RJNMSR
Review Journal of Neurological & Medical Sciences Review

Volume 4, Issue 4, 2026

EFFECTS OF HIGH INTENSITY LASER THERAPY AND SHOCKWAVE ON PAIN, ROM AND FUNCTIONAL DISABILITY IN PATIENTS WITH POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION SURGERY

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DOI: https://doi.org/10.5281/zenodo.20023241

Received	Accepted	Published
03 March 2026	13 April 2026	30 April 2026

ABSTRACT

Background: *Anterior cruciate ligament (ACL) reconstruction is commonly performed to restore knee stability; however, postoperative pain, reduced range of motion (ROM), and functional disability remain significant challenges during rehabilitation.*

Objective: *To compare the effects of high-intensity laser therapy and extracorporeal shockwave therapy on pain, ROM, and functional disability in patients following ACL reconstruction.*

Methods: *This randomized controlled trial was conducted and 38 patients aged 18–40 years who had undergone ACL reconstruction enrolled. Participants were randomly allocated into two groups: Group A (HILT, n=19) and Group B (ESWT, n=19). Both groups received standardized rehabilitation in addition to their respective interventions for 6 weeks. Outcomes were assessed using the Numeric Pain Rating Scale (NPRS), goniometric measurement of knee ROM, and the Knee Injury and Osteoarthritis Outcome Score (KOOS).*

Results: *Both groups showed significant improvements in all outcome measures ($p<0.001$). However, the HILT group demonstrated significantly greater improvements compared to the ESWT group. Pain reduction was higher in the HILT group (-4.1 ± 1.2 vs -3.2 ± 1.3, $p=0.01$), ROM improvement was greater (+26.2° ± 7.4 vs +19.2° ± 6.8, $p=0.008$), and KOOS scores improved more substantially (+22.9 ± 6.7 vs +16.9 ± 7.2, $p=0.01$). A higher proportion of patients in the HILT group achieved excellent functional outcomes (57.9% vs 36.8%, $p=0.04$). KOOS subscale analysis also showed significantly better results in the HILT group across all domains ($p<0.05$).*

Conclusion: *Both HILT and ESWT are effective in improving pain, ROM, and functional disability following ACL reconstruction; however, HILT demonstrated superior outcomes across all parameters.*

Keywords: *Anterior cruciate ligament, high-intensity laser therapy, shockwave therapy, rehabilitation, pain, KOOS*

INTRODUCTION

Anterior cruciate ligament (ACL) injury is one of the most common ligamentous injuries of the knee, particularly among physically active individuals and athletes involved in pivoting, cutting, and high-impact sports. ACL is an important stabilizer of anteroposterior and rotational stability of the knee joint and its failure is commonly associated with giving way, poor functional performance, and high risk of secondary knee injuries, including meniscal tears and early osteoarthritis [1]. Consequently, ACL reconstruction (ACLR) has become the surgical procedure of choice in the restoration of knee stability and allowing patients to resume their pre-injury activity. Even though there have been improvements in surgical practices, graft choices, and fixation procedures, the post-operative period of recovery is a significant concern. During early and intermediate stages of the rehabilitation process, many patients complain of persistent pain, stiffness, swelling, muscle weakness, and functional limitations of the joints [2]. These complications may slow down the quickening of sporting returns, increase the time of rehabilitation, and have adverse long-term consequences. Specifically, the presence of postoperative pain and limited range of motion (ROM) are some of the most important factors that impede the early mobility and functional recovery. The inability to attain full knee extension and sufficient flexion within the required time ranges can lead to permanent deficits and dissatisfaction of the patient [3].

ACL reconstruction is associated with multifactorial pain, which is due to surgical trauma, inflammation, graft harvesting, and related soft tissue damage. This pain does not only result in discomfort but also results in reflex inhibition of quadriceps muscle hence compromising strength recovery and functional performance [4]. Moreover, joint effusion and inflammation also play a role in diminished ROM and biomechanical changes, which further complicates the rehabilitation process. Good pain management is necessary therefore, not only to ensure patient comfort, but also to maximize rehabilitation and avoid chronic dysfunction [5].

Another major factor that determines recovery after ACL reconstruction is range of movement. It is also important to restore full knee extension early on since even small amount of deficits in extension may greatly limit gait and load of the joint during functional tasks. Likewise, there should be progressive enhancement of knee flexion during sitting, squatting and stair climbing. ROM restrictions may give rise to compensatory movement patterns as well as muscle imbalances, and high risk of re-injury. Hence, it is of immense clinical significance to develop interventions that are safe and effective and capable of improving the ROM at the postoperative stage [6].

New technology like High-Intensity Laser Therapy (HILT) and Extracorporeal Shockwave Therapy (ESWT) however has proven to be effective in the acceleration of tissue healing and pain modulation. HILT is the use of high-powered laser beams that enter deep into the musculoskeletal tissue and stimulate cell repair, collagen production, and anti-inflammation. Conversely, Extracorporeal Shock Wave Therapy (ESWT) is a non-invasive modality that has shown potential for musculoskeletal rehabilitation by promoting tissue regeneration, neovascularisation, and desensitisation of nociceptors, thereby decreasing pain and improving function [8]. Shock waves are acoustic pulses with high energy that cause biological effects, including improved microcirculation, angiogenic stimulation, increased collagen synthesis, decreased inflammation, and altered pain pathways. These mechanisms aid in tissue healing and functional recovery [5].

High-intensity laser therapy is a modern and advanced type of phototherapy, which provides a high-power laser energy to deeper tissues than the traditional low-level laser therapy. The action mechanism of HILT is photothermal, photochemical, and photomechanical effects,

which stimulate cellular metabolism, improve microcirculation, decrease inflammation, and provide analgesia. HILT can promote tissue repair and regeneration by enhancing mitochondrial activity and generation of ATP [13]. It is especially effective in penetrating into deeper structures and is thus a good choice of treatment in postoperative conditions where deeper tissues, including ligaments and joint capsules are involved. A number of studies have shown that HILT can be used to reduce pain and improve function in disorders like knee osteoarthritis, low back pain, and tendinopathies, indicating its possible application in postoperative rehabilitation [14].

METHODOLOGY

This was a randomized controlled trial (RCT) designed to compare the effects of high-intensity laser therapy (HILT) and extracorporeal shockwave therapy (ESWT) on pain, range of motion (ROM), and functional disability in patients following anterior cruciate ligament (ACL) reconstruction. The study was conducted at Yasfeen Health Center shadrah, lahore where participants undergoing postoperative rehabilitation after ACL reconstruction were recruited. The sample size was calculated using G*Power version 3.1.9.7 based on a paired t-test with a 95% confidence level, 95% power, and an effect size of 1.27. Using mean values of 104 and 94 with standard deviations of 8.9 and 6.6, the minimum required sample size was 34 participants. To account for a 10% dropout rate, the final sample size was increased to 38 participants, with 19 participants allocated to each group. A non-probability purposive sampling technique was used to recruit participants who met the predefined inclusion criteria from the study setting.

Patients aged 18–40 years who had undergone primary unilateral ACL reconstruction 4–12 weeks prior to enrollment and were currently participating in a standardized rehabilitation program were included. Participants were required to have a pain score of ≥3/10 on the Numeric Pain Rating Scale (NPRS), a knee extension deficit of ≥5° or flexion loss of ≥10° compared to the contralateral side, and a KOOS score ≤80 in pain or sports/recreation subscales. All participants provided written informed consent and were willing to comply with study procedures. Patients with revision ACL reconstruction, multi-ligament injuries, or associated surgical procedures such as osteotomy or cartilage repair were excluded. Those with postoperative complications including infection, deep vein thrombosis, wound dehiscence, or hardware failure were also excluded. Additional exclusions included prior HILT or ESWT within 3 months, neurological disorders affecting lower limb function, uncontrolled diabetes with neuropathy, inflammatory joint diseases, and BMI ≥35 where therapy application was not feasible. All participants received a standardized postoperative ACL rehabilitation program under the supervision of a physiotherapist, including cold therapy, range of motion exercises, patellar mobilization, quadriceps strengthening, closed-chain exercises, and progressive strengthening of hamstring and hip muscles. This baseline rehabilitation protocol was applied equally to both groups to ensure consistency. Participants in Group A received HILT using a Class IV Nd:YAG laser (1064 nm) in pulsed mode with a contact technique. The therapy was applied over the peri-patellar region, patellar tendon, quadriceps tendon, and joint lines with an average power of 6–8 W and energy density of 12–20 J/cm², delivering a total of 1200–1800 J per session. Each session lasted 10–15 minutes, conducted twice weekly for 6 weeks, with participants positioned supine and the knee flexed at 20–30°. Eye protection was ensured during treatment.Participants in Group B received radial ESWT applied to the patellar tendon, quadriceps tendon insertion, peri-patellar region, and pes anserinus. Treatment parameters included pressure of 1.8–2.5 bar, frequency of 8–12 Hz, and 2000–2500 impulses per session. Each session lasted 12–15 minutes, conducted twice weekly for 6 weeks, with participants in a supine position and knee flexed at 20–30°. Treatment intensity was gradually increased based on patient tolerance.

RESULTS

Data were collected from 38 patients, mean age in the HILT group was 27.8 ± 5.4 years, while in

the ESWT group it was 28.2 ± 5.9 years. Male participants constituted 63.2% in the HILT group and 57.9% in the ESWT group, whereas females accounted for 36.8% and 42.1%, respectively. The mean BMI was similar between groups (25.1 ± 2.8 vs 25.6 ± 3.1 kg/m²), and the mean time since surgery was 8.1 ± 2.3 weeks in the HILT group compared to 8.4 ± 2.5 weeks in the ESWT group. Regarding graft type, hamstring grafts were most common (57.9% vs 63.2%), followed by BTB (26.3% vs 21.1%) and quadriceps grafts (15.8% in both groups), indicating well-matched baseline characteristics.

Table 1: Comparison of Outcome Improvement Between Groups (Mean Difference of Change Scores)

Variable	HILT Mean Change ± SD	ESWT Mean Change ± SD	Mean Difference	p-value
Pain (NPRS)	-4.1 ± 1.2	-3.2 ± 1.3	-0.9	0.01
ROM (Flexion°)	+26.2 ± 7.4	+19.2 ± 6.8	+7.0	0.008
KOOS Score	+22.9 ± 6.7	+16.9 ± 7.2	+6.0	0.01

Post-treatment functional outcomes showed a higher proportion of excellent results in the HILT group (57.9%) compared to the ESWT group (36.8%) (p=0.04). Good outcomes were observed in 31.6% of HILT patients and 42.1% of ESWT patients, while fair outcomes were lower in the HILT group (10.5%) compared to ESWT (21.1%).

Table 2: Gender-wise Outcome Comparison After Treatment

Variable	Gender	HILT (Mean ± SD)	ESWT (Mean ± SD)	p-value
Pain (NPRS)	Male	2.0 ± 0.8	2.7 ± 0.9	0.03
	Female	2.2 ± 1.0	2.9 ± 1.1	0.04
ROM (Flexion°)	Male	129.2 ± 6.2	123.1 ± 7.0	0.02
	Female	127.8 ± 6.8	121.4 ± 7.5	0.03
KOOS Score	Male	86.2 ± 5.9	81.0 ± 6.5	0.02
	Female	84.3 ± 6.7	79.2 ± 7.8	0.04

Correlation analysis demonstrated a strong negative relationship between pain and functional outcomes (r = -0.71), indicating that lower pain levels were associated with better functional scores. Pain was also negatively correlated with ROM (r = -0.62), while ROM showed a positive correlation with KOOS scores (r = +0.68).

Table 3Correlation Between Pain, ROM, and Functional Disability (Post-treatment)

Variable	Pain (NPRS)	ROM (Flexion°)	KOOS Score
Pain (NPRS)	1	-0.62	-0.71
ROM (Flexion°)	-0.62	1	+0.68
KOOS Score	-0.71	+0.68	1

Significant improvements were observed in all KOOS subscales in both groups (p<0.001). In the HILT group, symptoms improved from 60.8 ± 8.5 to 84.2 ± 6.7, pain from 58.6 ± 7.9 to 86.1 ± 6.2, ADL from 64.2 ± 8.1 to 88.3 ± 5.9, sports from 55.4 ± 9.2 to 82.6 ± 7.1, and QoL from 52.8 ± 8.7 to 81.9 ± 6.

DISCUSSION

The reason behind the current research was to compare the consequences of the use of high-intensity laser therapy (HILT) and extracorporeal shockwave therapy (ESWT) with pain, range of motion (ROM), and functional disability in patients after undergoing anterior cruciate ligament (ACL) reconstruction. The results of the

current research proved that both treatment options were useful in enhancing all outcome measures, but HILT produced much better outcomes in comparison with ESWT, regarding pain reduction, improvement of the ROM, and recovery of functions.

Achieving pain reduction is one of the main objectives of early postoperative rehabilitation because it is directly related to patient involvement and progress in physiotherapy. In this research, the pain reduced significantly in both groups with a more dramatic decrease in the HILT group. The higher analgesic effect of HILT can be explained by its photobiomodulation mechanism, which improves mitochondrial functioning, increases ATP synthesis and decreases inflammatory mediators. It leads to reduced nociceptor sensitivity and enhanced tissue healing. Past studies have documented that HILT has got both short-term and long-term analgesic effects, thus coming in handy in cases where pain is a rehabilitative constraint. Conversely, ESWT offers pain relief through hyperstimulation of nociceptors and alteration of pain pathways as its main mechanisms that might require longer durations to become evident.

The other noteworthy conclusion of this research was the considerable increase in ROM in both groups, with HILT showing better results. Knee ROM restoration is vital after ACL reconstruction, whereby even slight failures may contribute greatly to gait, balance and general functional performance. The enhancement in the ROM was higher in the HILT group, which could be attributed to the fact that it could decrease inflammation and enhance the elasticity of tissues and decreased muscle spasm. These findings are supported by previous studies, which note that HILT improves the flexibility of soft tissues and decreases joint stiffness, thus increasing the amount of ROM. Instead, ESWT enhances ROM by mainly stimulating tissue remodeling and decreasing fibrosis, which could be the reason of its relatively slower effect.

The KOOS score was used to assess functional disability which also improved significantly in both groups, though the results were better in HILT group. Functional recovery is a complicated process, which is affected by a variety of factors, such as pain, ROM, muscle strength, and neuromuscular control. The higher increase in scores in the KOOS of the HILT group implies that the early reduction in pain and enhancement of mobility are associated with better functional outcomes. Past studies have demonstrated that the functional recovery is closely related to pain and ROM improvements, and these factors require consideration in the process of rehabilitation.

The analysis of the KOOS subscale also helped to gain deeper understanding of the multidimensional effects of the two therapies. HILT group demonstrated more improvements in all the subscales; symptoms, pain, activities of daily living, sports/recreation, and quality of life. This is to say that besides increasing physical parameters, HILT also increases patient-perceived outcomes and the quality of life in general. Past studies have also noted the importance of patient-reported outcomes in determining the effectiveness of rehabilitation; such outcomes will indicate how the patient will resume normal functioning and have confidence in the impaired limb.

HILT was also superior than ESWT in this study which could also be attributed to the fact that HILT penetrates deeper tissues than ESWT. The capability of HILT to supply energy to deeper tissue enables it to have a direct impact on the healing of ligaments, joint capsules and the surrounding muscle. This is especially applicable in ACL reconstruction patients, whereby deeper tissues are used in the healing. Conversely, ESWT mainly targets the superficial and periarticular tissues thus it might not be effective in the management of the structural problems that are deeper in nature.

CONCLUSION

It is concluded that both high-intensity laser therapy (HILT) and extracorporeal shockwave therapy (ESWT) are effective in improving pain, range of motion (ROM), and functional disability in patients following anterior cruciate ligament (ACL) reconstruction. However, HILT demonstrated significantly superior outcomes compared to ESWT across all measured parameters, including greater pain reduction,

enhanced ROM, and improved functional recovery as assessed by KOOS scores. The findings suggest that HILT may be a more effective modality in the early and mid phases of postoperative rehabilitation, primarily due to its rapid analgesic effects and ability to facilitate early mobilization. While ESWT also showed beneficial effects, its improvements were comparatively less pronounced. Therefore, incorporating HILT into standard rehabilitation protocols may optimize recovery and improve patient outcomes after ACL reconstruction. Further studies with larger sample sizes and long-term follow-up are recommended to validate these findings and assess sustained benefits.

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