Immunopathologia Persa
http immunopathol.com
DOI:10.34172/ipp.44021

Comparative efficacy of high-intensity laser therapy and radial shock wave therapy in the management of mild to moderate carpal tunnel syndrome; a randomized clinical trial

Babak Vahdatpour[1], Hamed Zare[1], Mahdi Dastanpoor[1], Hossein Masomi[2], Shila Haghighat[1*]

[1]Department of Physical Medicine and Rehabilitation, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran
[2]School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran

***Correspondence to**
Shila Haghighat,
Email:
Shila_haghighat@Med.mui.ac.ir,
haghighatshila@gmail.com

Received 30 Nov. 2025
Revised: 5 Jul. 2026
Accepted 10 Aug. 2026
ePublished 17 Sep. 2026

Keywords: Carpal tunnel syndrome, High-intensity laser therapy, Extracorporeal shock wave therapy, Electrophysiology, Visual analog scale, Boston questionnaire, Non-invasive treatment

Abstract

Introduction: Carpal tunnel syndrome (CTS), a prevalent form of peripheral entrapment neuropathy, is typically treated conservatively in cases that are mild to moderate. Although wrist splinting is considered a primary treatment option, physical therapies like extracorporeal shock wave therapy (ESWT) and high-intensity laser therapy (HILT) have demonstrated effectiveness in alleviating pain and enhancing nerve function. Extracorporeal shockwave therapy facilitates axonal regeneration and decreases inflammation through mechanotransduction, while HILT promotes tissue healing through photobiomodulation.

Objectives: This study aims to fill that gap by evaluating the effects of radial ESWT and HILT on pain intensity (visual analogue scale, VAS), functional status (Boston Carpal Tunnel Questionnaire, BCTQ), and nerve conduction metrics (distal sensory latency, motor latency, and sensory conduction velocity) over a 12-week follow-up period.

Materials and Methods: This research is a randomized, controlled clinical trial. Sixty participants with mild to moderate idiopathic CTS, allocated equally (30 patients in each group) to two intervention groups; HILT and ESWT. All participants received standard care, including nighttime wrist splinting and oral vitamin B1 supplementation. The HILT group underwent five sessions over two weeks using a Fisioline Device (910-1064 nm wavelength, 1168 Hz frequency, and 4 J/cm^2 102 energy), while the ESWT group received three sessions of ESWT (1000 shocks at a pressure of 1.5 Bar and a rate of six pulses per second). Assessments of outcomes were conducted at the beginning, as well as at 4 weeks and 12 weeks.

Results: Baseline characteristics, including age, body mass index (BMI), symptom duration, and gender distribution, showed no significant differences between groups ($P > 0.05$). At 4- and 12-week post-intervention, both groups demonstrated significant within-group improvements in BCTQ scores (total, functional, and symptom severity subscales) and VAS pain scores ($P < 0.001$). Nevertheless, no meaningful differences were found between the groups at either follow-up time. Electrophysiological parameters [distal sensory latency (sensory nerve action potential (SNAP) latency], distal motor latency [compound muscle action potential (CMAP) latency], and sensory nerve conduction velocity (NCV)) remained unchanged across time in both groups.

Conclusion: In our study, HILT and ESWT significantly improved pain, symptom severity, and functional status in patients with CTS. While both modalities demonstrated comparable clinical efficacy, ESWT showed greater improvement in sensory nerve conduction latency.

Trial Registration: The trial protocol was approved by the Iranian Registry of Clinical Trials (identifier: IRCT20240317061317N1; ethical code: IR.MUI.MED.REC.1402.473)

Citation: Vahdatpour B, Zare H, Dastanpoor M, Masomi H, Haghighat Sh. Comparative efficacy of high-intensity laser therapy and radial shock wave therapy in the management of mild to moderate carpal tunnel syndrome; a randomized clinical trial. Immunopathol Persa. 2027;13(1):e44021. DOI:10.34172/ipp.44021.

Introduction

Carpal tunnel syndrome (CTS), the most prevalent entrapment neuropathy worldwide, is caused by compression of the median nerve within the carpal tunnel. It presents as discomfort, loss of sensation, tingling, and limitations in hand function, especially impacting the thumb, index and middle finger (1). While surgical decompression is reserved for severe cases, most patients with mild to moderate CTS are managed conservatively using physical modalities, splinting, pharmacologic agents, and rehabilitation strategies (2). Among the non-invasive interventions, extracorporeal shock wave therapy (ESWT) and high-intensity laser therapy (HILT) have gained attention for their potential to modulate pain, improve nerve function, and enhance tissue healing (3). However, despite promising results, comparative studies evaluating their efficacy in CTS remain scarce.

High-intensity laser therapy involves the application of acoustic pulses to targeted

Key point

- Both high-intensity laser therapy and extracorporeal shockwave therapy effectively reduced pain, improved symptoms, and enhanced functional capacity.
- The two modalities showed comparable overall clinical efficacy and were well tolerated as non-invasive treatment options.
- Extracorporeal shockwave therapy demonstrated a trend toward greater sensory nerve conduction improvement, suggesting a potential advantage in neurophysiological recovery.

tissues, inducing mechanical stress that triggers a cascade of biological responses (4). In musculoskeletal disorders, ESWT has demonstrated anti-inflammatory, angiogenic, and neuroregenerative effects. Specifically in CTS, radial ESWT (RESWT) has shown potential to Stimulate Schwann cell proliferation and axonal regeneration, improve microvascular perfusion and reduce local inflammation, and modulate nociceptive pathways and reduce neuropathic pain (5). Radial ESWT differs from focused ESWT in its energy dispersion and depth of penetration. It does not require precise anatomical targeting and is generally better tolerated due to its lower energy density (6). Clinical trials have reported improvements in sensory latency and subjective pain scores, though long-term efficacy and optimal dosing protocols remain under investigation (7).

HILT utilizes high-powered infrared laser beams, typically in the 808–1064 nm range, to penetrate deep tissues and induce photo biomodulation (8). Unlike low-level laser therapy, HILT delivers higher energy doses capable of reaching deeper neural and vascular structures (9). Its therapeutic effects include reduction of inflammatory mediators and oxidative stress, enhancement of mitochondrial activity, and ATP production and promotion of tissue repair and nerve conduction velocity (10). In CTS, HILT has been associated with significant reductions in pain and improvements in nerve latency parameters (11). However, existing studies are limited by small sample sizes and methodological variability. The lack of head-to-head comparisons with other modalities like ESWT has left clinicians without clear guidance on which therapy offers superior outcomes. Although the use of ESWT and HILT in managing CTS is increasing, there have been no randomized clinical trials that have directly evaluated their effectiveness in enhancing both subjective symptoms and objective electrodiagnostic measurements.

Objectives

This study aims to fill that gap by evaluating the effects of radial ESWT and HILT on pain intensity (visual analogue scale, VAS) (12), functional status (Boston Carpal Tunnel Questionnaire, BCTQ) (13), and nerve conduction metrics (distal sensory latency, motor latency, and sensory conduction velocity) over a 12-week follow-up period. By establishing comparative effectiveness, this research may inform clinical decision-making and optimize non-surgical treatment strategies for patients with mild to moderate CTS.

Materials and Methods

Study design and participants

This study was conducted as a prospective randomized clinical trial in 2025 in Physical Medicine and Rehabilitation Clinics of Isfahan University of Medical Sciences, on patients with mild to moderate idiopathic CTS. Eighty-one participants were recruited from outpatient physical medicine and rehabilitation clinics; finally, 60 patients were included in the analysis, with 30 patients in each group. Meanwhile, CTS diagnosis was confirmed by a specialist based on clinical examination and electrodiagnostic studies (EMG-NCV).

Inclusion and exclusion criteria

Inclusion criteria

- Age 18–60 years
- Clinically and electrophysiologically confirmed mild to moderate CTS (14).
- Presence of pain and functional impairment related to CTS
- Ability to participate in treatment sessions and follow-up evaluations
- Written informed consent was obtained from all participants.

Non-inclusion criteria

- Severe CTS (absent sensory or motor responses)
- Previous wrist surgery or recent corticosteroid injection
- Cervical radiculopathy, polyneuropathy, or systemic neurological disorders
- Inflammatory arthritis, pregnancy, malignancy, or pacemaker implantation
- Use of other physical therapy modalities for CTS during the study period

Exclusion criteria

- Unwillingness to continue the study

Sampling

In our study, 81 participants were recruited using simple randomized sampling from eligible patients attending the clinics during the study period. After applying the inclusion and exclusion criteria, 60 patients were randomized into two groups.

$$n = \frac{2\times(z_{1-\alpha/2}+z_{1-\beta})^2\delta^2}{d^{*2}}$$

Randomization

Eligible participants were randomly allocated to the HILT or ESWT groups using computer-generated block randomization. Allocation concealment was ensured through sealed opaque envelopes.

Blinding

This study designed as a single blinded clinical trial. Outcome assessments were conducted by investigators blinded to group allocation. Due to the nature of the interventions, participant blinding was not feasible.

Group allocation

Participants were assigned to two parallel intervention groups: HILT group and ESWT group.

Intervention

All participants received standard conservative care: Nighttime wrist splint (Cockup) in 0-5 degree extension for 3 months, oral vitamin B1 (300 mg/day for 1 month), and lifestyle modification advice (avoid repetitive wrist movements)

High-intensity laser therapy group

High-intensity laser therapy was applied over the carpal tunnel region using standardized treatment parameters. Therapy was delivered in multiple sessions over a two-week period (15).

Extracorporeal shock wave therapy group

Extracorporeal shock wave therapy was administered over the median nerve region of the wrist and palm using standardized parameters. Treatment consisted of three sessions over two weeks (16).

Data collection

Assessments were performed at baseline, 4 weeks post-intervention, and 12 weeks post-intervention. Electrodiagnostic testing was conducted at baseline and at 12 weeks, with skin temperature controlled prior to testing. Adverse events were monitored throughout the study.

Outcome measurement – clinical outcomes

- Pain intensity measured using the VAS
- Symptom severity and functional status assessed using the BCTQ (13).
- Electrophysiological outcomes
- Distal sensory latency (Sensory nerve action potential (SNAP) latency)
- Distal motor latency (Compound muscle action potential (CMAP) latency)
- Sensory nerve conduction velocity (NCV)

Statistical analysis

Statistical analyses were performed using SPSS software. Continuous variables were expressed as mean ± standard deviation. Normality of data distribution was assessed using the Shapiro–Wilk test, and homogeneity of variances was evaluated using Levene's test. Independent t-tests and chi-square tests were conducted for baseline and between-group comparisons. Repeated measures ANOVA (LSD post hoc analysis) was applied to assess within-group changes over time. Accordingly, paired t-tests were conducted to compare electrophysiological parameters between baseline and 12-week follow-up. A P value < 0.05 was considered statistically significant.

Results

Baseline demographic and clinical characteristics

A total of 60 patients diagnosed with CTS participated in

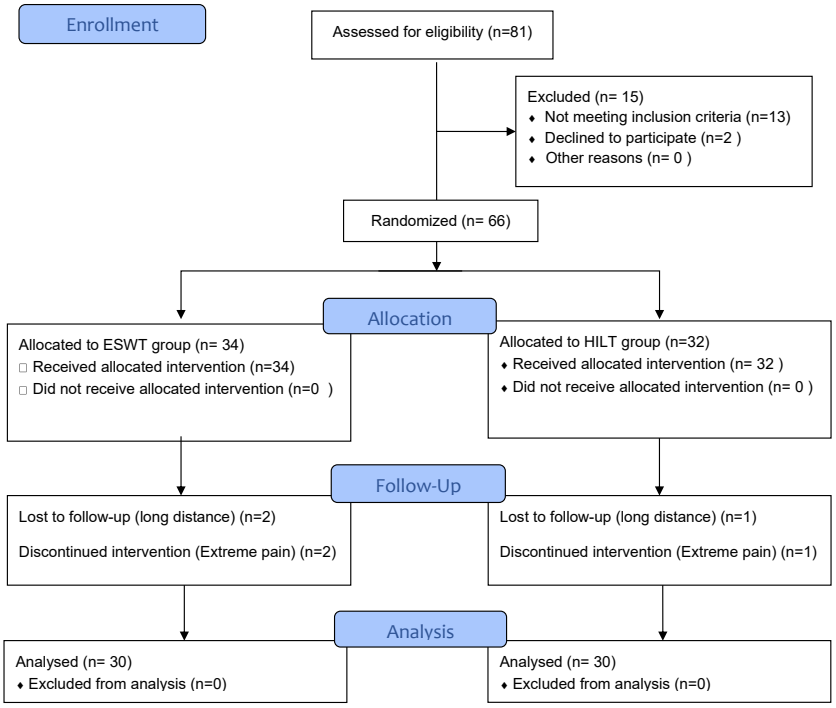

Figure 1. The CONSORT flow diagram of the study process.

the study, with 30 individuals allocated to the HILT group and 30 to the ESWT group. Participants' ages ranged from 32 to 59 years (Figure 1). Baseline demographic characteristics, including sex distribution, were comparable between the ESWT and HILT groups, with no statistically significant differences observed (female: 76.7% versus 80%, respectively; $P=0.755$). Similarly, baseline clinical and electrophysiological variables did not differ significantly between groups ($P>0.05$ for all comparisons), indicating adequate baseline comparability (Table 1).

Between-group comparisons of outcome variables

Baseline

At baseline, no significant between-group differences were observed for any outcome measure (Table 2).

Four weeks post-intervention

At four weeks, between-group comparisons showed no statistically significant differences in pain or functional outcomes. Both groups demonstrated clinically meaningful improvement, but with comparable magnitudes of effect (Table 3).

Twelve weeks post-intervention

At 12 weeks, no significant intergroup differences were identified for clinical or electrophysiological variables. These findings indicate similar overall efficacy of HILT and ESWT (Table 4).

Within-group comparisons over time

All within-group changes were statistically significant, with 95% CIs not crossing zero. the post hoc LSD test showed that the mean Boston Total Pain Score, Boston Functional Pain Score, Boston Symptom Pain Score and VAS Pain Score, 12 weeks after the intervention were significantly lower than 4 weeks after the intervention and 4 weeks after the intervention were significantly lower than before the intervention ($P<0.05$; Table 5).

Table 1. Comparison of age, body mass index and symptom duration between groups

Variable		ESWT, Mean ± SD	HILT, Mean ± SD	*P* value*
Age (years)		47.5 ± 7.8	46.5 ± 6.2	0.583*
Gender	Female	23 (76.7%)	24 (80%)	0.755**
	Male	7 (23.3%)	6 (20%)	
BMI (kg/m^2)		25.5 ± 3.4	26.0 ± 2.8	0.521*
Symptom duration (months)		8.01 ± 1.4	9.1 ± 2.4	0.142*

ESWT: Extracorporeal shock wave therapy; HILT: high-intensity laser therapy; BMI: Body mass index. *Independent T-test, **Chi-square test.

Table 2. Baseline comparison of pain and electrophysiological measures

Variable	ESWT, Mean ± SD	HILT, Mean ± SD	*P* value*	Mean difference	95% CI of the difference	
					Lower	Upper
Boston total pain score	64.4 ± 13.6	67.2 ± 11.4	0.383	-2.8	-9.4	3.6
Boston functional pain score	27.4 ± 7.01	29.6 ± 6.6	0.213	-2.2	-5.8	1.3
Boston symptom pain score	37.0 ± 7.5	37.6 ± 6.6	0.735	-0.6	-4.3	3.02
VAS pain score	7.0 ± 1.6	7.3 ± 1.8	0.450	-0.3	-1.2	0.5
SNAP latency**	4.5 ± 0.6	4.6 ± 0.6	0.624	-0.08	-0.4	0.2
CMAP latency**	4.3 ± 0.7	4.4 ± 0.6	0.596	-0.09	-0.4	0.2
NCV**	32.6 ± 6.2	31.2 ± 5.7	0.352	1.4	-1.7	4.5

ESWT: Extracorporeal shock wave therapy; HILT: high-intensity laser therapy; VAS: Visual analogue scale.
*Independent T-test, ** Distal sensory latency (sensory nerve action potential (SNAP) latency), distal motor latency (compound muscle action potential (CMAP) latency), sensory nerve conduction velocity (NCV).

Table 3. Pain scores at 4 weeks post-intervention

Variable	ESWT, Mean ± SD	HILT, Mean ± SD	*P* value*	Mean difference	95% CI of the difference	
					Lower	Upper
Boston total pain score	56.7 ± 16.9	60.4 ± 13.5	0.356	-3.7	-11.6	4.2
Boston functional pain score	24.2 ± 7.9	27.1 ± 6.5	0.132	-2.9	-6.6	0.9
Boston symptom pain score	32.5 ± 9.5	33.3 ± 8.4	0.722	-0.8	-5.5	3.8
VAS pain score	5.9 ± 1.9	5.8 ± 1.8	0.894	0.06	-0.9	1.03

ESWT: Extracorporeal shock wave therapy; HILT: high-intensity laser therapy; VAS: Visual analogue scale.
*Independent T-test.

Electrophysiological outcomes

Within-group comparisons from baseline to 12 weeks revealed no statistically significant changes in SNAP latency, CMAP latency, or NCV in either group ($P > 0.05$ for all). Mean differences were small, and 95% CIs consistently crossed zero, indicating limited short-term neurophysiological change despite clinical improvement (Table 6).

Discussion

This randomized clinical trial demonstrated that both HILT and ESWT significantly improved pain intensity, symptom severity, and functional status in patients with mild-to-moderate CTS. Improvements were observed in both subjective measures (VAS and BCTQ) and objective electrodiagnostic parameters (distal sensory latency, distal motor latency, and sensory conduction velocity), with no

Table 4. Pain and electrophysiological scores at 12 weeks post-intervention

Variable	ESWT, Mean ± SD	HILT, Mean ± SD	*P* value*	Mean difference	95% CI of the difference	
					Lower	Upper
Boston total pain score	53.9 ± 18.1	56.4 ± 15.5	0.575	-2.5	-11.2	6.2
Boston functional pain score	22.9 ± 8.1	25.5 ± 7.4	0.196	-2.6	-6.6	1.4
Boston symptom pain score	31.1 ± 10.4	30.6 ± 9.1	0.840	0.5	-4.5	5.5
VAS pain score	5.2 ± 2.2	5.2 ± 1.9	0.909	-0.06	-1.1	1
SNAP latency**	4.4 ± 0.7	4.5 ± 0.7	0.565	-0.1	-0.5	0.3
CMAP latency**	4.3 ± 0.7	4.5 ± 0.6	0.491	-0.2	-0.5	0.2
NCV**	33.8 ± 6.5	32.5 ± 6.8	0.461	1.3	-2.2	4.7

ESWT: Extracorporeal shock wave therapy; HILT: high-intensity laser therapy; VAS: Visual analogue scale.
*Independent T-test, ** Distal sensory latency (sensory nerve action potential (SNAP) latency), distal motor latency (compound muscle action potential (CMAP) latency), sensory nerve conduction velocity (NCV).

Table 5. Boston total pain score and VAS pain score comparison between times in ESWT group and HILT group by post hoc LSD test

Variable	Group	Pre	4 Weeks	12 Weeks	Time comparison	*P* value*	Mean difference	95% CI lower	95% CI upper
Boston total pain score	ESWT	64.4	56.7	53.9	Pre vs 4 weeks	<0.001	7.6	4.6	10.7
					Pre vs 12 weeks	<0.001	10.4	6.9	14.0
					4 weeks vs 12 weeks	<0.001	2.8	1.5	4.1
	HILT	67.2	60.4	56.4	Pre vs 4 weeks	<0.001	6.8	3.8	9.8
					Pre vs 12 weeks	<0.001	10.8	6.7	15.0
					4 weeks vs 12 weeks	<0.001	4.0	2.3	5.7
Boston functional pain score	ESWT	27.4	24.2	22.9	Pre vs 4 weeks	<0.001	3.1	1.8	4.5
					Pre vs 12 weeks	<0.001	4.5	2.9	6.1
					4 weeks vs 12 weeks	<0.001	1.4	0.8	1.9
	HILT	29.6	27.1	25.5	Pre vs 4 weeks	0.001	2.5	1.1	3.9
					Pre vs 12 weeks	<0.001	4.1	2.2	6.0
					4 weeks vs 12 weeks	0.004	1.6	0.5	2.7
Boston symptom pain score	ESWT	37.0	32.5	31.1	Pre vs 4 weeks	<0.001	4.5	2.6	6.4
					Pre vs 12 weeks	<0.001	5.9	3.7	8.2
					4 weeks vs 12 weeks	0.003	1.4	0.5	2.3
	HILT	37.6	33.3	30.6	Pre vs 4 weeks	0.001	4.3	1.8	6.8
					Pre vs 12 weeks	<0.001	7.1	4.1	10.0
					4 weeks vs 12 weeks	<0.001	2.8	1.6	3.9
VAS pain score	ESWT	7.0	5.9	5.2	Pre vs 4 weeks	<0.001	1.1	0.7	1.6
					Pre vs 12 weeks	<0.001	1.8	1.2	2.5
					4 weeks vs 12 weeks	<0.001	0.7	0.4	1.0
	HILT	7.3	5.8	5.2	Pre vs 4 weeks	<0.001	1.5	1.1	2.0
					Pre vs 12 weeks	<0.001	2.1	1.6	2.6
					4 weeks vs 12 weeks	<0.001	0.6	0.3	0.9

*Repeated measures ANOVA (LSD post hoc analysis).

Table 6. Comparison of SNAPLAT, CMAPLAT, and NCV in the ESWT group before and 12 weeks after intervention

Variable		Pre-intervention Mean ± SD	12 Weeks post-intervention Mean ± SD	P-value*	Mean difference	95% CI of the difference	
						Lower	Upper
ESWT	SNAP Latency**	4.5 ± 0.6	4.4 ± 0.7	0.118	0.1	-0.9	1.2
	CMAP Latency**	4.35 ± 0.7	4.33 ± 0.7	0.445	0.02	-1.04	1.08
	NCV**	32.6 ± 6.2	33.8 ± 6.5	0.213	-1.1	-2.8	0.5
HILT	SNAP Latency**	4.6 ± 0.6	4.5 ± 0.7	0.149	0.1	-1	1.2
	CMAP Latency**	4.4 ± 0.6	4.5 ± 0.6	0.803	-0.01	-1.1	1.08
	NCV**	31.2 ± 5.7	32.5 ± 6.8	0.255	-1.3	-3.2	0.6

SNAPLAT: sensory nerve action potential (SNAP) latency; CMAPLAT: compound muscle action potential (CMAP) latency.
*Paired T-test, ** Distal sensory latency (SNAPLAT), distal motor latency (CMAPLAT), sensory nerve conduction velocity (NCV).

serious adverse events reported.

The findings align with previous studies supporting the efficacy of ESWT in CTS management. Previously, Seok and Kim reported that ESWT was as effective as local corticosteroid injection in reducing pain and improving function, though their study used focused shock waves (17). Our use of radial ESWT, which disperses energy more broadly and is better tolerated, yielded comparable clinical benefits and a significant reduction in distal sensory latency, suggesting neurophysiological recovery. Similarly, Romeo et al demonstrated ESWT's utility in post-surgical pillar pain, reinforcing its role in modulating neuropathic pain through mechanical stimulation (18).

High-intensity laser therapy also showed substantial therapeutic effects in our study, consistent with findings by Ortiz et al , who observed significant improvements in pain and nerve conduction following HILT in CTS patients (8). The deeper tissue penetration and photobiomodulatory effects of HILT, such as enhanced mitochondrial activity, anti-inflammatory cytokine suppression, and improved microcirculation likely contributed to the observed outcomes. However, Demiroğlu et al noted that differences between HILT and low-level laser therapy were not always statistically significant (19). Interestingly, while both modalities improved nerve conduction metrics, ESWT showed a greater reduction in all electrophysiological parameters compared to HILT. This finding may reflect ESWT's direct mechanical influence on Schwann cell proliferation and axonal regeneration, as supported by Hausner et al in animal models (20). However, HILT demonstrated more consistent improvements in functional scores, possibly due to its broader anti-inflammatory and analgesic effects. Our results also support the findings of Yiğit and Ordahan, who reported superior outcomes with HILT compared to conservative management, including improvements in pain, grip strength, and median nerve cross-sectional area (21). The current study adds to this evidence by directly comparing HILT with ESWT, highlighting that both are effective, but may differ in their mechanisms and specific strengths.

Conclusion

Both HILT and ESWT greatly enhanced pain levels, symptom intensity, and functional capacity. While both modalities demonstrated comparable clinical efficacy, ESWT showed greater improvement in sensory nerve conduction latency. These findings support the use of either modality as effective non-invasive options, with ESWT offering potential advantages in neurophysiological recovery.

Limitations of the study

This research had constraints due to its brief follow-up period of 12 weeks, which might not fully reflect the lasting effects of the treatment. Furthermore, although both treatments were applied consistently, personal differences in nerve conditions and responses to therapy might affect the results. Subsequent studies with bigger sample groups, extended follow-up periods, and the incorporation of imaging biomarkers (such as ultrasound cross-sectional area) could yield more comprehensive insights.

Authors' contribution

Conceptualization: Hamed Zare.
Data curation: Mahdi Dastanpour.
Formal analysis: Mahdi Dastanpour.
Funding acquisition: Hamed Zare.
Investigation: Hossein Masomi.
Methodology: Babak Vahdatpour.
Project administration: Shila Haghighat.
Resources: Hossein Masomi.
Software: Mahdi Dastanpour.
Supervision: Babak Vahdatpour.
Validation: Shila Haghighat.
Visualization: Hamed Zare.
Writing–original draft: Mahdi Dastanpour and Hamed Zare.
Writing–review & editing: Babak Vahdatpour and Shila Haghighat.

Ethical issues

The research conducted in accordance with the guidelines of the Declaration of Helsinki. The Ethics Committee of Isfahan University of Medical Sciences approved this study (Ethical code#IR.MUI.MED.REC.1402.473). Accordingly, written informed consent was taken from all participants before any intervention. This study was performed as part of the graduation thesis for the specialty

of Physical Medicine and Rehabilitation at Isfahan University of Medical Sciences (Thesis code: 3402592). Additionally, the trial protocol was approved by the Iranian Registry of Clinical Trials (identifier: IRCT20240317061317N1; https://irct.behdasht.gov.ir/trial/76054). Ethical issues (including plagiarism, data fabrication, double publication) have been completely observed by the authors.

Conflicts of interest

The authors declare that they have no competing interests.

Funding/Support

This is a self-funded study.

References

1. Genova A, Dix O, Saefan A, Thakur M, Hassan A. Carpal Tunnel Syndrome: A Review of Literature. Cureus. 2020;12:e7333. doi: 10.7759/cureus.7333.
2. Padua L, Coraci D, Erra C, Pazzaglia C, Paolasso I, Loreti C, et al. Carpal tunnel syndrome: clinical features, diagnosis, and management. Lancet Neurol. 2016;15:1273-1284. doi: 10.1016/S1474-4422(16)30231-9.
3. Huisstede BM, Hoogvliet P, Franke TP, Randsdorp MS, Koes BW. Carpal Tunnel Syndrome: Effectiveness of Physical Therapy and Electrophysical Modalities. An Updated Systematic Review of Randomized Controlled Trials. Arch Phys Med Rehabil. 2018;99:1623-1634.e23. doi: 10.1016/j.apmr.2017.08.482.
4. Kim JC, Jung SH, Lee SU, Lee SY. Effect of extracorporeal shockwave therapy on carpal tunnel syndrome: A systematic review and meta-analysis of randomized controlled trials. Medicine (Baltimore). 2019;98:e16870. doi: 10.1097/MD.0000000000016870.
5. Gesslbauer C, Mickel M, Schuhfried O, Huber D, Keilani M, Crevenna R. Effectiveness of focused extracorporeal shock wave therapy in the treatment of carpal tunnel syndrome: A randomized, placebo-controlled pilot study. Wien Klin Wochenschr. 2021;133:568-577. doi: 10.1007/s00508-020-01785-9.
6. Wang YC, Chen SJ, Huang PJ, Huang HT, Cheng YM, Shih CL. Efficacy of Different Energy Levels Used in Focused and Radial Extracorporeal Shockwave Therapy in the Treatment of Plantar Fasciitis: A Meta-Analysis of Randomized Placebo-Controlled Trials. J Clin Med. 2019;8:1497. doi: 10.3390/jcm8091497.
7. Kertzman P, Császár NBM, Furia JP, Schmitz C. Radial extracorporeal shock wave therapy is efficient and safe in the treatment of fracture nonunions of superficial bones: a retrospective case series. J Orthop Surg Res. 2017;12:164. doi: 10.1186/s13018-017-0667-z.
8. de la Barra Ortiz HA, Avila MA, Parizotto NA, Liebano RE. A systematic review and meta-analysis of the effectiveness of high-intensity laser therapy in patients with carpal tunnel syndrome. Physiotherapy. 2025;128:101780. doi: 10.1016/j.physio.2025.101780.
9. Kim J, Cho M, Chung Y. The effects of transcutaneous electrical nerve stimulation and ultrasound treatment combined with high intensity laser treatment on pain, grip strength, and hand function in patients with carpal tunnel syndrome. Physical Ther Rehabil Sci. 2024;13:231–9.
10. Ashour AA, Yehia RM, ElMeligie MM, Hanafy AF. Effectiveness of high intensity laser therapy on pain, grip strength and median nerve conductivity in pregnant women with carpal tunnel syndrome: A randomized controlled trial. J Hand Ther. 2023;36:536-545. doi: 10.1016/j.jht.2022.03.005.
11. Saleh MS, Shahien M, Mortada H, Elaraby A, Hammad YS, Hamed M, et al. High-intensity versus low-level laser in musculoskeletal disorders. Lasers Med Sci. 2024;39:179. doi: 10.1007/s10103-024-04111-1.
12. Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). Arthritis Care Res (Hoboken). 2011;63 Suppl 11:S240-52. doi: 10.1002/acr.20543.
13. De Kleermaeker FGCM, Boogaarts HD, Meulstee J, Verhagen WIM. Minimal clinically important difference for the Boston Carpal Tunnel Questionnaire: new insights and review of literature. J Hand Surg Eur Vol. 2019;44:283-289. doi: 10.1177/1753193418812616.
14. Dumitru D, Amato A, Zwarts M. Approach to peripheral neuropathy. Electrodiagnostic medicine. 2nd ed. Philadelphia, PA: Hanley & Belfus, Inc; 2002. p. 885–99.
15. ElMeligie MM, Gbreel MI, Yehia RM, Hanafy AF. Clinical Efficacy of High-Intensity Laser Therapy on Lateral Epicondylitis Patients: A Systematic Review and Meta-analysis. Am J Phys Med Rehabil. 2023;102:64-70. doi: 10.1097/PHM.0000000000002039.
16. Sharahili TM, Alzahrani HA. Effect of radial extracorporeal shockwave therapy combined with evidence-based physical therapy for adhesive capsulitis of the shoulder: A randomized controlled trial. Saudi Med J. 2025;46:816-824. doi: 10.15537/smj.2025.46.7.20250213.
17. Seok H, Kim SH. The effectiveness of extracorporeal shock wave therapy vs. local steroid injection for management of carpal tunnel syndrome: a randomized controlled trial. Am J Phys Med Rehabil. 2013;92:327–34. doi: 10.1097/PHM.0b013e31826edc7b.
18. Romeo P, d'Agostino MC, Lazzerini A, Sansone VC. Extracorporeal shock wave therapy in pillar pain after carpal tunnel release: a preliminary study. Ultrasound Med Biol. 2011;37:1603-8. doi: 10.1016/j.ultrasmedbio.2011.07.002.
19. Demiroğlu SBA, Özişler Z, Dinçer S, Özel S. Comparison of the efficacy of high-intensity laser therapy and low-level laser therapy in carpal tunnel syndrome: A randomized-controlled study. Hand. 2025;4:6.
20. Hausner T, Pajer K, Halat G, Hopf R, Schmidhammer R, Redl H, et al. Improved rate of peripheral nerve regeneration induced by extracorporeal shock wave treatment in the rat. Exp Neurol. 2012;236:363-70. doi: 10.1016/j.expneurol.2012.04.019.
21. Yiğit F, Ordahan B. Effects of high-intensity laser therapy on pain, functional status, hand grip strength, and median nerve cross-sectional area by ultrasonography in patients with carpal tunnel syndrome. Lasers Med Sci. 2023;38:248. doi: 10.1007/s10103-023-03913-z.