RESEARCH PAPER

# Effect of Different Doses of Therapeutic Ultrasound in the Treatment of Carpal Tunnel Syndrome

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**ABSTRACT**
**Introduction:** Carpal tunnel syndrome (CTS) represent a frequent medical condition. it is among the most frequent type of compression or pressure of the median nerve while travelling in the wrist. **Subjects and methods:** Sixty subjects with mild to moderate CTS from both sexes, aged from 25–55 years. They were chosen from the outpatient clinic of Ismailia medical complex. They were assigned randomly by closed envelop method into four groups. Group A: was given a ‘sham’ plus conventional physical therapy (PT) session in form of hot packs, tendon glide as well as nerve glide exercises, wrist splint. Group B: was given low dose US plus PT session, Group C: was given medium dose US plus PT session, and Group D: was given high dose of US plus PT session, treatment sessions US performed for 6 min, three days a week, for 4 weeks. **Results:** Motor and sensory distal delay are significantly reduced. All treatment groups showed a statistically significant enhancement in pinch strength. While group B has the most prominent effect in all variables compared with the others post treatment, on the other hand groups C, D have no significant difference post treatment. **Conclusion:** Adding US therapy especially with low dose to traditional PT session would be beneficial on nerve conduction parameters, pinch strength, pain intensity, symptoms severity and functional status in the treatment of CTS.
**Keywords:** Carpal tunnel Syndrome, Median Nerve, Ultrasound therapy.
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## INTRODUCTION:

Carpal tunnel syndrome (CTS) represents one of the most common peripheral neuropathies related to the upper limbs. this condition is brought on by increased pressure in the carpal tunnel or reduction of its volume which causes compression of the median nerve and interruption of its blood flow[1]. Delays in treatment can result in long-term disorders with motor and sensory functions, decreased productivity and quality of life at work, higher health care costs, as well as early disability. Fine motor skills are severely impaired in patients with this condition [2].

Although the frequency of CTS varies greatly in the literature, it is thought to be 8.0% in the general population, especially among individuals between the ages of 40 and 60. In addition, the risk is two to three times higher in women than in men, particularly after menopause[3].

Many individuals with CTS find relief of their symptoms via the use of physiotherapy techniques. Additionally, they can both aid in alleviating the signs of CTS and solve the problem that causes it. Physiotherapy aims to treat and improve symptoms via the use of electrotherapy modalities, specialized exercises, mobilizations, ergonomic treatments, as well as advice [4].

A common supplementary method in physical therapy is therapeutic ultrasound (US). Therapeutic US, with an intensity ranging from 0.5 to 2.0 W/cm 2, may be able to cause a number of biophysical changes in tissues. Research on the anti-inflammatory properties of therapeutic ultrasound and its potential to stimulate nerve transmission and regeneration provided evidence to the idea that this modality may aid in the healing of nerve compression [5].

There are two main categories for the therapeutic effects of US: thermal and non-thermal. As a result of raising tissue temperature and accelerating molecular motion, ultrasonic energy has a variety of effects on tissues, including modulating nerve transmission velocity and pain threshold, enhancing collagen extensibility, improving local blood flow, and alleviating muscular spasm. The mechanical or nonthermal impacts of US are caused by microstreaming and cavitation, which can change the permeability of cell membranes and aid in the repair of soft tissues [6].

The exact mechanism by which the direct influence on the nerve improves electrophysiological parameters during ultrasonic treatment and decreases symptoms in entrapment neuropathies is not yet known. The surrounding tissues, including ligaments, tendons, along with connective tissue, may also have an impact, leading to this secondary consequence [7].

There were no previous studies identified the exact intensity of therapeutic ultrasound used to treat CTS so this study was carried out to examine the impact of various doses of therapeutic ultrasound in the treatment of carpal tunnel syndrome to know which is more effective.

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## METHODS

### Study Design

This study employed four groups, pre–test post–test randomized controlled trial design to explore the short-term effects of different doses of therapeutic ultrasound in patient with CTS. The study was performed at the department of physical therapy, Ismailia medical complex from September 2023 to April 2024. To participate in this study, each participant signed an informed consent form. Both the Faculty of Physical Therapy's research ethics committee (NO: P.T.REC/012/003996) and the Clinical Trial Registry (NCT05863546) gave their approval to the study's protocol.

### Participants

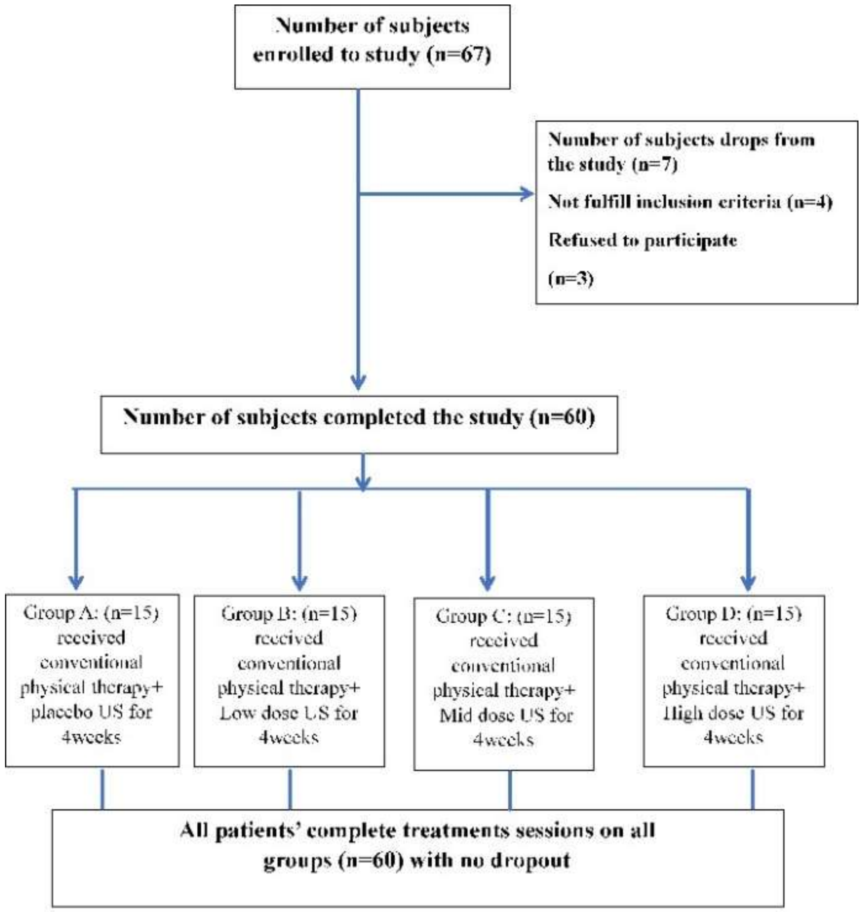


**Figure (1): Flow chart for recruitment of the participants.**

The study was being conducted on 60 patients (calculated by G*power) with mild to moderate CTS, their age range of 25–55 years. They assigned randomly by closed envelop method into four groups. **Group A**: (control group) involved fifteen participants who was given 'sham' US application, thus, the US device was open but was not producing any output[8]. Six-minute US treatments were done six minutes in session[9], one time a day, 3 days per week, for an overall duration of four weeks in addition to conventional PT treatment for CTS, which involves hot packs, tendon and nerve glide gliding, in addition to a wrist splint. **Group B**: (low–dose group) involved fifteen participants who was given US treatments that was be applied to the carpal tunnel area using pulsed mode with a frequency of 1 MHz and an intensity of **0.8 W/cm²** as well as a duty cycle of 1: 4 [10] plus traditional treatments. **Group C**: (Mid–dose group) involved fifteen participants a program of US treatments that was be administered to the carpal tunnel area with pulsed mode at a frequency of 1 MHz with an intensity of **1.0 W/cm²** and a duty cycle of 1: 4 [11] plus traditional treatments. **Group D**: (high–dose group) involved fifteen participants who was given the same US device using pulsed mode, with a frequency of 1 MHz, along with an intensity of **1.25W/ cm²** as well as a duty cycle of 1: 4 [12] in addition to conventional treatments.

They were recruited based on the following criteria: Subject's age ranged from 25–55 years [11] from both sex, they were diagnosed as mild to moderate CTS, their pain intensity greater than 5 according to visual analogue scale (VAS), they were asked not to take any drugs or

NSAID over the course of the study. They were excluded if they have one or more of the following criteria: patient suffering from any orthopedic or neuropathic or neurological disorders of neck or upper extremity as cervical radiculopathy or double crush syndrome, Wasting of thenar muscles, individuals who suffered from prior carpal tunnel release procedures, experienced damage to the wrist or median nerve (e.g., contusions or fractures), or undergone prior surgery on the forearm or wrist, diabetes, rheumatoid arthritis, peripheral neuropathy, pronator teres syndrome, history of steroid injection and Pregnant women.

**Instruments**

**A- Instrumentations were used for evaluation:**

Each patient was being tested using the following scales and tests before and after treatment:

- **1. Computerized Electromyography (EMG) Neuropack M1 EP/EMG measuring system with serial number MEB_9200 made in JAPAN:** It was used to measure motor and sensory nerve conduction parameters for all patients before and after treatment (measurements of median nerve sensory as well as motor distal latency), It shows moderate to excellent reliability (ICC 0.66–0.99) and high validity for measuring muscle activation amplitude during isometric and dynamic contractions[13]**. Before assessment the patients were prepared as follow:** A special identification number (ID) was given for every patient, Patient body temperature was checked, room temperature controlled by an air conditioner. Before electrode placement, the areas above the volar aspect of the wrist, above the thenar eminence, the tip of the thumb and medial to biceps tendon were cleaned with alcohol 70% to decrease skin resistance [14]**.** The patients were informed about the aim of the test and the procedures.

a) **Measurement of Median motor distal latency (MMDL) at wrist:**

- The patients positioned in sitting position; the tested forearm was rested on a table in a supinated position. The active recording electrode was placed on the motor point of the abductor pollicis brevis (APB) muscle, the reference electrode was placed on the distal phalanx of the thumb over bone or tendon, the ground electrode was placed with Velcro around wrist in between the stimulating and recording electrodes, electrodes were fixed to the hand by adhesive plaster straps. The bipolar stimulating electrode was placed above the wrist joint between the tendons of palmaris longus and the flexor carpi radialis muscles on the course of the median nerve with the negative pole distal toward the active recording electrode and the positive pole proximal [14]**.**

**b) Measurement of Median sensory distal latency (MSDL):** The patients positioned in sitting position, the tested forearm was rested on a table in a supinated position. When the median nerve at the wrist is stimulated, antidromic sensory action potentials are triggered at the 2nd digit. The active recording electrodes were positioned at a fixed fourteen centimetre distance from the index finger's proximal interphalangeal flexion crease. The bipolar stimulating electrode was placed above the wrist joint among the flexor digitorum and flexor carpi radialis tendons proximal to the transverse carpal ligament on the course of the median nerve with the negative pole is pointed distal toward the active recording electrode and the positive pole is proximal. The reference (anode) electrode was positioned at the distal inter– phalangeal flexion crease of the index so a distance at least three cm is maintained between the active and reference electrode and the positive pole is proximal. The ground electrode was with velcro around wrist in between the stimulating and recording electrode. The measurement of median sensory conduction velocities is calculated based upon the latency and the distance between the stimulating and recording electrode [15]**.**

**2. Pinch dynamometer to measure pinch strength.** Pinch dynamometers are highly valid and reliable tools for assessing pinch strength, with studies indicating good to excellent reliability (ICC > 0.75) for lateral, tripod, and tip-to-tip pinch measurements. Digital and mechanical (Jamar/Preston) pinch gauges are standardized and often used interchangeably in clinical practice to measure strength in kg or Ibs[16]. A pinch meter was utilized to assess the patients' pinch strength. It was inserted between the patients' thumb tips and their second fingers on the affected arm before the first session (pretreatment record) and after treatment (post treatment record). Patients positioned in relaxed sitting position, asked the patients to hold the dynamometer by the affected hand, press then hold until recording the number on the screen. All three measures of the patient's pinch were taken in the same grip measuring position, and a mean of the three were represented in kg [17]**.**

**3. Visual analogue scale (VAS):** it was widely considered a valid and highly reliable tool for evaluating pain intensity and other subjective states, often acting as an interval scale. It shows excellent test-retest reliability (ICC+0.97) and is preferred for its simplicity and sensitivity to change in clinical settings[18]**.** The patients were provided with an Arabic version of VAS with 10 cm line.

**4. Arabic version of Boston carpal tunnel syndrome questionnaire:** The Arabic version of the Boston Carpal Tunnel Questionnaire (BCTQ-A) is a highly reliable, valid, and responsive tool for evaluating Arabic-speaking patients with CTS. It demonstrates excellent internal consistency (Cronbach's α > 0.87) and high test-retest reliability (> 0.89), with strong content validity and no significant ceiling or floor effects**.** The symptoms intensity (SSS) along with hand functional status (FSS) were measured with it. Eleven questions constitute up the (SSS), and they include items such as: daytime and nighttime pain severity, duration of daytime pain, dormancy, weakness, frequency of nighttime tingling sensation, as well as skill. The therapist gave the patients this scale and had them fill it out. Reliability, validity, reproducibility, and intervention responsiveness have been demonstrated in the Arabic version of the Boston carpal tunnel test [19]**.**

**B- Treatment instruments:**

**1. Therapeutic Ultrasound:** ProsoundULS–1000, Operational manual, therapeutic ultrasound stimulation, unit 1&3 MHz, dual frequency transducer. Before the ultrasound and electrodiagnostic evaluation, the patient's affected arm was cleaned with cotton and alcohol to lower the skin-electrode interface resistance. The aqua sonic gel used as couplant over carpal tunnel area during ultrasound application **(Figure 2).**

- **Group A**: (control group): they were given a program of 'sham' US application [8], in addition to conventional PT treatment for CTS which involves hot packs, tendon glide as well as nerve gliding exercises, wrist splint. For a duration of four weeks, patients had six-minute US therapy sessions three times weekly.
- **Group B**: (low–dose group): they were given a program of US that was be performed on the carpal tunnel area while the patient in sitting position using pulsed mode and a frequency of 1 MHz with an intensity of **$0.8W/cm^2$** with a duty cycle of 1: 4[10] in addition to conventional treatment.
- **Group C**: (Mid–dose group) they were given a program of US treatments for carpal tunnel while they positioned in sitting position, using pulsed mode along with a frequency of 1 MHz, with an intensity of 1.0 W/cm2, as well as a duty cycle of 1:4 11 in addition to conventional treatment.
- **Group D**: (high–dose group) they were given a program for the same US device that was to be configured to pulse at 1 MHz, 1.25 W/ cm2, using a duty cycle of 1: 4 12. in addition to the conventional treatment.

**Figure (2): Application of Ultrasonic therapy for carpal tunnel syndrome (CTS)**

**2. Hot packs:** It was applied to each subject's hand and distal part of the forearm for 20 min[10].

**3. Wrist splint:** These splints allowed the fingers to remain free while keeping the wrist in a neutral position. For four weeks, the participants were instructed to sleep with the splint on or wear it throughout the day if they experienced repeated wrist motions[10]. **(Figure 3)**

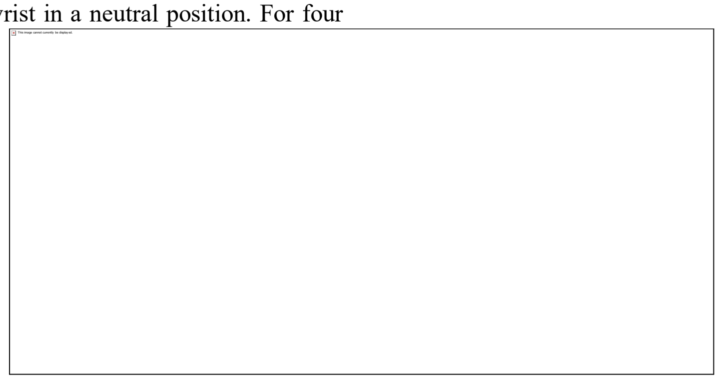

**Figure (3): wrist splint**

**4. Nerve and tendon gliding exercises:** A total of six different hand positions—straight, hook, fist, tabletop, as well as long fist—are used in tendon glide exercises. The fingers are held fully extended between each of these positions. Wrists should remain neutral during the all phases of exercises. Each session consisted of three to five repetitions of each position for seven seconds, with an overall three to five sessions per day [21]. **The six positions for mobilizing median nerve were:** wrist was positioned in neutral position, while the fingers and thumb were positioned in flexion.

a. Wrist was positioned in neutral position, while the fingers and thumb were positioned in extension.
b. Wrist as well as fingers were positioned in extension, while the thumb was positioned in neutral position.
c. Wrist, fingers in addition to thumb were positioned in extension.
d. Wrist, fingers in addition to thumb were positioned in extension, with the forearm was supinated.
e. Wrist, fingers in addition to thumb were positioned in extension, the forearm was supinated while the thumb was stretched gently by other hand **(Figure 4).**

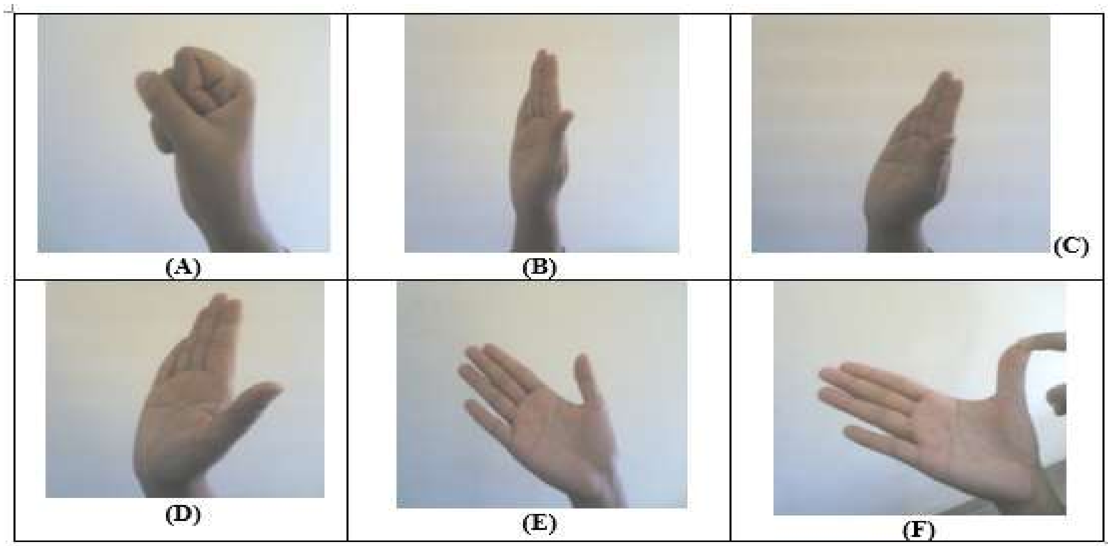


**Figure (4). Six positions for mobilizing the median nerve.**

**DATA ANALYSIS**

An ANOVA test was utilized to evaluate the participant's characteristics among the groups. Groups were compared according to the distribution of affected sides and age using a chi-squared test. To verify that the data was normally distributed, the Shapiro-Wilk test was employed. The homogeneity of variances among groups was tested utilizing Levene's test. To assess the effects of each group on motor and sensory distal latency, pinch strength, VAS, FSS, as well as SSS, a mixed MANOVA was conducted. Post hoc tests using the Bonferroni correction were conducted for the subsequent multiple comparisons. A significance level of $p < 0.05$ was incorporated into the design of all statistical tests. Statistics were all performed using SPSS version 25 for Windows, a program created by IBM SPSS in Chicago, IL, USA.

**RESULTS**

**- *Subject characteristics*:**

Subject characteristics of groups A, B, C, and D are shown in Table (1). Age, body mass index, gender, and the distribution of affected sides didn't differ significantly ($p > 0.05$) across the groups.

**Table 1. Basic characteristics of participants.**

| | Group A | Group B | Group C | Group D | p-value |
|---|---|---|---|---|---|
| | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | |
| **Age (years)** | 42.93±6.72 | 42.07±8.00 | 43.80±4.65 | 41.53±7.17 | 0.81 |
| **BMI (kg/m$^2$)** | 29.17±2.57 | 28.59±3.50 | 27.74±1.76 | 29.08±3.62 | 0.54 |
| **Sex, n (%)** | | | | | |
| **Females** | 12 (80%) | 11 (73%) | 10 (67%) | 11 (73%) | 0.87 |
| **Males** | 3 (20%) | 4 (27%) | 5 (33%) | 4 (27%) | |
| **Affected side, n (%)** | | | | | |
| **Dominant** | 8 (53%) | 10 (67%) | 8 (53%) | 10 (67%) | 0.77 |
| **Non-dominant** | 7 (47%) | 5 (33%) | 7 (47%) | 5 (33%) | |

**SD, standard deviation; p-value, level of significance**

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**Impact of treatment on motor and sensory distal latency, pinch strength, VAS, FSS and SSS:**

The results of the MIXED MANOVA showed that the treatment and time variables interacted significantly (F = 18.02, p = 0.001, Partial Eta squared = 0.67). The time had a significant impact (F = 403, p = 0.001, Partial Eta squared = 0.98). With F = 3.44, p = 0.001, and Partial Eta squared = 0.29, the treatment had a significant main impact.

**Regarding within group comparison**, the motor as well as sensory distal latency in all four groups significantly decreased after treatment when compared to before treatment ($p < 0.01$). After treatment, the four groups showed a significant improvement in pinch strength and significant reduction in VAS, FSS, and SSS when compared to before treatment ($p < 0.001$) (table 2).

Group B showed a significantly greater pinch strength and a significantly lower motor and sensory distal delay compared with groups A, C, and D after treatment ($p < 0.01$). Pinch strength, motor and sensory distal delay, and group A vs. C and D were not significantly different ($p > 0.05$).

When comparing group B with groups A, C, and D, there was a significant decline in VAS, FSS, and SSS ($p < 0.05$). When comparing groups C and D with group A, there was a significant decline in VAS, FSS, and SSS ($p < 0.05$). The VAS, FSS, and SSS scores of groups C and D were not significantly different ($p > 0.05$) (Tables 3-4).

**Table 2.** ***Mean motor sensory distal latency, Mean pinch strength, VAS, FSS and SSS pre and post treatment of groups A, B, C and D:***

| | Group A<br>mean ± SD | Group B<br>mean ± SD | Group C<br>mean ± SD | Group D<br>mean ± SD |
|---|---|---|---|---|
| **Motor distal latency (msec)** | | | | |
| **Pre treatment** | 4.63 ± 0.44 | 4.40 ± 0.39 | 4.52 ± 0.42 | 4.45 ± 0.40 |
| **Post treatment** | 4.53 ± 0.45 | 3.66 ± 0.52 | 4.18 ± 0.39 | 4.20 ± 0.42 |
| **MD** | 0.10 | 0.74 | 0.34 | 0.25 |
| **95% CI** | 0.03: 0.17 | 0.67: 0.80 | 0.28: 0.41 | 0.18: 0.31 |
| | ***p = 0.004*** | ***p = 0.001*** | ***p = 0.001*** | ***p = 0.001*** |
| **Sensory distal latency (msec)** | | | | |
| **Pre treatment** | 4.51 ± 0.29 | 4.49 ± 0.25 | 4.50 ± 0.27 | 4.46 ± 0.20 |
| **Post treatment** | 4.35 ± 0.32 | 3.64 ± 0.38 | 4.23 ± 0.33 | 4.16 ± 0.27 |
| **MD** | 0.16 | 0.85 | 0.27 | 0.30 |
| **95% CI** | 0.06: 0.26 | 0.75: 0.95 | 0.17: 0.37 | 0.20: 0.40 |
| | ***p = 0.002*** | ***p = 0.001*** | ***p = 0.001*** | ***p = 0.001*** |
| **Pinch strength (kg)** | | | | |
| **Pre treatment** | 6.17 ± 0.90 | 6.13 ± 0.72 | 6.01 ± 0.66 | 6.27 ± 0.98 |
| **Post treatment** | 7.10 ± 0.54 | 8.57 ± 0.84 | 7.13 ± 0.83 | 7.57 ± 0.88 |
| **MD** | -0.93 | -2.44 | -1.12 | -1.30 |
| **95% CI** | -1.25: -0.62 | -2.75: -2.12 | -1.44: -0.80 | -1.62: -0.98 |
| | ***p = 0.001*** | ***p = 0.001*** | ***p = 0.001*** | ***p = 0.001*** |
| **VAS** | | | | |
| **Pre treatment** | 8.73 ± 0.59 | 8.47 ± 0.52 | 8.80 ± 0.77 | 8.60 ± 0.74 |
| **Post treatment** | 7.27 ± 0.88 | 4.67 ± 0.98 | 6.33 ± 0.98 | 5.60 ± 0.63 |
| **MD** | 1.46 | 3.80 | 2.47 | 3.00 |
| **95% CI** | 1.08: 1.86 | 3.41:4.19 | 2.08: 2.86 | 2.61: 3.39 |
| | ***p = 0.001*** | ***p = 0.001*** | ***p = 0.001*** | ***p = 0.001*** |
| **FSS** | | | | |
| **Pre treatment** | 41.53 ± 3.25 | 39.13 ± 3.27 | 39.93 ± 4.22 | 38.93 ± 4.48 |
| **Post treatment** | 38.47 ± 4.09 | 26.00 ± 4.64 | 31.73 ± 5.70 | 33.80 ± 3.90 |
| **MD** | 3.06 | 13.13 | 8.20 | 5.13 |
| **95% CI** | 1.66: 4.47 | 11.73: 14.54 | 6.79: 9.61 | 3.73: 6.54 |
| | ***p = 0.001*** | ***p = 0.001*** | ***p = 0.001*** | ***p = 0.001*** |
| **SSS** | | | | |
| **Pre treatment** | 30.27 ± 2.09 | 29.07 ± 3.81 | 29.60 ± 3.11 | 28.20 ± 3.51 |
| **Post treatment** | 28.67 ± 2.13 | 19.20 ± 2.93 | 23.47 ± 2.42 | 24.20 ± 3.12 |
| **MD** | 1.60 | 9.87 | 6.13 | 4.00 |
| **95% CI** | 0.88: 2.32 | 9.14: 10.59 | 5.41: 6.86 | 3.28: 4.72 |
| | ***p = 0.001*** | ***p = 0.001*** | ***p = 0.001*** | ***p = 0.001*** |

**SD, Standard deviation; MD, Mean difference; CI, Confidence interval; p-value, Probability value**

**Table 3.** ***Comparison of post treatment mean values of motor and sensory distal latency, between group A, B, C, and D.***

| | Motor distal latency (msec) | | Sensory distal latency (msec) | |
|---|---|---|---|---|
| | **MD (95% CI)** | **P value** | **MD (95% CI)** | **P value** |
| **Group A vs group B** | 0.87 (0.44: 1.30) | 0.001 | 0.71 (0.40: 1.03) | 0.001 |
| **Group A vs group C** | 0.35 (-0.08: 0.78) | 0.15 | 0.12 (-0.19: 0.44) | 0.71 |
| **Group A vs group D** | 0.33 (-0.10: 0.76) | 0.19 | 0.19 (-0.12: 0.51) | 0.37 |
| **Group B vs group C** | -0.52 (-0.94: -0.08) | 0.01 | -0.59 (-0.90: -0.27) | 0.001 |
| **Group B vs group D** | -0.54 (-0.97: -0.11) | 0.009 | -0.52 (-0.83: -0.21) | 0.001 |
| **Group C vs group D** | -0.02 (-0.46: 0.40) | 0.99 | 0.07 (-0.25: 0.38) | 0.94 |

**MD, Mean difference; CI, Confidence interval; p-value, Probability value**

**Table 4.** ***Comparison of post treatment mean values of pinch strength, VAS, FSS and SSS between group A, B, C, and D.***

| | Pinch strength (kg) | | VAS | | FSS | | SSS | |
|---|---|---|---|---|---|---|---|---|
| | **MD (95% CI)** | **P value** | **MD (95% CI)** | **P value** | **MD (95% CI)** | **P value** | **MD (95% CI)** | **P value** |
| **Group A vs group B** | -1.47 (-2.23: -0.71) | 0.001 | 2.6 (1.75: 3.45) | 0.001 | 12.47 (7.99: 16.95) | 0.001 | 9.47 (6.88: 12.06) | 0.001 |
| **Group A vs group C** | -0.03 (-0.79: 0.73) | 0.99 | 0.94 (0.08: 1.78) | 0.02 | 6.74 (2.25: 11.21) | 0.001 | 5.2 (2.61: 7.79) | 0.001 |
| **Group A vs group D** | -0.47 (-1.23: 0.29) | 0.37 | 1.67 (0.82: 2.52) | 0.001 | 4.67 (0.19: 9.15) | 0.03 | 4.47 (1.88: 7.06) | 0.001 |
| **Group B vs group C** | 1.44 (0.67: 2.19) | 0.001 | -1.66 (-2.52: -0.82) | 0.001 | -5.73 (-10.21: -1.25) | 0.007 | -4.27 (-6.86: -1.68) | 0.001 |
| **Group B vs group D** | 1 (0.24: 1.76) | 0.005 | -0.93 (-1.78: -0.08) | 0.02 | -7.8 (-12.28: -3.32) | 0.001 | -5 (-7.59: -2.41) | 0.001 |
| **Group C vs group D** | -0.44 (-1.19: 0.33) | 0.44 | 0.73 (-0.12: 1.58) | 0.11 | -2.07 (-6.55: 2.41) | 0.62 | -0.73 (-3.32: 1.86) | 0.87 |

**MD, Mean difference; CI, Confidence interval; p-value, Probability value**

## DISCUSSION

This study was carried out to investigate the effect of different doses of therapeutic ultrasound in the management of CTS.

**Regarding the effect of Sham US and conventional physical therapy to group (A) patients:** As shown in the present study, results from group A showed a statistically significant reduction in motor as well as sensory distal latency, VAS, FSS, and SSS with percent of change were 2.16%, 3.55%,16.72%, 7.37%, 5.29% respectively. However, there was significant increase in pinch strength with percent of change was 15.07% post treatment compared to that pre treatment in group A.

These improvements might be as conventional physical therapy modalities as hot backs can dilates blood vessels, increasing blood flow to the median nerve and surrounding tissues, which can promote healing and reduce inflammation, also it can help alleviate pain associated with CTS and then can reduce pressure on the median nerve that can by its role improve latency and amplitude.

That was come in the agreements with the study done by **Farhat and Mughal** [22] who showed that studies have shown that thermotherapy may enhance circulation to the median nerve, which reduces the carpal tunnel pain. It also facilitates the body's natural healing process and relaxes muscles in the hands and wrists.

Although heat therapy has been shown to alleviate CTS symptoms and pain in some trials [23,24], others have concluded that it is not a recommended treatment for CTS [25,26].

Tendon gliding exercises were done by Bardak et al.[27]. For seven seconds, the fingers were held in 5 various positions: straight, hook, fist, tabletop, as well as straight fist. Every exercise was done three times per day for six weeks, with five repetitions of each. Furthermore, splinting in combination Massage therapy consisted of a sequence lasting 3 minutes: 30 seconds of effleurage, 60 seconds of friction, 30 seconds of petrissage, 30 seconds of shaking, followed by another 30 seconds of effleurage. Additionally, this therapy utilized nerve as well as tendon gliding exercises, which contributed to a significant improvement of grip strength as a result of the enhanced motor and sensory latency involved [28].

**Also,** Splinting can be an effective conservative treatment for CTS by reducing pressure upon the median nerve within the carpal tunnel. Splints, particularly those maintaining a neutral wrist position (0–15 degrees of extension), help to widen the carpal tunnel, thereby minimizing pressure and alleviating symptoms. While splinting is generally considered safe and relatively inexpensive, its effectiveness can vary, and some individuals may find it uncomfortable [29].

**Regarding the effect of Low–dose US and conventional physical therapy to group (B) patients:** This study found that group B experienced a significant decline in motor distal latency (16.62%), sensory distal latency (18.93%), VAS scores (33.55%), and SSSS scores (33.95%). However, there was significant increase in pinch strength with a percent of change was 39.80%.

These results might because of US with low dose can work as anti–inflammatory modalities as its waves work as a scavenger that by its role remove the waste products around the area of application and then improve the circulation so it can decrease pain, decrease adhesions around the tendon, and improving nerve conduction and grip strength. LIPUS has shown promise in improving biostimulation of the median nerve in patients suffering from CTS, potentially leading to improved pain, nerve function, and overall hand function [30].

The study carried out by Duymaz et al. found that specific parameters including VAS score, pinch meter evaluation, monofilament examination, two-point discrimination testing, provocative tests, APB manual muscle testing, in addition to median nerve motor conduction velocity demonstrated a statistically significant enhancement in the iontophoresis group both at the after treatment in addition to 3 months after treatment compared to the control group. Consistent with our findings, a reduction in symptoms was observed in the low-dose US group, and these improvements often observed post treatment [31].

The LIPUS has been demonstrated in several studies to increase cytosolic calcium levels while also stimulating dentinogenesis, cell regeneration, protein synthesis, collagen synthesis, membrane permeability, along with integrin expression [32].

**Concerning the effect of mid–dose US and conventional physical therapy to group (C) patients:** Group C showed a significant reduction in motor distal latency (7.52%), sensory distal latency (6%), VAS scores (28.07%), FSS (20.54%), in addition to SSS (20.71%), as shown in this study's data analysis. However, there was significant increase in pinch strength with a percent of change was 18.64%.

A probable explanation for current results is that the thermal effect of US can improve circulation, decrease the compression that was done on the median nerve then decrease the level of pain that by its role it will improve the pinch grip.

In an additional study that compared groups that received continuous and intermittent US with a 1.0 W/cm2 intensity using a 1 MHz frequency to those that received a placebo, all groups showed improvements on the VAS, BSS, and BFS scales, but only the groups that received intermittent ultrasound showed improvements on the coarse grip [33].

In a RCT of mild to moderate CTS, one group received active therapeutic ultrasound (1 MHz, 1.0 W/cm2) across the carpal tunnel, while the other group received treatment that was almost identical to a sham ultrasound. Active treatment resulted in a significantly greater rate of symptom enhancement or full remission (74% vs. 20% for sham treatment) at the 6-month follow-up. Electroneurography showed that SNCV and DML both improved with active treatment but showed no change with sham treatment. Active therapy also greatly improved the patient's grip strength and finger pinch strength during physical examinations. All of the outcomes were consistent with therapeutic US having a positive impact on CTS.

**Regarding the effect of high–dose US and conventional physical therapy to group (D) patients:** Findings from the present study showed that group D exhibited a significant decline in motor distal latency (5.62%), sensory distal latency (6.73%), VAS scores (14.18 percent), in addition to SSS scores (14.18%). However, there was significant increase in pinch strength with a percent of change was 20.73%.

Continues US wave can cause thermal effect that can decrease the compression that was performed on the median nerve and the nerve conduction would improve then the motor latency would have decreased and finally the pinch strength will have increased as mentioned in all previous explanation.

Earlier research by Oztas et al. was consistent with our findings. He evaluated the efficacy of 0.8 W/cm2 along with 1.5 W/cm2 US sessions against that of a placebo session in CTS. There was a statistically significant enhancement in all groups' clinical measurements at the end of treatment, including pain intensity, hand grip, along with electrophysiological activity. He hypothesized that the local massaging effects of placebo US may alleviate pain [35].

Additionally, our findings are in line with that of a single-blind trial conducted by Asadi et al. in which 45 patients (84 wrists) with CTS were randomized into one of three treatment groups: US therapy alone (15 patients), US therapy plus laser (15 patients), or laser therapy alone (15 patients). Ten treatments were administered to the carpal tunnel using low-level laser therapy (LLLT) (an overall of nine J on 5 locations) and US therapy (1.25% W/cm, 20% duty cycle, 5 minutes per session). The study's authors came to the conclusion that, for individuals suffering from mild to severe CTS, both laser and ultrasonic treatments provide short term pain relief and enhanced functional hand performance. When used together, these two approaches may be more beneficial treating these patients. Additionally, our findings are in line with that of a single-blind trial conducted by Asadi et al. in which 45 patients (84 wrists) with CTS were randomly assigned to one of three treatment groups: ultrasound therapy alone (15 patients), US plus laser (15 patients), or laser therapy alone (15 patients). Ten treatments were administered to the carpal tunnel using LLLT (a total of 9 J on 5 locations) and US (1.25% W/cm, 20% duty cycle, 5 minutes per session). The study's authors came to the conclusion that, for individuals suffering from mild to severe CTS, both laser and US treatments provide SH pain relief and enhanced functional hand performance. When used together, these two approaches may be more effective in treating these patients [12].

**Regarding comparison between the four groups (A), (B), (C) and (D):**

This study's data analysis revealed that, when compared to groups A, C, and D, group B had a significantly shorter motor distal delay ($p = 0.001$, $p = 0.01$, and $p = 0.009$). Nonetheless, when comparing motor distal latency among groups A and C ($p = 0.15$), A and D ($p = 0.19$), and C and D ($p = 0.99$), no significant differences were found.

Additionally, when comparing groups A, C, and D, group B had a significantly shorter sensory distal latency ($p = 0.001$). Nevertheless, when comparing motor distal latency between groups A and C ($p = 0.71$), A and D ($p = 0.37$), and C and D ($p = 0.94$), no significant differences were found.

In contrast, when we examined the pinch strengths of groups A, C, and D, we found that group B had a significantly higher value (p = 0.001), followed by group D with a value of 0.005. Although groups A and C did not vary significantly in pinch strength (p = 0.99), neither did groups A and D (p = 0.37), and neither did groups C and D (p = 0.44).

A probable explanation for that is the best results was reported in group B compared with the other as in this group we applied the low dose which was very safe as the patients feel comfortable while doing it so we can increase the manual compression during the session that normally it decrease the compression applied on the median nerve improve the circulation toward the affected area and then the sensory and motor latency improved then the pinch strength would increase. Also, due to their sensation of relaxation they can tolerate the conventional physical therapy modalities as tendon glide and neural glide.

In addition, regarding, our findings revealed that group B's VAS was significantly lesser than group A's (p = 0.001), group C's was lesser than group A's (p = 0.02), group D's was lower than group A's (p = 0.001), group B's was lesser than group C's (p = 0.001), and group B's was lesser than group D's (p = 0.02). Although groups C and D did not vary significantly on VAS (p = 0.11).

When comparing groups A, B, C, D, and E, we found that FSS was significantly lesser in group B (p = 0.001), significantly lesser in group C (p = 0.001), significantly lesser in group D (p = 0.03), and significantly lower in group B (p = 0.001). However, FSS did not differ substantially (p = 0.62) between groups C and D.

Lastly, no significant difference was detected among group C and D (p = 0.87), while all other groups saw a substantial reduction in FSS (p = 0.001) in relation to SSS.

In addition, when it came to VAS, our findings revealed that group B's VAS was substantially lower than group A's (p = 0.001), group C's was lower than group A's (p = 0.02), group D's was lower than group A's (p = 0.001), group B's was lower than group C's (p = 0.001), and group B's was lower than group D's (p = 0.02). Although groups C and D did not vary significantly on VAS (p = 0.11).

When comparing groups A, B, C, D, and E, we found that FSS was substantially lower in group B (p = 0.001), substantially lower in group C (p = 0.001), substantially lower in group D (p = 0.03), and substantially lower in group B (p = 0.001). However, FSS did not differ substantially (p = 0.62) between groups C and D. Lastly, group C and D did not differ substantially from one another (p = 0.87), while all other groups saw a significant reduction in FSS (p = 0.001) in relation to SSS.

A probable explanation for that is that the opposite was happened in groups with moderate and height dose both of them have high thermal effected that might not tolerated by the patients so they might feel uncomfortable, so pain, FSS and SSS improved equally that would interfere with their response to conventional physical therapy sessions.

Our results are in accordance with those of a study by Amin et al. 30 that found that patients in the experimental group who were given low-dose US therapy as well as a traditional physiotherapy program showed significant improvements in pain intensity, median nerve short- and long-term effects, pinch grip strength, as well as hand function.

When we compared electrophysiological data before and after treatment, as well as between the study and placebo groups, Oztas et al. found that 0.8 W/cm2 and 1.5 W/cm2 of ultrasonic intensity had an effect on CTS, although our findings contradicted their findings. The results did not reveal any significant difference (p > 0.05) [35].

Ultrasound has a greater impact on larger A fibres and less on smaller C fibres, according to the inverse connection between the two variables (36). Reducing the transmission of pain may be possible through this selective absorption by smaller fibres. Possible improvement in symptoms might be caused by alterations in sympathetic fibers. No difference in the electrophysiological function of tiny, unmyelinated nerve fibers could be detected as the authors used the conventional approach of nerve conduction investigations, which only provide information on the biggest and fastest conduction the myelinated nerve fibers.

**Strength and limitation:**

To the best of our knowledge, this study is considered one of the few that compares the efficacy of varying dosages of ultrasound therapy for CTS in combination with traditional physical therapy. In contrast to existing non-operative treatments, such as medication injections for compression neuropathy, therapeutic US is less invasive, less costly, safer, and additionally portable; if it is effective, it might be provided to some patients as a non-operative treatment option. Our study has some limitations. It includes a limited number of patients, Additionally, due to ethical constraints.

## CONCLUSIONS

The findings of this study supported that pulsed US with different doses in addition to physical therapy sessions were very beneficial treatment for CTS. Also, US therapy with low dose can improve electro–neurophysiological parameters, decrease pain and improve pinch strength and functional ability in patients with CTS. Overall, US therapy with low dose in addition to traditional physical therapy session might be very effective rehabilitation tools on the treatment of CTS.

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## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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