Effectiveness of low-level laser and polarized light therapies in treating carpal tunnel syndrome in women with type 2 diabetes

Eficacia de las terapias con láser de baja intensidad y luz polarizada en el tratamiento del síndrome del túnel carpiano en mujeres con diabetes tipo 2

Authors

Saher Lotfy Elgayar [1]
Ehab Abdelhalim [2]
Mohamed Gamil Omar [3]
Saad Mohamed Elgendy [4]
Mohamed Bayoumi Ibrahim Bayoumi [1, 5]
Mohammed Youssef Elhamrawy [6]
Nader Ibrahim Elsayed [7]
Tarek M. Youssef [1]

[1] Middle East University, Amman, Jordan
[2] Cairo University, Cairo, Egypt
[3] October University for Modern Sciences & Arts, Cairo, Egypt
[4] Cairo University Hospitals, Cairo, Egypt
[5] Cairo University, Giza, Egypt
[6] Ahram Canadian University, Giza, Egypt
[7] Ahram Canadian University, Giza, Egypt

Corresponding author:
Saher Lotfy Elgayar
saherlotfy020@gmail.com

Received: 23-06-25
Accepted: 17-09-25

How to cite in APA

Lotfy Elgayar, S., Abdelhalim, E., Gamil Omar, M., Mohamed Elgendy, S., Bayoumi Ibrahim Bayoumi, M., Youssef Elhamrawy, M., Ibrahim Elsayed, N., & M. Youssef, T. (2025). Effectiveness of low-level laser and polarized light therapies in treating carpal tunnel syndrome in women with type 2 diabetes. *Retos, 73*, 429-438. https://doi.org/10.47197/retos.v73.116876

Abstract

Introduction: Carpal tunnel syndrome remains an issue of concern among diabetic women.
Objective: This trial aimed to compare the effectiveness of low-level laser and polarized light therapies in treating carpal tunnel syndrome in women with type 2 diabetes.
Methods: sixty-six women were randomized into three groups (n = 22 each): wrist splinting alone (control), splinting plus low-level laser, and splinting plus polarized light over 10 weeks. Baseline and post-treatment assessments included median nerve motor and sensory distal latencies, cross-sectional area, Arabic Numerical Pain Rating Scale, hand grip strength, and Boston Carpal Tunnel Questionnaire (symptom and functional severity scales).
Results: Low-level laser therapy led to significantly greater improvements than polarized light in median motor latency, sensory latency, pain, hand grip strength, symptom severity, and functional severity ($p < 0.05$). Cross-sectional area reductions were similar in both study groups ($p > 0.05$).
Conclusions: Low-level laser is more effective than polarized light for treating carpal tunnel syndrome in women with type 2 diabetes, although further studies are needed to confirm whether these effects are comparable in non-diabetic populations.

Keywords

Carpal tunnel syndrome; low-level laser therapy; polarized light; type 2 diabetes mellitus; women.

Resumen

Introducción: El síndrome del túnel carpiano sigue siendo un problema de preocupación entre las mujeres con diabetes.
Objetivo: Este ensayo tuvo como objetivo comparar la eficacia de la terapia con láser de baja intensidad y la luz polarizada en el tratamiento del síndrome del túnel carpiano en mujeres con diabetes tipo 2.
Métodos: Sesenta y seis mujeres fueron asignadas aleatoriamente a tres grupos (n = 22 cada uno): férula de muñeca sola (control), férula más láser de baja intensidad, y férula más luz polarizada durante 10 semanas. Las evaluaciones antes y después del tratamiento incluyeron latencias distales motora y sensitiva del nervio mediano, área transversal, escala árabe de calificación numérica del dolor, fuerza de prensión manual y el Cuestionario de Boston para el Síndrome del Túnel Carpiano (escalas de gravedad de los síntomas y funcional).
Resultados: La terapia con láser de baja intensidad produjo mejoras significativamente mayores que la luz polarizada en la latencia motora del mediano, la latencia sensitiva, el dolor, la fuerza de prensión manual, la gravedad de los síntomas y la gravedad funcional ($p < 0.05$). Las reducciones del área transversal fueron similares en ambos grupos de estudio ($p > 0.05$).
Conclusiones: El láser de baja intensidad es más eficaz que la luz polarizada para el tratamiento del síndrome del túnel carpiano en mujeres con diabetes tipo 2, aunque se necesitan más estudios para confirmar si estos efectos son comparables en poblaciones no diabéticas.

Palabras clave

Síndrome del túnel carpiano; terapia con láser de baja intensidad; luz polarizada; diabetes mellitus tipo 2; mujeres.

Introduction

Carpal tunnel syndrome (CTS), the most common form of nerve compression, is characterized by entrapment of the median nerve and is especially prevalent among individuals with diabetes (Zimmerman et al., 2022). Diabetes increases the risk of CTS by more than twofold due to biochemical and structural changes affecting the median nerve (Pourmemari and Shiri, 2016; Saadh et al., 2025). Approximately 14% to 30% of people with type 2 diabetes mellitus develop CTS (Perkins et al., 2002), with a higher incidence in women (Zimmerman et al., 2022). Common symptoms of CTS include numbness, tingling, and pain, which may progress to sensory loss, reduced muscle strength, clumsiness, and difficulty with daily tasks (Sevy et al., 2023), ultimately impairing hand function and quality of life (Postma and Kemler, 2022). Electrophysiological studies in mild CTS typically reveal sensory abnormalities, while moderate to severe cases show both sensory and motor deficits (Joshi et al., 2022).

Several standard treatments, such as splinting, light therapy, ultrasound waves, exercises and surgical decompression, are commonly used for managing CTS (Mohsen et al., 2025; Padua et al., 2016). Among non-surgical interventions, low-level laser therapy (LLLT) (Ahmed et al., 2017; Mostafa et al., 2019) and polarized light therapy (PLT) (Dimitrios and Stasinopoulos, 2017; Stasinopoulos et al., 2005) have been explored. PLT is a low-power light source, similar to laser, but it emits polychromatic, incoherent light combining visible and infrared wavelengths (Stasinopoulos et al., 2005). In patients with type 2 diabetes and CTS, LLLT has been shown to enhance median nerve conduction, handgrip strength (Ahmed et al., 2017), and hand function (Mostafa et al., 2019). PLT has been reported to reduce pain and paresthesia (Dimitrios and Stasinopoulos, 2017; Stasinopoulos et al., 2005) and improve finger pinch strength (Dimitrios and Stasinopoulos, 2017) in non-diabetic CTS patients.

Despite previous findings, it remains unclear which modality—LLLT or PLT—is more effective for CTS in diabetic patients. Therefore, this randomized controlled trial aimed to compare their effectiveness on median nerve conduction (primary outcome), as well as cross-sectional area (CSA), pain, hand grip strength, hand function, and symptom severity (secondary outcomes) in type 2 diabetic women with CTS.

Method

A. Sampling

This study adhered to the 2010 CONSORT guidelines (Schulz et al., 2010) and the principles of the Declaration of Helsinki. Conducted from February to December 2024, this trial employed a prospective, randomized controlled, and parallel-group design at a single center. Due to clinical limitations in recruiting men, the sample was restricted to women. Recruitment was conducted at the outpatient neurology clinic of El Mahalla El Kobra Public Hospital in Egypt through referrals by neurologists. Of 193 women screened, 95 (49.22%) met the inclusion criteria, and 66 consented to participate. Interventions were administered at a private rehabilitation center. The study protocol was approved by the Ethics Committee for Human Scientific Study at Cairo University in Egypt and given the acceptance number P.T.REC/012/005116. Clinical trial number: prospectively registered with the Pan African Clinical Trial Registry (PACTR) with the registration number PACTR202402541572962, available at: https://pactr.samrc.ac.za/TrialDisplay.aspx?TrialID=27195. All participants gave written informed consent prior to enrollment.

Sample size estimation

The optimal sample size was determined using G*Power software (G*Power 3.1, Heinrich Heine University, Düsseldorf, Germany). Calculations were based on the study by Rayegani et al. (2013), using median motor distal latency (MMDL) as the reference variable. A one-way ANOVA test was applied, considering a 5% alpha error probability, 85% statistical power, and an effect size of 0.51. Based on these parameters, the required sample size was calculated to be 22 participants per group. This sample size was considered adequate not only for the primary outcome but also to provide sufficient statistical power for all other planned outcome measures and statistical tests performed in the study.

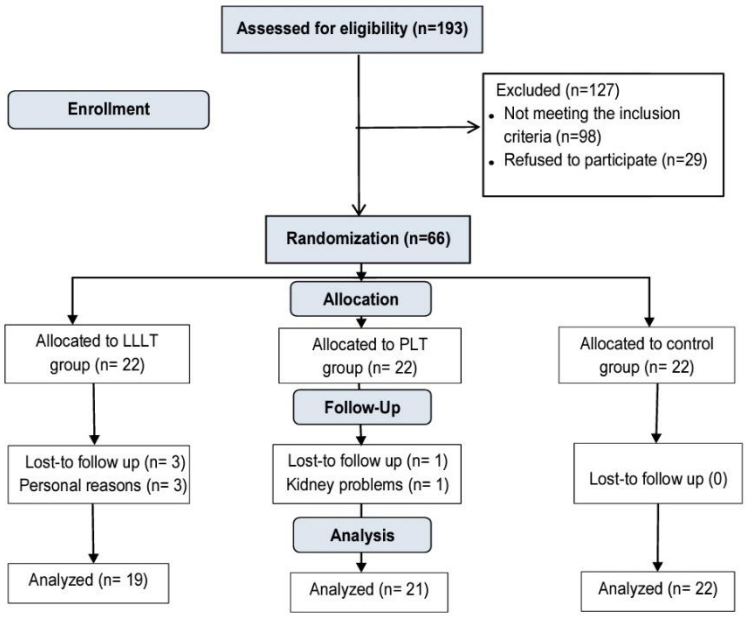
Randomization, allocation and blinding

Participants were randomly assigned to three groups using software (Stata 9, Computing Resource Center in California, USA) generated sequence with a 1:1:1 allocation ratio. Two physiotherapists, uninvolved in the study, handled recruitment, and allocation was concealed in sequentially numbered, sealed opaque envelopes. Outcome assessments were performed by blinded neurologists and physiotherapists, and the statistician remained blinded throughout. Due to the nature of the interventions, treatment supervisors and participants were not blinded.

Participants

A total of 66 women with type 2 diabetes and mild to moderate CTS, classified by electrophysiological criteria (Sasaki et al., 2022), were recruited, with all women having well-controlled diabetes with glycated hemoglobin ≤ 7%. Exclusion criteria included diabetic polyneuropathy, other types of diabetes, pregnancy, prior carpal tunnel surgery or steroid injections, rheumatoid arthritis, thyroid disorders, and CTS-mimicking conditions such as thoracic outlet syndrome and cervical radiculopathy. Eligibility was confirmed by a neurologist through clinical evaluation and medical history review. Participants were randomly assigned to one of three groups: LLLT (LLLT and wrist splinting), PLT (PLT and wrist splinting), and the control group (wrist splinting only). Participant flow is shown in Figure 1.

Figure 1. Participant flow chart



B. Study Technique

Evaluations

Each participant's demographic, anthropometric, and clinical characteristics were recorded. Additionally, height and body weight were measured at baseline using an electrical weight and height scale (BYH01; Zhejiang, China).

Median nerve conduction measures (Primary outcome)

Median nerve distal sensory and motor latencies were assessed using an electromyography/nerve conduction velocity system (Nihon Kohden, DWL EMG Company, Germany GmbH, Singen), following the guidelines of the American Association of Electrodiagnostic Medicine et al. (2002). For MMDL, surface electrodes were placed over the abductor pollicis brevis, with stimulation 7 cm proximally at the wrist. Latency was measured from stimulus onset to the compound action potential. For median sensory distal latency (MSDL), ring electrodes were placed on the index finger, with antidromic stimulation 14 cm proximally. The cutoff values for CTS diagnosis are MMDL > 4.2 ms and MSDL > 3.7 ms (Sasaki et al., 2022). Measurements were taken at baseline and after 10 weeks.

Median nerve cross sectional area (Secondary outcome)

Wrist ultrasonography was performed at baseline and after 10 weeks by a radiologist using a diagnostic ultrasound device (Toshiba Xerio, Japan, 8 to 14 MHz) to assess median nerve CSA. Participants were seated with the forearm supinated, wrist neutral, and fingers relaxed. The transducer was placed at the carpal tunnel inlet, 1 cm distal to the proximal flexion crease. CSA was automatically calculated in square millimeters by tracing the nerve border. Normal median nerve CSA is < 10.5 mm^2 (Sarraf et al., 2014).

Pain (Secondary outcome)

Pain levels were assessed at baseline and after the intervention using the validated Arabic Numerical Pain Rating Scale (ANPRS) (Alghadir et al., 2016). This 11-point horizontal scale (0–10) uses Arabic numerals, where 0 indicates no pain and 10 represents the worst pain (Alghadir et al., 2016). Participants selected the number that best described their pain intensity.

Hand grip strength (Secondary outcome)

Hand grip strength of the affected hand was measured at baseline and post-intervention using a hydraulic dynamometer (Jamar, Sammons Preston, Canada). Participants were seated in an adjustable chair with a straight back, hips and knees at 90 degrees, and feet flat on the floor. The shoulder was adducted and in a neutral position by the side of the body, the elbow flexed at 90 degrees, and the wrist and forearm in a neutral position. Participants exerted maximum force using the affected hand. Three trials were conducted with a one-minute rest between each, and the average value in kilograms was used for analysis.

Symptom severity and overall functional status (Secondary outcome)

Women's functional status and symptom severity were assessed using the Arabic version of the Boston Carpal Tunnel Questionnaire (BCTQ), translated and validated by Alanazy et al. (2019). The BCTQ includes 11 items for the Symptom Severity Scale (SSS) and 8 for the Functional Status Scale (FSS), each rated from 1 to 5. Mean scores are calculated for each scale, with higher scores indicating greater severity or dysfunction. BCTQ assessments were conducted at baseline and post-intervention through in-person interviews.

Interventions

All participants continued their regular prescribed medications for CTS throughout the study period. In addition, all participants, regardless of group allocation, were instructed to wear custom-designed wrist splints made from thermoplastic material and secured with adjustable compression straps for eight hours each night throughout the 10-week intervention. The splints were designed to maintain the wrist in a neutral position. Each participant kept a wrist splinting log, recording the date and time of splint use.

Low-level laser therapy (LLLT)

For ten weeks, participants in the LLLT group received three weekly sessions of low-power laser therapy using a gallium arsenide near-infrared laser device (GaAs, Italy, 904 nm wavelength, 20 mW average power, 7 mm probe diameter). Treatment involved applying 1.2 J of energy to four specific points at the wrist. The laser probe was held perpendicular to the skin, with the hand relaxed, supinated, and supported, and the wrist in a neutral position. Each point was treated for 60 seconds, delivering a total energy of 4.8 J over 360 seconds.

Polarized light therapy (PLT)

For ten weeks, participants in the PLT group received polarized polychromatic non-coherent light treatments using the Bioptron 2 device (BIOPTRON AG, Switzerland). Treatments were administered three times a week. After cleaning the carpal tunnel area, the Bioptron light probe was positioned perpendicular to the exposed skin, 5 to 10 cm away and maintained in this position for 8 minutes.

Analysis of data

Statistical analyses were performed using SPSS for Windows (SPSS 22, Inc., Chicago, IL). The Shapiro–Wilk and Levene's tests confirmed normality and homogeneity of variances for continuous variables ($p > 0.05$). For baseline characteristics, continuous variables were compared using one-way ANOVA, and

categorical variables using chi-square tests. To compare intervention effects, analysis of covariance (ANCOVA) was applied for each post-intervention outcome, with the corresponding baseline value entered as a covariate and group (LLLT, PLT, control) as the fixed factor. For each outcome, the overall ANCOVA F-test was first examined to determine whether a significant group effect existed. When significant, pairwise comparisons of estimated marginal means were performed with Bonferroni adjustment for multiple testing. Results are reported as adjusted mean differences (Adjusted MDs) with 95% confidence intervals (CI). Partial eta squared (η^2) was calculated as a measure of effect size for the overall ANCOVA. Statistical significance was set at $p < 0.05$.

Results

Of the 66 women, three in the LLLT group withdrew at their own request, and one in the PLT group was excluded due to kidney-related medical issues that impacted her ability to participate. No adverse effects were recorded as a result of the interventions during the trial. Treatment adherence was assessed based on participants' attendance at their planned sessions and their self-reported use of wrist splints, which were recorded daily in individual wrist splinting logs, noting the date and duration of use. Adherence levels were 89.1%, 90.3%, and 92.7% in the LLLT, PLT, and control groups, respectively ($p = 0.19$) (Table 1). General baseline characteristics did not differ among groups ($p > 0.05$) (Table 1). All outcome measures at baseline and post-study are presented in table 2.

Median nerve conduction measures

At post-study, 47.4% of LLLT, 42.9% of PLT, and 13.6% of control participants scored MMDL ≤ 4.2 ms. ANCOVA revealed a significant group effect on post-intervention MMDL scores ($F = 13.4$, $p < 0.001$, partial $\eta^2 = 0.25$). Both LLLT (Adjusted MD = -0.92 ms; 95% CI –1.37 to –0.47; $p = 0.001$) and PLT (Adjusted MD = –0.56 ms; 95% CI –0.99 to –0.12; $p = 0.007$) resulted in significantly greater MMDL reductions than control (Table 3). Additionally, the MMDL reduction was significantly greater in the LLLT group compared to the PLT group (Adjusted MD = -0.36 ms; 95% CI = -0.81 to -0.02; $p = 0.04$) (Table 3). Regarding MSDL, 84.2% of LLLT, 52.4% of PLT, and 40.9% of control participants scored ≤ 3.7 ms at post-study. Comparing post-intervention MSDL scores revealed a significant group effect on ANCOVA ($F = 11.32$, $p < 0.001$, partial $\eta^2 = 0.22$). LLLT (Adjusted MD = –0.43 ms; 95% CI –0.66 to –0.21; $p = 0.001$) and PLT (Adjusted MD = –0.18 ms; 95% CI –0.42 to –0.02; $p = 0.04$) both achieved significantly greater declines than control. Furthermore, the MSDL reduction was significantly greater following LLLT than PLT (Adjusted MD = -0.24 ms; 95% CI = -0.47 to -0.008; $p = 0.02$) (Table 3).

Median nerve cross-sectional area

At baseline, all participants had a median nerve CSA ≥ 10.5 mm^2, with means of 12.77 ± 1.43 mm^2 (LLLT), 13.07 ± 1.18 mm^2 (PLT), and 12.99 ± 1.25 mm^2 (control) (Table 2). Post-intervention, the proportion of participants with CSA < 10.5 mm^2 rose to 57.9% in LLLT, 42.9% in PLT, and 18.2% in control. ANCOVA revealed a significant group effect on post-intervention median nerve CSA scores ($F = 6.96$, $p = 0.002$, partial $\eta^2 = 0.15$). Both LLLT (Adjusted MD = –1.73 mm^2; 95% CI –2.91 to –0.55; $p = 0.002$) and PLT (Adjusted MD = –1.17 mm^2; 95% CI –2.32 to –0.02; $p = 0.04$) achieved significantly greater CSA reductions than control, while the difference between LLLT and PLT was not significant (Adjusted MD = –0.55 mm^2; 95% CI –1.75 to 0.64; $p = 0.76$) (Table 3).

Pain level

Comparing post-intervention ANPRS scores through ANCOVA revealed a significant group effect ($F = 14.26$, $p < 0.001$, partial $\eta^2 = 0.27$). Both study groups achieved significantly greater pain reduction than the control—LLLT (Adjusted MD = –2.14; 95% CI –3.14 to –1.14; $p = 0.001$) and PLT (Adjusted MD = –1.19; 95% CI –2.16 to –0.22; $p = 0.01$)—and LLLT also significantly outperformed PLT (Adjusted MD = –0.95; 95% CI –2.04 to –0.02; $p = 0.03$) (Table 3).

Hand grip strength

Comparing post-intervention scores of hand grip strength through ANCOVA revealed a significant group effect ($F = 18.21$, $p < 0.001$, partial $\eta^2 = 0.31$). Hand grip strength increased significantly more with both LLLT (Adjusted MD = 4.82 kg; 95% CI = 2.38 to 7.26; $p = 0.001$) and PLT (Adjusted MD = 1.93 kg; 95%

CI = 0.18 to 4.21; p = 0.04), compared to the controls (Table 3). Furthermore, the LLLT group showed greater gains than the PLT group (MD = Adjusted 2.89 kg; 95% CI = 0.41 to 5.37; p = 0.01) (Table 3).

Symptom severity and overall functional status

ANCOVA of post-intervention scores revealed significant group effects for both FSS (F = 17.25, p < 0.001, partial η^2 = 0.29) and SSS (F = 9.32, p < 0.001, partial η^2 = 0.18). In comparison with the control group, FSS scores declined significantly in both the LLLT group (Adjusted MD = –4.69; 95% CI = –6.67 to –2.71; p = 0.001) and the PLT group (Adjusted MD = –2.64; 95% CI = –4.56 to –0.71; p = 0.004) (Table 3). Moreover, the reduction in the FSS scores was greater in LLLT than in PLT (Adjusted MD = –2.05; 95% CI = –4.04 to –0.05; p = 0.04). Similarly, SSS scores decreased significantly with LLLT (Adjusted MD = –6.73; 95% CI = –11.36 to –2.1; p = 0.002) and PLT (Adjusted MD = –2.01; 95% CI = –2.49 to –0.52; p = 0.04), compared to the controls, with LLLT gains outperforming PLT (Adjusted MD = –4.71; 95% CI = –9.39 to –0.03; p = 0.009) (Table 3).

Table 1. Women's characteristics

Variable		LLLT (n = 19)	PLT (n = 21)	Control (n = 22)	p-value
Age (years)		50.21± 5.03	51.47 ± 4.1	51.77 ± 4.02	0.49
Weight (kg)		72.64± 6.02	73.66± 8.12	74.79 ± 9.02	0.68
Height (cm)		162.89 ± 5.27	162.86 ± 5.32	161.09 ± 7.07	0.53
BMI (kg/m^2)		27.18 ± 1.45	27.3 ± 1.38	27.65± 1.48	0.54
Occupation	House wife	23 (51.11%)	25 (58.14%)	22 (51.16%)	0.63
	Employed	20 (48.89%)	18 (41.86%)	21 (48.84%)	
Duration of CTS (months)		6.73± 3.79	6 ± 3.8	7.86± 4.35	0.31
Duration of diabetes (months)		27.68± 8.61	27.38± 8.43	25.90± 7.67	0.75
Diabetes treatments	Oral hypoglycemic	38 (88.37%)	35(81.39%)	40 (93.02%)	0.88
	Insulin	13 (28.88%)	11 (25.58%)	9 (20.9%)	0.89
HbA1c (%)		6.46 ± 0.49	6.23 ± 0.5	6.49 ± 0.52	0.2
Menopausal women		24 (55.81%)	26 (57.77%)	23 (51.11%)	0.8
Hormonal replacement therapy		8 (18.6%)	12 (27.9%)	14 (32.55%)	0.8
Hand activities (hours/day)		3.68± 1.79	4.09± 1.86	3.90± 1.84	0.78
Affected hand	Right	32 (74.42%)	31 (72.9%)	34 (79.1%)	0.9
	Left	11 (25.58%)	12 (27.9%)	9 (20.9%)	0.9
CTS medications	Analgesics	24 (55.81%)	22 (51.16%)	20 (46.51%)	0.52
	Systemic corticosteroids	14 (32.55%)	16 (37.21%)	14 (32.55%)	0.9
Adherence to treatments		89.1%	90.3%	92.7%	0.19

Means± standard deviations express the data. One-way ANOVA compared continuous measures whereas the chi-square test compared categorical ones. LLLT = Low-level laser therapy; PLT = polarized light therapy; BMI = Body mass index; CTS = Carpal tunnel syndrome; HbA1c = Glycated hemoglobin.

Table 2. Measures of outcomes before and after the study

Outcome		LLLT (n = 19)	PLT (n = 21)	Control (n = 22)
MMDL (ms)	Baseline	5.58± 0.88	5.8± 0.87	5.65± 0.89
	Post-study	4.33 ± 0.47	4.81 ± 0.81	5.29± 0.88
MSDL (ms)	Baseline	4.07± 0.35	4.06± 0.26	4.1± 0.26
	Post-study	3.39 ± 0.33	3.62± 0.42	3.85± 0.29
Median nerve CSA (mm^2)	Baseline	12.77± 1.43	13.07± 1.18	12.99± 1.25
	Post-study	9.95± 1.39	10.59± 1.76	11.74 ± 1.44
ANPRS	Baseline	5.21± 1.61	5.33 ± 1.23	5.36± 1.46
	Post-study	2.42± 1.26	3.42± 1.59	4.63± 1.43
Hand grip strength (kg)	Baseline	22.05± 4.02	23.01± 3.89	22.07± 3.22
	Post-study	29.15± 2.97	26.71± 3.86	24.33± 3.80
BCTQ – FSS	Baseline	25.42± 4.04	25.76 ± 3.85	26.40± 2.63
	Post-study	18.73± 3.79	21 ± 3.39	24.04 ± 2.88
BCTQ – SSS	Baseline	30.89± 5.55	29.33 ± 4.8	30.45 ± 4.92
	Post-study	20.84± 4.15	25 ± 5.35	27.13 ± 5

Data are expressed as means with standard deviations. LLLT = Low-level laser therapy; PLT = polarized light therapy; MMDL = Median motor distal latency; MSDL = Median sensory distal latency; CSA = Cross sectional area; ANPRS = Arabic numerical pain rating scale; BCTQ = Boston Carpal Tunnel Questionnaire; FSS = Functional Status Scale; SSS = Symptom Severity Scale.

Table 3. Pairwise comparisons between groups.

Outcome		LLLT versus PLT	LLLT versus control	PLT versus control
MMDL (ms)	p-value	0.04*	0.001*	0.007*

		Adjusted MD (95% CI)	-0.36 (-0.81, -0.02)	-0.92 (-1.37, -0.47)	-0.56 (-0.99, -0.12)
MSDL (ms)		p-value	0.02*	0.001*	0.04*
		Adjusted MD (95% CI)	-0.24 (-0.47, -0.008)	-0.43 (-0.66, -0.21)	-0.18 (-0.42, -0.02)
Median nerve CSA (mm^2)		p-value	0.76	0.002*	0.04*
		Adjusted MD (95% CI)	-0.55 (-1.75, 0.64)	-1.73 (-2.91, -0.55)	-1.17 (-2.32, -0.02)
ANPRS		p-value	0.03*	0.001*	0.01*
		Adjusted MD (95% CI)	-0.95 (-2.04, -0.02)	-2.14 (-3.14, -1.14)	-1.19 (-2.16, -0.22)
Hand grip strength (kg)		p-value	0.01*	0.001*	0.04*
		Adjusted MD (95% CI)	2.89 (0.41, 5.37)	4.82 (2.38, 7.26)	1.93 (0.18, 4.21)
BCTQ	FSS	p-value	0.04*	0.001*	0.004*
		Adjusted MD (95% CI)	-2.05 (-4.04, -0.05)	-4.69(-6.67, -2.71)	-2.64 (-4.56, -0.71)
	SSS	p-value	0.009*	0.002*	0.04*
		Adjusted MD (95% CI)	-4.71 (-9.39, -0.03)	-6.73 (-11.36, -2.1)	-2.01 (-2.49, -0.52)

P-values of the post-hoc test are used to depict the results. * indicates a significant post-hoc result. LLLT = Low-level laser therapy; PLT = polarized light therapy; MMDL = Median motor distal latency; MSDL = Median sensory distal latency; CSA = Cross sectional area; ANPRS = Arabic numerical pain rating scale; BCTQ = Boston Carpal Tunnel Questionnaire; FSS = Functional Status Scale; SSS = Symptom Severity Scale; MD = Mean difference, CI = Confidence interval.

Discussion

Although several light therapy modalities have been proposed for managing CTS, the optimal option remains under investigation. Our study is the first to compare LLLT and PLT in diabetic women with CTS, assessing their effects on nerve conduction, CSA, pain, grip strength, and functional status. Both treatments led to significant improvements across all outcomes compared to the control group, which received wrist splinting alone. However, LLLT was more effective in improving median nerve conduction, reducing pain, enhancing grip strength, and achieving greater reductions in both BCTQ components.

The current study showed that LLLT was superior to PLT in improving MMDL and MSDL. Since no established minimal clinically important difference (MCID) exists for these parameters, the clinical significance of the improvements remains uncertain. Further research is needed to connect these latency changes with meaningful symptom relief or functional gains. The superior effect of LLLT may be due to mechanisms such as reduced collagen fiber swelling (Sasaki et al., 2019), improved vascular endothelial function via TNF-α downregulation (Góralczyk et al., 2016), and enhanced neural regeneration through increased fiber density and better myelin integrity (Duarte et al., 2018). These results are consistent with previous studies reporting LLLT's benefits on nerve conduction in both diabetic (Dimitrios and Stasinopoulos, 2017) and non-diabetic CTS populations (Bakhtiary and Rashidy-Pour, 2004; Ali et al., 2020). However, one placebo-controlled study found no significant electrophysiological improvements with LLLT (Ekim et al., 2007), possibly due to protocol differences or patient variability.

Both LLLT and PLT therapies resulted in comparable reductions in median nerve CSA, with mean changes of -2.81 ± 1.88 mm^2 in the LLLT group and -2.48 ± 2.11 mm^2 in the PLT group. CSA reductions greater than 1 mm^2 are clinically meaningful in CTS (Padua et al., 2008), supporting the effectiveness of both treatments in reducing nerve swelling. LLLT's structural improvements are likely due to its anti-inflammatory and vascular effects (Sasaki et al., 2019; Góralczyk et al., 2016), while PLT benefits may stem from collagen remodeling and fibroblast activation through its infrared and visible light wavelengths (Feehan et al., 2018). However, Raeissadat et al. (2014) found no significant PLT-induced changes in CSA, possibly due to their short treatment duration of three weeks.

Pain outcomes, assessed using the ANPRS, showed a statistically significant advantage for LLLT over PLT. Mean ANPRS reductions in the LLLT group (-2.78 ± 1.51) and the PLT group (-1.9 ± 1.48) exceeded the MCID of 1.5 points for CTS pain (López-de-Uralde-Villanueva et al., 2024), indicating clinically meaningful improvements. LLLT's analgesic effects likely result from its modulation of inflammatory mediators and enhancement of microcirculation (Rayegani et al., 2013). These findings align with previous research showing LLLT's effectiveness in relieving pain in both diabetic (Ahmed et al., 2017) and non-diabetic (Bakhtiary and Rashidy-Pour, 2004; Ali et al., 2020) CTS populations. However, a placebo-controlled study did not report significant pain reduction following LLLT (Ekim et al., 2007), possibly due to treatment duration or parameters. In contrast, PLT's analgesic effects may arise from modulating nociceptive pathways and exerting anti-inflammatory effects (Dimitrios, 2020), with evidence from trials on pregnant (Dimitrios and Stasinopoulos, 2017) and idiopathic CTS patients (Stasinopoulos et al., 2005).

Regarding grip strength, LLLT resulted in significantly greater gains compared to PLT. The LLLT group showed an improvement of 7.1 ± 4.41 kg, exceeding the 5 kg MCID set in rehabilitation (Bohannon, 2019), while the PLT group improved by 3.7 ± 3.12 kg, which did not reach this threshold. The increases in grip strength after LLLT may be due to enhanced neuromuscular function from improved nerve conduction, while PLT's effects may stem from reduced muscle tension and better tissue extensibility (Dimitrios, 2020), aligning with findings of improved finger strength in pregnant CTS patients following PLT (Dimitrios and Stasinopoulos, 2017).

Functional outcomes measured via the BCTQ showed superior effects with LLLT over PLT in both FSS and SSS components. The mean changes in the LLLT group were -6.68 ± 3.4 for FSS and -10.05 ± 6.74 for SSS, compared to -4.76 ± 2.52 for FSS and -5.33 ± 6.69 for SSS in the PLT group. These changes exceed the MCID for both scales (López-de-Uralde-Villanueva et al., 2024), confirming their clinical relevance. Consistent with our findings, LLLT has demonstrated superior functional outcomes in patients with total knee arthroplasty (Bahrami et al., 2022), highlighting its broader therapeutic value.

There are some limitations in the present study. The exclusive inclusion of female participants and the single-center focus may limit the generalizability of the results. The 10-week follow-up period may not fully capture long-term effects. Additionally, participant dropout and the lack of blinding for intervention supervisors and participants could introduce bias.

Conclusions

Both LLLT and PLT are effective in treating CTS in women with type 2 diabetes. However, LLLT showed superior outcomes across electrophysiological measures, pain reduction, grip strength, symptom severity and functional improvement. These findings support LLLT as a more effective non-invasive treatment option for this patient population. Future studies with longer follow-up periods, larger sample sizes, and inclusion of male participants are recommended to validate these results.

Acknowledgements

The authors wish to reveal their gratitude to the neurologists and physiotherapists who were working at the recruitment and intervention sites for their valuable support.

Financing

The authors self-funded this study; thus, no financial support was received.

References

Ahmed, O. F., Elkharbotly, A. M., Taha, N., & others. (2017). Treatment of mild to moderate carpal tunnel syndrome in patients with diabetic neuropathy using low level laser therapy versus ultrasound: Controlled comparative study. *BBA Clinical, 8*, 43–47. https://doi.org/10.1016/j.bbacli.2017.07.001

Alanazy, M. H., Alaboudi, M., Almaari, A., & others. (2019). Translation and validation of the Arabic version of the Boston carpal tunnel syndrome questionnaire. *Neurosciences, 24*(4), 296–301. https://doi.org/10.17712/nsj.2019.4.20190014

Alghadir, A. H., Anwer, S., & Iqbal, Z. A. (2016). The psychometric properties of an Arabic numeric pain rating scale for measuring osteoarthritis knee pain. *Disability and Rehabilitation, 38*(24), 2392–2397. https://doi.org/10.3109/09638288.2015.1129441

Ali, M., Elgendy, A., Medhat, A., & others. (2020). Therapeutic and photobiomodulation effects of low-level laser irradiation on Egyptian patients with carpal tunnel syndrome: A placebo-controlled study. *Journal of Arab Society for Medical Research, 15*(1), 18. https://doi.org/10.4103/jasmr.jasmr_7_20

American Association of Electrodiagnostic Medicine, American Academy of Neurology, & American Academy of Physical Medicine and Rehabilitation. (2002). Practice parameter for electrodiagnostic studies in carpal tunnel syndrome: Summary statement. *Muscle & Nerve, 25*(6), 918–922. https://doi.org/10.1002/mus.10185

Bahrami, H., Moharrami, A., Mirghaderi, P., & Mortazavi, S. M. J. (2022). Low-level laser and light therapy after total knee arthroplasty improves postoperative pain and functional outcomes: A three-arm randomized clinical trial. *Arthroplasty Today, 19*, 101066. https://doi.org/10.1016/j.artd.2022.10.016

Bakhtiary, A. H., & Rashidy-Pour, A. (2004). Ultrasound and laser therapy in the treatment of carpal tunnel syndrome. *Australian Journal of Physiotherapy, 50*(3), 147–151. https://doi.org/10.1016/s0004-9514(14)60152-5

Bohannon, R. W. (2019). Minimal clinically important difference for grip strength: A systematic review. *Journal of Physical Therapy Science, 31*(1), 75–78. https://doi.org/10.1589/jpts.31.75

Dimitrios, S. (2020). The effectiveness of polarized light in musculoskeletal, skin problems and burns. *American Journal of Biomedical Research, 10*(2), 159–167. https://doi.org/10.34297/ajbsr.2020.10.001492

Dimitrios, S., & Stasinopoulos, L. (2017). Treatment of carpal tunnel syndrome in pregnancy with polarized polychromatic non-coherent light (Bioptron light): A preliminary, prospective, open clinical trial. *Laser Therapy, 26*(4), 289–295. https://doi.org/10.5978/islsm.17-OR-18

Duarte, K. C. N., Soares, T. T., Magri, A. M. P., & others. (2018). Low-level laser therapy modulates demyelination in mice. *Journal of Photochemistry and Photobiology B: Biology, 189*, 55–65. https://doi.org/10.1016/j.jphotobiol.2018.09.024

Ekim, A., Armagan, O., Tascioglu, F., & others. (2007). Effect of low level laser therapy in rheumatoid arthritis patients with carpal tunnel syndrome. *Swiss Medical Weekly, 137*(23–24), 347–352. https://doi.org/10.4414/smw.2007.11581

Feehan, J., Burrows, S. P., Cornelius, L., & others. (2018). Therapeutic applications of polarized light: Tissue healing and immunomodulatory effects. *Maturitas, 116*, 11–17. https://doi.org/10.1016/j.maturitas.2018.07.009

Góralczyk, K., Szymańska, J., Szot, K., Fisz, J., & Rość, D. (2016). Low-level laser irradiation effect on endothelial cells under conditions of hyperglycemia. *Lasers in Medical Science, 31*(5), 825–831. https://doi.org/10.1007/s10103-016-1880-4

Joshi, A., Patel, K., Mohamed, A., & others. (2022). Carpal tunnel syndrome: Pathophysiology and comprehensive guidelines for clinical evaluation and treatment. *Cureus, 14*(7), e27053. https://doi.org/10.7759/cureus.27053

López-de-Uralde-Villanueva, I., Fernández-de-Las-Peñas, C., Cleland, J. A., & others. (2024). Minimal clinically important differences in hand pain intensity (Numerical Pain Rate Scale) and related-function (Boston Carpal Tunnel Questionnaire) in women with carpal tunnel syndrome. *Archives of Physical Medicine and Rehabilitation, 105*(1), 67–74. https://doi.org/10.1016/j.apmr.2023.07.018

Mohsen, A. A., Jassim, R. E., Al-Mousawi, S. Q. S., & others. (2025). The effect of rehabilitation exercises accompanied by ultrasound waves in reducing pain and healing from carpal tunnel compression. *Retos*, *66*, 1094–1102. https://doi.org/10.47197/retos.v66.113746

Mostafa, A. O., El-ghaffar, A. A., Hagag, A. A., & others. (2019). Laser therapy versus kinesio taping in treatment of carpal tunnel syndrome in type 2 diabetic patients: Comparative study. *IOSR Journal of Nursing and Health Science, 8*(4), 19–33. https://www.iosrjournals.org/iosr-jnhs/papers/vol8-issue4/Series-9/C0804091218.pdf

Padua, L., Coraci, D., Erra, C., & others. (2016). Carpal tunnel syndrome: clinical features, diagnosis, and management. *The Lancet. Neurology*, *15*(12), 1273–1284. https://doi.org/10.1016/S1474-4422(16)30231-9

Padua, L., Pazzaglia, C., Caliandro, P., & others. (2008). Carpal tunnel syndrome: Ultrasound, neurophysiology, clinical and patient-oriented assessment. *Clinical Neurophysiology, 119*(9), 2064–2069. https://doi.org/10.1016/j.clinph.2008.05.004

Perkins, B. A., Olaleye, D., & Bril, V. (2002). Carpal tunnel syndrome in patients with diabetic polyneuropathy. *Diabetes Care, 25*(3), 565–569. https://doi.org/10.2337/diacare.25.3.565

Postma, J. D., & Kemler, M. A. (2022). The effect of carpal tunnel release on health-related quality of life of 2346 patients over a 5-year period. *Journal of Hand Surgery (European Volume), 47*(4), 347–352. https://doi.org/10.1177/17531934211045634

Pourmemari, M. H., & Shiri, R. (2016). Diabetes as a risk factor for carpal tunnel syndrome: A systematic review and meta-analysis. *Diabetic Medicine, 33*(1), 10–16. https://doi.org/10.1111/dme.12855

Raeissadat, S. A., Rayegani, S. M., Rezaei, S., & others. (2014). The effect of polarized polychromatic noncoherent light (bioptron) therapy on patients with carpal tunnel syndrome. *Journal of Lasers in Medical Sciences, 5*(1), 39–46. https://applications.emro.who.int/imemrf/j_lasers_med_sci/j_lasers_med_sci_2014_5_1_39_46.pdf

Rayegani, S. M., Bahrami, M. H., Eliaspour, D., & others. (2013). The effects of low intensity laser on clinical and electrophysiological parameters of carpal tunnel syndrome. *Journal of Lasers in Medical Sciences, 4*(4), 182–189. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4282005/pdf/jlms-4-182.pdf

Saadh, M. J., Allela, O. Q. B., Kareem, R. A., & others. (2025). Immune cell dysfunction: A critical player in development of diabetes complications. *Current research in translational medicine*, *73*(3), 103510. https://doi.org/10.1016/j.retram.2025.103510

Sarraf, P., Malek, M., Ghajarzadeh, M., Miri, S., Parhizgar, E., & Emami-Razavi, S. Z. (2014). The best cutoff point for median nerve cross sectional area at the level of carpal tunnel inlet. *Acta Medica Iranica, 52*(8), 613–618. https://pubmed.ncbi.nlm.nih.gov/25149885/

Sasaki, S., Ikeda, T., Okihara, S. I., & others. (2019). Principles and development of collagen-mediated tissue fusion induced by laser irradiation. *Scientific Reports, 9*, 9383. https://doi.org/10.1038/s41598-019-45486-4

Sasaki, T., Koyama, T., Kuroiwa, T., & others. (2022). Evaluation of the existing electrophysiological severity classifications in carpal tunnel syndrome. *Journal of Clinical Medicine, 11*(6), 1685. https://doi.org/10.3390/jcm11061685

Schulz, K. F., Altman, D. G., & Moher, D. (2010). CONSORT 2010 statement: Updated guidelines for reporting parallel group randomised trials. *Journal of Pharmacology and Pharmacotherapeutics, 1*(2), 100–107. https://doi.org/10.4103/0976-500X.72352

Sevy, J. O., Sina, R. E., & Varacallo, M. (2023). Carpal tunnel syndrome. In *StatPearls*. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK448179/

Stasinopoulos, D., Stasinopoulos, I., & Johnson, M. I. (2005). Treatment of carpal tunnel syndrome with polarized polychromatic noncoherent light (Bioptron light): A preliminary, prospective, open clinical trial. *Photomedicine and Laser Surgery, 23*(2), 225–228. https://doi.org/10.1089/pho.2005.23.225

Zimmerman, M., Gottsäter, A., & Dahlin, L. B. (2022). Carpal tunnel syndrome and diabetes—A comprehensive review. *Journal of Clinical Medicine, 11*(6), 1674. https://doi.org/10.3390/jcm11061674

Authors' and translators' details:

Saher Lotfy Elgayar	saherlotfy020@gmail.com	Author
Ehab Abdelhalim	withoutmido@ yahoo.com	Author
Mohamed Gamil Omar	mohamedgamil2810@gmail.com	Author
Saad Mohamed Elgendy	Saad_01015553230@yahoo.com	Author
Mohamed Bayoumi Ibrahim Bayoumi	mbayoumi@meu.edu.jo	Author
Mohammed Youssef Elhamrawy	dr_melhamrawy@yahoo.com	Author
Nader Ibrahim Elsayed	ibrahimnader796@gmail.com	Author
Tarek Mohamed Youssef	tibrahim@meu.edu.jo	Author
Malak Ibrahim Abo Elmagd	malakmagd726@gmail.com	Translator