Effect of High-Intensity Laser Therapy on Carpal Tunnel Syndrome Patients

A Systematic Review and Meta-analysis

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Objective: To provide a strong foundation for the use of high-intensity laser therapy in carpel tunnel syndrome, we conducted a systematic review and meta-analysis to investigate the outcomes of short- and long-term follow-up studies.

Design: This is a systematic review and meta-analysis.

Results: Sample sizes of included studies ranged from 16 to 98 patients ($N = 308$). Overall, a significant difference between the treatment and control groups were found across majority of the measures. Studies using a 4-wk follow-up period, however, only found significantly greater benefits for high-intensity laser therapy in visual analog scale compared with placebo ($P = 0.0191$), transcutaneous electrical nerve stimulation ($P = 0.0026$), and low-intensity laser therapy 20 J/cm^2 ($P < 0.0002$), and exercise ($P < 0.0001$). For improvement in visual analog scale score over a long treatment period, high-intensity laser therapy was also preferred over control group ($P < 0.0071$). Insufficient evidence exists to determine effect of high-intensity laser therapy on nerve conduction examinations. The only statistically significant differences observed in examinations were in relation to sensory nerve action potential ($P = 0.0083$) and sensory nerve conduction velocity ($P = 0.0468$).

Conclusions: Moderate evidence exists regarding efficacy of high-intensity laser therapy compared with placebo, high-intensity laser therapy + wrist splint, and exercise in a short period of follow-up time but evidence on long-term follow-up is limited.

Key Words: High-Intensity Laser Therapy, Carpel Tunnel Syndrome, Treatment, Management, Visual Analog Scale, Sensory Nerve Action Potential

(*Am J Phys Med Rehabil* 2024;103:979–985)

What Is Known

- High-intensity laser therapy (HILT) has been proposed as a potential treatment for carpal tunnel syndrome (CTS), but the efficacy of this treatment remains unclear.

What Is New

- Our meta-analysis confirms that HILT improves pain levels in CTS patients compared with placebo, transcutaneous electrical nerve stimulation, low-intensity laser therapy, and exercise within a short-term follow-up period. In addition, HILT was found to be more effective than control for long-term improvement in visual analog scale scores. Despite insufficient evidence regarding the impact of HILT on nerve conduction examinations, our findings suggest that HILT may be a promising treatment option for CTS.

Carpal tunnel syndrome (CTS), the most prevalent neuropathy of the median nerve, accounts for 90% of all neuropathies.[1] Carpal tunnel syndrome affects 50 of 1000 adult population in the United States alone.[2,3] It results from compression of the median nerve as it passes through the osteofibrous canal at the wrist.[4,5] Compressive neuropathy caused by edema, tendon swelling, hormonal problems, physical activity, and other factors such as genetic predisposition, repetitive hand use, or certain health conditions like diabetes or rheumatoid arthritis, can occasionally cause CTS.[6,7] Numbness, tingling, and weakness in the hand and arm are possible symptoms.

Different approaches and techniques have been addressed for treatment of CTS. In severe cases, surgery is advised to cut the transverse carpal ligament to increase space and relieve pressure.[8] On the other hand, patients with mild to moderate symptoms are typically given conservative treatment, which includes corticosteroids, vitamins, anti-inflammatory medications, yoga, carpal bone mobilization, and the use of hand splints.[5,9,10] Although there are several alternatives for treating CTS, the best treatment course of action is yet undetermined.

The American Association of Orthopedic Surgeons reported that individuals with more severe and persistent CTS

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Required data will be provided upon request from the corresponding author.
The data that support the findings of this study are available from the corresponding author upon reasonable request.
Financial disclosure statements have been obtained, and no conflicts of interest have been reported by the authors or by any individuals in control of the content of this article.
Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.ajpmr.com).

ISSN: 0894-9115
DOI: 10.1097/PHM.0000000000002427

would not benefit from continuous conservative therapy.[11] In addition, it is inconsistent and difficult to draw conclusions about the best CTS treatment methods due to a dearth of data. For instance, in a systematic review by Hernández-Secorún and colleagues (2021),[12] surgical treatment was found to be preferable to splinting, anti-inflammatory medicines, and hand therapy for treating CTS in the short-, medium-, and long-term follow-up. The best therapies for CTS, however, according to the study published by Martins and Siqueira,[13] include wrist immobilization and corticosteroid injection.

As a noninvasive treatment option, laser therapy has lately grown in popularity because it offers patients with CTS a quick and efficient treatment option.[14–18] More significantly, low-level laser therapy (LLLT) is widely used and has direct photochemical activities that have a secondary biological impact as opposed to heat effects.[15,16] It is also believed that high-intensity laser therapy (HILT) may be more effective because it penetrates more deeply into the tissue and has slower light dispersion and absorption.[18] Effects of HILT include improved mitochondrial oxidative responses, higher DNA and ATP regeneration, increased tissue stimulation, and reduced pain and inflammation.[18–21] High-intensity laser therapy parameters have been described in detail by Xie and colleagues,[22] suggesting relative uniformity across studies. The present evidence, however, does not provide strong evidence that HILT is more effective than LLLT or other therapy in terms of clinical and electrophysiological CTS features.

According to research by Li et al.,[23] LLLT improves grip strength more than placebo does, but there is no discernible difference in functional status improvement, pain relief, or motor electrodiagnostic assessments. According to Franke et al.,[24] LLLT was also shown to be more effective than placebo in the short term before the beneficial effects started to wear off. Most studies contrasting HILT with other treatment options for CTS and other musculoskeletal disorders found that there is no significant difference between them, while others report the significance in terms of improving pain and functional status of patients.[18,20,21,25–28] Unfortunately, the findings in the literature are contradictory and may be explained by the variety of elements such as laser font, dosage intensity, application length, and various approaches used to analyze the outcomes.[13,24,29]

There is neither a systematic review nor a meta-analysis that evaluated the effectiveness of HILT in treatment of CTS so far. Given the evidence gap in the field, this study aims to (1) provide an overview and synthesis of the research on the efficacy of HILT in the treatment of CTS and (2) provide a strong foundation for the use of HILT in CTS through exploring the outcomes of short- and long-term follow-up studies, as well as their cost-effectiveness and degree of significance. Fulfillment of these aims makes this systematic review the first of its type to evaluate the impact of HILT on CTS patients globally.

METHODOLOGY

We conducted this systematic review following the reporting guidelines established by the Preferred Reporting Items for Systematic Reviews and Meta-analyses guideline. The protocol was registered in the International Prospective Register of Systematic Reviews, CRD42022345819, on July 22, 2022, see PRISMA checklist, http://links.lww.com/PHM/C570.

Eligibility Criteria

Studies were included based on the "population," "intervention," "comparator/control," "outcomes," and "study design" (PICOS) described below.

P: Patients with carpal tunnel syndrome (CTS).

I: High-intensity laser therapy (HILT).

C: Sham, surgery, ultrasound, TENS, OR low-level laser therapy (LLLT).

O: Pain, grip strength, symptoms severity, and functional status.

S: Randomized controlled trials (RCTs).

Furthermore, studies that met the following criteria were included: the studies involved adult participants of both sexes older than 18 yrs diagnosed with mild to moderate carpal tunnel syndrome. The treatments administered were compared with no treatment, placebo, sham treatment, drug treatment, or other physical therapies like TENS or LLLT. The studies used pain and electrophysiological findings as primary outcome measures. They used function, grip strength, and pinch strength as secondary outcomes. The findings were presented quantitatively as before and after treatment comparisons. Studies published in language other than English and have PEDro scale less than 5 were excluded. In addition, preprints, trial protocols, and reviews were excluded from this study.

Electrophysiological measures, particularly in CTS, offer two critical benefits. First, diagnostic confirmation is a benefit to electrophysiological tests, such as nerve conduction studies, because they offer objective evidence of a median nerve dysfunction at the wrist and help in establishing the severity of CTS. Thus, by considering studies that used these measures, we ensured that the diagnosis of CTS in the included studies was confirmed through objective, standardized methods. Second, efficacy of treatment is a benefit of electrophysiological measures because postintervention changes in these measures shed light on the therapeutic efficacy of the treatment modalities. Improvements in parameters like nerve conduction velocities or latency times can be indicative of alleviated nerve compression and enhanced neural function. Such changes can reflect the therapeutic efficacy of the interventions on the neural physiology within the carpal tunnel.

For the purpose of this review, our primary interest was in studies that reported changes in electrophysiological measures after treatment. However, given the diagnostic importance of these measures, we also ensured that the included studies had confirmed the CTS diagnosis using electrophysiological tests. This approach allowed us to achieve a comprehensive assessment of the direct effects of interventions on neural function in the carpal tunnel and the associated symptomatic relief.

STUDY SEARCH AND SELECTION

The literature search technique was developed using the main key words and Boolean operators, and/or see Supplementary Material S1, http://links.lww.com/PHM/C571. Then, the search strategies were customized to suit each database. Trials published on PubMed, Embase, the Cochrane Central Register of Control Trials, Scopus, Web of Science, and CINAHL databases were searched from inception to October 2022. In addition, the reference lists of relevant articles were manually searched to identify relevant studies missed during searching.

All retrieved articles were imported into the Mendeley reference manager software (2008 Glyph & Cog, LLC.), where duplicate articles were manually removed. The remaining studies were screened independently by two authors based on the prespecified eligibility criteria. Any disagreement between the two authors was resolved by other authors. The screening of the articles was done in two phases. In the first phase, we evaluated the titles and abstracts of each article according to inclusion and exclusion criteria. When it was impossible to include or exclude studies based on their titles and abstracts, articles were moved to phase 2 for full-text assessment. In the second phase, the full texts of all the articles included in phase one were reviewed. During the full-text review, reasons for the exclusion of each document were recorded and justified.

DATA EXTRACTION

Two independent reviewers extracted data from the included studies and recorded it using a standardized extraction form guided by the CONSORT checklist for reporting of RCTs and the Template for Intervention Description and Replication checklist for intervention reporting. The extracted data included the following: baseline characteristics of participants; general criteria of included studies; primary outcomes including visual analog scale (VAS; pain scale [1–10]) score, symptom severity scale (SSS) score, and functional status score (FSS); secondary outcomes including sensory nerve action potential (SNAP), sensory distal latency (SDL), motor distal latency (MDL), compound muscle action potential (CMAP), and grip strength. Disagreements were resolved on the opinion of a third reviewer.

RISK OF BIAS ASSESSMENT

The PEDro 11-point scale was used to judge the quality of included studies according to excellent, good, fair, and low for a score of ≥9, 6–8, 5, and <5, respectively. Two authors independently assessed the risk of bias and quality of each article, and disagreements were resolved through discussion among authors. In this study, articles with a score less than 5 were considered having high risk of bias and therefore not included. Meanwhile, those with a score greater than 5 were considered moderate to low risk of bias.

STATISTICAL ANALYSES

RevMan software version 5.4 was used for data analysis. The results of continuous outcomes were presented as standardized mean difference (SMD). Meta-analysis was only conducted when at least two RCTs used the same outcome measure. To determine whether fixed-effects or random-effects models were best suited for analysis, statistical heterogeneity was evaluated using Cochran Q test and quantified through the I^2 statistic. According to Higgins et al. (2003),[30] the I^2 statistic describes the percentage of variation across studies that are due to heterogeneity rather than chance. The I^2 value was also assessed, with a value of 50% or higher regarded as substantial heterogeneity. This metric describes the variation percentage across studies due to heterogeneity rather than chance. Hence, when the I^2 was greater than 50%, the pooled data were analyzed using a random-effects model, as this model accounts for heterogeneity and variability between studies. Alternatively, a fixed-effects model was used for the analysis when I^2 was lower than 50%, as this model assumes that all studies have the same underlying effect size. All analyses were set to have a statistical significance of $P < 0.05$, which indicates that the findings are unlikely to occur by chance.

RESULT AND DISCUSSION

Study Characteristics

The primary search resulted in 693 articles, from which 569 articles were removed (124 duplication, 311 primary screening, and 258 title/abstract/full-text screening). In all, 258 full texts were assessed for eligibility, and seven trials were included in this study. The major reasons for exclusion were as follows: the studies were reviews, non-RCT, not reported outcome of interest, and unclear methods (PICO definition) (Fig. 1).

The sample size in analyzed studies ranged from 16 to 98 patients, with a total of 308 study participants. The majority of enrolled patients in included studies were females, with an age range of 30–58 yrs. The effectiveness of HILT was compared against placebo in one study,[31] physical therapy or exercise in two studies,[14,32] and other treatments like LLLT and TENS in three studies[18,26,33,34] (see Table 1 for details). Furthermore, Ezzati et al.[18] assessed the effectiveness of HILT based on their dose.

Table 2 provides details of HILT methods for the treatment of CTS patients. High-intensity laser therapy with a wavelength of 830–1064 nm, energy density of 8–250 J/cm^2, and power average of 3.2–600 W, used for a follow-up period of 2–12 wks with a total therapy session range of 10–15, was thus included in the analysis. Presented in Table 3 are the details of data extraction used in meta-analysis, such as the VAS, SSS, FSS, SNAP, SDL, MDL, CMAP, CSI, and grip strength.

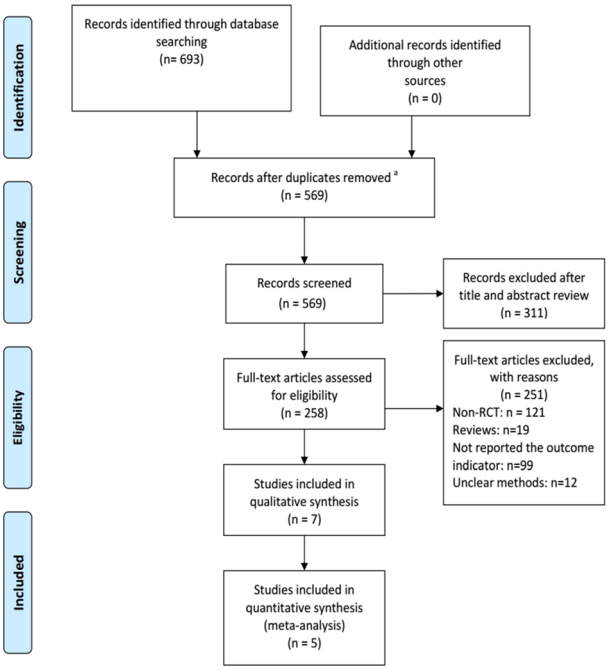

FIGURE 1. The Preferred Reporting Items for Systematic Reviews and Meta-analyses flow diagram of study selection.

TABLE 1. Study characteristics included in this systematic review and meta-analysis

Authors	Country	Method	Subjects (F =Female, M = Male)	Age
Casale et al.[26] (2013)	Italy	G1: HILT	10 (5 F, 5 M)	57.3 ± 12.9
		G2: TENS	10 (5 F, 5 M)	56.8 ± 12
Sudiyono and Handoyo[33] (2020)	Indonesia	G1: HILT	8 (8 F, 0 M)	39.38 ± 7.41
		G2:LLLT	8 (7 F, 1 M)	41.63 ± 5.63
Pattapong et al.[31] (2016)	Thailand	G1: HILT + Splint	15 (15 F, 0 M)	54.60 + 10.582
		G2: placebo + Splint	15 (14 F, 1 M)	52.53 + 12.200
Tabatabai et al.[34] (2016)	Iran	G1: HILT	15 (15 F, 0 M)	53.6 (8.59)
		G2: HILT + TENS	15 (13 F, 2 M)	48.60 (9.40)
		G3: TENS	15 (10 F, 5 M)	58.62 (2)
Ashour et al.[14] (2023)	Egypt	G1: HILT + Physical therapy	27 (27 F, 0 M)	30.55 (5.31)
		G2: Physical therapy only	27 (27 F, 0 M)	30.07 (5.76)
Hojjati et al.[32] (2020)	Iran	G1: HILT + splint	15	46.9 ± 1.7
		G2: LLLT + splint	15	48.7 ± 1.9
		G3: Splint	15	46.9 ± 1.7
Ezzati et al.[18] (2020)	Iran	G1: LLLT (8 J/cm^2)	20	48.50 (11.01)
		G2: LLLT (20 J/cm^2)	19	47.32 (9.15)
		G3: HILT (8 J/cm^2)	20	46.7 (8.89)
		G4: HILT (20 J/cm^2)	19	49.84 (7.16)
		G5: Control	20	49.4 (6.88)

Except for one study,[32] all included articles reported mean and SD value of the clinical and electrodiagnostic parameters as shown in Tables 3 and 4, where within- and between-group difference are presented. Regarding outcomes, SSS and FSS were reported in two studies, SNAP and MDL in four studies, DSL in one study, as well as CMAP and nerve conduction velocity in three studies (Tables 3, 4).

In- and Between-Group Difference

Studies included reporting the in- and between-group differences and testing the significance level accordingly. The summary statistics for each study are presented in Table 3, demonstrating that the treatment and control groups were provided with pre and post mean and standard deviation with pre-post correlation (P) between groups.

From the included RCT studies, only a few studies have shown a statistically significant difference between the treatment HILT group and control groups. Casale and colleagues[26] performed a paired t test, which revealed that VAS score significantly improved, indicating a reduction in self-reported pain intensity, in patients treated with HILT (decrease = 2.1, $P = 0.024$) and only marginally improved in patients treated with TENS (decrease = 0.4, $P = 0.047$); MDL significantly improved in the HILT group (decrease = 0.3, $P = 0.028$), remained unchanged in the TENS group ($P = 0.15$), and sensory nerve conduction velocity (SNCV) significantly improved in the HILT group than in the control group. Similar to this, Tabatabai et al.[34] used a paired t test to report mean changes in the HILT and control groups before and after treatment. They found that the mean VAS score, and pain intensity scores in the HILT group, significantly decreased after treatment, while there was no significant decrease in the TENS group.

The clinical parameters were measured in mild to moderate CTS patients, and the results from Pattapong and colleagues[31] revealed statistically significant improvements in the HILT group compared with baseline at 4 and 12 wks, but nonsignificant differences across groups at 4 wks. In addition, at 12 wks into the program, only the VAS parameters in the intervention group had substantially better results than those in the control group ($P = 0.016$). When comparing baseline and treatment outcomes within the same group as well as across the groups at baseline and 12 wks after treatment, the majority of

TABLE 2. Details of HILT method used in the treatment of CTS

Authors	Wavelength, nm	Energy Density, J/cm^2	Power Average, W	Frequency, Hz	Time Per Point	Duration	Total Therapies
Casale et al.[26] (2013)	830–1064 nm	250 J cm^{-2}	25 W		100 secs for 1 point	3 wks	15
Sudiyono and Handoyo[33] (2020)	1064 nm	10 J/cm^2 and 120 J/cm^2	12 W			2 wks	10
Pattapong et al.[31] (2016)	808 and 905 nm	15.01 J/cm^2		700 Hz	10 mins for 2 points	4 and 12 wks	12
Tabatabai et al.[34] (2016)	808 nm	6.5 J/cm^2	3.2 W–600 W		7 secs for 2 points	2 wks	10
Ashour et al.[14] (2023)	647 J		8 W	25 Hz	3 secs for 1 point	5 wks	15
Hojjati et al.[32] (2020)	1064 nm	20 J/cm^2	5 W		36 secs for 1 point		
Ezzati et al.[18] (2020)	808 nm	8 and 20 J/cm^2	1.6 W	10 Hz	100 and 250 secs for 1 point	2 wks	10

TABLE 3. In- and between-group differences reported in mean (X), SD, and *P* value for clinical parameters

				HILT Treatment					Control					
Author (Year)	**Comparison**	**Outcome**	**Follow-up**	**Pre X**	**Pre SD**	**Post X**	**Post SD**	**SS**	**Pre X**	**Pre SD**	**Post X**	**Post SD**	**SS**	***P***
Pattapong et al.[31] (2016)	Placebo	VAS	<4 wks	4.49	2.77	1.27	1.24	15	2.77	2.89	2.43	2.08	15	0.07
Pattapong et al.[31] (2016)	Placebo	VAS	>4 wks	4.49	2.77	1.37	1.26	15	2.77	2.89	3.29	2.62	15	0.016
Tabatabai et al.[34] (2016)	TENS	VAS	<4 wks	6.93	2.23	4.57	2.07	15	6.03	2.58	5.61	2.58	15	0
Casale et al.[26] (2013)	TENS	VAS	<4 wks	6.6	1.1	4.4	1.4	10	6	0.8	5.6	1	10	0.44
Ezzati et al.[18] (2020)	LILT 8 J/cm^2	VAS	<4 wks	6.8	1.6	2.17	1.48	20	6.77	1.47	4.77	1.15	20	0.02
Ezzati et al.[18] (2020)	LILT 20 J/cm^2	VAS	<4 wks	6.94	1.71	4.02	1.2	19	6.78	1.31	4.89	1.03	19	0.05
Ezzati et al.[18] (2020)	Exercise	VAS	<4 wks	6.8	1.6	2.17	1.48	20	7.05	1.7	6.55	1.16	20	0.05
Pattapong et al.[31] (2016)	Placebo	SSS	<4 wks	2.17	0.39	1.63	0.36	15	2.14	0.66	1.9	0.67	15	0.189
Pattapong et al.[31] (2016)	Placebo	FSS	<4 wks	1.79	0.47	1.42	0.35	15	1.67	0.69	1.41	0.58	15	0.962
Pattapong et al.[31] (2016)	Placebo	SSS	>4 wks	2.17	0.39	1.53	0.28	15	2.14	0.66	2.06	0.97	15	0.05
Pattapong et al.[31] (2016)	Placebo	FSS	>4 wks	1.79	0.47	1.4	0.35	15	1.67	0.69	1.6	0.66	15	0.332

electrophysiological parameters did not reveal any statistically significant changes.

Suzyono and Handoyo[33] (2020) revealed that other neurophysiological variables were the same before and after therapy. However, after the therapy, the CSI value of the HILT group significantly improved. Both groups showed a marked rise in the SNCV score. Although the intergroup comparison was determined to be insignificant, the MDL value considerably dropped in the HILT group. In addition, Ezzati et al.[18] demonstrated a significant difference in pain relief between the HILT 20 J/cm^2 group and the control group ($P < 0.02$). They also found a significant interaction between group and time for the latency of CMAP ($P < 0.001$), indicating that the effect of the treatment group on CMAP latency varied over time. Finally, Ashour et al.[14] (2022) showed through post hoc analysis using the Tukey test that posttreatment pain intensity decreases were significant in both the HILT and control groups ($P < 0.001$). In addition, a comparison of the pain levels between the two groups showed that the HILT group's pain level was considerably lower than the control group's (MD = −2.48, $t = -5.41$, $P < 0.001$).

Meta-analysis

The clinical parameter of the patient's VAS score was computed based on the comparison group and test duration. We defined less than 4 wks as a short period and more than 4 wks as a long period in the analysis because the included trials used different follow-up durations for clinical or electrophysiological testing. Overall, the majority of the measures showed a significant variation between the treatment and control groups. Studies using a 4-wk follow-up period were combined to compare HILT with any type of intervention (placebo, TENS, LLLT 8 J/cm^2, LLLT 20 J/cm^2, and exercise). Because of limited number of studies, we performed a subgroup analysis for HILT versus TENS alone; because to perform meta-analysis, we need at least two studies. Accordingly, the meta-analysis result shows significant favor for HILT compared with any intervention (SMD = −0.99 [−1.66 to −0.31], $P < 0.004$). Similarly, the subgroup analyses confirm a significant favor for HILT compared with TENS (SMD = −0.62 [−1.20 to −0.05], $P < 0.03$). Furthermore, the results of individual studies reported a significant favor for HILT in VAS scores for the comparison groups of placebo, LLLT 20 J/cm^2 exercise ($P < 0.05$).[18,26,31] For improvement in VAS score over a long treatment period, HILT was also preferred over control group (Fig. 2, Table 3).

Table 4 provides summaries of the various electrodiagnostic parameters that were assessed to examine how HILT affected CTS. The clinical and electrodiagnostic parameters assessed are shown in Figure 3. Contrary to clinical assessments, the majority of nerve conduction examinations revealed moderate

TABLE 4. In- and between-group differences reported in mean (X), SD, and *P* value for electro diagnostic parameters

		HILT Treatment					Control					
Author (Year)	**Outcome**	**Pre X**	**Pre SD**	**Post X**	**Post SD**	**SS**	**Pre X**	**Pre SD**	**Post X**	**Post SD**	**SS**	***P***
Iamlaoor et al.[35] (2016)	CMAP	6.7	2.44	7.21	2.33	15	6.34	2.02	5.6	1.62	15	0.041
Iamlaoor et al.[35] (2016)	Motor Distal Latency	5.06	1.57	4.75	1.52	15	4.77	1.46	4.89	1.41	15	0.8
Iamlaoor et al.[35] (2016)	SNAP	16.54	11.31	19.71	12.75	15	17.58	8.22	20.05	8.87	15	0.934
Iamlaoor et al.[35] (2016)	SNCV	45.12	10.5	46.9	11.9	15	46.57	11.9	49.12	7.27	15	0.489
Tabatabai et al.[34] (2016)	CMAP	54.81	19.32	30.4	14.04	15	52	17.028	43.18	17.5	15	0.002
Casale et al.[26] (2013)	Motor Distal Latency	4.5	0.6	4.2	0.3	15	4.8	0.6	4.9	0.7	15	0.07
Casale et al.[26] (2013)	SNCV	33.2	5.3	36.3	3.5	15	33.3	4.8	32.4	4.7	15	0.35
Ezzati et al.[18] (2020)	CMAP	53.37	7.3	57.94	7.29	20	50.47	8.57	51.73	8.46	20	0.05
Ezzati et al.[18] (2020)	SNAP	4.52	0.31	4.09	0.45	20	4.22	0.55	4.37	0.63	20	0.12
Sudiyono and Handoyo[33] (2020)	Motor Distal Latency	4.59	0.19	4.39	0.26	8	5.34	1.46	5.2	1.48	8	0.527
Sudiyono and Handoyo[33] (2020)	SNCV	40.11	5.17	43.28	4.04	8	36.75	5.74	39.49	6.26	8	0.735

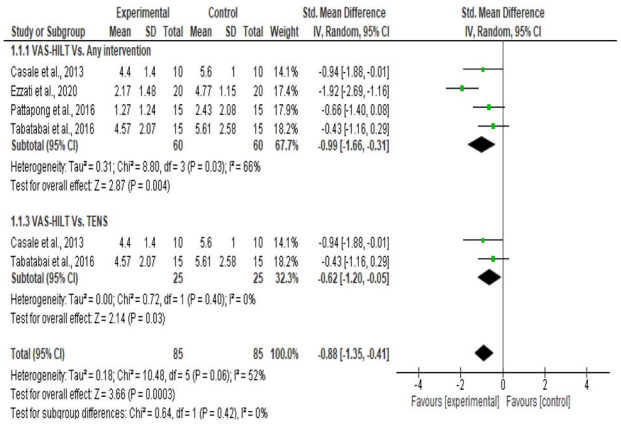

FIGURE 2. Summaries of the clinical parameter meta-analysis findings.

heterogeneity but no statistically significant differences between the two groups. However, some individual studies[18,26] reported statistically significant differences were seen for SNAP (SMD = −0.8737 [−1.5224 to −0.2250], $P < 0.008$) and SNCV (SMD = 0.7513 [0.0108 to 1.4918], $P < 0.046$).

DISCUSSION

In this study, we evaluated the efficacy of HILT in the context of tendon gliding exercises, TENS, placebo LLLT, various HILT and LLLT dosages, and HILT plus physical therapy. In a short period of follow-up, we have discovered compelling data supporting the efficacy of HILT in improving measures of pain and electrophysiology, compared with placebo, HILT plus wrist splint, and exercise. When it comes to long-term follow-up, only comparison with the placebo group showed notable difference. In addition, it was discovered that the HILT group was successful in treating mild to severe carpal tunnel syndrome when the combined wavelengths of 830 and 1064 nm were used, as well as increased energy transfer. Both short- and long-term follow-up periods revealed insufficient evidence for HILT's impact on electrodiagnostic variables (SNAP, SDL, MDL, CMAP, grip strength).

In line with Ezzati et al.,[18] we agreed that studies reporting significant treatment effectiveness in pain improvement had common features like: long-term follow-up period, higher energy and power, patients did not use other interventions, and the treatment was used for at least 10 sessions.

Moreover, the pooled, standardized mean difference for pain improvement in HILT group was −0.8981 (−1.6490 to −0.1472), $P < 0.0191$, compared with placebo, −1.5348 (−2.5321 to −0.5376); $P < 0.0026$, compared with TENS, and −1.3092 (−1.9921 to −0.6262), $P < 0.0002$, compared with LLLT 20 J/cm^2, and −1.9972 (−2.7560 to −1.2385); $P < 0.0000$, compared with exercise only group. A recent systematic review that assessed the impact of HILT on pain and function in patients with spinal disorders found that HILT combined with exercise was significantly more effective than placebo HILT combined with exercise in terms of pain reduction (SMD = −1.11 [−1.42 to −0.80], $P < 0.00001$) and functional

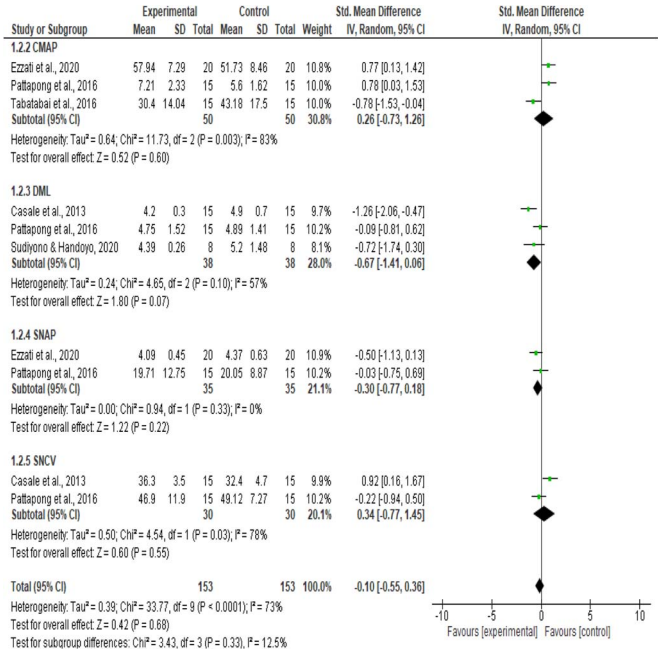

FIGURE 3. The clinical and electrodiagnostic parameters included.

improvement (SMD = −1.03 [−1.33 to −0.72], $P < 0.00001$), and HILT combined with conventional physiotherapy was found to produce better results.[19]

In addition, according to a study by Wyszyńska and Bal-Bocheńska,[35] HILT seems to be efficient in reducing pain and providing functional improvements in patients with knee osteoarthritis. Furthermore, Ezzati et al.[18] evaluated the efficacy of HILT in musculoskeletal pain management and found similar results in terms of HILT effectiveness, and the authors concluded that it is too early to determine that HILT may be an effective noninvasive agent in the management of musculoskeletal pain. They discovered that combining HILT with related cointerventions may enhance its beneficial effects.

Laser therapy has grown in popularity as a noninvasive treatment option because it offers patients with carpal tunnel syndrome a quick and efficient treatment option. This study provides evidence about the efficacy of high-intensity laser therapy for treating CTS. While two studies are a minimum number to perform a meta-analysis, provided that they can be meaningfully pooled and their results are sufficiently similar. Because the results of HILT versus placebo, HILT versus LLLT and HILT versus exercises on VAS were reported in a single study; we did not pool the results to perform a meta-analysis. Similarly, SSS and FSS were reported in a single study, and a meta-analysis of these outcomes was not performed. These are the major limitation of this study.

CONCLUSIONS

Strong to moderate evidence supports the efficacy of HILT when compared with placebo, HILT + wrist splint, and exercise in the short term. High-intensity laser therapy also showed significant pain relief over longer periods when compared with a placebo. However, for other comparison groups, the evidence is limited or inconsistent. Studies demonstrating HILT's notable efficacy often used multiple treatment sessions, longer follow-ups, higher energy and power settings, and HILT as a standalone treatment. However, because of methodological differences and limited robust evidence, definitive conclusions about HILT's efficacy for CTS remain elusive. The optimal parameters, doses, and combinations for HILT in treating CTS are still uncertain, warranting further research.

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