Original Article

Effectiveness of High-Intensity Laser Therapy in Combination with Conventional Conservative Treatment for Carpal Tunnel Syndrome Compared with Conventional Conservative Treatment Alone in Clinical Outcomes and Electrophysiologic Parameters: An Experimental, Non-Randomized Clinical Trial Single-Blind Study

Sucha Kumnoonsup

Department of Physical medicine and Rehabilitation, Saraburi Hospital, Saraburi, Thailand

ABSTRACT

Objectives: To determine the effectiveness of the combination of high-intensity laser therapy (HILT) with conventional conservative treatment for individuals with carpal tunnel syndrome (CTS) compared to conventional treatment alone.

Study design: An experimental study using non-randomized clinical trials in a single-blind study.

Setting: Outpatient Rehabilitation Clinic, Saraburi Hospital.

Subjects: Patients diagnosed with CTS classified as minimal, mild, or moderate, based on the modified neurophysiologic grading system.

Methods: The 60 participants were divided equally into two groups, a HILT treatment (experimental) group and a conventional conservative treatment (control) group. The participants freely choose their own treatment group. Clinical outcomes and electrophysiological parameters were measured before treatment and five weeks after treatment. Results were compared between the groups.

Results: At baseline, none of the demographic, clinical, or electrophysiologic parameters were statistical significantly different between the two groups with the exception of the chief complaint and the sensory nerve action potential amplitude (SNAP amp). Repeated-measures analysis of variance found a significant group-by-time interaction among the numeric rating scale of numbness (NRS numbness), the numeric rating scale of pain (NRS pain), the Boston questionnaire symptom severity score (BQSSS), the Boston questionnaire functional severity score (BQFSS), sensory nerve action potential peak latency (SNAP PL), sensory nerve conduction velocity (SNCV), median-ulnar sensory latency difference to the ring finger (Median vs. Ulnar), and compound motor action potential onset latency (CMAP OL).

Conclusions: This study demonstrated that the addition of HILT to conventional conservative treatment is an effective and noninvasive treatment method for minimal, mild, and moderate CTS.

Keywords: high-intensity laser therapy, carpal tunnel syndrome, numbness, pain, electrophysiologic parameters

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Introduction

Carpal tunnel syndrome is the most common peripheral nerve entrapment, accounting for 90% of all neuropathies and a clinical prevalence of 3.8% in the general population.[1,2] It is most prevalent in women and frequently bilateral, but dominant-side symptoms tend to be more severe.[3,4] The typical symptoms of this condition include numbness and pain in the index and middle fingers, as well as the thumb and ring finger.[5] Electrodiagnostic testing can confirm the diagnosis and determine the severity of the disease, ranging from minimal to extremely severe, using the modified neurophysiologic grading system.[6]

The treatment consists of the use of non-steroidal anti-inflammatory drugs (NSAIDs), vitamin B to enhance nerve regeneration, intracarpal tunnel steroid injection, as well as the wearing of wrist support with the wrist extended between 0 and 10 degrees, including wrist posture education for the workplace and daily life, avoiding flexing the wrist.[5,7-9] Other treatments, including nerve gliding, ultrasound, extracorporeal shockwave, and laser therapy, are considered conservative treatments for CTS.[7,8,10,11] Carpal tunnel release surgery is often reserved for patients whose symptoms are severe or unresponsive to conservative treatment.[12,13]

Light Amplification by Stimulated Emission of Radiation (laser) is a device that emits a single wave-length with coherent, constant phases and one direction. The range of wavelengths that affect human tissue is between 650 and 1100 nanometers (nm). The human body absorbs light energy that varies with each wavelength of light (chromophores).[14,15] The power of laser light can also be used to classify the type of laser. Class 3B and above is for therapy, meaning the energy is less than 500 mW, referred to as “low-intensity laser therapy” (LILT). In contrast, class 4, greater than 500 mW, is referred to as “high-intensity laser therapy” (HILT), and the energy is transferred more deeply.[15-17]

Correspondence to: Sucha Kumnoonup, MD; Department of Physical medicine and Rehabilitation, Saraburi Hospital, Saraburi 18000, Thailand, E-mail: sucha_k@hotmail.com

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Laser therapy has the potential to produce biophysical effects within tissues, which can accelerate the wound-healing process and reduce inflammation, pain, and scarring in the tissues.[18-23] The previous study in rats demonstrated that laser could promote axonal sprouting in axonotmesis lesions and more severe trauma, such as neurotmesis.[24]

There have been a limited number of studies on using HILT in CTS patients, and the sample sizes of these studies have been small.[16,17,25] While the preliminary results of these studies have shown promising treatment outcomes in both clinical and electrophysiologic parameters, there are significant differences in the protocols used. These differences include the duration, energy, method of treatment, and techniques for utilizing HILT, which vary greatly or lack specificity. As a result, the physiatrist cannot follow along effectively. From the experience of using a HILT on individuals diagnosed with carpal tunnel syndrome at Saraburi Hospital, most treatment outcomes were favorable with no adverse effects. However, no data were collected for statistical analysis, and there was no control group. Consequently, the purpose of this study was to compare the effectiveness of HILT to conventional conservative treatment in patients with carpal tunnel syndrome. In the future, the outcomes of this study will likely inform the decision to prescribe treatment for CTS patients.

Methods

Study design

This research was an experimental study (non-randomized clinical trials) single-blind study. The post-treatment electrodiagnosis study will be conducted by a physiatrist who is not involved in the research and will be blinded. The Saraburi Hospital Research Ethics Committee approved the protocol of this study (Research Project No. SRBR65-013, Certificate No. EC018/2565) and was registered in the Thai Clinical Trials Registry (TCTR20230103002).

Participants

Study participants were adults (age ≥ 20 years) who presented with hand pain or numbness and underwent electrodiagnosis. The result was minimal, mild, or moderate CTS levels based on the modified neurophysiologic grading system.[6] The definition is 1) "Minimal CTS" is abnormal only for the median-ulnar sensory latency difference to the ring finger (Median vs. Ulnar); 2) "mild CTS" is slowing of sensory nerve action potential peak latency (SNAP PL) and normal compound motor action potential onset latency (CMAP OL); 3) "moderate CTS" is slowing of SNAP PL and CMAP OL. The patient would be excluded if any of the following conditions were found: 1) contraindication to laser such as undergoing cancer treatment, having had radiation therapy within the past six months, and the patient had bleeding from the arm to the finger;[26] 2) underlying disease that may disturb experimental measurements such as polyneuropathy, cervical radiculopathy, brachial plexopathy, ulnar neuropathy, radial neuropathy, and rheumatoid arthritis; 3) receiving conservative treatment within the past six months such as physical modality, orthosis, and intracarpal tunnel steroid injection; 4) History of carpal tunnel release; 5) Numeric rating score of pain ≥ 8

Sample size

The sample size was determined using the equality design formula to compare the two independent groups in terms of the mean difference. The sample size calculation was based on a study by Casale et al.[16] The primary outcome is the numeric rating scale of numbness (NRS numbness), the calculated variable using the largest sample size. For an alpha level of 0.05, a power of 80%, and an estimated drop-out rate of 20%, the target sample size was 64 hands. (32 hands per group)

Randomization

There was no randomization in this study. Patients with confirmed minimal, mild, or moderate CTS were given a description of the research. Then, they were allowed to voluntarily choose a treatment group, divided into 32 laser hands and 32 control hands.

Intervention

The control group was treated with suggested behavioral modifications by the researcher. The suggestion included wrist posture education for the workplace and daily life, avoiding flexing or moving the wrist, taking only a vitamin B complex tablet three times daily, and using wrist support with a 10-degree wrist extension during sleeping time.

The experimental group maintained the treatment on the same basis as the control group. In addition, the researcher will add the HILT using Mectronic healthcare iLux Triax, power 15 watts (The device simultaneously released three wavelengths: 810 nm, 980 nm, and 1,064 nm, which equally distributed the power over the three wavelengths, 5 watts for each wavelength) with intensity dosage of 20 J/cm^2, the laser was applied to 10 cm proximal from the wrist crease to palmar crease (refer to number 1 of figure 1), and cover the specific finger area where the patient has numbness or pain (refer to number 2 of figure 1). The calculated intensity dosage was distributed evenly in all areas, place the probe no more than 1 centimeter away from the skin and move the probe at a speed of approximately 30-40 cm/sec. During treatment, the researcher will periodically touch the patient's skin and pause the laser if he or she feels too hot or the skin temperature is equal to or higher than 38 degrees Celsius. Once the patient feels comfortable and the temperature is lower than 38 degrees Celsius, the treatment will resume until completion. The HILT was applied twice weekly (Tuesday and Thursday) for ten treatment sessions.

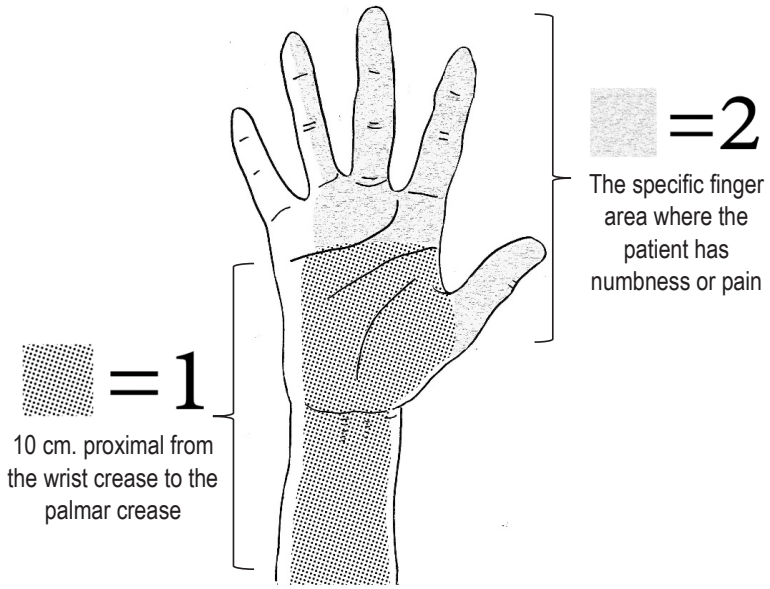

Figure 1. The location of a HILT was applied

Outcome

The variables listed below were recorded twice, first collected before therapy, then again five weeks following treatment completion.

The primary outcome measure was the NRS numbness, ranging from 0 to 10. The secondary outcome measures were the numeric rating scale of pain (NRS pain), which ranges from 0-10, the Boston questionnaire (Thai version),[27] which consists of eleven items of symptom severity (BQSSS), and eight items of functional severity score (BQFSS), each item on a scale of 1-5, and the electrophysiologic parameters as follows: 1) sensory nerve action potential peak latency (SNAP PL); 2) sensory nerve conduction velocity (SNCV); 3) sensory nerve action potential amplitude (SNAP amp); 4) median-ulnar sensory latency difference to the ring finger (median vs. ulnar); 5) compound muscle action potential onset latency (CMAP OL); 6) compound muscle action potential amplitude (CMAP amp); 7) compound muscle action potential area under the curve (CMAP area).

Nicolet EDX® electrodiagnosis is performed by stimulating a surface electrode on the skin to examine 1) sensory study of the median and ulnar nerves at the wrist 13 cm from the ring electrode. 2) motor study of the median and ulnar nerves at the wrist, 7 cm from the disc electrode point, and at the elbow. 3) comparative study (median-ulnar sensory latency difference to the ring finger), by using a ring electrode on the ring finger, stimulation median and ulnar nerve at the wrist 13 cm proximal to ring electrode. Using the normal electrophysiologic parameters as follows: 1) SNAP PL ≤ 3.5 ms. 2) CMAP OL ≤ 4.4 ms. 3) Comparative study (Median vs. Ulnar) peak latency different < 0.5 ms. All electrodiagnosis studies using supramaximal level and skin temperature not lower than 33 Celsius.[28]

For the NRS numbness, NRS pain, BQSSS, and BQFSS, the participants completed the test by themselves. If they were unable to read, the researcher read aloud to them.

The patients completed the first electrodiagnosis before the researcher invited them to participate in the research. The second electrodiagnosis study was conducted by an independent physiatrist blinded from the intervention group.

Statistical methods

The variables were described using descriptive statistics, including percentage, frequency, mean, and standard deviation (SD). Shapiro-Wilk tests were used to determine if the variable had a normal distribution. The comparison between two groups at baseline: 1) gender, affected side, chief complaint, and severity of CTS using Chisquare 2) Age, symptom duration, working hour per day, BMI, NRS numbness, NRS pain, BQSSS, BQFSS and all electrophysiologic parameters using an independent T-test (Mann-Whitney U test if the data are not of normal distribution). The comparison between pre-post treatment in the same group using pair T-test (Wilcoxon-signed rank test if the data are not of normal distribution). In comparing the control and treatment groups using two-way repeated measures in an ANOVA, the within-subjects variables are defined as two periods, and the between-subject factor is the treatment group (control and HILT). A *p*-value of less than 0.05 was considered to be significant. All analyses were carried out using SPSS.

Results

Between May 1, 2022, and Oct 31, 2022, a total of 76 hands were enrolled in this study, 12 hands met an exclusion criterion, and the remaining 64 hands were divided into two groups

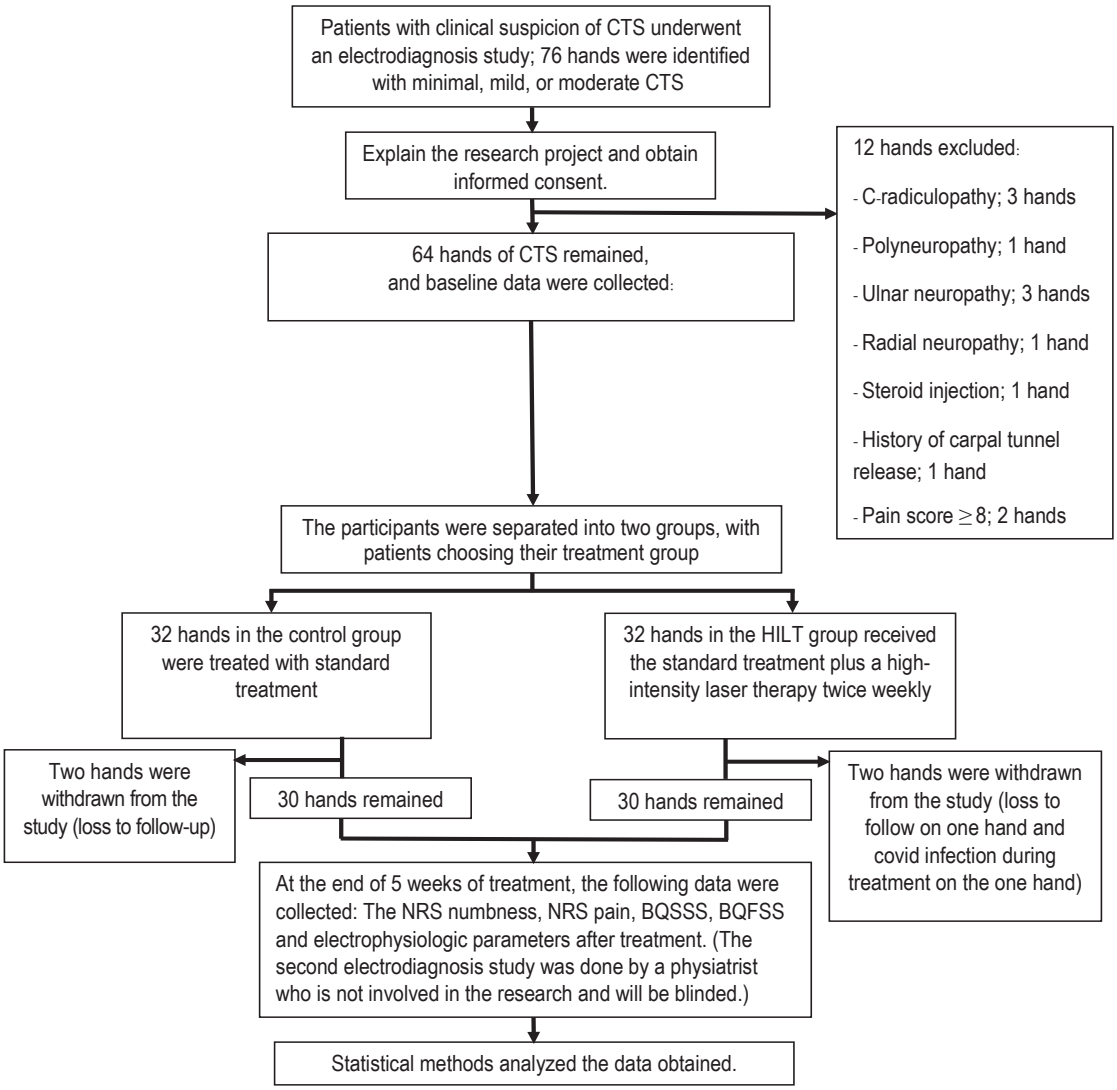

Figure 2. Flow Chart of the study

regarding patients' preferences. There were 32 hands in the control group and 32 in the HILT group. As depicted in Figure 2, 4 hands were removed from the study.

The baseline demographic and clinical characteristics were comparable between the two groups, except for the chief complaint, as shown in Table 1. The patients in the HILT group presented with more pain than those in the control group. No disparities in baseline electrophysiologic parameters were observed between the groups, except for the amplitude of SNAP, which was found to be higher in the HILT group.

A paired T-test was performed within each group to determine the effect of the treatment. The test results revealed that the HILT group demonstrated statistically significant improvement in all four symptom measures and five out of seven electrophysiological parameters, with *p*-values less than 0.05. The two electrophysiological parameters that did not show statistically significant improvement were the CMAP amplitude and CMAP area. On the other hand, the control group showed statistically significant improvement in one symptom measure (NRS numbness) and one electrophysio-logical parameter (SNAP amplitude). See table 2.

Table 3 provides a summary of the repeated-measures analysis of variance results. Group-by-time interaction was found to be significant for NRS numbness, NRS pain, BQSSS, BQFSS, SNAP PL, SNCV, Median vs. Ulnar, and CMAP OL, with *p*-values less than 0.05. These results demon-strate that the effects of the two treatment groups on these variables were differentiated. The results of a repeated measures analysis of variance indicate that NRS numbness improved before and after treatment in both groups. However, the HILT group displayed more outstanding outcomes. The improvement in SNAP amplitude before and after treatment did not differ between the two groups. Before and after therapy, neither the CMAP amp nor the CMAP area was different in either group.

Discussion

Overall, both groups had similar baseline characteristics, except for the chief complaint, where the HILT group presented with more pain than the control group. This finding may be because individuals with pain may experience tremendous suffering and, therefore, may need "more than usual" treatment.

Table 1. Baseline demographic and clinical characteristics by treatment group

Characteristic	Group		*p*-value
	Control	HILT	
Age[1]	52.17 (9.74)	47.63 (8.79)	0.063[a]
BMI[1]	26.31 (3.85)	27.31 (4.72)	0.371[a]
Symptom duration (week)[1]	30.67 (39.15)	47.20 (42.28)	0.084[b]
Hands used per day (hour)[1]	7.77 (1.63)	8.73 (3.93)	0.515[b]
Gender[2]			
- Female	27 (90.0)	24 (80.0)	0.278[c]
Affected side[2]			
- Right	15 (50.0)	18 (60.0)	0.436[c]
Chief complaint[2]			
- Numbness	29 (96.6)	24 (80.0)	0.044[c*]
- Pain	1 (3.4)	6 (20.0)	
Grade CTS[2]			
- Minimal	1 (3.3)	2 (6.6)	0.408[c]
- Mild	13 (43.3)	17 (56.6)	
- Moderate	16 (53.3)	11 (36.6)	
Severity of symptoms			
- NRS numbness[1]	6.23 (2.161)	5.60 (1.976)	0.241[a]
- NRS pain[1]	2.20 (2.68)	3.43 (2.60)	0.086[b]
- BQSSS[1]	23.53 (6.39)	25.77 (7.47)	0.205[b]
- BQFSS[1]	13.07 (4.97)	14.63 (6.14)	0.436[b]
Electrophysiologic parameters			
- SNAP PL[1]	5.08 (1.33)	4.58 (1.34)	0.069[b]
- SNCV[1]	27.11 (6.42)	30.15 (6.50)	0.064[b]
- SNAP amp[1]	16.74 (12.54)	26.26 (13.52)	0.009[b*]
- Median VS ulnar[1]	2.02 (1.14)	2.01 (1.58)	0.608[b]
- CMAP OL[1]	5.33 (1.82)	4.86 (1.56)	0.252[b]
- CMAP amp[1]	5.92 (1.81)	6.56 (2.33)	0.506[b]
- CMAP area[1]	19.74 (6.55)	21.57 (7.78)	0.473[b]

[1]mean (standard deviation), [2]number (%), [a]; Independent T-test, [b]; Mann-Whitney U test, [c]; Chi-square, [*]significant
CTS; carpal tunnel syndrome, HILT; high-intensity laser therapy
NRS numbness, numeric rating scale of numbness; NRS pain, numeric rating scale of pain; BQSSS, Boston questionnaire symptom severity score; BQFSS, Boston questionnaire functional severity score; SNAP PL, sensory nerve action potential peak latency; SNCV, sensory nerve conduction velocity; SNAP amp, sensory nerve action potential amplitude; Median VS ulnar, median–ulnar sensory latency difference to the ring finger; CMAP OL, compound muscle action potential onset latency; CMAP amp, compound muscle action potential amplitude; CMAP area, compound muscle action potential area under the curve

Table 2. Summary of all pre-post treatment variable results from the paired T-test in each group

Characteristic	Control		*p*-value[a]	HILT		*p*-value[a]
	Pre	Post		Pre	Post	
NRS numbness[1]	6.23 (2.161)	4.70 (2.29)	0.001[*]	5.60 (1.976)	2.37 (1.67)	< 0.001[*]
NRS pain[1]	2.20 (2.68)	2.17 (2.81)	0.905	3.43 (2.60)	0.97 (1.40)	< 0.001[*]
BQSSS[1]	23.53 (6.39)	22.13 (7.49)	0.288	25.77 (7.47)	15.43 (3.21)	< 0.001[*]
BQFSS[1]	13.07 (4.97)	13.38 (5.23)	0.984	14.63 (6.14)	9.93 (2.11)	< 0.001[*]
SNAP PL[1]	5.08 (1.33)	5.12 (1.30)	0.545	4.58 (1.34)	4.27 (1.24)	< 0.001[*]
SNCV[1]	27.11 (6.42)	26.92 (6.49)	0.567	30.15 (6.50)	32.33 (7.15)	< 0.001[*]
SNAP amp[1]	16.74 (12.54)	19.49 (15.20)	0.005[*]	26.26 (13.52)	30.29 (17.91)	0.015[*]
Median VS ul-nar[1]	2.02 (1.14)	2.09 (1.24)	0.524	2.01 (1.58)	1.43 (1.30)	< 0.001[*]
CMAP OL[1]	5.33 (1.82)	5.19 (1.66)	0.171	4.86 (1.56)	4.42 (1.39)	< 0.001[*]
CMAP amp[1]	5.92 (1.81)	6.26 (2.33)	0.478	6.56 (2.33)	6.75 (1.91)	0.436
CMAP area[1]	19.74 (6.55)	21.29 (8.38)	0.434	21.57 (7.78)	21.55 (7.07)	0.829

[1]mean (standard deviation), [a]Wilcoxon Signed Rank Test, [*]significant
NRS numbness, numeric rating scale of numbness; NRS pain, numeric rating scale of pain; BQSSS, Boston questionnaire symptom severity score; BQFSS, Boston questionnaire functional severity score; SNAP PL, sensory nerve action potential peak latency; SNCV, sensory nerve conduction velocity; SNAP amp, sensory nerve action potential amplitude; Median VS ulnar, median–ulnar sensory latency difference to the ring finger; CMAP OL, compound muscle action potential onset latency; CMAP amp, compound muscle action potential amplitude; CMAP area, compound muscle action potential area under the curve

Table 3. Summary of all variables results from repeated measure analysis of variance

Variable	Group		Time		Group-by-time interaction	
	F statistic	*p*-value	F statistic	*p*-value	F statistic	*p*-value
NRS numbness	13.927	< 0.001	78.356	< 0.001	8.149	0.006*
NRS pain	0.280	0.599	18.996	< 0.001	17.962	< 0.001*
BQSSS	1.675	0.201	44.506	< 0.001	24.762	< 0.001*
BQFSS	0.375	0.543	14.156	< 0.001	17.973	< 0.001*
SNAP PL	2.919	0.093	5.258	0.026	8.399	0.005*
SNCV	4.456	0.039	15.713	< 0.001	21.747	< 0.001*
SNAP amp	6.652	0.013	12.901	0.001	0.845	0.362
Median vs ulnar	0.819	0.369	7.776	0.007	11.979	0.001*
CMAP OL	1.787	0.187	27.161	< 0.001	6.594	0.013*
CMAP amp	2.459	0.123	0.410	0.524	0.002	0.963
CMAP area	1.063	0.307	0.146	0.704	0.395	0.532

*significant

NRS numbness, numeric rating scale of numbness; NRS pain, numeric rating scale of pain; BQSSS, Boston questionnaire symptom severity score; BQFSS, Boston questionnaire functional severity score; SNAP PL, sensory nerve action potential peak latency; SNCV, sensory nerve conduction velocity; SNAP amp, sensory nerve action potential amplitude; Median VS ulnar, median–ulnar sensory latency difference to the ring finger; CMAP OL, compound muscle action potential onset latency; CMAP amp, compound muscle action potential amplitude; CMAP

However, there was no significant difference in NRS pain scores between the two groups at baseline, so this should not alter the statistical analyses.

In this trial, the average decrease in NRS numbness for the HILT group was 3.23 point. Based on the findings of Ogura et al.,[29] if the NRS numbness dropped by 2 point, there was a mean clinically significant difference (MCID), showing that the numbness was significantly improved following HILT. Salaffi et al.[30] discovered an MCID if NRS pain was reduced by 1 point or more than 15% compared to the prior. This study found a mean reduction of 2.46 point (71%) in the HILT group. According to the study of De Kleermaeker et al.,[31] there will be MCID for BQSSS and BQFSS if the score is reduced by 46% and 28% compared to the previous score, respectively. This study for the HILT group indicated a decrease of 40.1% in BQSSS and 32.1% in BQFSS. Therefore, HILT should be effective in lowering clinical symptoms in CTS patients.

In this study, the clinical outcome and almost all electrophysiologic parameters improved for the HILT group, consistent with the study by Casale et al.[16] They found that treatment with HILT using a wavelength of 830 and 1,064 nm, intensity dosage 250 J/cm^2, and power 25 W, given in 15 sessions over three weeks (5 days a week), improved non-painful sensory alterations (VAS npsa), pain (VAS pain), SNCV, and CMAP OL in a group of 10 hands. This result is in line with the study by Sudiyono et al.,[17] which found that HILT with a wavelength of 1,064 nm, intensity dosage 10 J/cm^2 in analgesic mode and 120 J/cm^2 in biostimulation mode, and power 12 W, given in 10 sessions over two weeks (5 days a week), improved electrophysiological parameters including the combined sensory index (CSI), SNCV, and CMAP OL in a group of 8 hands.

Hojjati et al.[25] compared the effects of HILT (wavelength 1,064 nm, intensity dosage 20 J/cm^2, power 5 W) with LILT and wrist support on treating CTS patients. They found that VAS pain, BQSSS, and BQFSS improved significantly in all groups. However, electrophysiological parameters (SNAP PL, SNAP amp, CMAP OL, and CMAP amp) did not significantly change and were not different among the groups. The study included 15 hands in each group. The researchers pointed out that this effect may be due to the low energy used in the treatment, which requires more research to confirm the results.

Besides the findings mentioned earlier, this study had some limitations that should be discussed. This study is a non-randomized design, and some baseline characteristics were unbalanced (even though they were not statistically significant), which may affect the study's internal validity. The patients in the HILT group may have been more likely to take a break from work because they had more appointments (10 sessions). In addition, patients in the HILT group who are getting treatment frequently inquire about the disease and lifestyle modification in addition to the initial treatment, needing the physiatrist to answer these inquiries; hence, the HILT group may have had better treatment outcomes. Research may be needed to solve this issue. Even though there was no statistically significant difference in the duration of hands used per day (for work and home chores) between the two groups, this investigation could not guarantee that each occupation in each group had the same interfering effect on the therapy. This factor may affect the treatment outcomes of the study. Due to the lack of a sham device, this was a single-blind study with no blind patients. Therefore, the treatment outcome may have a placebo effect, influencing the patients' self-reported NRS numbness, NRS pain, BQSSS, and BQFSS scores. In this study, the participants were Thai people who needed to use the Thai version of the Boston questionnaire. However, it was only tested for internal consistency with Cronbach's alpha, which may affect the reliability of the result.

It is worth noting that the parameters of HILT used in earlier investigations varied greatly, including the number of

laser sessions. This research uses HILT with a wavelength of 810-1,064nm, intensity dosage 20 J/cm^2, power 5 W for each wavelength (810 5W, 980 5W, and 1,064 5W), and ten sessions (2 days per week). Patients may be more convenient to receive treatment because this disease is common in working age.[32,33] Five days per week of treatment can negatively impact work performance. The outcomes of this study were quite favorable, and no adverse effects of HILT were found. In the future, this may serve as a guide for prescribing HILT. However, the long-term outcomes still need further study.

Conclusions

This study showed that adding a HILT to conventional conservative treatment is an effective and noninvasive method. In addition, it provided a better result for minimal, mild, and moderate carpal tunnel syndrome in terms of clinical outcomes for numbness, pain, and electrophysiologic parameters.

Disclosure

The author declares no conflict of interest relating to the materials and equipment used in this study.

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