REVIEW ARTICLE

Effectiveness of therapeutic ultrasound for treating carpal tunnel syndrome in women: A systematic review

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Abstract:

Carpal tunnel syndrome (CTS) is a prevalent condition characterized by numbness, tingling, and weakness in the hand due to compression of the median nerve within the carpal tunnel of the wrist. This condition often results in pain during wrist movements and significantly restricts the range of motion, hindering daily activities. CTS disproportionately affects adult women, with increasing prevalence and severity with age. Given its substantial impact on daily functioning and quality of life, effective treatment strategies are essential. This systematic review aimed to evaluate the effectiveness of therapeutic ultrasound in alleviating symptoms and improving quality of life in adult women with CTS. Following PRISMA guidelines, literature searches were conducted in Web of Science, Scopus, PubMed, Medline, and Google Scholar for full-text English-language research articles published between 2014 and 2024. Out of 189 articles, nine met the inclusion criteria. The quality of the included studies was evaluated using the PEDro tool, and data on study demographics, intervention protocols, outcome measures, and results were extracted. The results indicated that therapeutic ultrasound is effective in reducing pain and enhancing daily activities for CTS. This review identified optimal treatment parameters, contributing to improved patient care for adult women with CTS. However, more research is needed to distinguish the specific benefits of therapeutic ultrasound compared to other treatments and placebos.

Keywords: Carpal Tunnel Syndrome (CTS), Therapeutic Ultrasound, pain, Activities Daily Living, Quality of life

1. INTRODUCTION

Carpal tunnel syndrome (CTS) is a prevalent neurological disorder characterized by numbness, tingling, and weakness in the hand, resulting from the compression of the median nerve as it traverses the carpal tunnel in the wrist (Genova et al., 2020). This syndrome often leads to pain during wrist movements and impairs wrist range of motion, significantly interfering with daily activities such as cooking, writing, and gripping objects. The condition not only affects the physical capabilities of individuals but also extends to emotional and psychological well-being due to the persistent discomfort and functional limitations it imposes. Additionally, the socioeconomic impact is profound, as patients with CTS frequently experience prolonged work absences and decreased productivity (Hulkkonen et al., 2019).

CTS affects a substantial segment of the population, with adult women being particularly susceptible to the condition. Studies have shown that women are approximately three times more likely to develop CTS compared to men, with the prevalence and severity of symptoms increasing with age (Genova et al., 2020); (Hulkkonen et al., 2019); (Wipperman & Goerl, 2016). The higher incidence in women has been attributed to various factors, including hormonal changes, anatomical differences, and occupational risks (Sevy et al., 2023). The increased susceptibility and greater impact on quality of life in women underscore the necessity for targeted and effective treatment options. Understanding these gender-specific aspects of CTS is crucial for developing and implementing therapeutic strategies that can better address the needs of female patients.

The chronic nature of CTS and its significant impact on daily functioning necessitate effective treatment interventions. Traditional approaches such as splinting, corticosteroid injections, and surgical decompression have been commonly employed. However, there is growing interest in non-invasive modalities that offer symptom relief with minimal side effects. Among these, therapeutic ultrasound has gained attention as a potential treatment for CTS. Therapeutic

ultrasound uses sound waves to penetrate tissues, promoting healing and reducing inflammation (Papadopoulos & Mani, 2020). Its non-invasive nature and ability to target specific areas make it an appealing option for patients seeking relief from CTS symptoms without the risks associated with more invasive procedures.

This systematic review aims to critically evaluate the effectiveness of therapeutic ultrasound specifically in adult women with carpal tunnel syndrome. By examining existing studies and clinical trials, this study aim to provide a comprehensive analysis of the efficacy of this treatment modality. This review was explore various aspects, including the reduction of symptoms, improvement in hand function, and overall quality of life in women undergoing therapeutic ultrasound for CTS. Through this evaluation, we hope to offer insights into the potential benefits and limitations of therapeutic ultrasound, guiding clinicians and patients in making informed decisions about incorporating this treatment into their management plans for CTS.

2. MATERIALS AND METHODS

2.1. Data source and search strategy

This review followed the PRISMA guidelines for systematic reviews and meta-analyses. The literature was evaluated using the PICO framework, focusing on women with carpal tunnel syndrome, therapeutic ultrasound as the intervention, and improvements in functionality and daily activities as outcomes. Article searches were conducted in Medline, Google Scholar, Web of Science (WoS), and Scopus databases between November 2014 and March 2024, specifically looking for randomized-controlled trials. Studies were included if they involved women with carpal tunnel syndrome, used therapeutic ultrasound, and measured improvements in functionality and daily activities. To avoid confusion among reviewers, only articles written in English were considered. The search terms used were "Carpal Tunnel Syndrome," "Women," and "Ultrasound," with Boolean operators "AND" and "OR." The search covered the period from 2014 to 2024. Exclusions included letters to the editor, symposium publications, conference abstracts, books, expert opinions, critically appraised topics, meta-analyses, and literature reviews.

2.2. Study selection

Following the search procedure, the articles that were located underwent the eligibility process, which is the last step. In order to make sure that every article met the requirements of the articles they were searching for, the researchers manually reviewed every one of them at this phase. Finding keywords associated with the title being searched for is the first step. According to earlier research, the conditions Amyotrophy, Thenar of Carpal Origin and Median Neuropathy, Compression Neuropathy, and Entrapment Neuropathy of Carpal Tunnel can be used to replace Carpal Tunnel Syndrome. Ultrasonic treatment and ultrasound therapy are terms that have been used to describe therapeutic ultrasound. For the intended population, which is women must be used in conjunction with other keywords (Table 1).

2.3. Data extraction and analysis

The authors extracted relevant data from the included literature based on demographic data, therapeutic ultrasound parameters, therapeutic ultrasound effectiveness, outcome measure, and result. The retrieved data was then analyzed to answer the research questions. Finally, the findings were summarized in a narrative synthesis to consolidate the outcomes of the studies.

2.4 Quality assessment

In this review, the PEDro scale was used to rate the quality of the included articles. The PEDro scale is a widely used tool for assessing the quality of randomized controlled trials (RCTs) in the field of physiotherapy and other healthcare interventions. This tool directs reviewers to consider 11 items of methodological quality such as random and concealed allocation, baseline comparability, blinding of participants, therapists and assessors, adequate follow-up (greater than 85%), intention-to-treat analysis, between-group statistical comparisons, and reporting of point measures and measures of variability. If the articles met each criterion outlined in the appraisal guidelines, they received “Yes” (1) for that item, and if they were not met, they received “No” (0). The total PEDro score is the sum of ratings for items 2 to 11, giving a score range of 0 to 10, with a higher score reflecting higher methodological quality. Once quality scores were calculated, these were divided into four quality categories that were poor (score: 0-3), fair (score: 4-5), good (score: 6-8), and excellent (score: 9-10). Each study was assessed by two reviewers, and in the event of a disagreement between the two reviewers, a third reviewer was consulted to determine the final PEDro score (Cashin & McAuley, 2020).

Database	Keyword used	Data range	Refine results
Web Of Science (WOS)	TS=((Carpal Tunnel Syndrome* OR Syndrome, Carpal Tunnel OR Syndromes, Carpal Tunnel OR Amyotrophy, Thenar, Of Carpal Origin OR Median Neuropathy, Carpal Tunnel OR Compression Neuropathy, Carpal Tunnel) AND (Therapies, Ultrasonic OR Ultrasonic Therapies OR Therapeutic Ultrasound OR Ultrasound, Therapeutic OR Therapy, Ultrasonic OR Ultrasound Therapy OR Therapies, Ultrasound OR Therapy, Ultrasound OR Ultrasound Therapies) AND (Women's Group OR Women Groups OR Women's Groups OR Woman))	2014 - 2024	• Article • English language
Scopus	TITLE-ABS-KEY (("Carpal Tunnel Syndrome" OR "Median Neuropathy, Carpal Tunnel" OR "Compression Neuropathy, Carpal Tunnel" OR "Entrapment Neuropathy, Carpal Tunnel" OR "Median Neuropathy, Carpal Tunnel") AND ("women") AND ("Ultrasonic Therapies" OR "Ultrasonic Therapy" OR "Therapeutic Ultrasound" OR "Ultrasound Therapy" OR "Ultrasound Therapies"))	2014 - 2024	• Full text • English language
Medline	((((((((((((Carpal Tunnel Syndrome*[Title/Abstract]) OR (Syndrome*, Carpal Tunnel[Title/Abstract])) OR (Amyotrophy, Thenar, Of Carpal Origin[Title/Abstract])) OR (Median Neuropathy, Carpal Tunnel[Title/Abstract])) OR (Compression Neuropathy, Carpal Tunnel[Title/Abstract])) OR (Entrapment Neuropathy, Carpal Tunnel[Title/Abstract])) AND (Therapies, Ultrasonic[Title/Abstract])) OR (Ultrasonic Therapies[Title/Abstract])) OR (Therapeutic Ultrasound[Title/Abstract])) OR (Ultrasound, Therapeutic[Title/Abstract])) OR (Therapy, Ultrasonic[Title/Abstract])) OR (Ultrasound Therapy[Title/Abstract])) OR (Therapies, Ultrasound[Title/Abstract])) OR (Therapy, Ultrasound[Title/Abstract])) OR (Ultrasound Therapies[Title/Abstract])	2014 - 2024	• Full text • English language • Randomised Control Trial • Female
Google Scholar	Carpal Tunnel Syndromes OR Syndrome, Carpal Tunnel OR Amyotrophy, Thenar, Of Carpal Origin OR Median Neuropathy, Carpal Tunnel OR Compression Neuropathy, Carpal Tunnel OR Entrapment Neuropathy, Carpal Tunnel AND Therapies, Ultrasonic OR Ultrasonic Therapies OR Therapeutic Ultrasound OR Ultrasound, Therapeutic OR Therapy, Ultrasonic OR Ultrasound Therapy OR Therapies, Ultrasound OR Therapy, Ultrasound OR Ultrasound Therapies AND women	2014 - 2024	• English language

Table 1 The search string

3. RESULTS AND DISCUSSION

3.1. Literature search

The initial literature search found 197 potential articles. After removing duplicates, 189 articles were left. Each article's title and abstract were evaluated using inclusion and exclusion criteria, leading to the exclusion of 169 articles that did not meet the criteria. The full texts of the remaining 19 articles were then thoroughly reviewed to determine their suitability for inclusion since the title and abstract analysis alone was insufficient. This detailed review excluded 10 articles that did not evaluate VAS as an outcome measure.

All subjects in the included studies had Carpal Tunnel Syndrome (CTS). Out of the 9 studies, 7 included both males and females, 1 focused only on males, and 1 only on females. Seven studies measured the severity of CTS using the Boston Carpal Tunnel Syndrome Questionnaire (BCTSQ), and four of these also used the Visual Analog Scale (VAS). Additionally, two studies assessed pain levels using the NPRS (Numerical Pain Rating Scale). The BCTSQ included the Functional Status Scale (FSS) to assess daily hand functions and the Symptom Severity Scale (SSS) to measure painful wrist episodes, numbness, weakness, and difficulties with grasping.

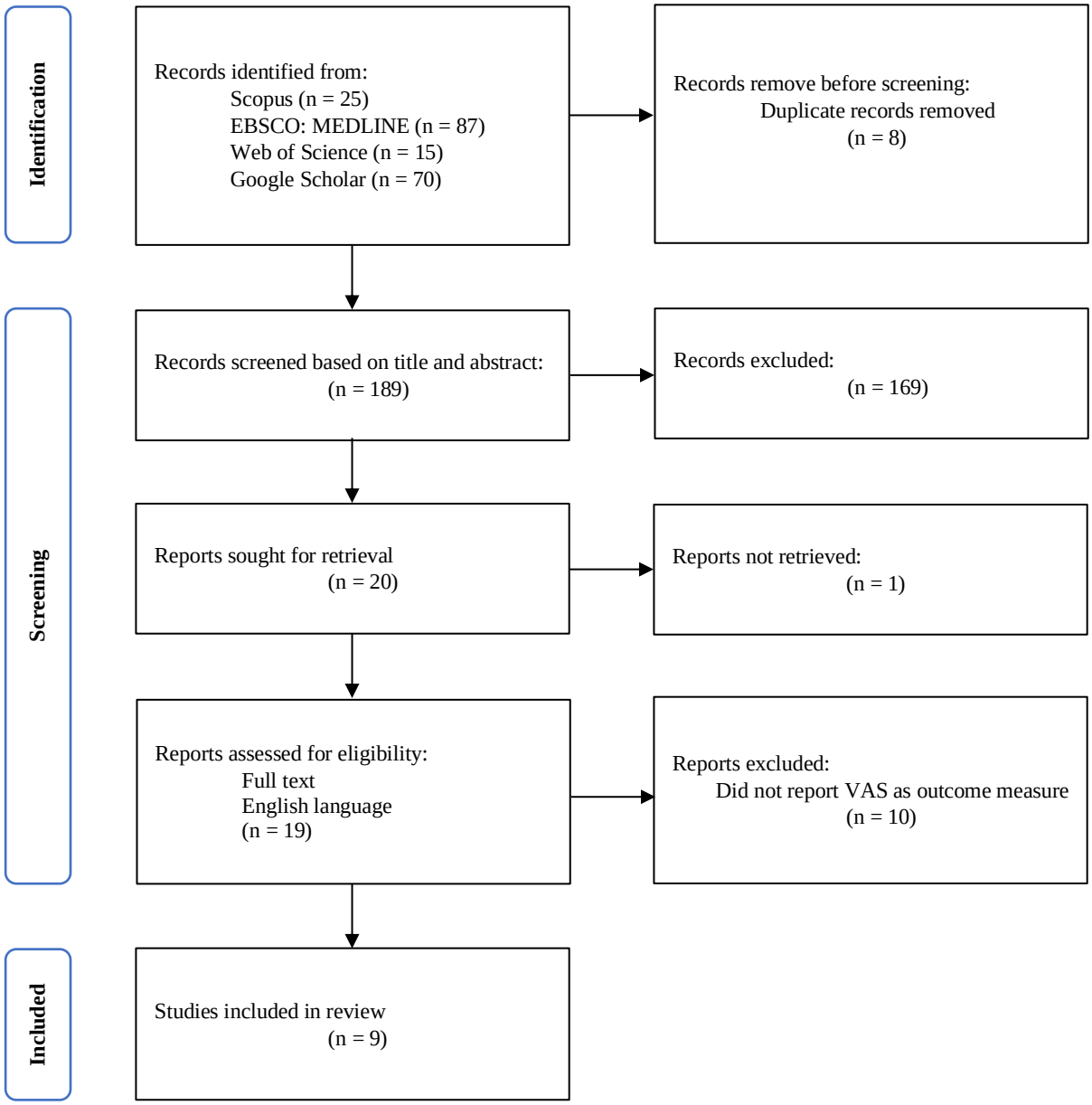

Figure 1 PRISMA flow diagram

The studies employed various methodologies and treatment protocols. While four studies combined ultrasound therapy with exercise, five focused solely on ultrasound therapy. Additionally, the studies varied in ultrasound parameters, including differences in frequency, intensity, and duration of application

3.2. Risk of bias in included studies

Two reviewers evaluated the methodological quality of included studies (n=9) independently using the Pedro Scale Critical Review Form for Randomized Control Trial. A discussion with the third reviewer was required to get an agreement on the validity and reliability of the outcome measures, the suitability of the intervention description, and the logic behind the sample size computation.

From a total score of 10, a minimum of 3 and a maximum of 9 were attained, signifying "poor" to "excellent" methodological quality (Table 2). A single study has been rated as excellent, six studies as good, one as fair, and one as poor.

3.3. Effectiveness of therapeutic ultrasound

The nine studies report on pain outcome and Boston Carpal Tunnel Syndrome Questionnaire (BCTSQ) data among participants who have undergone therapeutic ultrasound (Table 3). Chang et al. (2014), reported significant pain reduction in the ultrasound group (p=0.01). Awan et al. (2014), Paoloni et al. (2015), and Ansar et al. (2017) demonstrated significant improvements in pain levels for the experimental group, with no significant difference between groups (p=0.12, p=0.72, p=0.909 respectively). Mahmoud (2016) reported significant improvements in pain levels for both groups in mild symptoms (p=<0.05). However, for those with moderate symptoms, LLLT was more effective than ultrasound in pain reduction (p=<0.05). Further reinforcing these findings, Lazović et al. (2018) reported that ultrasound combined with exercise significantly reduced pain compared to a sham ultrasound group (p<0.001). Elmonem et al. (2024) showed significant decrease of pain in all groups (p=0.001).

For BCSTQ, Chang et al. (2014) reported significant improvements in symptom severity scores (SSS) for both ultrasound and paraffin therapy groups, with no significant difference between them (p=0.51). However, functional status scores (FSS) were significantly better in the ultrasound group compared to paraffin therapy (p=0.04). Similarly, Mahmoud (2016) found significant improvements in both SSS and FSS in patients with mild and moderate CTS, with ultrasound therapy showing greater effectiveness in improving functional status for moderate symptoms (p=0.037). Paoloni et al., (2015) reported significant effect of treatment (p<0.05) for SSS in both groups, while there was no significant effect of treatment (p=0.97) for FSS. Ansar et al. (2017) also reported significant improvements in both SSS and FSS for ultrasound and local steroid injection groups, with no significant differences between them (SSS: p=0.773, FSS: p=0.335). Elmonem et al. (2024) also show improvement with significant decrease of BCSTQ values in all groups (p=0.001).

Conversely, studies by Çatalbaş et al.(2018) and Jothi & Bland (2019) do not specify data for BCSTQ and pain outcome but they state that all outcome measures are significantly improved in all groups.

Table 2 Assessment of methodological quality by study (PEDro)

Study	Chang et al., 2014	Awan et al., 2014	Paoloni et al., 2015	Mahmoud, 2016	Ansar et al., 2017	Çatalbaş et al., 2018	Lazović et al., 2018	Jothi & Bland, 2019	Elmonem et al. ,2024
Eligibility criteria	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Random allocation	1	1	1	1	1	1	1	1	1
Concealed allocation	1	1	1	0	1	1	1	1	1
Baseline comparability	1	0	1	0	1	1	1	1	1
Blinded participants	0	0	0	0	0	1	1	1	0
Blinded therapist	1	0	0	0	0	0	1	1	0
Blinded assessor	1	0	1	0	0	1	0	1	0
Adequate follow-up	0	1	1	0	1	1	1	1	1
Intention-to-treat analysis	0	0	1	0	1	0	0	0	0

Between group comparison	1	1	1	1	1	1	1	1	1
Point estimation and variability	1	1	0	1	1	1	1	1	1
Total PEDro Score (/10)	**7**	**5**	**7**	**3**	**7**	**8**	**8**	**9**	**6**
Quality Descriptor	**Good**	**Fair**	**Good**	**Poor**	**Good**	**Good**	**Good**	**Excellent**	**Good**

Table 3 Summary of study

AUTHOR	PARTICIPANTS	INTERVENTION PROTOCOL	OUTCOME MEASURE	RESULTS
Chang et al., (2014) Comparative effectiveness of ultrasound and paraffin therapy in patients with carpal tunnel syndrome: a randomized trial	• 5 males, 42 females • **Age :** GI : 51.9±8.8 years GII : 48.8±11.2 years **Inclusion criteria:** • pain and/or numbness in the median nerve distribution of the digits or nocturnal pain • a positive Phalen's sign or Tinel's sign • electrophysiological evidence of CTS.	**Group I (GI) :** • 23 patients • Paraffin Therapy • Twice per week for 8 weeks. • Temperature paraffin: 55°C • Duration: 20 minutes **Group II (GII) :** • 24 patients • Ultrasound Therapy • twice per week for 8 weeks • Parameters : 1 MHz, 1.0 W/cm², Pulsed 1:4, 5 minutes	1. BCTSQ : • FSS 2. Pain scale : VAS 3. Physical examinations: • The Semmes-Weinstein monofilament sensory test • Palmar pinch strength • Tinel's test • Phalen's test. 4. Nerve conduction studies (NCs): • MDL • SDL	**<u>Primary outcome:</u>** **Symptom Severity Scores:** • Significant improvements were seen in both groups • Effect size is moderate (0.63) • No significant difference between groups (p=0.51). **Functional Status Scores:** • FSS in the GII > GI (p=0.04)*. • Effect size is small (p=0.38) **<u>Secondary Outcome:</u>** **Pain scale** • Significant improvement is only seen in the US group. • Effect size is moderate (p=0.74) • No significant difference between groups (p=0.81). **Palmar pinch power** • Significant improvement is

				only seen in the US group. ● No significant difference between groups (p=0.34). **NCSs** ● No significant difference for both groups. ● **Distal motor**: No significant difference (p=0.06). ● **Distal sensory:** No significant difference (p=0.83).
Awan et al., (2014) Effectiveness of stretching of the flexor retinaculum with ultrasonic therapy in the management of carpal tunnel syndrome	● 50 patients (Both gender) ● **Age :** 26-70 years **Inclusion criteria:** ● Having idiopathic CTS ● Positive for Tinel's sign and Phalen's test.	**Experimental Group (EG):** ● 25 patients ● Stretching of the flexor retinaculum + ultrasound. ● Parameters : 0.75W/cm^2, Pulsed, 5 min **Control Group (CG):** ● 25 patients ● Stretching of the flexor retinaculum only.	1. NPRS 2. Paresthesia 3. Muscle Strength	Results show significant improvement in the experimental group only. **Pain :** ● No significant difference between groups (p=0.12). **Paresthesia :** ● No significant difference between groups (p = 0.09). **Muscle Strength :** ● No significant difference between groups (p =0.16).
Paoloni et al., (2015) Extracorporeal shock wave therapy and ultrasound therapy improve pain and function in patients with carpal tunnel syndrome. A randomized controlled trial	● 25 patients (Both gender) ● **Age:** GA : 56.5±9.4 years GB : 54.7±9.2 years GC : 59.1±12.5 years **Inclusion criteria:** ● Mild to moderate CTS ● No indication for surgical treatment	**Group A (GA):** ● 13 patients ● Therapeutic Ultrasound (US) ● 15 sessions (5 sessions/week for three consecutive weeks) ● Parameters : 15 min, 1 MHz, 1.0 W/cm², Pulsed 1:4. **Group B (GB):**	1. VAS 2. BCTSQ ● FSS ● SSS	**Pain (VAS) :** ● Effect of time : Significant (F3=2.81; P<0.05). ● Effect of treatment : No significant difference (F2=0.33; P=0.72) ● Time*treatment interaction : No significant difference (F6=0.48; P=0.82).

T0: before treatment T1: the end of treatment T2: 4 weeks after the end of treatment T3: 12 weeks after the end of treatment	• 17 patients • cryo-US + Therapeutic Ultrasound (US) • 15 sessions (5 sessions/week for three consecutive weeks) • Parameters : 15 min, 0°C, 1 MHz, 1.0 W/cm², Pulsed 1:4 **Group C (GC):** • 12 patients • Extracorporeal Shock Wave Therapy (ESWT) • 4 sessions over three consecutive weeks • Type: Low-intensity focused ESWT • Pulses: 2500 pulses • Energy: 0.05 mJ/mm²	• Post hoc analysis showed No significant difference. **Paresthesias (VAS):** • Effect of time : significant ($F3=4.53$; $P<0.01$). • Effect of treatment : No significant difference ($F2=2.66$; $P=0.07$) • Time*treatment interaction : No significant difference ($F6=0.53$; $P=0.79$). • Significant reduction in paresthesias at T1 ($P<0.05$) and T2 ($P<0.01$) compared with T0. **- FSS :** • Effect of time : significant ($F3=3.97$; $P<0.01$). • Effect of treatment : No significant difference ($F2=0.035$; $P=0.97$) • Time*treatment interaction : No significant difference ($F6=0.44$; $P=0.85$). **BCTSQ - SSS :** • Effect of time : significant ($F3=11.91$; $P<0.001$). • Effect of treatment : significant ($F2=3.95$; $P<0.05$)

				● Time*treatment interaction : No significant difference (F6=0 .42; P=0.86).
Mahmoud, (2016) Comparison of the Selected Treatment Modalities of Carpal Tunnel Syndrome Depending on Symptom Severity	● 40 males ● Ages: 40-50 years old ● Idiopathic unilateral mild and moderate CTS ● no indication to surgical treatment	**Group I (GI) :** ● 10 patients with mild symptoms ● low-level laser therapy (LLLT) **Group II (GII) :** ● 10 patients with mild symptoms ● ultrasound therapy **Group III (GIII) :** ● 10 patients with moderate symptoms ● low-level laser therapy (LLLT) **Group IV (GIV) :** ● 10 patients with moderate symptoms ● ultrasound therapy **Therapeutic ultrasound** ● 15 minutes/session ● Once daily, 5 times/week for 6 weeks ● Parameters : 1MHz, 1.0 W/cm², pulsed 1:4 **Low-level laser therapy treatment (LLLT)** ● Once a day, 5 times a week for six weeks.	1. VAS - pain 2. VAS - paresthesia 3. BCTSQ : ● FSS	**Mild Symptoms Groups :** **Pain level (VAS)** ● Significant improvements were seen in both groups (p=<0.05) ● No significant difference between group (p=0.342) **BCTSQ - FSS** ● Significant improvements were seen in both groups (GI; p=<0.05, GII; p=0.001) ● No significant difference (p=0.367) **Moderate Symptoms Groups :** **Pain level (VAS)** ● Significant improvements were seen in both groups (p=<0.05) ● VAS significantly were higher in the GIII (p=<0.05) ● LLLT > US in improvement of pain level **BCTSQ - FSS** ● Significant improvements were seen in both groups (GIII; p=0.03, GIV; p=0.001) ● FSS significantly were higher in the GIV (p=0.037) ● US > LLLT in improvement of FSS.

		• low intensity (9J) • Infrared • laser diode at five points (1.8 J/point)		
Ansar et al., (2017) The Comparison of Therapeutic Ultrasound and Local Steroid Injection inTreatment of Mild to Moderate Carpal Tunnel Syndrome: A Randomized Controlled Trial	• 11 males, 49 females • **Ages :** GA : 44.9±11.6 years GB : 36.8±7.76 years • Mild to moderate CTS **Inclusion criteria :** • Presence of paresthesia, pain and vasomotor symptoms • positive Phalen's and Tinel's test • Mild to moderate intensity of median nerve lesion in NCs	**Group 1 :** • 30 patients (30 hands) • Therapeutic ultrasound (US) + Median nerve flossing exercise + Wrist range of motion exercise **Group 2 :** • 30 patients (30 hands) • Local steroid injection + Median nerve flossing exercise + Wrist range of motion exercise	1. NPRS 2. BCTSQ : • SSS • FSS	**Pain (NPRS) :** • Significant improvements in NPRS were seen in both groups • No significant difference between group (p=0.909) **BCTSQ - FSS :** • FSS found to be on a working level of efficiency for both groups. • No significant difference between group (p=0.335) **BCTSQ - SSS :** • SSS in Group 1 > Group 2. • No significant difference between group (p=0.773)
Çatalbaş et al., (2018) Ultrasonograp hic imaging of the effects of continuous, pulsed or sham ultrasound treatments on carpal tunnel syndrome: A randomized controlled study	• 46 females, 8 males (92 hands) • **Age :** GA : 51.1±10.1 years GB : 46.8±11.2 years GC : 46.2±8.8 years • Mild to moderate idiopathic CTS	**Group 1 (G1) :** • 18 patients, 33 wrist • Continuo us US + splint **Group 2 (G2) :** • 19 patients, 33 wrist • Pulsed US + splint **Group 3 (G3) :** • 19 patients, 30 wrist	1. VAS - pain 2. VAS - paresthesia 3. BCTSQ : • SSS • FSS 4. Hand grip strength (kgf) 5. Electrophysiological and ultrasonographic imaging parameters: • MDL (msn) • SDL (msn) • CA (mm2)	Results show No significant difference between all groups. **Clinical evaluation parameters:** • All clinical parameters significantly improved by the 2nd and 6th weeks in all groups. **Electrophysiological parameters:** • G1 **:** MDL improved by the 2nd and 6th weeks.

		• Sham US + splint		• G2 and G3 : MDL improved only by the 6th week; SDL improved by the 2nd and 6th weeks. **Ultrasonographic imaging parameters:** • All groups showed significant improvement in CA by the 2nd and 6th weeks.
Lazović et al., (2018) Effectiveness of combined ultrasound and exercise therapy in the treatment of carpal tunnel syndrome – randomized, placebo-controlled investigation	• 31 female, 4 male • **Age:** EG : 53.5±8.3 years CG : 52.6±8.7 years **Inclusion Criteria :** • symptoms (pain and/or numbness) in at least two digits on one hand (digits 1–4) lasting less than one year • no thenar atrophy • mild to moderate CTS	**Experimental Group (EG) :** • 20 patients • Parameters : 1MHz, 1.0 W/cm², pulsed 1:4, 15 min • 10 treatments were administered once a day, 5 days a week for 2 weeks, followed by 4 treatments every other day for 2 weeks, and 6 treatments twice a week for 3 weeks. • Nerve and tendon gliding exercise (10 rep/session) **Control Group (CG) :** • 15 patients • US probe was applied without turning the device on • Nerve and tendon gliding exercise (10 rep/session)	1. NPRS 2. Tinel's sign 3. Superficial sensibility • TPD Test - Electrophysiologic analyses • MDL - 2nd finger • SNAP - 2nd finger • SNCV - 2nd finger	**Pain (NPRS) :** • NPRS in EG > CG ($p < 0.001$)* **Superficial sensibility :** • TPD in EG > CG ($p=0.021$)* **Reduction of Positive Tinel's sign :** • EG > CG ($p < 0.001$)* **Reduction of MDL values :** • EG > CG ($p = 0.009$)* **Reduction of SNAP values :** • EG > CG ($p = 0.002$)* **Reduction of SNCV values :** • EG > CG ($p < 0.001$)*

Jothi & Bland, (2019) Ultrasound therapy adds no benefit to splinting in carpal tunnel syndrome	• 9 men, 31 women • **Age:** AG : 53.5±10.7 years SG : 58.3±10.8 years • Mild to moderate CTS • Symptoms consistent.	**Active Group (AG):** • 20 patients • US • Parameters : Pulsed mode, 1 MHz, 1.0 W/cm2, 15 min/session • 20 sessions over 7 weeks • Wrist splint **Sham Group (SG):** • 20 patients • Unpowered US • Wrist splint	**Primary Outcome**: 1. BCTSQ • SSS at 12 months **Secondary Outcome** : 1. NCS 2. CSA 3. BCTQ • FSS	• Results show No significant difference between groups. • Both groups showed improvement, but no differences between them.
Elmonem et al., (2024) Effect of low level laser therapy versus pulsed ultrasound on postpartum carpal tunnel syndrome	• 48 postpartum women • **Age:** GA : 30.4±3.4 years GB : 29.4±3.1 years GC : 31.2±2.8 years • Moderate to severe pain • VAS ≥ 4 • Positive for Tinel sign and Phalen test. • Body mass index (BMI) - 25-30 kg/m^2	**Group A**: • 16 patients • Low level laser therapy (LLLT) • Wavelength: 810 nm • Power: 500 MW • Laser beam diameter: 10 mm • 3 sessions weekly for four weeks (12 sessions as a total) • Wrist exercises **Group B**: • 16 patients • Parameters : Pulsed ultrasound, 1.0 MHz, 0.13 W/cm^2 • 3 weekly sessions for four weeks, a total of 12 sessions (10 min/session) • Wrist exercises **Group C**:	1. VAS 2. BCTSQ • FSS • SSS 3. Median NCS 4. Hand grip strength	Effect size is medium (0.556) **Pain (VAS) :** • Significant decrease of VAS values in all group (p=0.001) **BCTSQ (SSS & FSS) :** • Significant decrease of BCTSQ values in all group (p=0.001) **Hand Grip :** • Significant increase of hand grip values in all group (p=0.001) • **Median NCS :** • Significant improvement of DML and MCV in all group (p=0.026) Effect size is medium (0.556).

						• 16 patients • Wrist exercises	

Abbreviation: VAS; Visual Analog Scale, NPRS; Numeric Pain Rating Scale, BCTSQ; Boston Carpal Tunnel Syndrome Questionnaire, SSS; Symptom Severity Scale, FSS; Functional Status Scale, NCs; Nerve Conduction Studies, MDL; Motor Distal Latency of median nerve, SDL; Sensory Distal Latency of median nerve, CA; Ultrasonographic measurement of cross-sectional area of median nerve at the level of pisiform bone, SNAP; Sensory Nerve Action Potential, SNCV; Sensory Nerve Conduction Velocity, CSA; ultrasound imaging of the median nerves with measurement of cross-sectional area, TPD; Two-Point Discrimination, GA; group A, GB; group A, GC; group C, US; ultrasound.

3.4. Discussion

The primary aim of this systematic review was to evaluate the effectiveness of therapeutic ultrasound for treating CTS in adult women. The results from the nine studies included in this review provide mixed evidence on the benefits of ultrasound therapy, with seven studies indicating significant improvements in symptoms and functionality, while others show no substantial difference compared to control treatments.

Study by Chang et al. (2014) and Paoloni et al. (2015), reported significant improvements in both symptom severity scores and functional status scores among patients receiving ultrasound therapy. Chang et al. (2014) found that ultrasound therapy significantly improved pain levels and palmar pinch strength compared to paraffin therapy, though no significant differences were found in nerve conduction studies between the groups. This aligns with findings by Mahmoud (2016), where ultrasound therapy led to significant improvements in pain and functional status scores for patients with both mild and moderate symptoms, though the degree of improvement varied based on the severity of symptoms.

Conversely, studies such as those by Jothi & Bland (2019) and Çatalbaş et al. (2018) showed no significant difference between ultrasound therapy and control treatments, including sham ultrasound and wrist splinting. Jothi & Bland (2019) found that while both groups (active and sham ultrasound) improved over time, there was no significant difference between the two, suggesting that ultrasound may not provide additional benefits beyond standard treatments such as splinting. Similarly, Çatalbaş et al. (2018) reported significant improvements in clinical, electrophysiological, and ultrasonographic parameters across all groups, including the sham treatment, which raises questions about the specific efficacy of ultrasound therapy in CTS treatment.

The studies included in this review utilized varying protocols and parameters for ultrasound therapy, which might have influenced the outcomes. The majority of the studies utilized a frequency of 1 MHz, which is effective for targeting deeper tissues within the carpal tunnel region. The intensity of the ultrasound typically ranged from 0.75 to 1.5 W/cm², with most studies employing 1.0 W/cm². Duration of treatment sessions varied, typically between 5 to 15 minutes, with the 15-minute duration being the most common in studies such as Paoloni et al. (2015), Mahmoud (2016), Lazović et al. (2018), and Jothi & Bland (2019). The mode of ultrasound application was predominantly pulsed, with a duty cycle of 1:4. This pulsed mode likely helps to minimize thermal effects while maintaining therapeutic benefits. The consistency in frequency, intensity, and mode across different studies underscores the potential efficacy of these specific parameters in managing CTS symptoms. Based on the finding it can conclude that the optimum parameters to promote pain reduction are frequency (1MHz), intensity (1.0 W/cm2), mode (pulse) with 1:4 duty cycle as tabulates in *Table 4*.

Interestingly, the combination of ultrasound with other therapies appeared to yield better results in some studies. Ansar et al. (2017) demonstrated that ultrasound combined with median nerve flossing exercises and wrist range of motion exercises provided significant improvements in pain and functional status, comparable to local steroid injections. This suggests that the integration of ultrasound with exercise therapy could enhance treatment outcomes for CTS.

The review also highlights the importance of considering the severity of CTS symptoms when evaluating treatment efficacy. Mahmoud (2016) found that LLLT was more effective than ultrasound in improving pain levels for patients with moderate symptoms, whereas ultrasound was more beneficial for functional status improvements. This indicates that the choice of therapy might need to be tailored to the individual patient's symptom severity and specific treatment goals.

A notable limitation across the studies is the lack of long-term follow-up to assess the sustained efficacy of ultrasound therapy. Most studies, including those by Paoloni et al. (2015) and Elmonem et al. (2024), evaluated outcomes up to 12 weeks post-treatment. Future research should focus on longer follow-up periods to determine the durability of treatment effects.

Table 4 Parameters of therapeutic ultrasound based on studies

Study	Chang et al., 2014	Awan et al., 2014	Paoloni et al., 2015	Mahmoud, 2016	Ansar et al., 2017	Çatalbaş et al., 2018	Lazović et al., 2018	Jothi & Bland, 2019	Elmonem et al. ,2024
Frequency (MHz)	1	-	1	1	1	1	1	1	1
Intensity (W/cm^2)	1.0	0.75	1.0	1.0	1.5	1.0	1.0	1.0	0.13
Duration (minutes)	5	5	15	15	5	10	15	15	10
Mode	Pulse	Pulse	Pulse	Pulse	-	Pulse	Pulse	Pulse	Pulse
Duty cycle	1:4	-	1:4	1:4	-	1:4	1:4	-	-

4. CONCLUSION

Therapeutic ultrasound significantly shows its effectiveness in reducing pain and improving activities of daily living in adult women with carpal tunnel syndrome. Our review indicates that therapeutic ultrasound can effectively alleviate pain when administered with optimal parameters: a frequency of 1 MHz, intensity of 1.0 W/cm², in pulsed mode with a 1:4 duty cycle. Future studies should focus on standardizing treatment protocols to enhance reproducibility and clinical applicability. Additionally, integrating therapeutic ultrasound into comprehensive management strategies could potentially optimize outcomes for women suffering from carpal tunnel syndrome.

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