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Review Article

Physiotherapy Section

ACL Reconstruction with Enhanced Physiotherapy Interventions and Early Rehabilitation: A Narrative Review

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ABSTRACT

Anterior Cruciate Ligament Reconstruction (ACLR) is a common surgical knee procedure that requires intensive postoperative rehabilitation by the patient. Although ACLR restores the knee's mechanical stability, patients often experience postoperative limitations. This study aimed to examine the supplementary physiotherapy interventions incorporated into standard rehabilitation programs that enhance early-stage ACLR rehabilitation. In October 2025, a literature review was performed utilising electronic databases. The primary outcomes assessed included pain, oedema, muscle strength, Range of Motion (ROM), and knee function. For this review, 10 studies were selected that fulfilled the inclusion criteria (total n=210). The studies analysed the efficacy of Kinesio Taping (KT), Whole-Body Vibration (WBV), local vibration training, Trigger Point Dry Needling (TrP-DN), high tone power therapy, alternating magnetic field, and an App-based active muscle training program. The majority of the additional physiotherapy interventions demonstrated improvements in pain, oedema, ROM, knee muscle strength, or knee function during the early stages of postoperative ACL rehabilitation. With the exception of one study, no adverse events were reported in the included studies, indicating the safety of the physiotherapy interventions discussed. Further comprehensive research is warranted in this domain.

Keywords: Anterior cruciate ligament reconstruction, Knee therapy, Postoperative

INTRODUCTION

ACL injuries are among the most common and debilitating sports-related injuries, often leading to long-term functional impairments if not properly treated. The ACL is essential for the kinematics of the knee joint, as it restricts the anterior movement of the tibia and stabilises the knee joint [1]. It also contains mechanoreceptors that play a critical role in maintaining neuromuscular control of the joint. At the same time, it is a structure that, when injured, is one of the most common and serious locomotor injuries [2]. The result of an ACL rupture is a disturbance in the biomechanics of the joint, which can lead to the development of abnormal movement patterns and chronic instability, resulting in functional loss during dynamic tasks and potentially causing secondary damage to the menisci and cartilage [3,4]. A complete ACL rupture typically indicates the need for surgical reconstruction. It is important to highlight that the prognosis for patients following surgery is heavily dependent on the rehabilitation that is implemented [5].

Although ACLR restores mechanical stability of the knee, many patients continue to experience postoperative pain [6], joint effusion [7], muscle weakness [8], and restricted ROM for prolonged periods, which may result in functional impairment and diminished quality of life [9]. Conventional physiotherapy alone often does not adequately address these sequelae, underscoring the need to optimise and intensify existing rehabilitation protocols [10], particularly during the early postoperative period. Numerous systematic reviews have evaluated the impact of physiotherapeutic interventions following ACLR, encompassing studies of early and late postoperative rehabilitation [11-13], preoperative "prehabilitation" programs, and combined pre- and postoperative approaches [14,15]. In contrast, the present study focuses exclusively on interventions implemented in the early phase of postoperative ACL rehabilitation.

This review specifically analysed the early phase of ACL rehabilitation, as this stage may be constrained by postoperative complications such as pain or swelling, which frequently challenge both clinicians and patients during the first weeks postsurgery [16]. The occurrence of swelling results in diminished quadriceps strength due to arthrogenic muscle inhibition [17], and pain complicates both exercise and functional performance [18]. This review sought to explore which physiotherapy approaches effectively alleviate pain, minimise swelling, enhance knee mobility, strengthen muscles, and improve functional recovery during the early phase following ACLR. Accordingly, the study aimed to evaluate additional physiotherapy modalities integrated into conventional rehabilitation programs to optimise early postoperative outcomes after ACLR.

Effect of Kinesio Taping (KT) on ACLR

The KT functions by microscopically elevating the skin to relieve pressure in the interstitial space, thereby decreasing the pressure on subcutaneous nociceptors and mitigating pain according to the gate control theory [19]. This mechanical elevation concurrently improves localised blood flow, hastens lymphatic drainage, and offers ongoing somatosensory feedback to enhance joint proprioception [20]. In clinical practice, it acts as a beneficial adjunct therapy for immediate, short-term pain alleviation, reduction of oedema, and facilitation of functional movement without limiting the ROM [21,22]. Nevertheless, significant limitations remain; literature reviews indicate a deficiency of high-quality, long-term evidence, with therapeutic outcomes frequently not surpassing those of sham taping.

Three studies explored the effects of KT during the early postoperative phase after ACLR. Labianca L et al., (2022) enrolled 52 men (ages 18-45 years) after gracilis and semitendinosus autograft, assigning them on postoperative day two to KT every five days for four weeks plus standard rehab or rehab alone. At two and four weeks, KT significantly reduced pain and oedema (p-value <0.05), but did not improve ROM or knee function (p-value >0.05) [23].

Balki S et al., (2016) studied 30 men (ages 18-39 years) post-ACLR (hamstring tendon autograft and tibialis posterior or peroneus longus allograft), assigning them to either muscle/lymphatic KT or placebo KT, along with a standardised 12-week rehab program. Measurements on postoperative day four, after five and 10 days of KT, and at one and three months, showed KT significantly improved knee swelling, pain, hamstring strength, and flexion ROM (p-value <0.05), but not subjective function, extension, or extensor strength (p-value >0.05) [24].

Laborie M et al., (2015) assessed KT's role in reducing early postoperative pain in 57 patients (44 men, 13 women) after hamstring tendon graft, with KT applied for three days alongside anaesthesia-analgesia or anaesthesia-analgesia alone. Pain was measured at baseline and for three days after taping; KT did not significantly reduce early pain compared to control (p-value >0.05). Overall, KT may help reduce pain and swelling after ACLR, though evidence for improvements in function and ROM is inconsistent [25].

The influence of vibration training during the early stages of rehabilitation post-ACLR vibration training is generally administered through WBV platforms. The swift mechanical oscillations induce ongoing micro-instability, activating muscle spindle stretch reflexes that compel the neuromuscular system to refine motor unit recruitment and synchronisation [26]. From a mechanical perspective, this rhythmic loading promotes osteoblast activity, thereby improving bone mineral density, while also elevating localised nitric oxide production to enhance blood circulation [27]. Clinically, it functions as a remarkably effective low-impact intervention for groups who are unable to engage in conventional high-impact resistance training.

Two studies evaluating WBV and one assessing Local Vibration Therapy (LVT) during early rehabilitation after ACLR were analysed. Berschin G et al., randomised 40 patients (29 men, 11 women; aged 25-39) post-patellar tendon graft to eight weeks of WBV or standard rehab, with assessments at baseline, weeks 5, 8, and 11; WBV showed no significant gains in ROM, strength, or knee function versus control (p-value >0.05) [28].

Pistone EM et al., (2016) evaluated 34 patients one month after ACLR with hamstring tendon autograft, randomly allocating them to either four weeks of WBV training plus standard rehabilitation or to standard rehabilitation alone. Strength and balance were measured at baseline, and again at two and three months postsurgery. The WBV group demonstrated significant improvements in knee flexor strength symmetry and knee function (p-value <0.05) compared to control, but there was no significant difference in knee extensor strength symmetry between groups (p-value >0.05) [29].

Coulondre C et al., (2022) investigated the effect of LVT on quadriceps strength in 23 subjects (13 males, 10 females, aged 18-50 years) after ACLR with hamstring or patellar tendon autografts. Participants were allocated to receive either 24 LVT or 24 standard rehab sessions over 10 weeks, or 24 standard rehab sessions alone. Measurements taken before and after the intervention revealed that the LVT group had significantly greater improvements in extensor muscle strength compared to controls (p-value <0.05), but there were no significant differences in limb symmetry or functional test outcomes (p-value >0.05) [30].

Impact of Various Interventions on the Initial Rehabilitation following ACLR

Four investigations focused on a range of alternative physiotherapy treatments. Trigger Point Dry Needling (TrP-DN) is an invasive intramuscular procedure aimed at hyperirritable, taut bands of skeletal muscle fibres. Its fundamental mechanism involves the insertion of a slender monofilament needle into dysfunctional motor endplates, which mechanically disrupts shortened sarcomeres and induces a Local Twitch Response (LTR). This swift contraction aids in restoring the resting length of sarcomeres, eliminates accumulated chemical nociceptors, and activates spinal A-delta fibres to initiate descending inhibitory pathways that mitigate central sensitisation [31]. TrP-DN is recognised as an effective technique for the immediate, short-term alleviation of localised or referred myofascial pain, while also quickly restoring joint ROM [32]. It is commonly utilised by clinicians to address myofascial pain syndrome, tension headaches, and chronic athletic strains. Nevertheless, significant limitations remain due to a notable absence of high-quality evidence proving long-term advantages over non-invasive treatments. Additionally, potential risks encompass post-treatment soreness, localised bruising, compromised immunity, and active skin lesions [33]. TrPDN was evaluated by Velásquez-Saornil J et al., in 44 participants (28 males, 16 females; aged 19-51 years) after ACLR with patellar or hamstring tendon grafts. Subjects were randomised within 12-19 days postoperative to a single vastus medialis TrPDN intervention plus 5-week rehabilitation, or rehabilitation alone. Outcomes were measured at baseline, immediately, and one day, one week, and five weeks postintervention. TrPDN increased pain immediately postintervention (p-value <0.05), but also improved ROM and knee function (p-value <0.05), with no reported changes in stability [34].

High-Tone Power Therapy (HiToP) employs high-energy, medium-frequency alternating electrical currents (ranging from 4,096 to 32,768 Hz) that are delivered directly into intracellular structures. The primary mechanism of action is based on the simultaneous modulation of frequency and amplitude, which generates a cellular resonance effect that facilitates metabolic normalisation, eliminates waste, and disperses inflammatory mediators, while also diminishing neuromuscular hypertonia. In clinical practice, HiToP is utilised as a sophisticated adjunctive treatment for neuro-musculoskeletal pain. It is extensively used to decrease spasticity and enhance gait speed in post-stroke rehabilitation, relieve chronic diabetic or radicular neuropathic pain [35]. Nevertheless, significant limitations remain due to the absence of comprehensive, large-scale clinical trials, which complicates the ability to determine its specific efficacy apart from other concurrent therapies. Ogrodzka-Ciechanowicz K et al., investigated quadriceps electrostimulation combined with HiToP therapy versus standard rehabilitation in 35 male ACLR patients (ages 21-50 years, hamstring tendon graft) recruited on postoperative day 11. The HiToP group received one hour of quadriceps-targeted HiToP per rehab session over six months, while controls had standard rehab. At six months, the HiToP group showed significant improvements in extensor strength, knee and thigh circumference, knee extension, and knee function (p-value <0.05), but pain levels did not differ significantly between groups (p-value >0.05) [36]. In their second study, Ogrodzka-Ciechanowicz K et al., studied 38 patients (28 males, 10 females; ages 18-40 years) on the first postoperative day after ACLR with a semitendinosus tendon autograft, randomly assigning them to either 10 days of 30-minute alternating magnetic field therapy or a placebo protocol. Daily measurements for 11 days revealed that alternating magnetic field therapy did not significantly improve knee joint effusion or active ROM compared to placebo (p-value >0.05) [37].

App-based active muscle training provides digital exercise programs through algorithms, prerecorded media, or Artificial Intelligence (AI) computer vision. Its main function promotes neuromuscular adaptations- such as muscle protein synthesis and enhanced motor unit recruitment- by utilising progressive overload and repetitive practice. Simultaneously, it incorporates behavioural architecture elements like push notifications, real-time audio-visual feedback, and gamification to systematically enhance exercise adherence. Clinically, it acts as a highly scalable, remote digital intervention that enhances physical function, boosts muscular strength, and alleviates pain in patients dealing with knee osteoarthritis, post-stroke spasticity, geriatric sarcopenia, or orthopaedic postoperative recovery [38,39]. Nevertheless, significant drawbacks include high user dropout rates and a total lack of hands-on medical supervision, which increases the risk of improper movement mechanics and injury. Clausen JD et al., studied 26 individuals (12 men, 14 women) immediately after ACLR with hamstring graft, randomising them to three weeks of app-based active muscle training (serious gaming, five times daily) or standard rehabilitation only. At six weeks postoperative, the app-based training group showed significantly greater improvements in maximum strength (p-value <0.05), with no significant changes in knee function or pain versus the control group (p-value >0.05) [40].

Risk of Bias of the Included Studies

Across the nine randomised trials and one non-randomised trial, the risk of bias from the randomisation process and selective reporting was consistently judged as low, suggesting that sequence generation, allocation concealment, and outcome reporting were generally appropriate. The most frequent concerns arose in the domains of deviations from the intended interventions and measurement of outcomes, where several studies were rated as having "some concerns," indicating possible issues with adherence to the assigned intervention, co-interventions, or lack of blinding of outcome assessors. One study (Coulondre C et al., 2022) showed high-risk of bias due to substantial missing outcome data, leading to a high overall risk rating [30], while two studies (Velázquez-Saornil J et al., 2017; Ogrodzka-Ciechanowicz K et al., II, 2021) were at overall low risk [34,36]. Collectively, the evidence base is reasonably robust but may over or underestimate true intervention effects due to performance and detection biases, and results should be interpreted with appropriate caution.

DISCUSSION

This narrative review examined 10 studies on additional physiotherapy interventions during early rehabilitation after ACLR, focusing on improvements in pain, swelling, ROM, muscle strength, and knee function. Three studies investigated KT: most showed significant reductions in pain and swelling, though functional and strength improvements were inconsistent. Notably, one study with only a 3-day KT application reported no pain relief [26], and only Balki S et al., showed significant gains in knee flexion ROM and flexor strength [24].

Three studies evaluated vibration training. Results were mixed; Berschin G et al., found no benefit in ROM, muscle strength, or function [28], whereas Pistone EM et al., reported improvements in knee flexor strength and function, possibly due to later intervention timing [29]. LVT showed improvements in knee extension strength without significantly enhancing function [30].

Four other interventions were studied individually. TrPDN improved knee ROM and function but caused transient pain immediately after treatment [34]. Dry needling during late-stage ACLR rehabilitation also reduced pain and improved flexion. HiToP therapy enhanced swelling, ROM, knee function, and extensor strength, though not pain [36]. Alternating magnetic field therapy showed no significant effects on oedema or ROM, while app-based active muscle training improved knee extensor strength without impacting pain or swelling [37,40].

The studies displayed considerable methodological heterogeneity, with varied designs, patient populations, intervention protocols, and outcome measures, limiting comparability and generalisation.

Overall, the reviewed physiotherapy interventions demonstrated potential benefits for early ACL rehabilitation, especially in managing pain, swelling, and muscle strength. However, inconsistencies and methodological limitations highlight the need for standardised protocols and larger, high-quality trials to confirm these findings and optimise rehabilitation strategies post-ACLR.

CONCLUSION(S)

In this review, most of the additional physiotherapy interventions analysed have been found to improve pain, oedema, ROM, knee muscle strength, or knee function during the early postoperative rehabilitation phase following ACL surgery. Except for one study, no adverse events were reported in the included studies, which illustrate the safety of the physiotherapy interventions discussed. It is also noteworthy that in some studies, no significant differences were observed between the experimental and control groups. Further extensive research is essential to assess the physiotherapy interventions reviewed, taking into account standardised methodologies, a larger participant population, a longer study duration including follow-up, validated assessment techniques, and relevant outcome measures.

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