



Effectiveness of Low-Level and High-level Laser Therapy for Rotator Cuff–Related Shoulder Disorders: A Systematic Review and Meta-Analysis

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Abstract

Introduction: While photobiomodulation and high-power lasers are common for rotator cuff-related shoulder pain, evidence interpretation is hindered by inconsistent dosimetry and clinical findings. This systematic review and meta-analysis evaluate the effects of low-level (LLLT) and high-level laser therapy (HLLT) on pain, range of motion (ROM), and shoulder function.

Methods: This PROSPERO-registered review included randomized controlled trials comparing LLLT or HLLT against sham, no treatment, or conventional care. Two reviewers independently conducted screening, data extraction, and risk-of-bias assessment. Continuous outcomes were synthesized using random-effects models, supplemented by subgroup analyses (LLLT vs. HLLT; laser vs. laser plus exercise) and sensitivity analyses to address heterogeneity.

Results: Twenty-three trials (wavelengths 805–1064 nm) were included. Pooled analysis showed that laser therapy significantly reduced overall pain (VAS: MD –5.22; 95% CI –7.56 to –2.88; $P < 0.001$), though improvements in pain at rest, during movement, and at night were not statistically significant. After excluding outliers, modest improvements were noted in active internal rotation (MD 1.14; 95% CI 0.19–2.09; $P < 0.001$) and passive external rotation (MD –1.33; 95% CI –1.92 to –0.73; $P < 0.001$). Subgroup analysis indicated that HLLT yielded superior active-abduction outcomes compared to LLLT ($P = 0.016$). Certainty was limited by heterogeneity, small sample sizes, inconsistent dosimetry, and short follow-up.

Conclusion: Laser therapy provides modest, reproducible analgesic benefits, and selective ROM improvements, particularly when HLLT is combined with exercise. Given the limited functional gains and reporting inconsistencies, lasers should be used as an adjunct to structured rehabilitation rather than a standalone treatment. Future trials require standardized dosing and longer follow-ups.

Keywords: Rotator cuff injuries, Low-level laser therapy, High-level laser therapy, Meta-analysis



Introduction

Rotator cuff–related shoulder pain is a frequent cause of persistent shoulder symptoms and functional limitation.^{1,2} The condition includes a spectrum of tendon and periarticular disorders in which pain, impaired range of motion, weakness, and reduced daily activity may occur.^{3,4} Although many patients are initially managed with non-operative strategies such as exercise-based rehabilitation, anti-inflammatory medication, corticosteroid injection, and physical modalities, responses are variable and no single conservative approach is uniformly effective.^{5,6} Laser-based therapies have been proposed as adjunctive treatments for shoulder tendinopathy because of their potential biological effects on pain modulation, inflammation, tissue perfusion, and repair processes.⁷ Low-level laser therapy

(LLLT), also referred to as photobiomodulation, applies low-intensity light to stimulate cellular activity without producing a thermal tissue effect. In contrast, high-level laser therapy (HLLT) delivers greater energy to deeper tissues and may induce photochemical, photothermal, and photomechanical responses. These mechanistic differences suggest that the two modalities may not produce equivalent clinical effects.^{6,8,9}

Despite growing clinical evidence, the literature remains heterogeneous regarding laser parameters, dosimetry, treatment duration, and outcome measures, making it difficult to establish standardized clinical protocols. Several systematic reviews have evaluated physical-agent modalities for rotator cuff–related shoulder disorders, and a recent review by Lin et al.¹⁰ specifically examined LLLT and

HLLT for pain and disability in rotator cuff tendinopathy. However, important uncertainties remain regarding the consistency of effects across clinically distinct outcome domains, particularly pain subtypes, active versus passive range of motion, and validated shoulder-specific functional scales. In addition, the interpretation of laser therapy is complicated by substantial heterogeneity in dosimetry, treatment regimens, co-interventions, comparator groups, and follow-up duration. Therefore, the present review was designed to provide an outcome-specific synthesis of randomized controlled trials evaluating LLLT and HLLT in rotator cuff-related shoulder disorders, with particular attention to pain, active and passive ROM, functional outcomes, subgroup patterns by laser type and co-intervention, sensitivity analyses for influential studies, and assessment of small-study effects where data permitted.

Accordingly, this systematic review and meta-analysis evaluated randomized controlled trials of LLLT and HLLT patients with rotator cuff-related shoulder disorders. The objectives were to estimate their effects on pain, shoulder range of motion, and functional outcomes, and to examine whether treatment modality and co-interventions modified the observed clinical response.

Methods

Protocol and reporting

This systematic review and meta-analysis was reported in accordance with the PRISMA 2020 statement. The protocol and eligibility criteria were defined a priori, and the final search was conducted on October 14, 2024.

Eligibility criteria

Randomized controlled trials were eligible if they compared low-level laser therapy LLLT or HLLT with sham treatment, no intervention, or conventional nonsurgical therapy in adults with rotator cuff disease, subacromial impingement syndrome, or rotator cuff tendinopathy. Eligible studies had to report pain measured using the visual analog scale (VAS), active or passive range of motion, or function measured using the SPADI, Constant–Murley, QuickDASH, or UCLA score. Only English-language studies with extractable numerical data were included.

Intervention definition

LLLТ was defined as low-power, nonthermal red or near-infrared photobiomodulation that stimulates cellular and anti-inflammatory pathways without meaningful tissue heating. HLLT was defined as higher-power laser therapy with greater peak power and energy, deeper penetration, and photobiomodulatory and photothermal effects.

Information sources and search strategy

MEDLINE via PubMed, Embase, Cochrane CENTRAL, Web of Science, and Scopus were searched from inception to October 14, 2024. After duplicate removal, two reviewers independently screened titles and abstracts and assessed potentially eligible full-text reports against the predefined eligibility criteria. Disagreements were resolved through

discussion or consultation with a third reviewer.

Data extraction and data items

Two reviewers independently extracted study setting, sample size, participant characteristics, diagnosis, laser modality and parameters, treatment schedule, co-interventions, comparator, follow-up duration, and outcome data. Disagreements were resolved by consensus or consultation with a third reviewer.

Risk of bias assessment

Two reviewers independently assessed risk of bias using the Cochrane Risk of Bias 2 tool. The domains included bias arising from the randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of the reported result. Disagreements were resolved by consensus or consultation with a third reviewer.

Outcomes

The primary outcome was total pain measured using the VAS; scores reported on a 0–100 scale were converted to a 0–10 scale. Secondary outcomes included VAS pain at rest, during movement, and at night; active and passive range of motion; and function measured using the SPADI, Constant–Murley, QuickDASH, or UCLA score. Follow-up was classified as short term, from the end of treatment to 3 months, or mid-term, from more than 3 to 6 months.

Data synthesis and statistical analysis

For continuous outcomes measured on a common scale, such as VAS scores reported on standardized 0–100 or 0–10 scales, pooled effects were expressed as mean differences (MDs) with 95% confidence intervals (CIs). When studies assessed the same underlying construct using different measurement scales, standardized mean differences (SMDs) were calculated. All meta-analyses were performed using a DerSimonian–Laird random-effects model to account for between-study heterogeneity. Statistical heterogeneity was evaluated with Cochran’s Q test and quantified using the I^2 statistic, with values of 25%, 50%, and 75% interpreted as indicating low, moderate, and high heterogeneity, respectively. Prespecified exploratory subgroup analyses were conducted according to laser type, comparing LLLT with HLLT, and according to co-intervention, comparing laser therapy alone with a laser combined with exercise or physiotherapy. Sensitivity analyses were performed by sequentially excluding identified outliers and studies considered to have a higher risk of bias.

When outcome data were reported as medians with interquartile ranges or ranges, we estimated the corresponding means and standard deviations using validated conversion methods, including Wan, Hozo, or comparable approaches as appropriate, so that the data could be pooled. If standard deviations were not reported and could not be estimated, the study was excluded from the corresponding pooled analysis but described qualitatively. When multiple laser arms versus a single control arm were

reported, we either (a) pooled laser arms when clinically appropriate or (b) split the control group sample size to avoid double-counting as per Cochrane recommendations. All decisions and calculations are documented in the extraction file. Analyses were conducted using Review Manager (RevMan) for forest plot generation and primary pooled estimates, and Stata or equivalent statistical software for publication bias assessment, including Begg's and Egger's tests and trim-and-fill analyses. Publication bias and small-study effects were examined visually with funnel plots and statistically using Begg's and Egger's tests. When trim-and-fill analyses resulted in meaningful changes to the pooled estimates, the adjusted estimates were reported.

Handling of heterogeneity and outliers

For outcomes with substantial heterogeneity ($I^2 > 75\%$), we explored potential sources of variability by examining laser type, co-interventions, comparator type, follow-up duration, risk of bias, and visually influential studies in forest plots. These analyses were interpreted as exploratory because the number of studies per outcome was limited. Studies were classified as influential when they appeared to exert a disproportionate impact on the pooled effect estimate or between-study heterogeneity, based on the visual inspection of forest plots and sensitivity analyses. When such studies were identified, additional sensitivity analyses were conducted to evaluate the robustness of the pooled estimates. These analyses were intended to assess the stability of the findings rather than to determine the primary effect estimates. The possible effect of excluding influential studies on both the magnitude and direction of treatment effects was considered in the interpretation of results.

Ethics

Because this review used published data and recruited no participants or collected individual patient-level data, institutional review board approval was not required. Corresponding authors were contacted when additional or missing data were needed.

Results

Literature Search and Study Selection

The database search identified 1,342 records. After removal of 657 duplicates, 685 records underwent title and abstract screening, of which 644 were excluded. Forty-one full-text reports were assessed, and 18 were excluded because of insufficient data. Consequently, 23 studies involving 1,317 participants were included. Because two studies each contributed two eligible comparisons, 25 comparisons were included in the meta-analysis [Figure 1](#).

Characteristics of the Studies

The included studies evaluated LLLT or HLLT at wavelengths ranging from 805 to 1,064 nm. Their main characteristics are summarized in [Table 1](#).

Meta-Analysis

The pooled analysis showed a significant reduction in total VAS pain in the laser group compared with the control group (MD, -5.22 ; 95% CI, -7.56 to -2.88 ; $P < 0.001$). However, VAS pain during movement, at rest, and at night did not differ significantly between groups, although all estimates favored laser therapy ([Figure 2](#)).

The studies by Kamal et al.¹¹ and Elsodany et al.⁶ were identified as outliers in the analyses of internal and external rotation and were therefore excluded from the

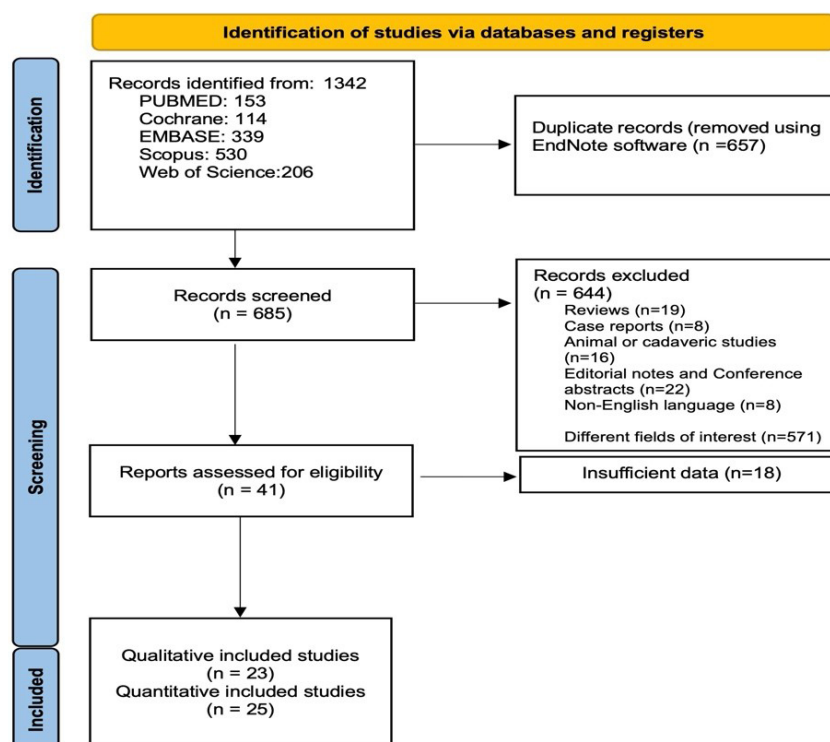


Figure 1. Study flowchart according to the PRISMA-DTA 2020 statement.

Table 1. Characteristics of the Included Studies*

Study	No. of Patients	Female/Male		Age † (yr)		Laser Type	Wave Length	Laser Duration	Follow-up
		control	Laser	Control	Laser				
Elsodany ⁶	60	NR	NR	NR	NR	HILT	1064	Pulse duration 120–150 micros	6 m
Kamal ¹¹	40	10/10	10/10	36.85±11.33	37.35±11.22	HILT	NR	total: 15 min	6 w
Yilmaz ¹²	63	21/10	21/11	53.3±7.5	48±7.7	HILT	1064	NR	12 w
Mahmoud ¹³	45	NR	NR	41.60±3.64	40.27±3.65	HILT	NR	NR	8 w
Yesilyaprak ¹⁴	30	8/7	4/11	50.1±10.2	49.2±9.0	HILT	1064	total treatment time was 16–18min	NR
Aceituno-Gomez ¹⁵	46	12/11	16/7	61.3±8.95	56.7±8.90	HILT	1064	NR	3 m
Abrisham ¹⁶	80	26/14	24/16	51.2±6.7	52.2±5.7	LLLT	890	120 s	2 w
Kelle ¹⁷	90	34/11	36/9	48.0	50.7	LLLT	904	150 s	6 m
Agir ¹⁸	112	48/8	47/9	47.61±10.49	51.48±5.51	LLLT	860	120 s	4 w
England ¹⁹	30	NR	NR	NR	NR	LLLT	904	300s	2 w
Abufoul ²⁰	50	12/16	9/13	54 (52 to 57)	56 (52 to 60)	LLLT	808	NR	6 m
Alfredo ²¹	78	NR	NR	45±10.4	54.2±7.1	LLLT	904	50 s	3 m
Vecchio ²²	35	14/2	11/8	NR	NR	LLLT	830	total: 600 s	8 w
Bingöl ²³	40	19/1	12/8	57.25±10.21	63.80±9.77	LLLT	904	60 s	2 w
Dogan ²⁴	52	13/9	20/10	53.45±9.64	53.7±12.6	LLLT	850	60 s	3 w
Yeldan ²⁵	60	22/4	25/9	55.00±8.75	55.32±8.73	LLLT	904	NR	3 w
Sen ²⁶	37	10/8	15/4	48.5±11.9	52.2±8.3	LLLT	850	60 s	3 m
Calis ²⁷	36	14/7	10/5	50.42±12.41	46.2±12.14	NR	904	120 s	3 w
Zaki ²⁸	30	6/4	5/5	53.43±11.4	45.86±13.28	HILT	904	50 s	12 w
Pekyavas ²⁹	70	NR	NR	49.4±12.6	40.6±11.7	HILT	1064	NR	2 w
Bal ³⁰	40	13/7	15/5	53.1±8.4	51.7±14.1	LLLT	904	120 s	12 w
Faria-Souza ³¹	69	NR	NR	NR	NR	LLLT	904	15 min and 20 s	2 w
Abd-Allah MA ³²	30	11/4	8/7	41.46±6.97	42.46±6.13	LLLT	905	150 s	4 w

*LLLT=low-level laser therapy, HILT=high-intensity laser therapy, NR=not reported. †The values are given as the mean, with or without the standard deviation and with or without the range in parentheses, unless otherwise noted. ‡This study used 2 different comparisons to compare 2 different laser groups for evaluating laser therapy versus non-surgical interventions for shoulder tendinopathies. §This study compared 2 different laser groups in the same study for evaluating laser therapy versus non-surgical interventions.

pooled analysis. No significant between-group differences were observed, except for active internal rotation, which improved significantly in the laser group compared with the control group (MD, 1.14; 95% CI, 0.19–2.09; $P < 0.001$; Figure 3.)

In the analyses of internal and external rotation, the study by Elsodany et al. ⁶ was identified as an outlier and excluded from the pooled analysis. After its exclusion, a significant between-group difference was observed for passive external rotation (MD, –1.33; 95% CI, –1.92 to –0.73; $P < 0.001$; Figure 4.)

The study by Elsodany et al. ⁶ was identified as an outlier and excluded from the SPADI analysis. No significant between-group differences were observed for the SPADI, Constant–Murley, QuickDASH, or UCLA scores (Figure 5).

Subgroup Analysis

The results of the subgroup analysis are shown in Table 2. Due to significant heterogeneity, we conducted subgroup analyses to identify potential sources of variability.

In terms of active abduction, a significant difference was noted between HLLT and LLLT, with HLLT yielding more favorable outcomes (–0.52 vs. 2.82, $P = 0.016$). No

statistically significant differences were detected between HLLT and LLLT with respect to the other variables.

Small-Study Effects and Reporting Bias

Funnel plots are presented in Supplementary File 1. No evidence of funnel-plot asymmetry was observed for any outcome except passive flexion. For passive flexion, both Begg's and Egger's tests indicated significant small-study effects ($P < 0.05$). Trim-and-fill analysis changed the pooled estimate from –0.67 (95% CI, –1.93 to 0.59) to –0.05 (95% CI, –1.40 to 1.30).

Risk of Bias Assessment

Risk-of-bias judgments are presented in Table 3.

Discussion

This meta-analysis indicates that laser therapy may offer a small analgesic effect in patients with rotator cuff-related shoulder disorders; however, the available evidence does not demonstrate consistent benefits across all clinical outcomes. The clearest pooled signal was observed for total VAS pain, whereas pain at rest, pain during movement, night pain, most range-of-motion outcomes, and

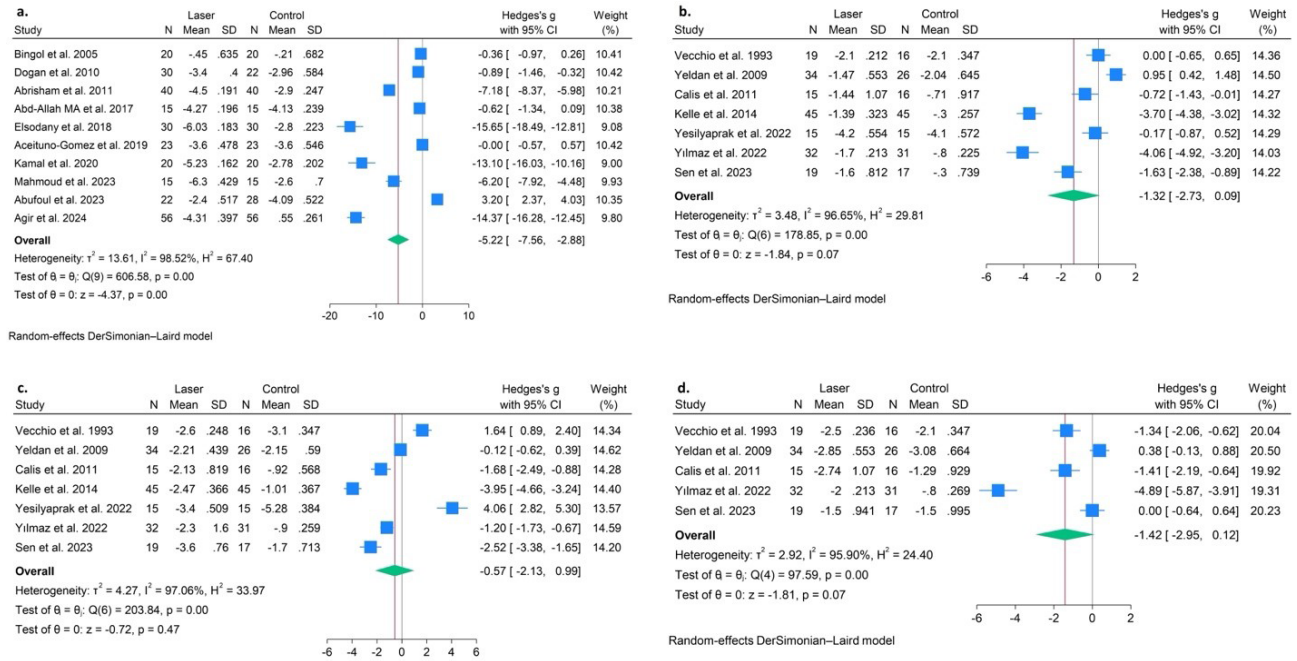


Figure 2. Forest plot of the effect sizes for the visual analog scale (VAS). For each parameter, the blue square indicates the value in the included studies (with weighting indicated by the square sizes), and the horizontal line indicates the 95% CI; the corresponding set of values is stated to the right. The green diamond indicates the random-effects model for the pooled data and its CI. The pooled effect size, chi-square, Cochran Q, and I² (inconsistency) values for the model are stated at the bottom of the panel. a) total VAS, b) VAS at rest, c) VAS at movement, d) VAS at night. CI = confidence interval.

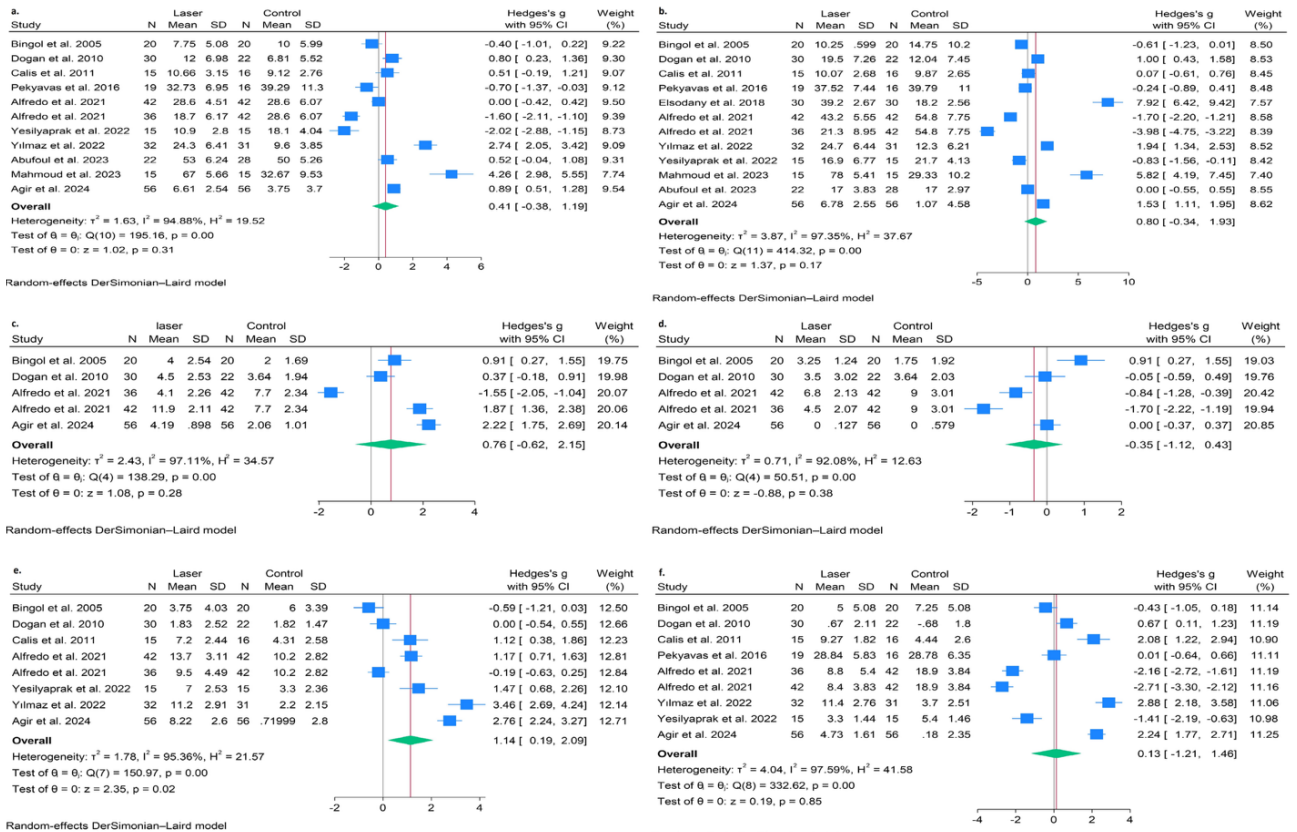


Figure 3. Forest plot of the effect sizes for the active range of motions. For each parameter, the blue square indicates the value in the included studies (with weighting indicated by the square sizes), and the horizontal line indicates the 95% CI; the corresponding set of values is stated to the right. The green diamond indicates the random-effects model for the pooled data and its CI. The pooled effect size, chi-square, Cochran Q, and I² (inconsistency) values for the model are stated at the bottom of the panel. a) active flexion, b) active abduction, c) active extension, d) active adduction, e) active internal rotation, f) active external rotation. CI = confidence interval.

functional scores showed inconsistent or non-significant effects. Therefore, the main clinical message is not that laser therapy is broadly effective, but that it may offer limited

pain reduction in selected settings, particularly when used as part of a rehabilitation program rather than as an isolated intervention.

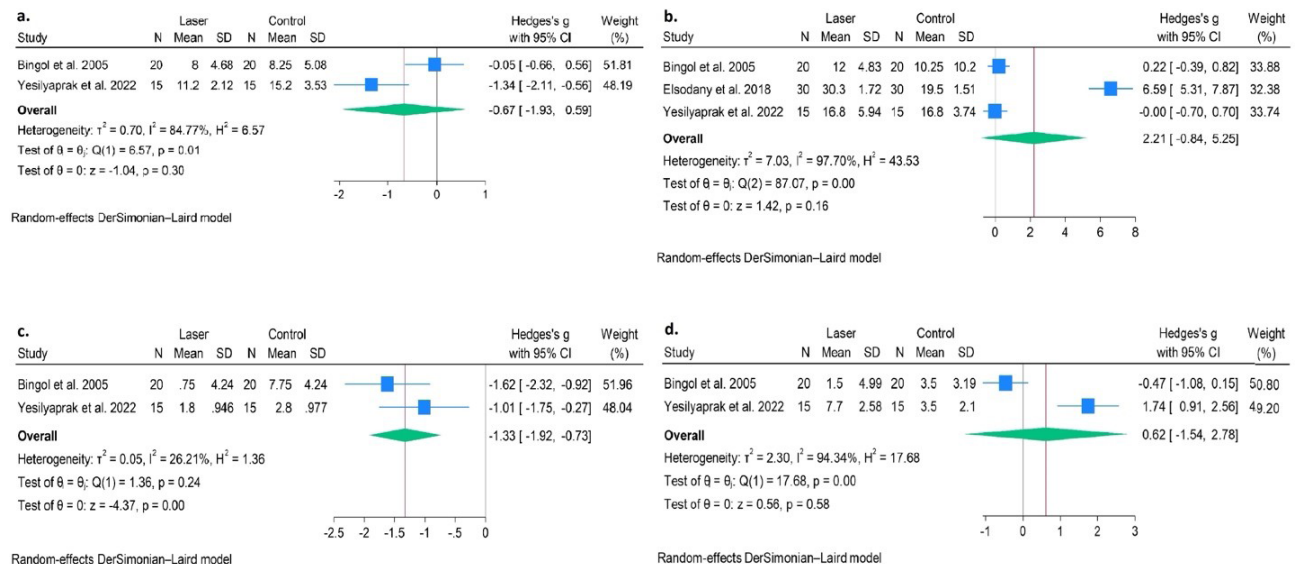


Figure 4. Forest plot of the effect sizes for the passive range of motions. For each parameter, the blue square indicates the value in the included studies (with weighting indicated by the square sizes), and the horizontal line indicates the 95% CI; the corresponding set of values is stated to the right. The green diamond indicates the random-effects model for the pooled data and its CI. The pooled effect size, chi-square, Cochran Q, and I² (inconsistency) values for the model are stated at the bottom of the panel. a) passive flexion, b) passive abduction, c) passive external rotation, d) passive internal rotation. CI = confidence interval.

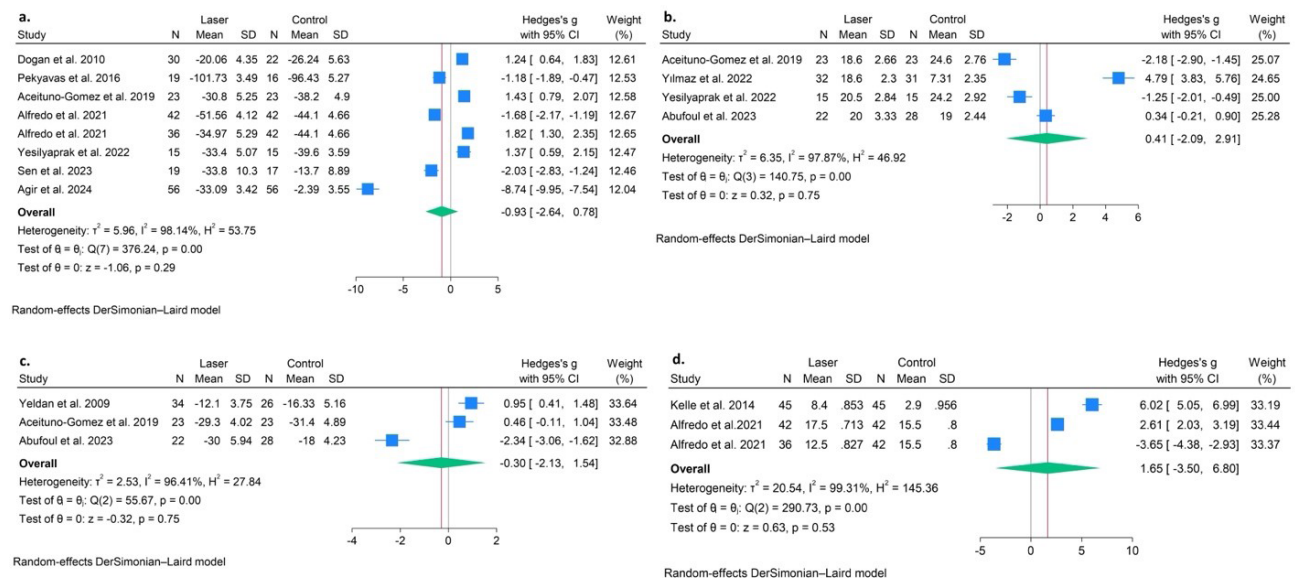


Figure 5. Forest plot of the effect sizes for other functional outcomes. For each parameter, the blue square indicates the value in the included studies (with weighting indicated by the square sizes), and the horizontal line indicates the 95% CI; the corresponding set of values is stated to the right. The green diamond indicates the random-effects model for the pooled data and its CI. The pooled effect size, chi-square, Cochran Q, and I² (inconsistency) values for the model are stated at the bottom of the panel. a) Shoulder Pain and Disability Index (SPADI), b) Constant-Murley score (CMS), c) Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH), d) The University of California-Los Angeles (UCLA) shoulder scale. CI = confidence interval.

Unlike previous reviews that evaluated LLLT or HLLT separately, often within specific diagnostic subgroups such as subacromial impingement syndrome, this review integrates both modalities across a broader range of rotator cuff-related shoulder pain conditions. By jointly assessing pain, range of motion, and function, it provides a more comprehensive evaluation and identifies consistent and uncertain findings in the literature.¹⁰

The inconsistency across outcomes is clinically important: pain relief did not consistently improve function, and range-of-motion gains were small, variable, and outcome-specific. This dissociation suggests that laser therapy may reduce symptoms or local inflammation without restoring tendon mechanics, neuromuscular control, or shoulder

performance, limiting support for its use as a standalone treatment.

Pain relief was the most consistent benefit across the included RCTs. Laser therapy significantly reduced overall VAS pain, with a larger effect for HLLT than LLLT, although the between-group difference was not statistically significant. Individual studies also consistently showed analgesic benefits of HLLT, particularly when combined with exercise therapy. The findings of Elsodany et al.⁶ provide compelling evidence that HLLT, when combined with exercise, results in sustained and superior reductions in VAS pain scores compared with sham treatment plus exercise at three and six months of follow-up. Kamal et al.¹¹ similarly reported significant reductions in pain intensity

Table 2. Subgroup Analyses*

Variable	Effect size (95% CI)	I ² (%)	P-value
VAS total			
LLLT	-3.25 (-6.15 to -0.35)	98.73	0.173
HLLT	-8.64 (-15.83 to -1.44)	98.58	
VAS at rest			
LLLT	-1.01 (-2.63 to 0.60)	96.73	0.602
HLLT	-2.11 (-5.92 to 1.70)	97.89	
VAS at movement			
LLLT	-1.32 (-3.19 to 0.55)	97.14	0.331
HLLT	1.40 (-3.75 to 6.55)	98.29	
Active flexion			
LLLT	0.10 (-0.57 to 0.77)	91.60	0.490
HLLT	1.04 (-1.54 to 3.63)	97.47	
Active abduction			
LLLT	-0.52 (-1.79 to 0.76)	97.20	0.016
HLLT	2.82 (0.41 to 5.23)	97.53	
Active internal rotation			
LLLT	0.71 (-0.29 to 1.71)	95.23	0.115
HLLT	2.47 (0.52 to 4.42)	91.92	
Active external rotation			
LLLT	-0.06 (-1.77 to 1.66)	98.05	0.710
HLLT	0.50 (-1.91 to 2.9)	97.11	
SPADI			
LLLT	-1.83 (-4.43 to 0.77)	98.77	0.134
HLLT	0.54 (-1.15 to 2.24)	94.23	

*CI=confidence interval, VAS=visual analog scale, LLLT=low-level laser therapy, HLLT=high-level laser therapy, SPADI=Shoulder Pain and Disability Index.

when HLLT was combined with exercise compared with exercise alone. Yılmaz et al.¹² demonstrated HLLT superiority for VAS scores maintained at the 12-week follow-up. Mahmoud et al.¹³ conducted a 3-arm trial, demonstrating that the HLLT+PT group achieved larger reductions in VAS pain than the PT alone and RSWT (radial shockwave therapy) + PT groups, after both 6 and 8 weeks. Yeşilyaprak et al.¹⁴ uniquely assessed HLLT only with HLLT+exercise and observed that adding exercise to HLLT enhanced pain improvement during activity, emphasizing the synergistic value of multimodal therapy. In contrast to these supportive findings, Aceituno-Gómez et al.¹⁵ found no superiority of HLLT plus exercise over sham treatment plus exercise in reducing pain at three months, tempering generalized enthusiasm for HLLT as an adjunctive intervention and underscoring the continued role of exercise as a pragmatic foundation for pain relief.

LLLT trials exhibited broader variability in outcomes, likely influenced by disparate dosimetry, wavelength, and study design. Nonetheless, several high-quality trials define the potential of LLLT as an adjunct for analgesia. Abrisham et al.¹⁶ demonstrated that LLLT combined with exercise achieved superior pain reduction compared with exercise+sham laser at two weeks. Kelle/Kozanoğlu extended the same results to a 6-month follow-up;

additionally, they established comparable results to local corticosteroid injection.¹⁷ Agir et al.¹⁸ reported that LLLT and peloid therapy, each administered alongside exercise, produced significant improvements in pain compared with exercise alone, although no significant difference was observed between the two treatment modalities. In an older study by England et al.,¹⁹ which compared active laser therapy, dummy laser, and drug therapy (naproxen sodium), LLLT produced significant improvements in both groups for pain and objective movement measures. Abufoul et al.⁸ expanded the evidence base to postoperative rehabilitation, showing that self-administered photobiomodulation (PMB) after rotator cuff repair accelerated pain resolution relative to sham therapy at 6 months. The necessity of concurrent rehabilitation remains paramount. Alfredo et al.²⁰ randomized patients with subacromial impingement syndrome to LLLT plus exercise, exercise alone, or LLLT alone. At three months, LLLT alone produced markedly worse pain and SPADI outcomes than both exercise-containing groups, highlighting the limited effectiveness of laser therapy without concurrent rehabilitation.

However, even when combined with exercise, LLLT remains controversial and often shows no superiority over sham treatment, suggesting that observed improvements may largely reflect exercise effects and natural recovery in control groups. This limitation was reinforced by rigorous randomized, double-blind, placebo-controlled trials using standardized exercise regimens across all groups. For instance, Vecchio et al.²¹ and Bingöl et al.²² reported substantial within-group improvements in pain from baseline across all treatment arms; however, active laser therapy did not demonstrate superiority over dummy laser treatment at any follow-up assessment. These findings are in line with other studies employing cold therapy, such as those by Doğan et al.²³ and Yeldan et al.,²⁴ which also showed no significant pain relief. More recently, Sen et al.²⁶ also confirmed this non-superiority, and although there were short-lived benefits (one-month gains in pain and function), they dissipated entirely by three months.

Further complicating the interpretation of LLLT heterogeneity, even across studies using comparable laser doses, may be partly related to the variable use of co-interventions, particularly thermal modalities. Alfredo et al.²⁰ proposed that the failure of LLLT to demonstrate additive efficacy in studies such as Doğan and Yeldan's^{24,25} may be due to the concomitant use of cold packs. They proposed the plausible explanation that cryotherapy-induced reductions in local metabolic activity and vasoconstriction may limit the delivery or absorption of laser energy. However, a similar negative result was shown in Calis et al.'s⁵ trial, which combined hot packs with LLLT and exercise and failed to demonstrate any superiority of LLLT over the exercise-only group. These findings suggest that any potent thermal stimulus may introduce physiological variables that neutralize or mask the subtle biostimulative effects of LLLT.

Pooled data showed no overall range-of-motion benefit of laser therapy over controls. The only reproducible

Table 3. The risk of bias in randomized trials (RoB 2) tool assessment for the included studies

Study	D1	D2	D3	D4	D5	Overall
Elsodany ⁶	Some concerns	Low	Low	Low	Some concerns	Some concerns
Kamal ¹¹	Low	Some concerns	Low	Some concerns	Some concerns	Some concerns
Yılmaz ¹²	low	low	Some concerns	Some concerns	Some concerns	Some concerns
Mahmoud ¹³	Some concerns	Some concerns	Low	Some concerns	Some concerns	Some concerns
Yesilyaprak ¹⁴	low	low	Some concerns	Some concerns	Some concerns	Some concerns
Aceituno-Gomez ¹⁵	Some concerns	Low	Some concerns	Low	Low	Some concerns
Abrisham ¹⁶	Low	Low	Low	Low	Some concerns	Low
Kelle ¹⁷	High	High	High	High	Some concerns	High
Agir ¹⁸	Some concerns	High	Some concerns	High	Some concerns	High
England ¹⁹	Some concerns	Low	Some concerns	Low	Some concerns	Some concerns
Abufoul ⁸	Low	Low	Low	Low	Low	Low
Alfredo ²⁰	Low	Low	Low	Low	Some concerns	Some concerns
Vecchio ²¹	Low	Low	low	low	Some concerns	low
Bingöl ²²	Some concerns	Low	Low	Low	Some concerns	Some concerns
Dogan ²³	Some concerns	Low	Low	Low	Some concerns	Some concerns
Yeldan ²⁴	Some concerns	low	Some concerns	Some concerns	Some concerns	Some concerns
Sen ²⁵	Some concerns	Low	low	Some concerns	Some concerns	Some concerns
Calis ⁵	Some concerns	Low	Low	Low	Some concerns	Some concerns
Zaki ²⁶	low	low	Some concerns	Some concerns	Some concerns	Some concerns
Pekyavas ²⁷	Some concerns	Low	low	Some concerns	Some concerns	Some concerns
Bal ²⁸	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
Faria-Souza ²⁹	Some concerns	Low	Some concerns	Some concerns	Some concerns	Some concerns
Abd-Allah MA ³⁰	Some concerns	Low	Low	Some concerns	Some concerns	Some concerns

Domains: D1 = bias due to the randomization process, D2 = bias due to deviations from intended interventions, D3 = bias due to missing outcome data, D4 = bias in the measurement of the outcome, D5 = bias in the selection of the reported result

group-level finding was a modest improvement in active internal rotation, whereas passive external rotation favored controls. Active range-of-motion gains may reflect pain reduction enhanced by rehabilitation. Although some differences were statistically significant, their clinical importance remains uncertain because MCID values were inconsistently reported; however, the small effect sizes suggest limited clinical relevance.

Studies evaluating HLLT more frequently reported measurable improvements in shoulder motion. Elsodany et al.,⁶ for example, found that active and passive abduction, external rotation, and internal rotation improved after treatment, with these gains sustained at the three- and six-month follow-up assessments. Mahmoud et al.¹³ showed greater improvements in flexion and abduction in the HLLT+PT group. Kamal et al.¹¹ reported comparable findings in the HLLT plus exercise group. They also used ultrasonography as an objective correlate of clinical improvement and demonstrated a significant reduction in supraspinatus tendon thickness in the HLLT group. This observation was later supported by Zaki et al.²⁶ in a notable three-arm randomized placebo-controlled trial comparing LLLT plus kinesiology taping (KT), high-power laser therapy (HPL) plus KT, and sham KT. The HPL-KT group demonstrated greater improvement than the LLLT-KT group, particularly in terms of reduced supraspinatus tendon thickness and increased tendon echogenicity.

Furthermore, although formal statistical comparisons did not establish definitive superiority between groups for ROM outcomes, Zaki et al. highlighted a clinical advantage of HPL, suggesting that it may improve ROM across more directions than LLLT or sham treatment. Yılmaz et al.'s¹² HLLT + exercise treatment compared with sham HLLT + exercise treatment significantly improved active shoulder flexion, external rotation, and transiently improved internal rotation at 3 weeks, with persistent benefits in flexion and external rotation by 12 weeks, while abduction remained unchanged. On the other hand, Pekyavas et al.²⁸ in a multimodal trial observed incremental benefits only in abduction when HLLT was added to manual therapy and kinesio-taping.

Evidence on the effect of LLLT on ROM remains heterogeneous. Abrisham et al.¹⁶ reported improvements in both active and passive range of motion for shoulder flexion, abduction, and external rotation. In contrast, Alfredo et al.²⁰ listed abduction as the only motion that improved significantly compared to the exercise group. However, Yeldan et al.²⁴ and several others showed equivalent ROM recovery between active and sham treatments, and Abufoul reported no ROM advantage in postoperative rehabilitation.⁸

Functional outcomes improved within most intervention arms but did not demonstrate significant pooled between-group differences in the overall meta-

analysis. When delivered with exercise, HLLT produced the most convincing functional signals in individual trials, namely reports of sustained SPADI gains for six months by Elsodany et al.⁶ and superior Constant-Murley classifications in Yeşilyaprak et al.'s¹⁴ trial. This positive functional trend was in line with the same studies that showed coinciding pain improvement. However, the study by Aceituno-Gómez et al.¹⁵ found no superiority of HLLT plus exercise over sham plus exercise in reducing pain and improving functionality.

A more pronounced disassociation between pain improvement and functional outcomes was observed in LLLT trials. LLLT trials showed a clearer dissociation between pain relief and functional improvement. However, Alfredo et al.,²⁰ reported that LLLT combined with exercise improved both SPADI and modified UCLA scores more than either intervention alone. Kelle and Kozanoğlu observed improvements in UCLA and Nottingham Health Profile scores.¹⁷ Agir et al.¹⁸ reported comparable short-term effects of LLLT plus home exercise therapy on functional status and quality of life, measured using SPADI and SF-36, respectively. Other studies reported no pain relief and non-significant functional changes, similar to Doğan et al. and Yeldan et al.,^{23,24} while studies by Abufoul et al.⁸ and Bal et al.²⁸ indicated no functional advantage despite analgesic benefits, which aligns with our observations regarding analgesia and function in the overall meta-analysis.

The dissociation between pain reduction and functional improvement warrants consideration. Shoulder function depends on muscle strength, tendon integrity, neuromuscular control, movement coordination, and rehabilitation adherence; therefore, short-term analgesia may reduce symptoms without improving validated functional outcomes. This may explain the greater responsiveness of pain-related measures to laser therapy.

Mechanistically, the clinical pattern we observed is biologically plausible: Both LLLT and HLLT deliver light energy within the near-infrared spectrum (805–1064 nm) that gets absorbed by cellular chromophores and appears to enhance mitochondrial activity and ATP synthesis, promoting fibroblast proliferation, collagen remodeling, decreased prostaglandin-mediated inflammation, and improved subacromial perfusion.^{13,16,17,27} HLLT's higher power density and pulsed emission likely permit deeper tissue penetration (due to reduced heat accumulation at depth) and greater metabolic stimulation (enhancing photochemical effects in deep structures).^{6,11,13} Several studies attribute the rapid but often transient early analgesic effect to delayed nociceptive transmission, inhibition of axonal flow in dorsal root ganglion neurons, and altered sensory input to the central nervous system. Additional mechanisms include increased pain thresholds at nerve endings and enhanced tissue production of serotonin, endogenous opioids, and morphine-mimetic substances.^{6,17,23,24,26,28,29} Laser therapy may act as a biostimulatory and anti-inflammatory adjunct that supports tissue recovery without directly restoring tendon

structure or neuromuscular coordination.^{6,11,13,16,26}

Because excluding influential studies may alter pooled effects, outlier-removed models were used only for sensitivity analyses, whereas primary interpretation relied on the full dataset. Findings should be interpreted cautiously given substantial heterogeneity in laser modality, dosimetry, treatment protocols, co-interventions, comparators, and study designs. Laser therapy was often combined with multimodal rehabilitation, while controls ranged from sham or no treatment to active therapy; thus, pooled estimates reflect heterogeneous clinical comparisons rather than standalone laser efficacy. Clinically, laser therapy produced statistically significant but modest pain relief without consistent functional improvement, suggesting potential symptom relief in selected patients but limited functional recovery when used alone.

This problem is amplified in HLLT trials, where perceptible warmth may unblind participants and assessors. Sample sizes were often small, commonly <20 per arm, and follow-up was short; only three studies extended to six months, leaving effect durability uncertain. Publication bias was detected for passive flexion, and trim-and-fill adjustment shifted the estimate toward neutrality, warranting caution. Meta-regression was not performed because few studies contributed to each outcome and dosimetry reporting was incomplete; therefore, subgroup and sensitivity analyses were used exploratorily to assess heterogeneity.

Given persistent high heterogeneity despite subgroup and sensitivity analyses, pooled estimates should be considered exploratory rather than definitive, with narrative synthesis preferred when heterogeneity remained unexplained. Future studies should assess laser therapy as an adjunct to multimodal rehabilitation, examine dose-response relationships and treatment frequency, and evaluate comparative effectiveness and cost-utility to define its role among conservative treatments for rotator cuff-related shoulder disorders.

Conclusion

In this study, laser therapy produced a small reduction in overall pain among patients with rotator cuff-related shoulder disorders. However, effects on pain subdomains, functional outcomes, and most active and passive ROM measures were inconsistent or non-significant in pooled analyses. Although exploratory subgroup analyses suggested a possible advantage of HLLT over LLLT for active abduction, this finding should not be interpreted as definitive evidence of generalized HLLT superiority. The clinical applicability of the findings is limited by high between-study heterogeneity, small trial sizes, variable comparators, incomplete laser-dosimetry reporting, and limited follow-up duration. Current evidence supports laser therapy, particularly HLLT, as a potential adjunct to structured rehabilitation rather than as a standalone intervention. Future trials should use standardized dosimetry, adequately blinded sham controls, longer follow-up, and complete reporting of treatment parameters

to clarify dose–response relationships and clinically meaningful benefits.

Authors' Contribution

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Consent for Publication

Not applicable.

Ethical Approval

As this study is a systematic review and meta-analysis of previously published studies, ethical approval and informed consent were not required.

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Supplementary Files

Supplementary file 1. Funnel plots of the functional outcomes. The red line indicates the overall effect size or risk difference using the random-effect model.

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