rehabilitation groups.

RTS	SVR Group	HBR Group
Same level	23 (76.6 %)	16 (53.3 %)
Lower level	5 (16.6 %)	9 (30 %)
No return	2 (6.6 %)	5 (16.6 %)

4.5. ACL Re-Injury

Evaluating ACL re-injury rates requires distinguishing between re-injuries to the previously operated knee and new injuries to the contralateral knee. The overall re-injury rate was 3.3% in both the SVR and HBR groups. However, the contralateral ACL injury rate was higher in the SVR group at 6.6%, compared to 3.3% in the HBR group.

5. Conclusions

Both rehabilitation approaches showed comparable outcomes among competitive athletes post-ACLR. However, SVR offered some additional benefits, leading to better patient-reported outcomes and RTS to the same level. Despite these advantages, the re-injury rate was similar for both groups, possibly due to limited psychological recovery, especially around eight months after ACLR. To ensure successful RTS and reduce re-injury risk, criterion-based rehabilitation programs are essential, including continuous psychological support under the supervision of a physiotherapist. Further research should incorporate comprehensive psychological assessments beyond common measures like the ACL-RSI. Future studies should focus on larger sample sizes, narrower age ranges, and longer-term follow-ups to fully evaluate the effectiveness of different rehabilitation strategies in preventing re-injury after ACLR.

6. Bibliography of the Candidate's Publications

6.1. List of original publications related to the PhD thesis

1. **Syed Rehan Iftikhar Bukhari**, Hangody László Rudolf, Frischmann Gergely, Kós Petra, Kopper Bence, Berkes István Comparative Effectiveness of Supervised and Home-Based Rehabilitation after Anterior Cruciate Ligament Reconstruction in Competitive Athletes JOURNAL OF CLINICAL MEDICINE 13: 8 Paper: 2245, 14 p. (2024) Article (Journal Article) | Scientific Scopus - Medicine (miscellaneous) Rank: Q1

2. Hangody László Rudolf, Gál Tamás, Vásárhelyi Gábor, Hangody György, **Iftikhar Bukhari Syed Rehan**, Hangody László Results of ultra-fresh osteochondral allograft transplantation for large cartilage defects in the knee joint JOINT DISEASES AND RELATED SURGERY 33: 3 pp. 521-530. (2022) Article (Journal Article) | Scientific Scopus - Rehabilitation Rank: Q2 Scopus - Surgery Rank: Q2 Scopus - Orthopedics and Sports Medicine Rank: Q3

6.2. List of original publications not related to the PhD thesis

1. **Syed Rehan Iftikhar Bukhari**, Syed Shakil-ur-Rehamn, Shakeel Ahmad, Aamer Naeem Comparison between effectiveness of mechanical and manual traction combined with mobilization and exercise therapy in patients with Cervical Radiculopathy PAKISTAN JOURNAL OF MEDICAL SCIENCES 32: 1 pp. 31-34. (2016) Article (Journal Article) | Scientific

2. Aczél Dóra, György Bernadett, Bakonyi Péter, **Bukhari Rehan**, Pinho Ricardo, Boldogh István, Yaodong Gu, Radák Zsolt The Systemic Effects of Exercise on the Systemic Effects of Alzheimer's Disease ANTIOXIDANTS 11: 5 Paper: 1028, 16 p. (2022) Survey paper (Journal Article) | Scientific

3. Torma Ferenc, Bakonyi Péter, Regdon Zsolt, Gombos Zoltán, Jókai Mátyás, Babszki Gergely, Fridvalszki Marcell, Virág László, Naito Hisashi, **Iftikhar Bukhari Syed Rehan**, Radák Zsolt Blood flow restriction during the resting periods of high-intensity resistance training does not alter performance but

decreases MIR-1 and MIR-133A levels in human skeletal muscle SPORTS MEDICINE AND HEALTH SCIENCE 3: 1 pp. 40-45. (2021) Article (Journal Article) | Scientific