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Original Research Article

Effects of Therapeutic Ultrasound with Exercise, and High Intensity Laser Therapy with Exercise on Pain in Patients with Knee Osteoarthritis: A Comparative Study

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ABSTRACT

BACKGROUND: Knee osteoarthritis (KOA) is among the most prevalent musculoskeletal conditions, producing chronic pain and functional limitations and affecting nearly one-third of adults aged 65 years and above. Pain remains the primary driver of disability.
OBJECTIVES: This study aimed to compare the effectiveness of therapeutic ultrasound (TUS) combined with exercise and high-intensity laser therapy (HILT) combined with exercise in alleviating pain in individuals with KOA.
METHODS: A total of 160 male and female patients, aged 45–70 years and meeting predefined eligibility criteria, were randomly recruited from healthcare facilities including PMCH, Udaipur, and various physiotherapy clinics across Udaipur city, Rajasthan.
RESULTS: Analysis revealed significant reductions in pain scores (Grade 2, Grade 3, and combined Grades 2 & 3) in both treatment arms after 15, 30, and 45 days of intervention. However, patients receiving HILT showed a greater decrease in pain scores at each time point compared to those treated with TUS.
CONCLUSION: The findings suggest that high-intensity laser therapy demonstrates statistically superior efficacy over therapeutic ultrasound in reducing pain associated with knee osteoarthritis.

Keywords: Knee osteoarthritis; therapeutic ultrasound; high-intensity laser therapy; exercise; pain.

INTRODUCTION

Knee osteoarthritis (KOA) ranks among the most disabling musculoskeletal disorders, producing chronic pain and significant functional limitations that greatly diminish patients' quality of life. [1] The condition is typified by progressive degeneration of articular cartilage accompanied by subchondral bone sclerosis [2], changes that stem from a combination of biomechanical stresses and metabolic influences. [3, 4] The prevalence of KOA is steadily rising; for instance, Davatchi et al. documented a notably high rate of 41.9% in the urban Iranian population aged over 40 years [5], a burden that frequently results in reduced independence and self-sufficiency. [6]

Current management strategies primarily aim to enhance functional capacity and alleviate symptoms, with pain relief being the central target because pain is both the predominant symptom and the leading cause of disability. Conservative treatment typically focuses on symptomatic control through a variety of approaches such as pharmacological therapy, intra-articular injections, physical modalities, and structured exercise programs. [7–9] Exercise therapy, whether applied alone or in combination with other interventions, has consistently demonstrated a key role in reducing symptoms and improving physical performance in KOA. [10, 11] Numerous investigations have highlighted the benefits of regular exercise, showing gains in muscle strength and endurance, decreases in joint stiffness, improvements in proprioceptive acuity and balance, and an overall enhancement in patients' quality of life. [12–15] Additional evidence further supports the notion that integrating physical modalities with exercise produces even better clinical outcomes for individuals with KOA. [16, 17]

Therapeutic ultrasound (TUS) is one of the most widely used physical-therapy techniques and has long been accepted as an effective option for KOA management. TUS enhances blood flow, boosts metabolic activity, promotes tissue repair, and decreases pain and inflammation by delivering high-frequency sound waves that produce both thermal and mechanical effects in soft tissues. [18] A 2010 Cochrane review reported that TUS may help reduce knee pain and improve functional capacity in KOA patients, although the review also emphasized that the overall quality of supporting evidence remains low and called for well-designed, high-quality clinical studies to clarify its efficacy. [19] In current clinical practice and in multiple investigations, TUS is commonly delivered at a frequency of 1 MHz. [20, 21] Treatment intensities typically range from 0.8 to 2.5 W/cm², with 1 W/cm² generally considered a comfortable level at which patients experience mild warmth without discomfort. [22, 23]

High-intensity laser therapy (HILT), which employs more powerful laser radiation, is a relatively new, painless, and potent modality that has demonstrated significant effectiveness in alleviating pain. [24] Through its combined photochemical, photothermal, and photomechanical actions, HILT provides a range of therapeutic effects including analgesic, anti-edema, and bio-stimulatory benefits. [19, 20] A notable advantage of HILT, particularly when using a neodymium-doped yttrium aluminum garnet (Nd:YAG) laser, is its high output and deep tissue penetration. [21, 22] Although HILT has shown promising outcomes in pain management [25, 26], its specific analgesic impact on osteoarthritis has not been extensively investigated. [26] Only a limited number of comparative studies have assessed HILT against other therapeutic approaches, especially TUS. Thus, in the present study, the efficacy of these two therapeutic modalities was compared on pain relief improvement in individuals diagnosed with KOA.

MATERIALS AND METHODS

This prospective investigation enrolled a total of 160 individuals (both men and women), diagnosed with knee osteoarthritis (KOA) and ranging in age from 45 to 70 years. Recruitment was conducted through a randomized screening procedure that followed a predefined set of eligibility guidelines. Participants were sourced from multiple healthcare settings, including PMCH, Udaipur, as well as several physiotherapy clinics distributed across Udaipur city, Rajasthan, India. Once enrolled, the subjects were methodically assigned into two clearly defined treatment categories. Group-A consisted of 80 patients who received therapeutic ultrasound (TUS) together with exercise therapy (ET), whereas Group B included 80 patients treated with high-intensity laser therapy (HILT) in combination with the same ET protocol.

The inclusion criteria established for this study were as follows: (1) radiographic evidence of stage II or III osteoarthritis according to standard diagnostic norms, (2) age bracket of 45–70 years, (3) body mass index (BMI) of 30 kg/m² or lower, (4) knee pain persisting for a minimum of six months and registering a score of at least 3 on the Visual Analogue Scale (VAS) during activities such as stair climbing, sitting, or squatting, (5) no prior history of acute traumatic injuries, (6) absence of any previous surgical procedure or major injury affecting the knee or lower extremities, (7) no underlying neuromuscular disorders, (8) intact cognitive function with a normal mental state, (9) no bone implants present, (10) no record of recent fractures, (11) no evidence of malignant tumors, (12) absence of chronic illnesses or other medical conditions that could interfere with the study outcomes, (13) no participation in organized sports or physiotherapy programs within the preceding three months, and (14) no administration of intra-articular knee injections during the past six months.

The exclusion criteria encompassed the following: (1) unwillingness or refusal to participate, (2) failure to complete the evaluation or the scheduled treatment sessions, (3) any new injury or damage to the knee joint occurring during the course of the study, and (4) the use of any therapeutic interventions outside the prescribed treatment regimen.

Before the trial began, every participant provided explicit written informed consent, confirming their voluntary involvement and their clear understanding of the aims, procedures, and potential implications of the research. The study protocol received formal approval from the Institutional Ethical Committee.

Methods: To collect detailed demographic and clinical information, a pre-tested semi-structured questionnaire was carefully administered to all enrolled participants, ensuring comprehensive and systematic documentation of relevant data.

Numeric Rating Scale (NRS) for Pain

The Numeric Rating Scale (NRS) is a widely adopted instrument for gauging pain intensity in clinical research and practice, including investigations on knee osteoarthritis (KOA). Participants were requested to indicate their pain level on a continuum from 0 to 10, where 0 denotes an absence of pain and 10 represents the most severe pain imaginable. Each individual selected the number that best described their current discomfort. This straightforward scale offers a rapid, reliable means of quantifying pain severity, enabling clinicians and researchers to monitor changes in pain over time and to assess the efficacy of various interventions.

Therapeutic Ultrasound (TUS)

Therapeutic ultrasound is employed as a complementary technique in physical therapy to alleviate pain and support the healing of soft-tissue injuries. [27] Its therapeutic benefits are attributed to both thermal and non-thermal mechanisms, which depend on application variables such as intensity, frequency, duty cycle, and wavelength. [28]

When applied continuously, ultrasound generates heat within the tissue, producing an analgesic effect by elevating temperature, which in turn enhances capillary permeability and tissue metabolism. This process improves the extensibility of fibrous structures and raises the pain threshold. In contrast, pulsed ultrasound does not sustain continuous heating and instead exerts non-thermal actions, including alteration of cell membrane permeability, stimulation of protein synthesis, and activation of local immune responses near the injury site. These effects collectively facilitate tissue regeneration. Clinical protocols often employ a 1 MHz continuous ultrasound for 8–10 minutes daily, with a half-value depth of roughly 2.3 cm to target tissues located about 2.3–5 cm beneath the surface. [29,18] The current study adopted these same parameters to leverage both the thermal and non-thermal properties of TUS for pain management and tissue repair.

High-Intensity Laser Therapy (Class 4)

A semi-conductive neodymium laser (Class IV) with a wavelength of 1064 nm and a maximum output of 12 W was utilized. Treatment consisted of a single daily application over seven sessions. During the first three sessions, analgesic settings were employed, delivering a dose of 12 J/cm² (total energy of 300 J) over a 25 cm² treatment area. Laser irradiation was applied to the medial and lateral aspects of the knee from a distance, lasting 2 minutes at a frequency of 25 Hz. For the remaining four sessions, bio-stimulative parameters were used, administering a dose of 120 J/cm² (total energy of 3000 J) to a 25 cm² region on the medial side of the knee for 10 minutes. Analgesic parameters were delivered to two opposing fields because, at the disease stages under study, both intra-articular and peri-articular tissues contributed to nociceptive signaling. Bio-stimulation was concentrated on the medial compartment, which is typically more affected due to anatomical alignment, weight-bearing axis, Q-angle, and the rotational characteristics of the medial femoral condyle during the terminal range of motion.

Exercises

The exercise regimen incorporated quadriceps isometric strengthening, straight-leg raises, iliotibial-band stretching, hamstring stretching, and strengthening exercises for the hip abductors and adductors, along with additional stretching routines. Each session comprised three sets of 10 repetitions and was performed twice weekly for a total of four supervised sessions. Patients were instructed to repeat the program at home twice daily, and adherence was monitored through weekly follow-up phone calls. Exercise therapy is recognized as a fundamental non-pharmacological intervention and is endorsed by international guidelines for osteoarthritis management. It enhances functional ability and overall health and is generally safer than pharmacologic treatments [30] (Shahnawaz et al., 2016).

STATISTICAL ANALYSIS

All statistical evaluations were carried out using SPSS (Statistical Package for the Social Sciences), version 24. Descriptive data were presented as mean values with standard deviations (SD). Independent Student's t-tests were applied to compare normally distributed variables between groups, while paired t-tests assessed within-group changes. An alpha level of 0.05 was established, and p-values below 0.05 were deemed statistically significant.

RESULTS

Table 1 presents the descriptive statistics for pain-related variables in individuals with KOA who underwent treatment with TUS. Participants classified as Grade 2 recorded lower mean scores at baseline (6.516), after 15 days (5.000), after 30 days (4.000), and after 45 days (3.484) when compared with their Grade 3 counterparts, whose respective means were 6.592, 5.082, 4.082, and 3.510. Despite these numerical differences, the analysis revealed no statistically significant variation between the two grades.

The descriptive measures for pain outcomes among KOA patients managed with HILT are summarized in Table 2. Here, Grade 2 patients displayed higher mean scores at baseline (6.717), at 30 days (2.804), and at 45 days (2.463), while showing a slightly lower mean (4.261) at the 15-day mark, relative to Grade 3 participants who recorded means of 6.294, 1.934, 1.676, and 6.092, respectively. Again, statistical testing demonstrated no significant differences between the two grades.

Table 3 provides a comparison of pain-related variables for Grade 2 patients treated with either TUS or HILT. Within this subgroup, the TUS cohort exhibited higher mean scores after 15 days (5.000), 30 days (4.000), and 45 days (3.484), but a slightly lower baseline mean (6.516) when contrasted with the HILT group, whose corresponding values were 4.261, 2.804, 1.935, and 6.717.

Statistically significant differences ($p < 0.005–0.001$) emerged between the two treatment modalities at both the 30-day and 45-day evaluations.

Table 4 outlines the comparative data for Grade 3 patients receiving TUS versus HILT. Participants managed with TUS recorded higher mean values at baseline (6.592), 15 days (5.082), 30 days (4.082), and 45 days (3.510) relative to those treated with HILT, who reported means of 6.294, 3.853, 2.500, and 1.676, respectively. Here, statistically significant differences were observed after 15 days, 30 days, and 45 days of intervention, with p-values ranging from < 0.003 to < 0.001, indicating a greater reduction in pain with HILT.

Table 1. Descriptive statistics of variables related to pain (NRS) in patients with KOA treated with TUS

Conditions	Grade-2		Grade-3		t-value	p-value
	Mean	SD	Mean	SD		
Baseline	6.516	1.65	6.592	1.81	0.188	0.851
After 15 days	5.000	1.82	5.082	1.80	0.196	0.845
After 30 days	4.000	1.82	4.082	1.80	0.196	0.845
After 45 days	3.484	2.01	3.510	1.86	0.060	0.953

Table 2. Descriptive statistics of variables related to pain (NRS) in patients with KOA treated with HILT

Conditions	Grade-2		Grade-3		t-value	p-value
	Mean	SD	Mean	SD		
Baseline	6.717	1.75	6.294	1.59	1.113	0.269
After 15 days	4.261	1.81	6.092	1.59	0.997	0.322
After 30 days	2,804	1.73	1.934	1.54.	0.777	0.439
After 45 days	2.463	1.44	1.676	1.49	0.751	0.455

Table 3. Comparisons of variables related to pain (NRS Grade 2) in patients with KOA treated with TUS and HILT

Conditions	Patients treated with TUS		Patients treated with HILT		t-value	p-value
	Mean	SD	Mean	SD		
Baseline	**6.516**	**1.65**	**6.717**	**1.75**	**0.507**	**0.614**
After 15 days	5000	1.82	4.261	1.81	1.753	0.084
After 30 days	4.000	1.82	2.804	1.73	2.905	**<0.005**
After 45 days	3.484	2.01	1.935	1.54	3.819	**<0.001**

Table 4.5 presents a comparative overview of pain-related variables in Grade 2 and Grade 3 KOA patients receiving either TUS or HILT treatment. Individuals managed with TUS recorded higher mean scores at baseline (6.562), after 15 days (5.050), at 30 days (4.050), and at 45 days of intervention (3.500) when compared with those who underwent HILT, whose corresponding mean values were 6.537, 4.087, 2.675, and 1.825, respectively. Despite the close baseline figures, statistical analysis revealed highly significant differences ($p < 0.001$) between the two therapeutic groups at the 15-day, 30-day, and 45-day follow-ups, demonstrating a greater reduction in pain among the patients treated with HILT.

Table 4. Comparisons of variables related to pain (NRS Grade-3) in patients with KOA treated with TUS and HILT

Conditions	Patients treated with TUS		Patients treated with HILT		t-value	p-value
	Mean	SD	Mean	SD		
Baseline	6.592	1.81	6.294	1.59	0.773	0.442
After 15 days	5.082	1.80	3.853	1.81	3.050	**<0.003**
After 30 days	4.082	1.80	2.500	1.73	4.000	**<0.001**
After 45 days	3.510	1.86	1.676	1.49	4.776	**<0.001**

Table 5. Comparisons of variables related to pain (NRS Grade-2&3) in patients with KOA treated with TUS and HILT

Conditions	Patients treated with TUS		Patients treated with HILT		t-value	p-value
	Mean	SD	Mean	SD		
Baseline	6.562	1.74	6.537	1.68	0.092	0.927
After 15 days	5.050	1.80	4.087	1.81	3.374	**<0.001**
After 30 days	4.050	1.80	2.675	1.73	4.931	**<0.001**
4 After 5 days	3.500	1.91	1.825	1.51	6.145	**<0.001**

DISCUSSION

Osteoarthritis (OA) is a degenerative rheumatologic disorder that typically develops after the age of 40 and is characterized by persistent pain, reduced joint flexibility, swelling, and a distinctive grating sensation [31]. Both mechanical factors and genetic predisposition contribute to its development, with the knees being among the most commonly affected joints. [32,33] Worldwide, new therapeutic strategies continue to emerge to enhance the quality of life (QoL) of individuals with OA. Several studies have reported that TUS and HILT can provide meaningful benefits for patients with knee osteoarthritis (KOA). [34,35]

The present study demonstrated significant reductions in pain scores for both Grade 2 and Grade 3 KOA patients treated with HILT compared to those receiving TUS at 15, 30, and 45 days of intervention. These findings highlight the superior pain-relieving effect of HILT over TUS.

TUS is widely used as an adjunct to physical therapy programs aimed at reducing pain and promoting soft-tissue healing. Its analgesic action is thought to arise from a combination of thermal and non-thermal mechanisms. [18,28,29] Treatment parameters can be adjusted to either gently warm superficial tissues or stimulate cellular repair processes. [28] OA is increasingly recognized as having an inflammatory component [36,37], and pain symptoms may result from activation of inflammatory pathways that heighten the response of peripheral joint nociceptors. [38] TUS may help counter these inflammatory events by supporting the repair phase, thereby promoting overall tissue healing. [27] The modality exerts its therapeutic effects through both continuous (thermal) and pulsed (non-thermal) ultrasound settings, with efficacy influenced by factors such as intensity, wavelength, duty cycle, and frequency. [34,35]

A key outcome of this study was the immediate and sustained reduction in knee pain, lasting up to three months, observed with HILT, clearly demonstrating its superiority over the other interventions. Importantly, none of the participants reported adverse effects during or after the HILT sessions. These findings align with earlier research by Viliani et al. [39], Kheshie et al. [25], Sabbahi [40], Štiglić-Rogoznica et al. [26], Kim et al. [41], Angelova et al. [42], and Wyszynska et al. [43], all of which documented significant pain relief in KOA patients.

Based on the present results, HILT can be recommended as an effective short-term modality for pain control, owing to its distinctive mechanisms—analgesic effects on peripheral nerve endings [40]; photochemical and photothermic actions that enhance blood flow [42], vascular permeability, and cellular metabolism [39]. Furthermore, HILT may attenuate inflammatory activity by lowering levels of prostaglandins, C-reactive protein, interleukin-1, and neopterin. [43] The therapy's photomechanical effect is considered the primary driver of its rapid analgesic response. [44] In addition, in-vitro evidence suggests that HILT contributes to connective-tissue reorganization and overall tissue healing. [45]

CONCLUSION

A variety of physiotherapeutic approaches are employed in the management of KOA. Among these, TUS and HILT were selected for the present investigation because they are widely used in clinical practice. Based on the study's findings, HILT demonstrated a statistically significant and greater therapeutic efficacy than TUS in reducing symptoms of KOA.

Declaration by authors

The authors hereby declare that it was their original peace of research and had not been sent to any other journal for publication.

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