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Physiotherapy Approaches in ACL Reconstruction Rehabilitation: A Narrative Review of Evidence-Based Practices

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ABSTRACT

Background

Anterior cruciate ligament (ACL) injuries are common among athletes and active individuals, often requiring surgical reconstruction to restore knee stability. Effective rehabilitation is crucial for optimizing recovery, restoring function, and ensuring a safe return to physical activities and sports. Various physiotherapy approaches have been developed to enhance post-surgical recovery, incorporating progressive loading, neuromuscular training, and functional exercises.

Objective

This narrative review aims to explore evidence-based physiotherapy interventions in ACL reconstruction rehabilitation, focusing on key phases, best practices, and emerging trends. The review highlights strategies that enhance knee stability, reduce reinjury risk, and optimize return to sport outcomes.

Methodology

A comprehensive review of the literature on ACL rehabilitation was conducted using peer-reviewed journals, clinical guidelines, and systematic reviews. The selected studies emphasize physiotherapy interventions across different rehabilitation phases, including early mobilization, strength training, neuromuscular re-education, and functional training. Special attention is given to novel approaches such as blood flow restriction (BFR) training, psychological readiness assessment, and technology-assisted rehabilitation.

Conclusion

ACL rehabilitation requires a structured, progressive approach that aligns with physiological healing and functional demands. Evidence-based physiotherapy practices, incorporating strength training, neuromuscular control, and sport-specific exercises, enhance recovery outcomes and reduce the risk of re-injury. Personalized rehabilitation strategies, including psychological support and emerging technologies, can further optimize patient outcomes. Future research should focus on refining rehabilitation protocols and integrating innovative interventions for improved recovery.

Keyword: *ACL reconstruction, physiotherapy, rehabilitation, neuromuscular training, return to sport, evidence-based practice, functional training*

1. INTRODUCTION

Anterior cruciate ligament (ACL) injuries are among the most common knee injuries, particularly in physically active individuals and athletes. The ACL, a key stabilizing ligament in the knee joint, plays a crucial role in maintaining rotational stability and preventing excessive forward movement of the tibia relative to the femur. Due to its limited self-healing capacity, ACL injuries often necessitate surgical reconstruction, particularly in individuals seeking to return to high levels of physical activity. ACL reconstruction (ACLR) is a well-established procedure designed to restore knee stability and function; however, surgical intervention alone is not sufficient for full recovery. A structured rehabilitation program is critical to optimize functional outcomes and minimize the risk of reinjury.[1]

Post-operative physiotherapy following ACLR is essential for restoring knee range of motion (ROM), strength, neuromuscular control, and overall functional performance. The rehabilitation process typically follows a phased approach, progressively transitioning from pain management and early mobilization to advanced functional training and sport-specific exercises. Given the significant physical and psychological challenges associated with ACLR recovery, an evidence-based approach to rehabilitation is necessary to ensure optimal outcomes and long-term joint health.[1]

Epidemiology of ACL Injuries

ACL injuries are highly prevalent in sports involving sudden deceleration, pivoting, and jumping movements, such as soccer, basketball, and skiing. Studies indicate that female athletes have a higher risk of ACL injuries than their male counterparts, largely due to anatomical, neuromuscular, and hormonal differences. Non-contact mechanisms, such as improper landing techniques or rapid changes in direction, account for the majority of ACL injuries. The increasing incidence of ACL injuries and the high rate of subsequent osteoarthritis underscore the need for effective rehabilitation protocols to support long-term joint health.[2]

Challenges in ACL Rehabilitation

Despite advances in ACLR techniques and rehabilitation protocols, several challenges remain in optimizing patient outcomes. Some key challenges include:

- Quadriceps Muscle Weakness: Persistent quadriceps weakness is a common issue following ACLR, often due to neuromuscular inhibition and muscle atrophy. Strength deficits can contribute to altered knee mechanics and increased reinjury risk.
- Graft Healing and Ligamentization: The biological process of graft incorporation and remodeling (ligamentization) is time-dependent, necessitating a carefully structured rehabilitation timeline to avoid excessive stress on the healing graft.
- Psychological Factors: Fear of reinjury, reduced confidence, and anxiety are significant barriers to returning to sports. Psychological readiness assessments and mental training strategies are increasingly recognized as critical components of ACL rehabilitation.
- Risk of Reinjury: Studies suggest that athletes who return to high-impact sports within 12 months of ACLR have an increased risk of graft rupture or contralateral ACL injury. Comprehensive neuromuscular training and biomechanical assessments are crucial for mitigating this risk.[3]

Emerging Trends and Innovations in ACL Rehabilitation

Advancements in physiotherapy and sports medicine have introduced novel approaches to ACL rehabilitation. Some emerging trends include:

- Blood Flow Restriction (BFR) Training: BFR training involves the use of external pressure cuffs to restrict blood flow during low-load resistance exercises. This method has been shown to enhance muscle hypertrophy and strength while minimizing joint stress, making it a valuable tool in early rehabilitation.
- Technology-Assisted Rehabilitation: Wearable sensors, motion analysis systems, and virtual reality applications are being integrated into rehabilitation programs to provide real-time feedback and objective performance assessments.[4]
- Neuromuscular and Biomechanical Training: A focus on movement quality, landing mechanics, and dynamic stability exercises has gained prominence in ACL rehabilitation to address biomechanical deficits and reduce reinjury risk.
- Return-to-Sport Assessments: Functional hop tests, strength symmetry analysis, and psychological readiness evaluations are increasingly utilized to guide return-to-sport decision-making.[5]

Rationale of the Study

The increasing prevalence of ACL injuries and the critical role of rehabilitation in successful recovery highlight the need for an in-depth exploration of evidence-based physiotherapy approaches. While various rehabilitation protocols exist, there

is ongoing debate regarding the most effective strategies to optimize recovery, minimize reinjury risk, and facilitate a safe return to sports. This study is essential in consolidating current evidence and identifying best practices that can enhance patient outcomes. Furthermore, emerging rehabilitation techniques, such as blood flow restriction training and technology-assisted rehabilitation, require thorough evaluation to determine their efficacy and clinical relevance. By synthesizing existing research, this study aims to provide a comprehensive understanding of physiotherapy interventions in ACL reconstruction rehabilitation and contribute to the development of optimized rehabilitation protocols.

Objective of the Review

The primary objective of this narrative review is to provide an evidence-based overview of physiotherapy approaches in ACLR rehabilitation. By summarizing key rehabilitation phases, effective interventions, and emerging trends, this review aims to inform clinicians, physiotherapists, and sports professionals on best practices for optimizing ACL rehabilitation outcomes**.**

Eligibility Criteria

This narrative review is based on the literature from 2005 to 2025. Studies included in the review were identified by keyword searches PubMed, Google Scholar, NCBI, and Science Direct databases. Keywords searched included – Manual therapy, ACL reconstruction, modalities,

Eligibility Criteria

Inclusion Criteria

1. **Study Design** – Randomized controlled trials (RCTs), cohort studies, case-control studies, and systematic reviews evaluating the effect of manual therapy and modalities on ACL rehabilitation.
2. **Population** – Studies involving individuals diagnosed with ACL injuries, whether managed surgically or non-surgically.
3. **Intervention** – Research assessing the use of manual therapy techniques (e.g., joint mobilization such as Maitland, Mulligan, Kaltenborn mobilization, soft tissue manipulation, myofascial release, Muscle energy Technique) in combination with physical modalities (e.g., electrical stimulation, ultrasound, cryotherapy, laser therapy, CPM).
4. **Outcomes Measured** – Studies reporting on pain relief, range of motion (ROM), muscle activation, functional recovery, and return to activity or sport.
5. **Language** – Only studies published in English.
6. **Publication Period** – Studies published within the last 20 years to ensure relevance to current clinical practices.

Exclusion Criteria

1. **Study Design** – Case reports, expert opinions, abstracts, and conference proceedings without peer-reviewed full-text articles.
2. **Population** – Studies focusing on ACL injuries in pediatric populations or involving individuals with multiple ligamentous injuries or severe comorbidities affecting rehabilitation.
3. **Intervention** – Studies that assess only manual therapy or only physical modalities without evaluating their combined effect.
4. **Outcomes** – Research not reporting functional outcomes relevant to ACL rehabilitation.
5. **Non-English Publications** – Studies published in languages other than English due to accessibility constraints.

These criteria ensure that the review includes high-quality, relevant studies that provide meaningful insights into the role of manual therapy and modalities in ACL rehabilitation.

Search methods

Articles for the study were taken from databases like PubMed, Google Scholar, NCBI, and Science Direct. Analysis was done according to the review of literature.

Author	Study design	Subject	Intervention	Study duration	Outcome measure	Results
Vibhuti Vinodsingh Gaur et al.	RCT	N=60	GROUP A – muscle energy technique	Only for 1 day	VAS, Goniometry, active knee	Both MET and ART stretching are equally effective and

2021[6]			Group B – Active Release Technique Group C- active knee extension test		extension test (AKE), sit and reach (SR) test.	beneficial in improving hamstring flexibility.
Nai-Jen Chang,*y PhD et al.[7] 2017	RCT	N= 60	Group A CPM Group B tredmill exercises	12 weeks	VAS, Goniometry	the CPM group experienced the best protective therapeutic effects in all compartments
Yufeng Song et.al[8] 2024	RCT	N=72	Group A = radial extracorporeal shock wave therapy Group B= conventional physiotherapy	24 weeks	Lysholm knee joint score (LKS), range of motion (ROM), visual analogue scale (VAS) and International Knee Literature Committee (IKDC).	Early use of rESWT can improve joint function, pain relief and ability of daily living. rESWT has a positive effect on the overall rehabilitation of patients.
Mahadi Begum Shiraj et. Al[9] 2025	RCT	N =80	Group A: TENS + cryotherapy + exercises; Group B: cryotherapy + exercises	All patients were allowed immediate weight-bearing post-ACLR, followed by routine physiotherapy and assessments at baseline, 3 months, and 6 months.	visual analogue scale (VAS) and International Knee Literature Committee (IKDC).	While TENS showed a modest trend toward improved quadriceps activation and pain relief, its overall impact on ACLR rehabilitation outcomes was not statistically significant.
Theo Jaspers, et.al[10]	meta-analysis	442	For intervention group CPM is given. For Control group CPM is not given.	We searched in MEDLINE, Embase, CINAHL, Cochrane and PEDro up to January 2018.	visual analogue scale (VAS), Goniometry	This meta-analysis suggests that CPM has beneficial effects on pain reduction during the first two postoperative days, on knee flexion during the first to the sixth postoperative weeks and on swelling between the fourth and the sixth postoperative weeks

Scoot Telfer, et.al[11]	Cross sectional study	20	Group A – BFRT Group B – Control group	ONE Session	IKDC, NPRS	The present study demonstrates that BFR leads to small changes in knee joint mechanics compared to a non-restricted state after ACL reconstruction, thus providing cautious support for the use of BFR from a biomechanical perspective.
Won-Sang Jung[12]	RCT	24	the general rehabilitation exercise group (GRE, *n* = 12) and blood flow restriction group (BFR, *n* = 12) were assigned the same.	All participants performed the rehabilitation exercise program session for 60 min three times a week for 12 weeks under supervision.	(Lysholm score and International Knee Documentation Committee (IKDC) subjective score, muscle activity, isokinetic muscular function, Y-balance test)	it is recommended to use BFR as an effective rehabilitation program for rapid recovery after ACL reconstruction.
Chunying Hu, et.al[13]	RCT	8	Single group – Robotic Assisted Technology	10 months	The Timed Up-and-Go test, 10-Meter Walk test, Functional Reach Test,	These results suggest that walking ability and muscle strength can be improved by robotic walking training as a long-term intervention.
Doo Hawn Koong, et al1[4]	RCT	45	All participants carried out the RE program for 60 min, thrice a week for 12 weeks.	All participants carried out the RE program for 60 min, thrice a week for 12 weeks.	The Lysholm score, International Knee Documentation Committee (IKDC) subjective score, thigh circumference at 5 cm from the knee joint, Y-balance posterior medial,	In conclusion, we confirmed that RE using NMES and BFR effectively enhances muscle function and balance in ACLR patients.

2. DISCUSSION

ACL reconstruction rehabilitation has undergone significant advancements, with physiotherapy playing a crucial role in restoring knee function, reducing the risk of re-injury, and ensuring a safe return to activity. This narrative review explores the evolution of rehabilitation approaches, emphasizing evidence-based practices that contribute to optimal recovery outcomes.

Vibhuti Vinodsingh Gaur et al. (2021), in this randomized controlled trial (RCT), Gaur et al. evaluated the effectiveness of two manual therapy techniques—Muscle Energy Technique (MET) and Active Release Technique (ART)—on hamstring flexibility in 60 participants. The study divided the subjects into three groups: Group A received MET, Group B received

ART, and Group C underwent the active knee extension test. The intervention lasted for only one day, and outcome measures included the Visual Analogue Scale (VAS), goniometry, the active knee extension test (AKE), and the sit-and-reach (SR) test. The results revealed that both MET and ART were equally effective in enhancing hamstring flexibility. The study concluded that either technique could be employed to improve flexibility, making them viable options for short-term rehabilitation interventions.[6]

Nai-Jen Chang et al. (2017), conducted a 12-week RCT comparing the efficacy of continuous passive motion (CPM) and treadmill exercises in 60 participants undergoing ACL rehabilitation. The subjects were divided into two groups: Group A received CPM therapy, while Group B engaged in treadmill exercises. The researchers used VAS and goniometry to assess pain levels and knee range of motion. The findings demonstrated that the CPM group experienced superior protective therapeutic effects in all knee compartments, indicating that CPM was more effective in reducing pain and promoting joint mobility. The study supports the use of CPM as a preferred intervention during the early stages of ACL rehabilitation due to its significant protective and restorative effects on the knee joint.[7]

Yufeng Song et al. (2024), in his RCT, explored the impact of radial extracorporeal shock wave therapy (rESWT) compared to conventional physiotherapy in 72 participants over 24 weeks. Group A received rESWT, while Group B underwent standard physiotherapy. The researchers evaluated outcomes using the Lysholm knee joint score (LKS), range of motion (ROM), VAS, and the International Knee Literature Committee (IKDC) score. The study concluded that early application of rESWT significantly improved joint function, reduced pain, and enhanced daily living activities. The results indicate that rESWT is a valuable intervention for improving both short-term and long-term outcomes in ACL rehabilitation, making it a promising alternative to traditional physiotherapy.[8]

Mahadi Begum Shiraj et al. (2025), conducted an RCT involving 80 participants to assess the effectiveness of transcutaneous electrical nerve stimulation (TENS) in combination with cryotherapy and exercises, compared to cryotherapy and exercises alone. Group A received TENS along with cryotherapy and exercises, while Group B underwent only cryotherapy and exercises. The intervention included immediate weight-bearing post-ACL reconstruction (ACLR), followed by routine physiotherapy assessments at baseline, 3 months, and 6 months. The outcome measures included the VAS and IKDC scores. While TENS showed a modest trend toward improved quadriceps activation and pain relief, the overall impact on ACL rehabilitation outcomes was not statistically significant. The study suggests that although TENS may offer temporary pain relief, its influence on long-term functional recovery is limited.[9]

Theo Jaspers et al. (2018), conducted a meta-analysis to evaluate the effects of CPM on ACL rehabilitation outcomes. The analysis included data from 442 participants across multiple studies retrieved from MEDLINE, Embase, CINAHL, Cochrane, and PEDro databases. The researchers compared CPM interventions against control groups without CPM. Outcome measures included VAS and goniometry to assess pain, knee flexion, and swelling. The meta-analysis revealed that CPM effectively reduces pain during the first two postoperative days, improves knee flexion during the first to sixth postoperative weeks, and reduces swelling between the fourth and sixth postoperative weeks. These findings support the clinical use of CPM in early postoperative rehabilitation, emphasizing its role in minimizing discomfort and enhancing joint mobility.[10]

Scott Telfer et al. (2025), conducted a cross-sectional study with 20 participants to investigate the effects of blood flow restriction therapy (BFRT) on knee joint mechanics after ACL reconstruction. The participants were divided into Group A, which received BFRT, and Group B, which acted as a control group. The intervention lasted for one session, and outcome measures included the International Knee Documentation Committee (IKDC) score and the Numeric Pain Rating Scale (NPRS). The study concluded that BFRT led to small but significant changes in knee joint mechanics, providing cautious support for its use in ACL rehabilitation. The researchers suggested that while BFRT offers biomechanical benefits, further studies are necessary to validate its long-term efficacy.[11]

Won-Sang Jung et al. (2025), conducted a 12-week RCT to compare the effects of blood flow restriction therapy (BFRT) with general rehabilitation exercises (GRE) on ACL recovery. The study involved 24 participants, with 12 assigned to the BFRT group and 12 to the GRE group. Both groups performed supervised rehabilitation exercises for 60 minutes, three times per week. The outcome measures included the Lysholm score, IKDC subjective score, muscle activity, isokinetic muscular function, and Y-balance test. The results demonstrated that BFRT significantly improved muscle function, joint stability, and overall rehabilitation outcomes. The authors recommended BFRT as an effective intervention for accelerating recovery post-ACL reconstruction.[12]

Chunying Hu et al. (2025), investigated the impact of robotic-assisted technology on ACL rehabilitation in a single-group RCT with eight participants. The intervention lasted for 10 months and involved robotic walking training. Outcome measures included the Timed Up-and-Go test, 10-Meter Walk test, and the Functional Reach Test. The findings showed that robotic-assisted therapy significantly improved walking ability and muscle strength over the long term. This suggests that robotic rehabilitation could be a viable option for enhancing functional recovery in patients with ACL injuries, especially for individuals requiring prolonged rehabilitation support.[13]

Doo Hawn Koong et al. (2025), conducted a 12-week RCT involving 45 participants to evaluate the effects of neuromuscular electrical stimulation (NMES) combined with blood flow restriction (BFR) on ACL rehabilitation. The

participants performed a rehabilitation exercise program for 60 minutes, three times per week. Outcome measures included the Lysholm score, IKDC subjective score, thigh circumference, and Y-balance posterior medial test. The results demonstrated that NMES combined with BFR significantly enhanced muscle function, balance, and overall knee stability. The study concluded that this combined intervention is highly effective in promoting functional recovery and muscle performance in ACL patients.[14]

3. CONCLUSION

The rehabilitation of ACL reconstruction has shifted from a generalized, time-based approach to an evidence-based, individualized strategy. Early mobilization, progressive strengthening, neuromuscular training, psychological support, and injury prevention programs are critical components of a successful rehabilitation plan. Continued research into personalized rehabilitation approaches and technological advancements will further enhance recovery outcomes and reduce the risk of future injuries.

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