REVIEW ARTICLE

Synthesis of Evidence on the Combination of High-Intensity Laser Therapy and Rehabilitation Exercise for Knee Osteoarthritis: An Umbrella Review of Systematic Reviews

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ABSTRACT

High-intensity laser therapy (HILT) is a promising adjunctive treatment for knee osteoarthritis (KOA) due to its deep tissue penetration and anti-inflammatory effects. However, inconsistent findings hinder clinical interpretation. This umbrella review synthesised current evidence on the effects, safety, and clinical applicability of HILT in KOA management. A systematic search of five electronic databases was conducted in accordance with PRISMA guidelines, covering studies up to December 2024. Eligible systematic reviews included adult populations with KOA receiving HILT, assessing outcomes such as pain, stiffness, physical function, and safety. Methodological quality was evaluated using AMSTAR-2 and PRISMA checklists. The Corrected Covered Area (CCA) was calculated to assess overlap among primary studies. Seven systematic reviews published between 2017 and 2024 were included, comprising 50 unique primary studies involving adults aged 40–70 years. The CCA score of 0.047 indicated minor overlap. Most studies applied HILT in combination with rehabilitation exercise rather than as a standalone therapy. HILT significantly reduced pain and improved physical function, often exceeding minimal clinically important differences. Treatment parameters ranged from 808–1064 nm and 0.51–120 J/cm², administered over 4–8 weeks. Compared to low-level laser therapy, HILT demonstrated greater effects in pain relief and functional outcomes, with a favourable safety profile. While HILT can be used independently, combining it with exercise is the most commonly applied and effective approach for KOA. Despite promising results, variability in protocols and limited long-term data highlight the need for standardised treatment guidelines and further research.

Keywords:
High-Intensity Laser Therapy, Knee Osteoarthritis, Systematic Reviews, Pain Management, Rehabilitation Therapy

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INTRODUCTION

Knee osteoarthritis (KOA) is a chronic degenerative joint disease characterized by progressive cartilage loss, pain, stiffness, and reduced physical function.[1] It is a leading cause of disability, particularly among adults aged 40 years and older, with its global prevalence rising due to aging populations, sedentary lifestyles, and increasing obesity rates.[1,2] KOA significantly impacts individuals' quality of life by limiting mobility, reducing independence in daily activities, and contributing to substantial social and economic burdens.[3-7] Current management strategies for KOA include pharmacological therapies, rehabilitation exercise,[8,9] self-management and education[7] and, in severe cases, surgical intervention.[10,11] However, the most commonly prescribed pharmacological agents, specifically nonsteroidal anti-inflammatory drugs (NSAIDs), are associated with adverse effects, especially when used for extended periods,[11] highlighting the need for safer, non-pharmaceutical, non-invasive alternatives.[12,13]

Among non-pharmacological approaches, photobiomodulation therapy using high-intensity laser therapy (HILT) has gained significant attention due to its deep tissue

penetration, ability to stimulate biological processes, and promising effects on pain reduction and functional recovery.[14-16] HILT operates at wavelengths ranging from 808–1064 nm, with higher power outputs compared to low-level laser therapy (LLLT).[12,17] It can penetrate deeper tissues, stimulate cellular activity, promote ATP production, and reduce inflammation through photochemical and photothermal effects, making it a promising option for managing KOA symptoms. When combined with rehabilitation exercise, HILT may enhance the impact of rehabilitation by reducing pain, decreasing inflammation, and promoting tissue repair. Together, HILT and rehabilitation exercise can improve joint function, accelerate recovery, increase adherence to physiotherapy, and make progressive exercise more tolerable and effective.[16-18]

Despite emerging evidence supporting the efficacy of HILT in KOA, inconsistencies in study protocols, such as variations in laser parameters (e.g., wavelength, energy density, frequency, and duration of treatment), pose challenges in translating research findings into clinical practice.[3,14] Furthermore, the growing number of systematic reviews and meta-analyses investigating the effectiveness of HILT has led to potential duplication and overlap of evidence, making it increasingly difficult for clinicians and researchers to interpret and integrate findings into practice. These factors highlight the need for a higher-level synthesis of the available evidence.

In this umbrella review, we aim to systematically synthesize evidence from published systematic reviews, with or without meta-analyses, evaluating the effectiveness, safety, and clinical application of HILT in the management of KOA. By examining the scope, quality, and consistency of existing evidence, this review seeks to provide clinicians, researchers, and policymakers with a comprehensive understanding of HILT's role in KOA management and identify areas for future research.

MATERIALS AND METHODS

Review design

The review adhered to the PRISMA guidelines to ensure comprehensive and transparent reporting.[19] The protocol for this umbrella review was registered prospectively with the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42025628674.

Keywords and data sources

A comprehensive search strategy was implemented using five electronic databases: PubMed, Embase, Medline, Web of Science, and Scopus, covering all records from their inception to December 2024. The search strategy combined keywords and MeSH terms related to HILT, KOA, and systematic reviews. Specific search terms included combinations such as "high-intensity laser therapy," "laser," "photobiomodulation," "knee osteoarthritis," "knee arthr*," "gonarthrosis," and "review." Boolean operators (AND, OR) were used to refine the search. Reference lists were manually searched to identify additional studies. Two authors independently searched to reduce bias. Any discrepancies in the search process or inclusion decisions were resolved through discussion to reach a consensus.

Eligibility criteria

Systematic reviews, with or without meta-analyses, were eligible for inclusion. Primary studies within the systematic reviews had to involve: (i) adults aged 18 years or older diagnosed with KOA; (ii) HILT combined with the rehabilitation exercise as the primary intervention; (iii) control groups receiving placebo, sham laser therapy, conventional rehabilitation exercises, or no intervention; and (iv) outcomes such as pain reduction, physical function, disability, or quality of life. Narrative reviews, scoping reviews, primary research studies, protocols, conference abstracts, and non-English articles were excluded. Where systematic reviews included multiple conditions or intervention types, only data pertaining to KOA participants treated with HILT in combination with rehabilitation exercise were extracted for synthesis.

Quality assessment

Review quality was assessed using the A Measurement Tool to Assess Systematic Reviews 2 (AMSTAR 2), which covers 16 key domains of systematic reviews, including protocol registration, adequacy of literature

searches, risk of bias assessment, and appropriateness of meta-analytical methods.[20] Reviews will be categorized into four quality levels: high, moderate, low, or critically low quality, based on the presence and severity of flaws in critical domains.[21] Additionally, adherence to methodological standards was assessed using the PRISMA checklist, with scores of 24 and above indicating high compliance with reporting standards.[19]

Data extraction and synthesis

Two reviewers independently extracted data using a predefined form, capturing study characteristics, intervention details (e.g. wavelength, energy density, session frequency, irradiation site, mode) and outcomes (e.g. pain, function, disability, quality of life, adverse events). Discrepancies were resolved through discussion or third-party input. A third reviewer verified the data for accuracy. Findings were synthesised narratively with supporting tables and statistics. Overlap across reviews was assessed using the Corrected Covered Area (CCA) method as overlap can inflate the perceived body of evidence and introduce potential bias in conclusions.[22-24] The formula for CCA is:

$$CCA = \frac{N - r}{r(c - 1)}$$

where N represents the total number of primary study occurrences across the systematic reviews, r is the number of unique primary studies, and c is the number of systematic reviews.[22] The CCA score ranges from 0 to 1, where 0 indicates no overlap and 1 indicates complete overlap.[22]

RESULTS

Data screening, selection, and extraction process

A comprehensive search across five databases yielded 392 articles. After removing duplicates (N=245), 147 unique articles were screened based on their titles and abstracts, of which 107 were excluded for reasons such as (i) irrelevant study designs (e.g., primary research studies, narrative reviews, scoping reviews, conference abstracts or protocols), (ii) non-relevant populations (e.g., animal studies or conditions other than KOA), (iii) non-relevant interventions (e.g., LLLT or pharmacological treatments), and (iv) non-English publications. The remaining 40 articles underwent full-text screening, and 33 were excluded for various reasons, including non-systematic reviews (N=11), non-relevant to HILT (N=5), insufficient reporting of outcomes (e.g., pain, physical function, or safety measures) (N=9), and non-KOA populations (e.g., reviews that included other musculoskeletal conditions without separate data for KOA) (N=8). Finally, 7 systematic reviews met the eligibility criteria and were included in the final analysis. The study selection process is summarized in the PRISMA flowchart (Figure 1).

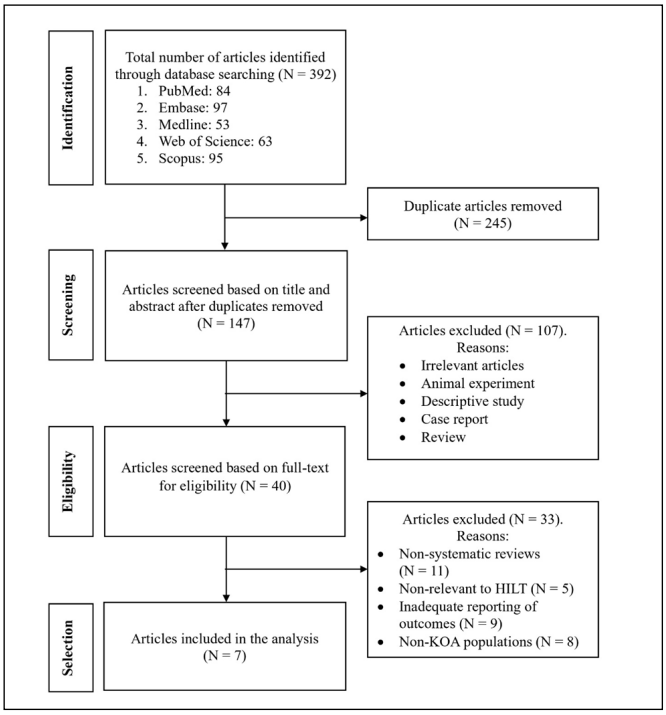

Figure 1. PRISMA flowchart depicting the study selection process.

Characteristics of included reviews

The seven systematic reviews included in this umbrella review were published between 2017 and 2024, reflecting growing research interest in the use of HILT for KOA management. The corresponding authors represented institutions from the United States, the United Kingdom, China, Iran, Poland, and Malaysia, highlighting the global relevance of the topic. All included reviews were verified to ensure that extracted data represented KOA populations. For reviews with broader musculoskeletal scopes, only KOA-specific outcomes were retained for analysis. The reviews used rigorous search strategies, screening between three[13,15] and six[14] electronic

databases, most commonly PubMed, Embase, Web of Science, and the Cochrane Library. The number of primary studies included in each review ranged from six[3] to nine,[4] with cumulative sample sizes varying from approximately 30[25] to over 700[15] participants. Interventions assessed across these reviews focused on HILT, with treatment parameters including wavelengths between 808 nm and 1064 nm, energy densities ranging from 0.51 to 120 J/cm², and session frequencies of two to three times per week over a treatment duration of four to eight weeks. Comparators included sham laser therapy,[12] LLLT,[14] and conventional physical therapy.[4] A summary of the included reviews is presented in Table I.

Table I. Summary of included systematic reviews on high-intensity laser therapy for knee osteoarthritis (N = 7).

Author & Year; Type; PRISMA score	Databases; Number of studies; Year of publication; Quality assessment; Inclusion criteria; Intervention; Outcomes	HILT intervention details: Sessions and frequency; Laser parameters	Exercise intervention details	Significant findings on pain, physical function, and/or disability: Yes/ No
Ahmad et al. (2022); Systematic review and meta-analysis; PRISMA score 25/27	PubMed, PEDro, CINAHL, SPORTDiscus, Web of Science; n=10; 2003–2019; PEDro score average 7.3; KOA-specific; RCTs included KOA patients; Intervention: HILT combined with exercise; Outcomes: pain intensity, WOMAC, functional tests	2–3 sessions/week, 4–6 weeks; Energy density: 0.51–120 J/ cm²; Wavelength: 808–1064 nm; Total energy delivered: 1250–3000 J/session	Knee ROM exercises, quadriceps strengthening, and functional training	Pain: Yes Stiffness: Yes Physical Function: Yes Disability/QOL: N/A
Cai et al. (2023); Systematic review and meta-analysis; PRISMA score 26/27	CENTRAL, MEDLINE, CINAHL, EMBASE, Web of Science, PEDro; n=9; 2005–2022; Cochrane Risk of Bias; KOA-specific; Inclusion of RCTs comparing HILT to placebo combined with conventional therapies or exercise for pain reduction; Outcomes: Pain intensity and functional tests	2–3 sessions/week, 4–8 weeks; Wavelength: 1064 nm; Energy density: 10–120 J/cm²	Lower limb stretching and mobility exercises	Pain: Yes Stiffness: N/A Physical Function: Yes Disability/QOL: Yes
Khalilizad et al. (2024); Systematic review and network meta-analysis; PRISMA score 27/27	PubMed, Embase, Scopus; n=11; 1990–2023; AMSTAR-2 High Quality; KOA-specific; RCTs focusing on KOA patients receiving HILT or LLLT with exercise; Outcomes: pain intensity, WOMAC, functional tests	3 sessions/week, 4–8 weeks; Wavelength: 808–1064 nm; Total energy delivered: 3000 J/ session; Combination with exercise therapy	Stretching, strengthening, aerobic, and balance exercises	Pain: Yes Stiffness: No Physical Function: Yes Disability/QOL: Yes
Saleh et al. (2024); Systematic review and meta-analysis; PRISMA score 25/27	Cochrane Library, PubMed, Scopus; n=12; 2000–2022; PEDro score average 6.8; Comparison of HILT to LLLT in musculoskeletal disorders with or without exercise (KOA subset data extracted only); Outcomes: Pain intensity and quality of life (KOA-specific)	2 sessions/week, 6 weeks; Wavelength: 808 nm; Energy density: 5–100 J/cm²	Not specified; rehabilitation exercises	Pain: No Physical Function: N/A Disability/QOL: Yes
Song et al. (2020); Systematic review and meta-analysis; PRISMA score 24/27	MEDLINE, EMBASE, Cochrane CENTRAL, Web of Science; n=6; 2008–2020; Cochrane Risk of Bias; KOA-specific; Inclusion of RCTs of HILT intervention with or without exercise; Outcomes: pain intensity, WOMAC, functional tests	2–3 sessions/week, 4–6 weeks; Wavelength: 1064 nm; Energy density: 20–80 J/cm²	Knee ROM and strengthening exercises	Pain: Yes Stiffness: Yes Physical Function: N/A Disability/QOL: N/A
Wu et al. (2022); Systematic review and network meta-analysis; PRISMA score 27/27	PubMed, Embase, Cochrane Library, Web of Science, PEDro; n=10; 2000–2022; AMSTAR-2 High Quality; KOA-specific; HILT with exercise compared to other physical therapy modalities; Outcomes: pain intensity, WOMAC, functional tests	3 sessions/week, 4–8 weeks; SUCRA value: 98.9% for WOMAC; Energy density: 25–100 J/cm²	Mobility, strengthening and balance exercises	Pain: Yes Stiffness: No Physical Function: Yes Disability/QOL: N/A
Wyszynska & Bal-Bochenska 2018; Systematic review; PRISMA score 24/27	PubMed, EBSCO, Web of Science; n=6; 2005–2017; CONSORT Risk of Bias; RCTs focusing on KOA and HILT intervention exclusively or with exercise (only HILT + exercise arm data included); Outcomes: pain intensity, WOMAC, functional tests	2–3 sessions/week, 4–6 weeks; Wavelength: 1064 nm; Energy density: 0.51–120 J/cm²	Knee ROM and strengthening exercises	Pain: Yes Stiffness: Yes Physical Function: Yes Disability/QOL: N/A

Note: When reviews included mixed musculoskeletal conditions or multiple intervention arms, only data for KOA participants receiving HILT combined with rehabilitation exercise were extracted for synthesis.

Abbreviation: AMSTAR-2: A Measurement Tool to Assess Systematic Reviews 2; CINAHL: Cumulative Index to Nursing and Allied Health Literature; CENTRAL: Cochrane Central Register of Controlled Trials; HILT: High-Intensity Laser Therapy; KOA: Knee Osteoarthritis; LLLT: Low-Level Laser Therapy; PEDro: Physiotherapy Evidence Database; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RCT: Randomized Controlled Trial; ROM: Range of Motion; SUCRA: Surface Under the Cumulative Ranking; VAS: Visual Analogue Scale; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index.

Participant characteristics

The included reviews primarily examined adults aged 40–70 years, both male and female, with body mass index values between 25 and 35 kg/m², reflecting overweight to obese populations.[12,15] KOA diagnosis was based on clinical and radiographic criteria, most commonly using the Kellgren-Lawrence grading system. Studies predominantly focused on mild to moderate KOA (Grades 1-3),[4,14] though some reviews also included cases of advanced disease (Grade 4).[4] Symptom duration ranged from 1 to 5 years, representing both early and chronic KOA.[3,15] Baseline pain, typically assessed using the Visual Analogue Scale (VAS), ranged from 5 to 8, indicating moderate to severe intensity.

Study quality and assessment of overlap

The PRISMA scores ranged from 24 [12] to 27,[14] reflecting high reporting quality across reviews. The AMSTAR-2 assessments rated three reviews as high quality,[4,14,25] with rigorous methods and comprehensive bias assessments. The remaining four were rated moderate due to limitations in protocol registration, publication bias assessment, or bias evaluation methods. No reviews were rated critically low, indicating overall reliable evidence. Overlap among primary studies was assessed using the CCA method. The calculated values were N=64 (total occurrences of primary studies), r=50 (unique primary studies), and c=7 (systematic reviews included), resulting in a CCA score of 0.047, indicating minor overlap.[22]

Characteristics of rehabilitation exercise

The systematic reviews described a range of rehabilitation exercise approaches delivered in conjunction with HILT. One review provided detailed synthesis, reporting that adjunctive rehabilitation exercise commonly included quadriceps strengthening, knee range of motion exercises, stretching, balance, and functional lower limb training.[12] These programmes were delivered through both supervised sessions and home based exercise, with supervised sessions typically prescribed two to three times per week for 45 to 50 minutes, and home based programmes performed daily.[12] Another meta-analysis highlighted progressive strengthening, stretching, aerobic, and balance exercises as core elements of multimodal programmes.[25] Similarly, one network meta-analysis reported mobility, strengthening, and balance training as part of conventional physiotherapy,[4] while another review described strengthening and range of motion exercises as the most common components.[3] In contrast, some reviews[14,15] referred more generally to "rehabilitation exercise" or "conventional physiotherapy" without providing specific details. One earlier review also noted the frequent inclusion of range of motion and strengthening activities.[13]

Across reviews, the most consistently reported elements included aerobic conditioning, stretching, quadriceps and hamstring strengthening, mobility training, balance work, and functional task practice. Nonetheless, the intensity, frequency, and delivery of exercise varied considerably. While some reviews[3,25] included trials where HILT was delivered with or without exercise, none conducted subgroup analyses directly comparing HILT alone to HILT combined with exercise. As such, although the combined approach reflects common clinical practice, this variability limits the ability to attribute observed benefits solely to exercise as an adjunct.

Characteristics of HILT intervention

The systematic reviews collectively analysed laser parameters, reporting wavelengths ranging from 808 nm to 1064 nm and energy densities between 0.51 and 120 J/cm² per session.[12] The total energy delivered per session ranged from 1250 [4] to 3000 J,[14] depending on the specific treatment protocols synthesized across the reviews. The systematic reviews reported that treatment protocols generally involved 2–3 sessions per week for 4–8 weeks, with session durations varying between 10[3] and 20 [15] minutes, depending on the targeted knee region. The included reviews documented that HILT was applied to key anatomical regions of the knee, such as the anterior, medial, and lateral compartments, with a focus on pain reduction and stiffness alleviation.[12]

To optimize therapeutic outcomes, the beam spot size ranged from 1 to 5 cm²,[4,14] ensuring precise targeting of affected tissues, as consistently noted across the systematic reviews. The reviews also highlighted variation

in the mode of application, with studies employing both continuous and pulsed laser modes.[25] The pulsed mode was particularly emphasized for minimizing thermal effects while enhancing photobiostimulation, contributing to tissue repair and inflammation modulation.[12] All systematic reviews that assessed safety protocols consistently reported the use of protective goggles for both practitioners and patients, treatment curtains, and adherence to established laser safety guidelines.[12] Furthermore, HILT was reported to be well-tolerated, with only mild and transient adverse effects such as localized warmth or temporary discomfort, reinforcing its favourable safety profile across multiple reviews.[3,4,12,13]

Several systematic reviews also synthesized findings on HILT combined with adjunctive therapies, such as conventional exercise therapy, to enhance clinical outcomes.[12,14,25] The evidence from these reviews supports the notion that multimodal approaches incorporating HILT yield superior benefits in pain relief, physical function, and quality of life, further endorsing its integration into comprehensive KOA rehabilitation strategies.[12,14,25]

Synthesis of findings

Pain reduction

The included systematic reviews consistently indicate that HILT combined with exercise is effective in reducing pain among individuals with KOA (Figure 2), with improvements often exceeding the Minimal Clinically Important Difference (MCID) for pain relief.[4,12,14] One systematic review with meta-analysis reported a mean difference (MD) of -2.04 (95% CI: -2.12 to -1.96) in VAS scores, demonstrating a significant analgesic effect compared to placebo or conventional therapies.[14] Additionally, a network meta-analysis found that HILT combined with rehabilitation exercise resulted in significantly greater pain reduction (MD= -1.41; 95% CI–1.90 to –0.92) than LLLT combined with rehabilitation exercise, highlighting the superior analgesic properties of HILT.[25] Another systematic review further supported these findings, reporting an MD of -1.18 (95% CI: -1.68 to -0.69) compared to placebo, reinforcing the effectiveness of HILT in pain management.[3]

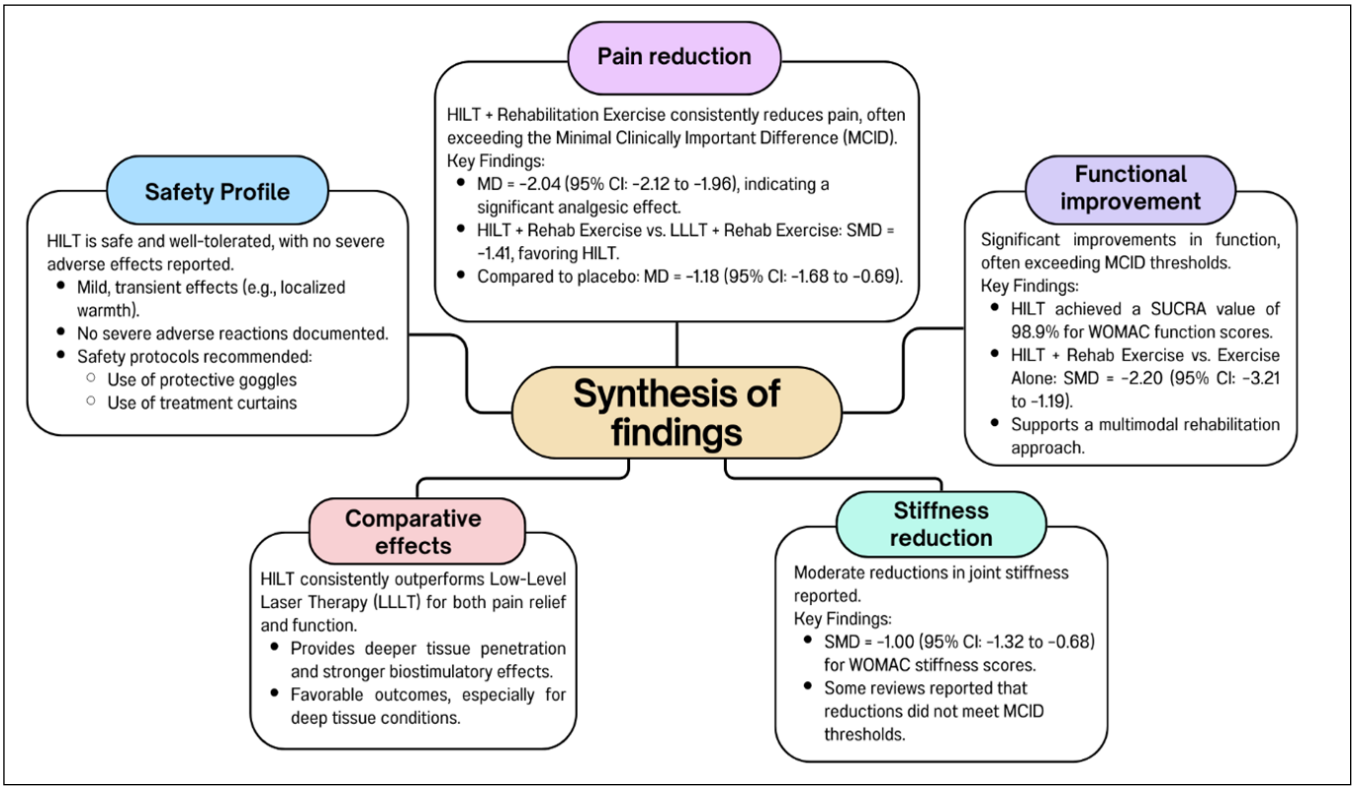

Figure 2. Summary of key findings from systematic reviews on the effectiveness of HILT combined with rehabilitation exercise in the management of KOA.

Functional improvement

HILT has been associated with significant improvements in physical function, with multiple systematic reviews highlighting functional gains that exceed MCID thresholds.[4,12,14] A meta-analysis reported that HILT outperformed other physical therapy modalities in improving Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) function scores, achieving a Surface Under the Cumulative Ranking (SUCRA) value of 98.9%, positioning it as the most effective intervention among those analysed.[4] Evidence also indicates that HILT combined with exercise leads to greater functional improvements compared with exercise alone, reinforcing the value of a multimodal rehabilitation approach.[12,14,25] For example, one systematic review [25] demonstrated significant improvements in WOMAC function scores for HILT combined with rehabilitation exercise (MD = –2.20; 95% CI: –3.21 to –1.19), providing strong support for its role in functional rehabilitation. Similarly, another recent systematic review [14] reported consistent benefits for WOMAC function (SMD = –0.70; 95% CI: –1.10 to –0.30) compared with placebo, further confirming the value of combining HILT with rehabilitation exercise.

Stiffness reduction

Multiple systematic reviews have reported reductions in stiffness following HILT intervention, though the clinical relevance of these findings remains uncertain.[3,4,12] One systematic review and meta-analysis found that HILT combined with exercise produced significant improvements in WOMAC stiffness scores (MD = –0.84; 95% CI: –1.43 to –0.24) compared with exercise alone, indicating a meaningful adjunctive effect.[12] Another meta-analysis also reported significant improvements in stiffness (MD = –1.00; 95% CI: –1.32 to –0.68).[3] However, some evidence suggests that although reductions were statistically significant, they did not consistently exceed MCID thresholds, indicating limited clinical significance in certain patient populations.[4]

Comparative effects: HILT vs LLLT

Several systematic reviews have compared HILT and LLLT, with findings consistently favouring HILT for pain relief and functional improvements.[4,12,14,15] Indirect evidence shows that HILT combined with exercise produced significantly greater improvements in knee pain compared with exercise alone, with a mean difference of –2.06 (95% CI: –3.14 to –0.98; $p < 0.001$) based on four primary trials.[12] In contrast, LLLT combined with exercise also demonstrated significant benefits over exercise alone, but the effect size was smaller, with a mean difference of –0.67 (95% CI: –1.05 to –0.29; $p<0.001$) across seven trials.[12] This difference in magnitude suggests that while both modalities are effective, HILT achieves more clinically meaningful reductions in pain, likely due to its deeper tissue penetration and stronger photobiostimulatory and photothermal effects.

Network meta-analyses further ranked HILT among the most effective physical therapy modalities for functional outcomes, and additional evidence reported superior results when comparing HILT plus exercise with LLLT plus exercise.[4,25] Although both modalities improve KOA symptoms, HILT was consistently associated with more pronounced benefits, particularly in deeper tissues.[4,25] Worth noting, these conclusions are based on indirect comparisons, as no systematic review has provided direct head-to-head analyses between HILT and LLLT.

Safety profile

HILT is consistently reported as safe and well tolerated, with only mild and temporary effects such as localized warmth or discomfort.[3,4,12,13] One review highlighted its non-invasive and painless nature, supporting its suitability for long term use.[13] Another confirmed no serious adverse events across included studies, reinforcing its favourable safety profil.[4] Additionally, the importance of safety measures is emphasized, including the use of protective goggles for both patients and practitioners and treatment curtains to prevent unintended laser exposure.[3,12]

DISCUSSION

This umbrella review synthesizes evidence from seven high-quality systematic reviews on the effects, safety, and clinical use of HILT for KOA. Findings consistently

showed that HILT combined with rehabilitation exercise effectively reduced pain and improved physical function, often surpassing MCID thresholds. It also had a favourable safety profile, with only mild, transient side effects reported, supporting its use as a non-invasive, well -tolerated option. While exercise therapy is widely recognized as a first-line, evidence-based intervention for KOA, emerging evidence suggests that it may not fully address the multifactorial nature of the condition when used in isolation.[26] Factors such as persistent pain, inflammation, and structural joint changes can limit participation and slow functional gains, indicating that exercise therapy alone may not be sufficient to achieve optimal outcomes without adjunctive interventions like HILT, which can enhance pain relief and tissue healing, thereby facilitating more effective rehabilitation. However, variations in treatment protocols and limited long-term data underscore the need for standardized guidelines and further research.

The included systematic reviews consistently report significant pain reduction following the use of HILT as an adjunct with rehabilitation exercise, with meta-analyses demonstrating substantial effect sizes compared to sham or conventional interventions. For instance, one review that analysed nine RCTs reported an MD of -2.04 in VAS scores, indicating a robust analgesic effect.[14] These findings are supported by the photobiological mechanisms of HILT, which include deep tissue penetration, modulation of inflammatory pathways, and stimulation of cellular regeneration.[18] HILT operates at wavelengths ranging from 808 to 1064 nm,[27] allowing it to penetrate deeper into tissues compared to LLLT, targeting key structures such as the synovial membrane, cartilage, and subchondral bone.[28] The photobiomodulation effects are mediated through the absorption of photons by mitochondrial chromophores, leading to increased adenosine triphosphate (ATP) production, enhanced cellular metabolism, and reduced oxidative stress.[29,30] These mechanisms contribute to the anti-inflammatory and analgesic effects observed in KOA, including the reduction of pro-inflammatory cytokines, as well as the modulation of pain pathways and release of endogenous opioids.[29]

In addition to pain relief, HILT significantly improves physical function, as measured using the WOMAC. Some reviews reported SMD as high as -2.20, exceeding MCID thresholds.[4,12] The combination of HILT with rehabilitation exercises yields superior outcomes compared to either intervention alone. For example, one review found that HILT combined with rehabilitation exercise resulted in greater improvements in pain and function compared to exercise alone or LLLT combined with rehabilitation exercise.[12] This synergistic effect is attributed to HILT's ability to reduce pain and inflammation, enabling individuals with KOA to engage more effectively in physical therapy and strengthening exercises.[29] Furthermore, HILT enhances tissue repair by stimulating collagen synthesis and promoting angiogenesis, which are critical for functional recovery in KOA.[29] These biological effects, combined with the mechanical benefits of exercise, create a multimodal approach that addresses both symptoms and underlying pathophysiology.[31]

It is also observed that HILT offers superior therapeutic outcomes compared to LLLT,[15] particularly in pain relief and functional improvement, due to its higher energy densities and deeper tissue penetration.[4,12,31] However, variability in laser parameters, such as wavelength, energy density, and treatment duration, remains a significant limitation, underscoring the need for standardized protocols to optimize treatment efficacy.[12] The safety profile of HILT is consistently favourable, with no serious adverse events reported. The most commonly observed side effects include localized warmth and temporary discomfort, which are mild and transient.[4,13] This reinforces HILT's suitability for long-term clinical use, particularly for individuals who may not tolerate pharmacological treatments well.

Strengths and limitations

This umbrella review provides a comprehensive synthesis of systematic reviews evaluating the effects, safety, and clinical application of HILT in KOA. A key strength is the rigorous methodological appraisal using AMSTAR-2 and PRISMA tools, which ensures high-quality evidence integration. The CCA score of 0.047 further indicates

only minor overlap among primary studies, reducing redundancy and strengthening the robustness of the findings. An important consideration is the diversity of exercise protocols reported across the reviews. Strengthening, stretching, aerobic, and balance training were commonly included, yet the type, intensity, and progression of exercises varied. While this reflects routine physiotherapy practice, it also introduces heterogeneity that may partly explain differences in effect sizes. The frequent inclusion of multimodal programmes aligns with current best practice guidelines for KOA rehabilitation.[2,8] Future trials should provide clearer descriptions of exercise type, progression, and supervision to improve comparability and clarify which exercise modalities yield the greatest benefits when paired with HILT.

Another limitation is the absence of direct comparisons between HILT alone and HILT combined with rehabilitation exercise. Although the combined approach was most commonly applied, none of the included systematic reviews conducted subgroup analyses by intervention type. This reflects the routine integration of exercise in KOA care but limits the ability to determine whether improvements are attributable to HILT itself or to its combination with exercise. Addressing this gap requires well-designed randomised controlled trials that directly compare HILT monotherapy with HILT plus exercise. Finally, heterogeneity in HILT treatment protocols including variations in wavelength, energy density, and session frequency complicates the development of standardised clinical guidelines. In addition, the limited availability of long-term follow-up data restricts conclusions about sustained benefits, highlighting the need for longitudinal studies to support clinical implementation.

CONCLUSION

This umbrella review consolidates evidence from seven systematic reviews, demonstrating that HILT is a safe and effective intervention for managing KOA. HILT with the combination of rehabilitation exercise, significantly reduces pain and improves physical function, often exceeding the MCID. Its greater efficacy compared to LLLT and its favourable safety profile make it a promising non-invasive adjunct for KOA. Clinicians should consider integrating HILT into conventional physiotherapy to optimize outcomes for individuals with KOA.

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CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

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