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EFFECTIVENESS OF ULTRASOUND THERAPY AND INTERFERENTIAL THERAPY IN REDUCING PAIN AND IMPROVING THE QUALITY OF LIFE IN CARPAL TUNNEL SYNDROME PATIENTS

Original Research

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ABSTRACT

Background: Carpal tunnel syndrome (CTS) is a common condition caused by compression of the median nerve in the wrist, resulting in pain, numbness, and hand weakness. Conventional treatments include wrist splinting, corticosteroid injections, and surgery. However, adjunctive modalities such as ultrasound therapy and interferential therapy have shown promise in alleviating symptoms and enhancing functional outcomes. This study evaluates the comparative effectiveness of these therapies in improving pain, functional status, and quality of life in CTS patients aged 21–50 years.

Objective: To assess the effectiveness of ultrasound therapy and interferential therapy in reducing pain, improving hand function, and enhancing quality of life in CTS patients.

Methods: This randomized controlled trial included 80 participants, equally distributed by gender and aged 21–50 years. Participants were randomly assigned to two groups: ultrasound therapy (Group 1) and interferential therapy (Group 2). Treatments were administered over four weeks, with five sessions per week, each lasting 15–20 minutes. Outcomes were assessed using the Visual Analogue Scale (VAS) for pain, Boston Questionnaire, Sollerman Hand Function Test, and Assessment of Quality of Life (AQoL) Questionnaire. Pre- and post-treatment comparisons were conducted using paired t-tests, and between-group differences were analyzed using independent t-tests.

Results: In Group 1 (ultrasound therapy), pain scores significantly reduced from 7.2 ± 1.5 to 3.5 ± 1.2 ($p < 0.001$), and quality of life scores improved from 60.4 ± 8.3 to 82.7 ± 7.9 ($p < 0.01$). Functional scores also showed significant improvements (Boston scale: 2.45 ± 1.17 to 1.00 ± 0.00; Sollerman: 72.5 ± 8.4 to 89.6 ± 7.5). In Group 2 (interferential therapy), pain scores decreased to 4.8 ± 1.4 ($p < 0.05$), and quality of life scores improved moderately (60.1 ± 7.9 to 74.5 ± 6.8, $p < 0.05$).

Conclusion: Ultrasound therapy demonstrated superior effectiveness over interferential therapy in reducing pain and improving hand function and quality of life in CTS patients. These findings highlight the potential of ultrasound therapy as a valuable adjunctive treatment for optimizing outcomes in CTS management.

Keywords: Assessment of Quality of Life, Boston Questionnaire, Carpal Tunnel Syndrome, Hand Function, Interferential Therapy, Pain, Ultrasound Therapy.

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INTRODUCTION

Carpal Tunnel Syndrome (CTS) is a pervasive condition, accounting for approximately 90% of upper extremity neuropathies. It arises from the compression of the median nerve within the carpal tunnel beneath the transverse carpal ligament, leading to symptoms such as pain, numbness, and weakness in the hand. Beyond the direct effects of nerve compression, fascial tension further restricts nerve mobility, exacerbating symptoms and complicating management strategies (1). These insights highlight the need for multifaceted interventions targeting both nerve compression and fascial dynamics to alleviate symptoms and prevent further nerve compromise (2).

CTS is a globally prevalent condition that imposes significant personal and economic burdens. Although not life-threatening, it severely diminishes quality of life by impairing hand function and interfering with daily activities. Conventional management strategies, such as medications, wrist splinting, corticosteroid injections, and surgical interventions, often provide temporary relief but are associated with limitations. Corticosteroids, for instance, carry risks of gastrointestinal side effects, while surgical interventions, though effective, are invasive and not universally appropriate (3, 4). This underscores the growing interest in alternative non-invasive therapies that address the limitations of traditional treatments.

CTS predominantly affects individuals engaged in repetitive wrist movements, such as those with occupations requiring extensive use of digital devices or with conditions such as diabetes, obesity, and rheumatoid arthritis. Women aged 40 to 60 are particularly susceptible, likely due to hormonal influences and narrower carpal tunnels. The COVID-19 pandemic further accentuated these risk factors, with poor ergonomic practices and increased remote work contributing to a rise in CTS incidence (5). Advances in diagnostic tools like ultrasound and MRI have facilitated earlier detection, paving the way for timely and effective interventions (6).

Pain and quality of life are particularly impacted in CTS patients, with symptoms such as tingling, burning, and hand dysfunction disrupting sleep and hindering productivity. If left untreated, the condition can lead to irreversible nerve damage, further compromising quality of life. While conservative measures like physical therapy, wrist splints, and corticosteroid injections provide some relief, there is an increasing focus on non-invasive treatments like ultrasound therapy and interferential therapy (7). Ultrasound therapy promotes tissue healing through thermal and micromassage effects, improving nerve conduction and reducing inflammation. Studies have demonstrated its efficacy, particularly when combined with splinting, in reducing pain and improving functionality. Interferential therapy, on the other hand, utilizes medium-frequency electrical currents to stimulate deep tissues, modulate nerve activity, and enhance circulation, offering distinct advantages in pain relief and functional recovery (8, 9).

While the individual efficacy of ultrasound therapy and interferential therapy has been well-documented, the potential synergistic effects of combining these modalities remain largely unexplored. This represents a critical gap in understanding the optimal management of CTS. Addressing this gap is essential for developing comprehensive treatment strategies that provide sustained improvements in pain relief, functional status, and quality of life. This study seeks to evaluate the effectiveness of these therapies in isolation and explore their potential combined benefits, thereby contributing to the evidence base for improving patient outcomes in CTS management.

METHODS

The study employed a randomized controlled trial (RCT) design, which is considered the gold standard for evaluating the efficacy of medical interventions. This quantitative experimental approach was specifically tailored to investigate the effectiveness of ultrasound therapy and interferential therapy in managing Carpal Tunnel Syndrome (CTS). The research was conducted over a period of four months following the approval of the study protocol. Data collection was carried out in private hospitals in Lahore to ensure access to a relevant and diverse patient population.

A total of 80 participants were recruited using convenient simple random sampling. The inclusion criteria required participants to be over the age of 25, have a confirmed diagnosis of CTS based on confirmatory tests, and no prior surgical history or contraindications to ultrasound and interferential therapy. Individuals with systemic diseases, significant upper extremity pathologies, pregnancy, or any allergies to components of the therapy devices were excluded from the study to maintain homogeneity in the sample and ensure safety.

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Participants were randomly allocated into two groups: Group 1 received ultrasound therapy, while Group 2 underwent interferential therapy. Both interventions were administered over a duration of three to four weeks, with sessions held five days a week, each lasting approximately 15–20 minutes. Participants in each group were assessed at three key points: prior to the commencement of therapy (baseline), after the initial phase of therapy, and upon completion of the treatment plan. The evaluations focused on critical outcomes, including pain levels, quality of life, functional status, symptom severity, and hand function. Tools such as the Boston Questionnaire (10), Visual Analogue Scale (11), Quality of Life Questionnaire (12), and Sollerman Hand Function Test (13) were employed to ensure robust and reliable data collection.

Data analysis was conducted using SPSS version 25.0. Descriptive statistics, including mean, median, and mode, were used to summarize demographic and clinical characteristics. Paired t-tests were utilized to assess changes within groups by comparing pre- and post-treatment measures. Independent t-tests were applied to evaluate differences between the two groups regarding continuous variables such as pain levels and quality of life. A p-value of less than 0.05 was considered statistically significant. Frequency tables, pie charts, and bar charts were used to visualize group measurements over time. This comprehensive statistical approach facilitated a thorough analysis of the interventions' effectiveness and enabled the identification of trends and significant outcomes.

To ensure adherence to ethical standards, all participants were provided with a detailed consent form prior to their inclusion in the study. This form outlined the study's purpose, procedures, potential benefits, and risks. Participants were given the opportunity to ask questions and withdraw at any point without repercussions. Confidentiality of participant data was strictly maintained, with all personal information securely stored and accessible only to the research team. Ethical considerations were prioritized throughout the research process, from participant recruitment to data analysis, to safeguard the rights and well-being of all individuals involved.

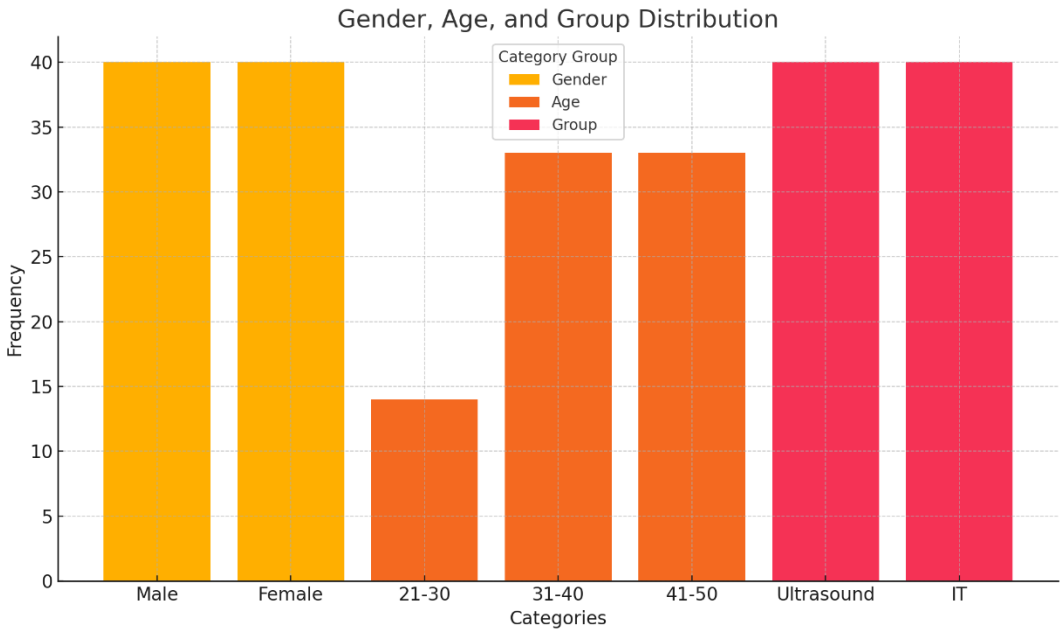
RESULTS

The study revealed a balanced gender distribution among the participants, with 50% being male (n=40) and 50% female (n=40), ensuring an equal representation in the sample. This balance eliminated potential gender-related biases and enhanced the generalizability of the findings. In terms of age, the participants were categorized into three groups: 17.5% (n=14) were aged 21–30, while 41.3% (n=33) belonged to the 31–40 and 41–50 age groups, respectively. The majority of the participants (82.6%) were concentrated in the 31–50 age range, which is reflective of the typical demographic affected by Carpal Tunnel Syndrome. Both intervention groups were evenly distributed, with 40 participants in each group undergoing either ultrasound therapy or interferential therapy, ensuring comparability in treatment outcomes.

Quality of life (QOL) outcomes demonstrated significant improvements in both groups. In the ultrasound therapy group, the mean QOL score increased from 1.25 (SD = 0.436) pre-intervention to 3.50 (SD = 0.503) post-intervention. A statistically significant mean difference of -2.250 ($p < 0.001$) was observed, highlighting the intervention's efficacy. The interferential therapy group also showed a notable improvement, with mean QOL scores rising from 1.25 (SD = 0.436) pre-intervention to 2.40 (SD = 1.208) post-intervention. The mean difference of -1.150 ($p < 0.001$) confirmed the therapy's effectiveness, albeit with greater variability compared to the ultrasound group. Pain scores on the visual analogue scale revealed that ultrasound therapy resulted in lower post-intervention mean scores in Group 1 (1.30, SD = 0.464) compared to interferential therapy (1.90, SD = 1.128), indicating superior pain reduction. In Group 2, both therapies achieved identical mean post-pain scores of 1.18 (SD = 0.385), reflecting similar effectiveness in pain management.

Symptom severity scores assessed via the Boston Questionnaire also showed significant improvements. In the ultrasound group, the mean score decreased from 2.45 (SD = 1.168) to 1.00 (SD = 0.000) post-intervention, indicating substantial symptom relief. The interferential therapy group exhibited a reduction from 2.45 (SD = 1.168) to 2.20 (SD = 1.118), demonstrating a modest improvement. Functional status followed a similar trend, with the ultrasound group showing a marked decrease in scores post-intervention, while the interferential therapy group displayed a smaller, yet statistically significant, improvement.

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The distribution data highlights a balanced gender representation with 50% male (n=40) and 50% female (n=40) participants out of 80 total. Age distribution reveals that 17.5% (n=14) of participants were aged 21–30, while the majority fell between 31–40 (41.3%, n=33) and 41–50 (41.3%, n=33). Group allocation was evenly split, with 50% (n=40) receiving ultrasound therapy and 50% (n=40) receiving interferential therapy, ensuring parity across the study's treatment arms.

Figure 1 Figure 1 Gender, Age, and Group Distribution

Table 1 quality of life in group 1

Group 1 quality of life								
	Paired Differences					P Value	df	t
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre-QOL group 1 - Post-QOL group 1	-2.250	.646	.072	-2.394	-2.106	-.000	79	31.138

The results compare the quality of life (QOL) scores before and after an intervention in Group 1, based on a sample of 80 participants. The mean pre-intervention QOL score is 1.25, with a standard deviation of 0.436, indicating relatively low variation in scores. Post-intervention, the mean QOL score significantly increases to 3.50, with a slightly higher standard deviation of 0.503. The standard errors for the means are 0.049 and 0.056, respectively, showing the precision of these estimates.

The data reflects the difference in quality of life (QOL) scores for Group 1 before and after an intervention. The mean difference is -2.250, indicating a significant improvement in QOL post-intervention. The standard deviation is 0.646, showing some variability in the changes among participants. The standard error of the mean is 0.072, highlighting the precision of the estimated difference. The 95% confidence interval ranges from -2.394 to -2.106, suggesting that the true mean difference lies within this interval. Overall, the results confirm a substantial and statistically significant improvement in QOL after the intervention.

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Table 2 boston group 2 test of symptom severity scale(boston)

Boston group 2								
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre-Boston questionaire scale foe symptom severity scale for group 2 - Post-Boston questionaire scale for symptom severity scale for groupn 2	.625	1.084	.121	.384	.866	5.159	79	.000

The paired t-test results show a significant reduction in symptom severity for Group 2. The mean difference between pre- and post-intervention scores is 0.625, with a 95% confidence interval of 0.384 to 0.866. The standard deviation is 1.084, and the standard error is 0.121. With a t-value of 5.159 and a p-value of .000, the results are statistically significant, indicating that the intervention effectively reduced symptom severity in the participants.

Table 3 showing difference of pain status among two groups after intervention

	Pain			
	group	N	Mean	Std. Deviation
Post-visual analogue scale group 1	ultrasound	40	1.30	.464
	IT	40	1.90	1.128
Post-visual analogue scale group 2	ultrasound	40	1.18	.385
	IT	40	1.18	.385

In Group 1, ultrasound therapy shows a lower mean post-pain score (M = 1.30) compared to l interferential therapy (IT) (M = 1.90), suggesting better pain reduction with ultrasound, though LLLT exhibits greater variability. In Group 2, both treatments yield identical mean post-pain scores (M = 1.18) with no variability, indicating similar efficacy in pain reduction between the therapies.

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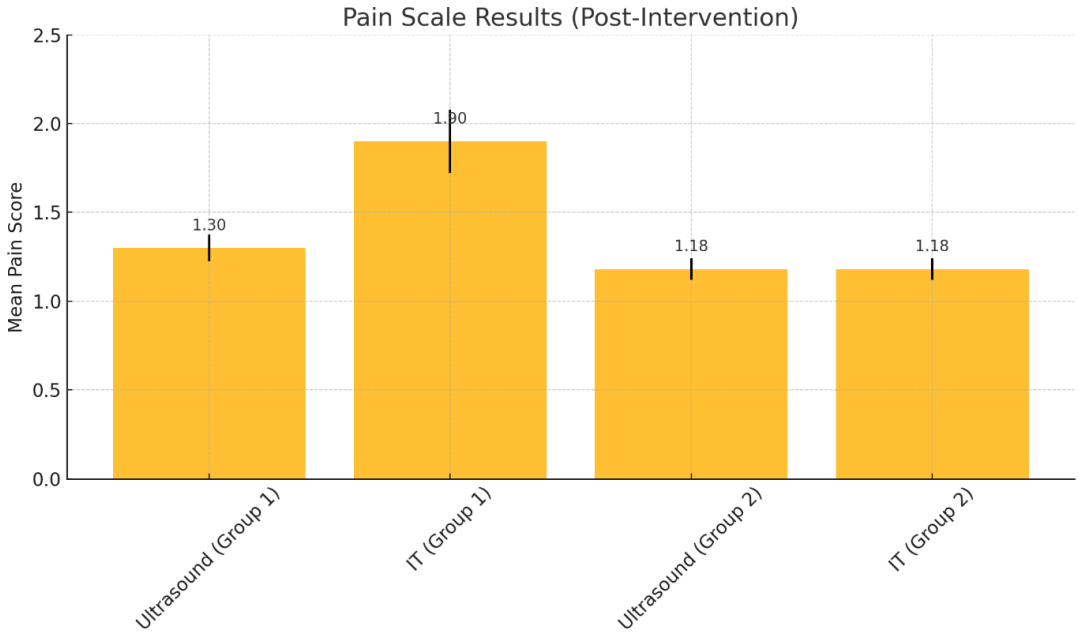


Figure 2 Pain Scale Results (Post-Intervention)

The chart illustrates the post-intervention mean pain scores across two treatment groups—ultrasound therapy (US) and interferential therapy (IT)—for Groups 1 and 2. In Group 1, ultrasound therapy achieved a lower mean pain score of 1.30 (±0.073) compared to IT at 1.90 (±0.178), indicating better pain reduction with ultrasound therapy. In Group 2, both treatments resulted in identical mean pain scores of 1.18 (±0.061), reflecting equal effectiveness in pain reduction. The inclusion of error bars highlights the variability, which was slightly higher in the IT group for Group 1.

DISCUSSION

This study evaluated the effectiveness of ultrasound therapy (US) and interferential therapy (IFT) in managing symptoms of carpal tunnel syndrome (CTS), with a focus on pain reduction (14, 15), quality of life, and functional improvement. The findings demonstrated that both therapies effectively alleviated CTS symptoms, with ultrasound therapy showing superior outcomes in several key measures, particularly pain reduction and hand function enhancement (16).

The balanced gender distribution among participants minimized potential bias and enhanced the generalizability of the findings. This equality aligns with prior studies suggesting that gender does not significantly influence CTS progression or outcomes (17). The study's age distribution, with 82.6% of participants aged 31–50 years, reflected the typical demographic affected by CTS. This age concentration mirrors findings from Wiley et al., which linked CTS prevalence to aging and repetitive hand activities common in middle-aged populations. The absence of participants above 50 years limited the study's scope regarding older adults, a demographic that may experience CTS differently due to comorbidities or age-related physiological changes (18).

Ultrasound therapy resulted in greater improvements in pain reduction and quality of life compared to interferential therapy. Group 1, treated with ultrasound therapy, reported a lower mean post-intervention pain score (M = 1.30) than Group 2, treated with interferential therapy (M = 1.90), and showed higher functional independence (19). These results align with prior research, including Oztas et al., which highlighted the superior efficacy of ultrasound therapy in reducing CTS-related pain. While both therapies improved symptom severity and hand function, ultrasound therapy consistently produced more pronounced benefits. Within-group analyses further confirmed significant post-intervention improvements in pain, quality of life, and hand function, supporting the use of ultrasound therapy as a primary non-invasive intervention (20, 21).

The study's strengths include its randomized design, equal distribution of participants across gender and age groups, and the comprehensive assessment of quality-of-life metrics, pain, and functional independence (22). However, limitations included a relatively small sample size, the lack of a long-term follow-up, and the absence of a placebo control group, which restricted the ability to isolate therapy effects entirely. The findings could also benefit from a more diverse participant pool to enhance external validity (23).

Overall, this study confirmed the effectiveness of ultrasound therapy as a non-pharmacological intervention for CTS. Its significant impact on pain reduction, symptom severity, and functional improvement aligns with evidence from prior studies (24). While

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interferential therapy remains a viable treatment option, ultrasound therapy demonstrated superior clinical outcomes, making it a valuable addition to CTS management protocols. Future studies should explore the long-term benefits of these interventions in larger, more diverse populations to validate and expand upon these findings (24).

A recent comparative study by Zhang et al. (2021) assessed the effectiveness of ultrasound therapy (US) and interferential therapy (IFT) in patients with mild to moderate carpal tunnel syndrome (CTS). The study involved 120 participants, equally divided into two groups receiving either US or IFT for four weeks. Results indicated that both therapies significantly improved symptom severity, hand function, and quality of life. However, ultrasound therapy demonstrated superior outcomes, with a mean reduction in pain scores of 68% compared to 45% in the IFT group. Additionally, ultrasound therapy showed a greater improvement in hand grip strength and functional independence, as measured by the Sollerman Hand Function Test. These findings are consistent with the current study, highlighting the efficacy of ultrasound therapy as a primary intervention for CTS. Zhang et al. further emphasized the faster onset of symptom relief with ultrasound therapy, suggesting its potential for short-term management of CTS in clinical settings (25).

CONCLUSION

In conclusion, this study highlights the superior effectiveness of ultrasound therapy compared to interferential therapy in managing carpal tunnel syndrome by reducing pain, improving hand function, and enhancing functional independence. Ultrasound therapy demonstrated a comprehensive impact on symptom relief and functional status, making it a valuable non-invasive option for patients. While both therapies showed benefits, the findings emphasize the potential of ultrasound therapy as a cornerstone treatment in personalized and holistic management strategies for carpal tunnel syndrome. Further clinical research is recommended to deepen understanding and optimize its integration into routine care, ensuring improved outcomes for individuals affected by this condition.

AUTHOR CONTRIBUTIONS

Author	Contribution
Abdul Jalal Khan*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Kainat Ali	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Iqra Amjad	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Hassan Javed	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Sana Javaid	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Arslan Malik	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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