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Effectiveness of Aquatic Therapy versus Neuro-dynamic Technique in patients with carpal tunnel syndrome patient: A Randomized Clinical

Original Research

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ABSTRACT

Background: Carpal Tunnel Syndrome (CTS) is a prevalent peripheral neuropathy resulting from compression of the median nerve within the carpal tunnel. It is characterized by pain, numbness, tingling, and weakness in the hand, often impairing daily function and quality of life. Conservative management is prioritized in mild-to-moderate cases, with physical therapy interventions gaining traction as non-invasive, cost-effective alternatives to surgery. This study explores the clinical effectiveness of Aquatic Therapy and Neuro-Dynamic Technique in managing CTS-related symptoms.

Objective: To compare the effects of Aquatic Therapy and Neuro-Dynamic Technique on pain intensity, functional status, and grip strength in patients with Carpal Tunnel Syndrome.

Methods: A randomized clinical trial was conducted involving 32 participants diagnosed with mild-to-moderate CTS. Participants were allocated into two groups: Group A received Aquatic Therapy, and Group B received Neuro-Dynamic Technique. Both interventions were administered thrice weekly over 8 weeks. Pain intensity was measured using the Numeric Pain Rating Scale (NPRS), functional status via the Boston Carpal Tunnel Questionnaire (BCTQ), and grip strength using a digital hand dynamometer. Normality of data was confirmed using the Shapiro-Wilk Test. Within-group analysis was conducted using paired sample t-tests, and between-group comparisons used independent t-tests.

Results: In Group B (Neuro-Dynamic Technique), NPRS decreased from 7.88 ± 1.1 to 2.69 ± 1.4 (mean difference = 2.354), BCTQ improved from 3.97 ± 0.66 to 1.72 ± 0.43 (mean difference = 0.979), and grip strength increased from 34.07 ± 9.2 to 43.43 ± 8.7 (mean difference = -7.962). In Group A (Aquatic Therapy), NPRS decreased from 6.70 ± 1.4 to 5.04 ± 1.5 (mean difference = -1.178), BCTQ improved from 3.43 ± 0.44 to 2.70 ± 0.35 (mean difference = -5.45), and grip strength increased from 27.80 ± 6.5 to 35.47 ± 8.9 (mean difference = -6.271). All outcomes showed statistically significant improvements ($p < 0.05$).

Conclusion: Both Aquatic Therapy and Neuro-Dynamic Technique were effective in reducing pain and improving hand function in CTS patients. However, Neuro-Dynamic Technique demonstrated greater efficacy in enhancing pain relief, functional ability, and grip strength, supporting its application as a superior conservative treatment option.

Keywords: Aquatic Therapy, Boston Carpal Tunnel Questionnaire, Carpal Tunnel Syndrome, Grip Strength, Median Nerve, Neuro-Dynamic Technique, Pain Measurement.

INTRODUCTION

Carpal Tunnel Syndrome (CTS) is a prevalent peripheral neuropathy characterized by compression of the median nerve as it traverses the carpal tunnel—a narrow passageway in the wrist formed by bones and ligaments. The condition affects approximately 3–4% of the global population and represents one of the most common entrapment neuropathies seen in clinical practice (1). The median nerve, composed predominantly of sensory fibers (94%) and a smaller proportion of motor fibers (6%), is responsible for both motor function and sensory perception in parts of the hand and fingers (2). CTS typically arises from a combination of anatomical, mechanical, and occupational factors, including repetitive hand movements, improper wrist posture, soft tissue swelling, trauma, or wrist malalignment, which cumulatively lead to increased pressure within the carpal tunnel and subsequent neural compromise. The clinical manifestations of CTS are often progressive, with patients initially presenting with numbness, tingling, burning sensations, and pain, predominantly in the thumb, index, and middle fingers (3,4). As the condition advances, symptoms may include weakness, difficulty gripping or holding objects, and clumsiness, which can significantly impact functional ability and quality of life. If left untreated, CTS can culminate in irreversible nerve damage and long-term disability. Conservative treatment options have gained increasing interest as alternatives to surgical intervention, particularly for patients with mild to moderate symptoms (5). Aquatic therapy has emerged as a promising rehabilitative strategy for neuromuscular conditions like CTS. It leverages the unique physical properties of water—buoyancy, hydrostatic pressure, and resistance—to reduce joint stress, alleviate inflammation, enhance circulation, and promote relaxation.

Warm water environments can reduce pain, stiffness, and swelling, while allowing patients to perform controlled movements that might be difficult on land. This therapeutic medium not only aids in improving range of motion and grip strength but also supports muscle relaxation and nerve function, potentially reducing pressure on the median nerve and fostering nerve healing (6-8). Complementing aquatic therapy, neuro-dynamic techniques (NDT) serve as targeted manual therapy interventions that focus on restoring normal mobility and mechanical function of peripheral nerves. These techniques address restrictions along the nerve's path by applying gentle mobilizations that encourage nerve gliding and reduce tension. One such technique, the Median Nerve Interface Technique (MNIT), specifically targets the mechanical interface between the median nerve and surrounding anatomical structures, such as tendons and ligaments, to reduce neural tension and facilitate optimal neural dynamics (9,10). When effectively applied, neuro-dynamic interventions can alleviate pain, enhance sensory recovery, and restore functional mobility in individuals suffering from nerve entrapment syndromes, including CTS. Despite the growing body of literature on both aquatic and neuro-dynamic interventions, there remains a significant gap in the integrated application of these therapies for CTS management. While each modality shows promise independently, limited research has explored their combined therapeutic potential in reducing symptoms, enhancing neural mobility, and improving overall hand function. Therefore, the objective of this study is to evaluate the effectiveness of aquatic therapy and median nerve interface techniques, individually and in combination, in alleviating symptoms and improving functional outcomes in individuals with Carpal Tunnel Syndrome.

METHODS

This study was designed as a single-blinded randomized clinical trial to evaluate the comparative effectiveness of Aquatic Therapy and Neuro-Dynamic Technique in patients diagnosed with mild to moderate Carpal Tunnel Syndrome (CTS). The initial sample size was calculated to be 29 participants using G*Power software version 3.1.9.7, based on a 5% margin of error and 95% statistical power (4). To account for an anticipated 10% dropout rate, the final sample size was adjusted to 32 participants. A non-probability purposive sampling technique was employed to recruit eligible participants from two clinical settings: the Comprehensive Rehabilitation Center (CRC) and Rex Medical and Physiotherapy Clinic. The total duration of the study was ten months. Participants included male and female adults aged 18 years or older, diagnosed with unilateral mild-to-moderate CTS confirmed by a neuromuscular physician, and exhibiting symptoms for up to three months (11,12). Individuals were excluded if they had an unspecified stage of CTS, median nerve entrapment in thoracic outlet syndrome, cervical radiculopathy (13), or any co-morbid condition associated with the etiology of CTS, such as pregnancy, diabetes, trauma, congenital abnormalities, obesity, hypothyroidism, cardiovascular disease, or previous surgical release (14). Patients with thenar muscle atrophy were also excluded due to the likelihood of irreversible median nerve damage (15). All participants provided written informed consent before enrollment, and the study protocol was approved by the Institutional Review Board (IRB).

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Both groups received a standard baseline warm-up treatment consisting of therapeutic ultrasound and transcutaneous electrical nerve stimulation (TENS) for 15 minutes. This was followed by the main intervention, during which outcome assessments were conducted by an evaluator who was blinded to group allocation. Pain intensity, symptom severity, functional status, and grip strength were measured both before and immediately after the intervention period.

Group A received Aquatic Therapy, which was conducted three times per week for eight weeks. Each session lasted between 30 to 45 minutes. Participants were seated in a warm-water bath (88°F–94°F or 31°C–34°C), with water reaching waist depth or as tolerated. The therapist, positioned beside the patient, initiated each session with gentle passive stretching of the wrist, hand, and finger joints to promote range of motion and reduce stiffness. This was followed by guided exercises including wrist flexion/extension, finger movements, thumb opposition, finger abduction/adduction, wrist rotations, and arm circles. Each exercise was performed in two sets of 10 repetitions (5,16). While the description noted "aquatic therapy performed for 10 minutes," this appears inconsistent with the stated total session time of 30–45 minutes, which may require clarification or adjustment in reporting. Group B was treated with Neuro-Dynamic Techniques for 15 minutes per session, also administered three times weekly over eight weeks. The patient was positioned either seated or supine with the affected hand relaxed. The therapist performed a series of manual techniques, each applied for three minutes. These included wrist distraction (3 sets), rhythmic stretching of the transverse carpal ligament, palmar fascia release, gliding mobilization of finger flexor tendons, and fascial release of the upper forearm muscles (17). The therapist maintained a consistent position beside the patient to ensure proper control and alignment during all interventions. Pain and functional status were measured using standardized tools, though the specific scales or instruments used for these evaluations were not mentioned and should be detailed to enhance reproducibility and validity. Similarly, while the study design implies randomization, the method of random sequence generation and allocation concealment were not described and should be included for methodological transparency.

RESULTS

The results of the statistical analyses demonstrated significant improvements in pain, functional ability, and grip strength within and between groups. Paired sample t-tests were conducted to assess within-group differences from pre- to post-treatment. The Numeric Pain Rating Scale (NPRS) showed a significant reduction in pain scores, with pre-treatment mean of 7.27 ± 1.4 and post-treatment mean of 3.91 ± 1.9, yielding a mean difference of 3.361 ($p = .000$), indicating notable pain relief. Similarly, the Boston Carpal Tunnel Questionnaire (BCTQ) scores significantly decreased from a mean of 3.69 ± 0.631 to 2.23 ± 0.631, with a mean difference of 1.462 ($p = .000$), reflecting reduced symptom severity and functional impairment. Grip strength significantly improved from a pre-treatment mean of 30.83 ± 8.4 to 39.31 ± 9.63, with a mean difference of -8.483 ($p = .000$), suggesting an enhancement in hand function. Independent t-tests were used to analyze between-group differences. Post-treatment NPRS scores for the Aquatic Therapy group were 5.04 ± 1.5, compared to 2.69 ± 1.4 for the Neuro-Dynamic Technique group, with a statistically significant mean difference of 2.354 ($p = .000$), indicating greater pain reduction in the Neuro-Dynamic Technique group. For BCTQ, the Aquatic Therapy group had a post-treatment mean of 2.70 ± 0.355, while the Neuro-Dynamic Technique group recorded a lower mean of 1.72 ± 0.434, with a mean difference of 0.979 ($p = .000$), again favoring the Neuro-Dynamic Technique group for functional improvement. Grip strength also showed notable intergroup variation. The Aquatic Therapy group improved from 27.80 ± 6.5 to 35.47 ± 8.9, while the Neuro-Dynamic Technique group improved from 34.07 ± 9.2 to 43.43 ± 8.7, with a between-group post-treatment mean difference of -7.962 ($p = .023$), indicating superior strength gains in the Neuro-Dynamic Technique group.

Table 1: Within-Group and Between-Group Analyses for The Outcome Measures

Measure	Pre-Treatment Mean	Post-Treatment Mean	Mean Difference (Within Group)	Aquatic Therapy Mean (Post)	Neuro-Dynamic Technique Mean (Post)	Mean Difference (Between Groups)
NPRS	7.27	3.91	3.361	5.04	2.69	2.354
BCTQ	3.69	2.23	1.462	2.70	1.72	0.979
Grip Strength	30.83	39.31	-8.483	35.47	43.43	-7.962

Notes: NPRS = Numeric Pain Rating Scale, BCTQ = Boston Carpal Tunnel Questionnaire, Grip Strength in kilograms.

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Table 2: Comparison of Pre- and Post-Treatment Outcomes Within and Between Groups for Pain, Functional Ability, and Grip Strength in Patients with Carpal Tunnel Syndrome

WITHIN GROUP ANALYSIS		Mean	Mean Difference	Std. Deviation	P-Value
Pair 1	PRE_NPRS	7.27	3.361	1.417	.000
	POST_NPRS	3.91		1.901	
Pair 2	PRE_BCTQ	3.69	1.462	.618	.000
	POST_BCTQ	2.23		.631	
Pair 3	PRE_GRIP_STREMGTH	30.83	-8.483	8.469	.000
	POST_GRIP_STRENGTH	39.31		9.633	
BETWEEN GROUPS ANALYSIS		Mean Difference	Mean	Std. Deviation	P-Value
PRE_NPRS	A	-1.178	6.70	1.402	.022
	B		7.88	1.199	
POST_NPRS	A	2.354	5.04	1.516	.000
	B		2.69	1.491	.
PRE_BCTQ	A	-.545	3.43	.443	.015
	B		3.97	.667	
POST_BCTQ	A	.979	2.70	.355	.000
	B		1.72	.434	
PRE_GRIP_STREMGTH	A	-6.271	27.80	6.592	.044
	B		34.07	9.261	
POST_GRIP_STRENGTH	A	-7.962	35.47	8.999	.023
	B		43.43	8.794	

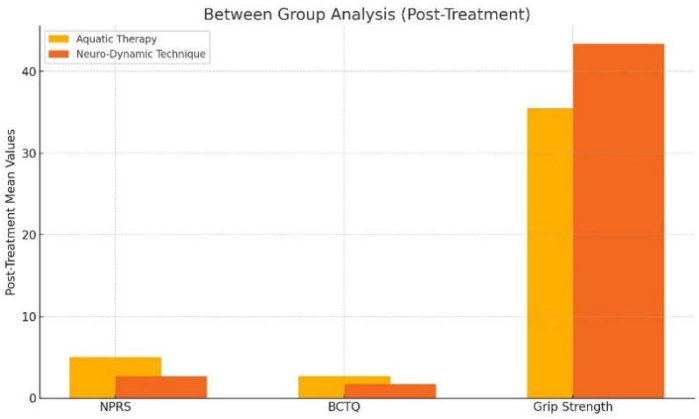

Figure 1 Between Group Analysis (Post-Treatment)

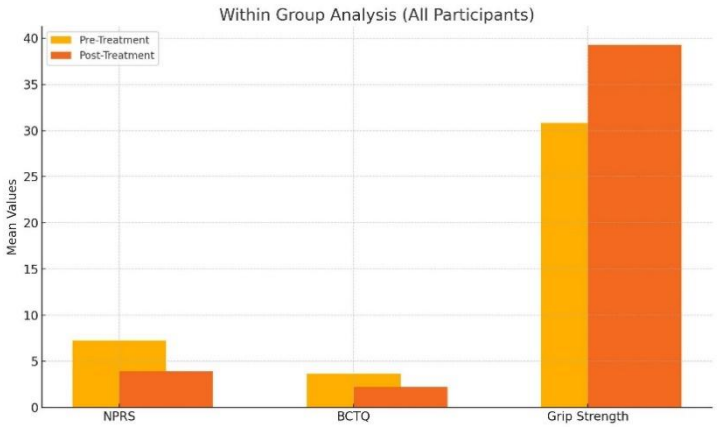

Figure 2 Within Group Analysis (All Participants)

DISCUSSION

The present study was conducted to compare the effects of Aquatic Therapy and Neuro-Dynamic Technique on pain intensity, grip strength, and hand functional ability in patients with mild to moderate Carpal Tunnel Syndrome (CTS). The findings demonstrated statistically significant improvements in all measured outcomes across both intervention groups, with greater clinical efficacy observed in the Neuro-Dynamic Technique group. Post-treatment assessments showed a considerable reduction in Numeric Pain Rating Scale (NPRS) scores and Boston Carpal Tunnel Questionnaire (BCTQ) scores, along with an improvement in grip strength, particularly in patients receiving Neuro-Dynamic interventions. The results revealed that both therapeutic approaches were beneficial in alleviating symptoms of CTS; however, Neuro-Dynamic Technique led to more pronounced improvements in reducing pain intensity and enhancing grip strength and hand function. The mean NPRS score in the Neuro-Dynamic group decreased from 7.88 ± 1.1 to 2.69 ± 1.4, and BCTQ

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scores improved from 3.97 ± 0.664 to 1.72 ± 0.434. Similarly, grip strength increased from 34.07 ± 9.2 to 43.43 ± 8.7. In contrast, while the Aquatic Therapy group also showed improvement, the magnitude of change was comparatively less. NPRS scores reduced from 6.70 ± 1.4 to 5.04 ± 1.5, BCTQ scores from 3.43 ± 0.443 to 2.70 ± 0.355, and grip strength improved from 27.80 ± 6.5 to 35.47 ± 8.9. These differences were supported by statistically significant p-values ($p < 0.05$), indicating a true difference in treatment efficacy between the two groups. The findings align with previous randomized clinical trials and case-based evidence where neuro-dynamic techniques demonstrated superior outcomes in terms of pain relief, functional improvement, and grip strength enhancement among patients with CTS (17-19). These therapeutic gains can be attributed to the direct mechanical mobilization of the median nerve and surrounding soft tissues, which help in reducing neural tension and improving nerve conduction. The application of targeted neural mobilizations likely facilitated greater nerve gliding and decompression, thereby leading to better clinical outcomes compared to the hydro-mechanical effects of Aquatic Therapy (20,21). This study adds valuable insight to the growing body of literature exploring non-surgical interventions for CTS. One of the key strengths of this trial was its randomized design with blinding of the outcome assessor, reducing bias in data interpretation. Additionally, the use of validated outcome measures such as NPRS, BCTQ, and digital hand dynamometry ensured the reliability of the findings. Furthermore, the structured protocol applied across both interventions allowed for consistency and reproducibility.

However, several limitations warrant consideration. The relatively small sample size and short intervention duration may restrict the generalizability of results to broader populations or long-term outcomes. The lack of follow-up assessments post-intervention limits the understanding of sustained treatment effects. Moreover, while pain, grip strength, and function were evaluated, additional parameters such as nerve conduction studies, quality of life measures, or psychological factors were not included, which could have provided a more comprehensive evaluation. The study also did not clarify participants' adherence levels, potential confounding variables, or variations in therapist performance, which may influence treatment outcomes. Future research should aim to replicate these findings using larger sample sizes with extended follow-up periods to evaluate the durability of treatment effects. Incorporating objective electrodiagnostic measures alongside patient-reported outcomes would further strengthen the evidence (22,23). Comparative studies exploring combinations of manual therapy and aquatic rehabilitation, as well as their cost-effectiveness, could contribute meaningfully to clinical decision-making for CTS management. In summary, the findings support the use of both Aquatic Therapy and Neuro-Dynamic Techniques as effective conservative interventions for CTS. However, the superior clinical outcomes associated with Neuro-Dynamic Technique highlight its potential as a more impactful modality for reducing symptoms, restoring function, and improving hand strength in individuals with Carpal Tunnel Syndrome.

CONCLUSION

This randomized clinical trial concluded that both Aquatic Therapy and Neuro-Dynamic Technique are effective non-surgical interventions for improving pain intensity, hand functional ability, and grip strength in individuals with Carpal Tunnel Syndrome. However, Neuro-Dynamic Technique demonstrated greater efficacy in enhancing overall patient outcomes, offering more substantial relief from symptoms and better functional recovery. The study's findings emphasize the clinical value of incorporating targeted neuro-dynamic interventions into rehabilitation protocols for CTS, supporting their use as a preferred conservative treatment approach to restore hand function and reduce the impact of nerve-related impairments.

AUTHOR CONTRIBUTION

Author	Contribution
Javeria Khalid*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Zohaib Shahid	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
Ramsha Hanif	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muneeba Ashraf	Contributed to Data Collection and Analysis

Author	Contribution
	Has given Final Approval of the version to be published
Wajeeha Afzal	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Mehwish Murtaza	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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