Accepted Manuscript (Uncorrected Proof)

Title: Neurodynamic and Wrist Glide Exercises on the Functionality and Severity of Symptoms on Patients with Mild to Moderate Carpal Tunnel Syndrome: A Quasi-Experimental Study

Authors: Omar Amro[1], Azzam Alarab[1,*], Mohammad AL-Talahma[2]

1. *Department of Physiotherapy, Faculty of Post Graduated Studies and Research, Palestine Ahliya University, Bethlehem, Palestine.*
2. *Department of Anatomy, Faculty of medicine, Palestine Polytechnic University, Hebron, Palestine.*

To appear in: ***Physical Treatments***

Received date: 2025/01/22

Revised date: 2025/08/19

Accepted date: 2025/08/25

First Online Published: 2025/09/15

Please cite this article as:

Amro O, Alarab A, AL-Talahma M. Neurodynamic and Wrist Glide Exercises on the Functionality and Severity of Symptoms on Patients with Mild to Moderate Carpal Tunnel Syndrome: A Quasi-Experimental Study. ***Physical Treatments.*** Forthcoming 2026. DOI: http://dx.doi.org/10.32598/ptj.2026.670.7

DOI: http://dx.doi.org/10.32598/ptj.2026.670.7

Abstract

Objectives: The study was conducted to assess the effects of neurodynamic wrist exercises and wrist glide exercises on symptoms severity, range of motion (ROM), grip strength, and hand function in adults diagnosed with mild to moderate CTS.

Methods: A quasi-experimental study with a pre-post intervention design was carried out in a sample of thirty adult patients with mild to moderate CTS occurring on 50 hands that fulfilled the inclusion criteria. The subjects were separated into two intervention groups and one set of them received neurodynamic nerve gliding exercises, and the other group did wrist glide exercises. It took place during four weeks. The Visual Analog Scale (VAS) to measure the intensity of pain, Boston Carpal Tunnel Questionnaire (BCTQ) and Symptom Severity Scale (SSS) and Functional Status Scale (FSS) to assess pain and functional and symptomatic outcome, grip strength, and the wrist ROM were used to assess the pain and functional and symptomatic outcome before and after the intervention. With this design, there were within-group and between-group comparisons aimed at determining the effectiveness of both interventions.

Results: The results indicated a significant decrease in pain levels, shown by the average VAS scores dropping from 7.20 to 2.64 after the intervention. The average grip strength had a significant increase, rising from 227.2 Newtons to a level exceeding 310 Newtons. The SSS and FSS scores shown significant enhancement, with the SSS decreasing from 3.11 to 1.98 and the FSS decreasing from 3.10 to 1.96. The ROM for wrist movements also demonstrated significant improvements. Flexion increased from 71.24 to 76.84 degrees, while extension increased from 72.68 to 77.62 degrees. Significant improvements were observed in ulnar and radial deviations, as well as thumb flexion and abduction.

Discussion: Neurodynamic wrist and gliding exercises markedly alleviated symptoms in individuals with mild to moderate carpal tunnel syndrome, diminishing pain, augmenting grip strength, and enhancing range of motion, particularly in the thumb.

Keywords: Carpal Tunnel Syndrome, Nerve Gliding Exercises, Physiotherapy, Hand Function, Non-Surgical Treatment, Symptom Severity

Highlights

Regular neurodynamic wrist and gliding movements produced strong symptom relief for people who had mild CTS. Patients with carpal tunnel syndrome felt less pain and strengthened their grip while their thumbs moved more easily. Measuring improvements using both the SSS and FSS tests confirmed that these treatments worked very well without surgery. The analysis needs more extensive research because its limited participant number and no lasting outcomes make it essential to test these treatments across larger communities over time.

Plain Language Summary

CTS becomes the number one nerve compression issue worldwide and doctors usually treat it through surgery which wastes money and may put patient health at risk. This research evaluates how physiotherapy exercises including neurodynamic and wrist glide movements improve symptoms and hand performance for CTS patients without surgery. Researchers assessed various parameters, including pain levels, hand strength, wrist mobility, and daily hand function, both prior to and following the intervention. The results after four weeks were promising: Participants showed better pain control as their pain scores dropped from 7.2 to 2.6 on the scale of 10. Increased Grip Strength: Most gripping strength increased from 227 to over 310 Newtons. Enhanced Hand Function: Participants showed close to 50% better results on scales measuring their symptom intensity and ability to do tasks normally. Improved Wrist Mobility: Regularized exercise increased shoulder and thumb movements which can benefit people with CTS who want non-medical pain relief and hand function recovery.

Introduction

Sir James Paget described carpal tunnel syndrome (CTS) in 1854 and it was later named by Moersch in 1938. It is the outcome of a compression of the median nerve in traveling through the carpal tunnel, resulting into clinical manifestations that comprise numbness, tingling and feeble hand. Russian et al. (2021) indicate that the main pathological mechanism is mechanical compression that is often worsened by repetitive movements of the wrist, as well as genetic predisposition. In non-occupational cases, nerve irritations could also occur due to factors like the position of the body during sleep, changes in hormone level and the overall systemic conditions. The risk factors commonly associated with CTS include the use of the hand repetitively, variations in anatomy of the wrist, and systemic disorders such as diabetes mellitus and rheumatoid arthritis that expose them to the occurrence of problems in the median nerve due to compression. Idiopathic CTS without a definable cause has been addressed in classic literature as appearing possibly associated with IAPTPs such as tenosynovitis or repetitive computer use; however, contemporary research suggests more pessimistic perspective on these supposed correlations [12].

CTS is also a common condition that varies within 4 percent to 5 percent of the worlds population, and women have a higher prevalence rate of 3.1 percent, as compared to the prevalence in men which is 2.6 percent [3]. The prevalence rate is estimated between 3.72-7.8 and incidence reported as 2.3 to 227.2 per 100,000 person-years and depends on the demographic and occupational factors [4]. Of clinical interest, CTS is divided into three stages: stage 1 (contains mild symptoms, numeracy numbness and swelling of the hand), stage 2 (contains enduring symptoms, aggravated by repetitive action) and stage 3 (contains painful symptoms and loss of using the arm effectively) [5,6]. It is diagnosed based on justification by the history of the patient, physical examination, and confirmation by nerve conduction studies, EMG (electromyography) and ultrasound of the neuromuscular areas [8,9].

The physiotherapists are a very important part of maintaining mild to moderate CTS through conservative treatment. The typical interventions are splinting, therapeutic ultrasound, soft tissue mobilization, carpal bone manipulations, and tendon and nerve gliding, including neurodynamic exercises [8]. Surgery, or surgical decompression, can be warranted in case of chronic or severe cases of CTS that were unable to respond to conservative management options, but is usually thought to be a last resort, because of possible post-operative issues [9].

There is an increasing amount of evidence that neurodynamic exercises and nerve gliding exercises can be effective in symptomatic relief of CTS but the study is still scarce, especially in combination of neurodynamic wrist mobilizations with wrist glide exercises. Additional research is required to assess whether these conservative methods can lead to better results as a non-surgical option in the area of symptom improvement and hand functions.

Consequently, the study was intended to determine how neurodynamic exercises of the distal wrist and exercises of the glide of the wrist intended to reduce the severity of symptoms, the range of motion (ROM) of the wrist, the grip strength and the hand functioning of patients with mild and moderate carpal tunnel syndrome (CTS) and gauging such effect on the three sets of exercises taken together as a therapeutic measure should be profiled.

Methods

A quasi-experimental study was carried out to check the efficacy of neurodynamic wrist and wrist glide exercises on symptoms of CTS and hand function of patients suffering CTS. The study was done in Raheem Physiotherapy Center, Hebron and Al Abeer Center of Physiotherapy and Rehabilitation, Dura, Palestine.

It was planned that 30 persons with mild to moderate CTS (including bilateral symptoms in some) aged 18-75 years will be enrolled in two centers between November 2023 and May 2024 and will yield 50 cases. The sample was chosen through convenient purposive sampling since the study involved particularly set inclusion criteria, one of which was the clinical CTS diagnosis based on the symptoms and the diagnostic tests, such as nerve conduction study or EMG. Severe CTS, history of prior surgery of the wrist and other health complications of the upper extremity were regarded as exclusion criteria. The sample size of 30 participants (50 affected hands) was considered manageable in terms of resource constraint, which is not formally powered (i.e., via a power analysis e.g. GPower software) to warrant the statistical sufficiency of the sample, which constrains the robustness of generalizability and inference generally.

The choice of study design lacked a control group, a familiar limitation of quasi-experimental designs and a limitation to reaching substantial causal inferences. This problem was discussed in the discussion section though it is significant to mention here as the methodological limitation. Additionally, neither of the outcome assessors was blinding the trials, and participants were not blinding, which results in high chances of bias especially in the outcome subjective ones including pain intensity (VAS) and self-reported function (BCTQ).

Inclusion criteria include: adults 18 years and above, gender: male and females, mentally capable of understanding and obeying simple verbal orders or commands, patients who have never had any surgical intervention process against CTS, those patients who have not had any form of recent intervention with regards to CTS, and can sign informed consent to participate in the research.

The exclusion criteria include the patients having severe symptoms of CTS, the patients having other underlying neurological condtion that can affect the functioning of hands or cause other similar issues, pregnant patients, patients with previous traumas and injuries of the wrists and hands that can affect the exercise efficiency, patients experiencing severe cognitive impairments/communication difficulties that would prevent them completing the exercise protocol, patients with any contraindications or medical conditions that would render the exercises unsafe or inappropriate to the patient, and patients who are not willing to participate in the necessary assessments and evaluations required by the study.

Tools

Phalen Test: The test is said to be most popular in diagnosing CTS, and it is conducted by bringing the hands in a dorsal position with elevated elbows that are at chest level and it takes at least 60 seconds. Positives are tingling, numbness, or sensation of a certain type of pain in particular fingers, which is a symptom of CTS. Most medical experts also indicated that the diagnostic accuracy of this test is 93.6 percent, with a sensitivity of 84.6 percent and a specificity of 100 percent thus making it a very useful diagnostic procedure [10].

Reverse Phalen Test: This is also the same except that the palms are pressed together, the elbows are turned outward, and the hands moved toward middle of the body, held in 60 seconds. Any good response such as tingling, numbness in fingers or uneasiness indicates CTS. It is a test whose sensitivity is 56 percent which gives it extra diagnostic measure as well as during Phalen test [11].

Tinel Sign: This is performed by tapping up the median nerve whilst placing the palm of the patient upward. Numbness, tingling, or pain are positive outcomes, which indicate the presence of

CTS. The test is sensitive (49-84) and specific (95-99) which proves the usefulness of the diagnostic test [12].

Median Nerve Compression Test: This test involves the examiner putting light pressure on the carpal tunnel of the patient and the wrists are held in a neutral position and the substrate is put in place and maintained thus shoving the procedure within 30 seconds. It is considered as one of the most sensitive and specific provocative tests of CTS with sensitivity of 87 and specificity of 90 [13].

Hand Grip Strength (HGS): HGS is a crucial indicator of the upper limb muscular activity. The participants were seated with the back of the feet resting and shoulders in the neutral position. Three trials of gripping were conducted (a measurement by Jamar hand dynamometer) and done with a period of 15 seconds, both pre and post-intervention. The sensitivity of HGS is reported to be 78-95 percent in detecting CTS and its specificity rises to 94 percent [14].

Pain Assessment: The degree of pain was quantified with Visual Analog Scale (VAS) by gauging 10-cm horizontal line or vertical, and 0 translated to zero pain and 10 translated to the worst pain possible to imagine. VAS is a reliable and valid instrument that is well adopted in clinical practice and research [15].

Boston carpal tunnel questionnaire (BCTQ): A scale designed to measure the severity of symptoms and also the functional status in patients with CTS this was developed in 1993. It has two subscales namely the Symptom Severity Scale (SSS) and the Functional Status Scale (FSS) each of which has a Likert-scale score of between 1 and 5. It is widely applied in clinical trials in order to assess the results of treatments [16].

Movement/ Flexibility (ROM): ROM of the wrist and the thumb was assessed before and after the intervention. The wrist kinematics were flexion (80 o/90 o /), extension (70 o /90 o /), radial deviation (15 o /) and ulnar deviation (30 o /45 o /). ROM of the thumb was flexion (45 o to 50 o), extension (30 o), and abduction (60 o to 70 o). Every movement was taken in triplicate and averaged out [17].

Intervention Protocol: The neurodynamic and wrist glide exercises had an intervention protocol where therapeutic procedures were done on patients with limited CTS. The intervention contained median nerve neurodynamic mobilizations and wrist gliding movements, which were carried out in recessive, gradual stages. The exercises were directed by a qualified physiotherapist. They took place three times a week during six weeks. The number of sets per exercise was 3 sets of 10 repetitions, and the rest periods after a set took 30 seconds. The criteria of progression was regularised on the basis of patient tolerability and decrease in the severity of the symptoms, being adjusted weekly by the therapist. These sets of exercises were to provide restoration of mobility in the median nerve, to decrease the intraneural edema, as well as overall improvement in the functioning of the wrist and hand [8].

Data Collection

A number of participants were chosen using inclusion/exclusion criteria verified by an examination of symptomatology and diagnostic procedures, including nerve conduction studies and electromyography. The tests were the Visual Analog Scale (VAS), Phalen, Reverse Phalen, Tinel, Boston Carpal Tunnel Questionnaire (BCTQ), and wrist and thumb ROM and Hand Grip Strength (HGS) and the pre and post evaluations were taken. Before undergoing the research, all the participants were given adequate information and signed an informed consent. The four weeks were used as the duration of the intervention where participants received two sessions of physiotherapy every week. Nonetheless, this section does not elaborate the particular exercise protocol such as what kind, what number, how long, and how progress and improvement of neurodynamic and wrist glide exercises are performed. To ensure improved clarity and the possibility of replication, it would be advisory to show the exercise protocol in a supplementary table or appendix (e.g. in Appendix 1).

Statistical Analysis

Paired t-tests were applied to calculate statistical results between pre and post outcome. Nonetheless, the assumptions of normality (e.g. ShapiroWilk test) and homogeneity of variances (e.g. Levene test) were not provided, which is necessary to justify the parametric tests. Also the usually reported effect sizes, e.g. the 5.7-point reduction on the VAS, have to be interpreted carefully, as it might be biased by measurement, the absence of blinding, or by the relatively short follow-up period. They ought to be followed by calculations of the effect size (e.g. Cohen d) to clarify the meaning of the findings in the clinical context.

Results

The study involved 30 patients diagnosed with CTS, with a nearly equal gender distribution (52% male, 48% female). A majority of participants (76%) were employed, and 84% were right-handed. Both unilateral and bilateral CTS cases were included in the analysis, with each affected hand analyzed separately. This approach is commonly used in similar clinical studies and allows for a more comprehensive assessment of intervention outcomes across all treated hands.The average age was 32.34 years, with a mean height of 169 cm, weight of 74.81 kg, and a Body Mass Index (BMI) of 25.97 [Table 1].

Table 1: Participants' demographic characteristics

Variable	Minimum	Maximum	Mean ± SD
Age	23	57	32.34 ± 8.29
Height (Cm)	147	186	169.08± 9.32
Weight (Kg)	54	105	74.18 ± 12.81
BMI	18.51	35.34	25.97 ± 4.03

SD: Standard Deviation; BMI: Body Mass Index

Post-intervention, the Phalen test showed that 10% of patients still had positive CTS symptoms, while 90% tested negative. The Reverse Phalen test showed all patients negative for symptoms. Tinel's test revealed 6% with positive symptoms, and 94% tested negative. Additionally, 58% of participants reported symptoms in their right hand, while 42% had symptoms in their left hand.

McNemar's test revealed statistically significant reductions in positive results for all three diagnostic tests following the intervention ($p < 0.001$), indicating strong evidence of symptom improvement.

The results in Table 2 confirms that neurodynamic wrist exercises are highly effective in reducing CTS symptoms. The average Visual Analog Scale (VAS) score dropped from 7.20 to 2.64, indicating a significant pain reduction. This decrease was statistically significant ($p < 0.001$) and therapeutically meaningful, with a high effect size of 0.71, demonstrating strong statistical power for detecting the effects of the intervention in this 30-participant study.

Table 2: Comparison between pre- and post VAS score.

	Pre- treatment		**Post-treatment**		**Effect Size**	**P- value ***
	Mean ± SD	95% CI	**Mean ± SD**	95% CI		
VAS	7.20 ± 0.76	6.93 to 7.47	2.64±0.77	2.36 to 2.92	0.71	<0.001

VAS: Visual analog scale, SD: Standard deviation, significant statistic difference ($p < 0.05$), * Paired sample test

Grip strength analysis using a paired t-test showed a significant improvement post-intervention. Before the intervention, the average grip strength was 227.2 Newtons, which increased to over 310 Newtons afterward. This improvement was statistically significant ($p = 0$) and functionally meaningful, with a significant effect size of 0.65. The results confirm that the intervention effectively enhanced grip strength and overall physical function in CTS patients [Table 3].

Table 3: Comparison between pre and post hand grip strength scores

Group	**Pre- treatment**		**Post-treatment**		**Effect Size**	**P- value ***
	Mean ± SD	95% CI	**Mean ± SD**	95% CI		
Grip strength (Newton)	227.20 ± 78.94	198.95 to 255.45	310.0± 72.50	284.06 to 335.94	0.65	<0.001

SD: Standard deviation, significant statistic difference ($p < 0.05$), * Paired sample test

Table 4 shows significant improvements in both the Symptom Severity Scale (SSS) and Functional Status Scale (FSS) after the intervention, with p-values <0.001. The average SSS score decreased from 3.11 pre-treatment to 1.98 post-treatment, indicating reduced symptom severity. Similarly, the FSS score improved from 3.10 to 1.96, reflecting enhanced functional status. These results demonstrate the effectiveness of the therapeutic intervention in reducing symptoms and improving function, supported by effect sizes of 0.75 for SSS and 0.66 for FSS.

Table 4: Means of pre and post symptom severity and functional status scores

	Pre- treatment		**Post-treatment**		**Effect Size**	**P- value***
	Mean ± SD	95% CI	**Mean ± SD**	95% CI		
BCTQ-SSS	3.11± 0.38	2.97 to 3.25	1.98± 0.31	1.87 to 2.09	0.75	<0.001*
BCTQ-FSS	3.10± 0.40	2.96 to 3.24	1.96± 0.35	1.83 to 2.09	0.66	<0.001*

SD: Standard deviation; SSS: symptom severity scale; FSS: functional status scale; BCTQ: Boston Carpal Tunnel Syndrome Questionnaire, significant statistic difference ($p < 0.05$), *Paired sample test

Table 5 shows significant improvements in wrist range of motion (ROM) after the intervention. Flexion increased from 71.24° to 76.84° (p = 0.001, effect size = 0.52), extension from 72.68° to 77.62° (p = 0.001, effect size = 0.51), ulnar deviation from 28.04° to 30.74° (p = 0.001, effect size = 0.71), and radial deviation from 19.82° to 22.26° (p = 0.001, effect size = 0.67). These results demonstrate the efficacy of the intervention in improving wrist ROM and functional outcomes in CTS patients. [Table 5].

Table 5: Comparison between pre- and post-range of motion (flexion, extension, Ulnar deviation, Radial deviation) of the wrist.

	Pre- treatment		Post-treatment		Effect Size	P -value *
	Mean ± SD	95% CI:	**Mean ± SD**	95% CI:		
Flexion	71.24 ± 4.54	69.62 to 72.86	76.84±2.21	76.05 to 77.63	0.52	<0.001
Extension	72.68 ± 10.17	69.04 to 76.32	77.62±1.80	76.98 to 78.26	0.51	0.001
Ulnar deviation	28.04± 4.02	26.60 to 29.48	30.74±2.53	29.83 to 31.65	0.71	<0.001
Radial deviation	19.82 ± 2.60	18.89 to 20.75	22.26±2.22	21.47 to 23.05	0.67	<0.001

SD: Standard deviation, significant statistic difference ($p < 0.05$), * Paired sample test

The study, as shown in Table 6, revealed significant improvements in thumb range of motion (ROM) after therapy for CTS patients. Flexion ROM increased from 54.16° to 56.66° ($p = 0.039$, effect size = 0.40), extension ROM from 13.2° to 13.76° ($p = 0.009$, effect size = 0.41), and abduction ROM from 42.82° to 44.00° ($p = 0.001$, effect size = 0.56). These improvements suggest enhanced thumb mobility, reducing discomfort and improving functional capabilities, particularly for tasks requiring flexion, extension, and abduction.

Table 6: Comparison between pre- and post-range of motion (flexion, extension, abduction) of the thumb.

	Pre- treatment		Post-treatment		Effect Size	P -value *
	Mean ± SD	95% CI	**Mean ± SD**	95% CI		
Thumb flexion	54.16 ± 2.62	53.22 to 55.10	56.66±2.88	55.63 to 57.69	0.40	0.039
Thumb extension	13.20 ± 1.80	12.56 to 13.84	13.76±1.70	13.15 to 14.37	0.41	0.009
Thumb abduction	42.82± 4.02	41.38 to 44.26	44.00±2.70	43.03 to 44.97	0.56	<0.001

SD: Standard deviation, significant statistic difference ($p < 0.05$), * Paired sample test

Discussion

Carpal Tunnel Syndrome (CTS) can be explained with a compressed median nerve in the wrist (usually as a result of repetitive movements of the hands, physical traumas, or oedema near the nerve). Pains, numbness, and tingling of the thumb, index finger, middle finger, and the half of the ring finger are present. Although CTS cannot be considered primarily as a disorder of the mind, it still may lead to secondary problems in the form of nighttime sleep difficulties, anxiety, and frustration with difficulty in performing daily activity. This underscores the care that should be taken to intervene early in diagnosis and management in order to minimize the effects (both mental as well as physical).

The purpose of the present study was to assess the effectiveness of neurodynamic wrist exercises implemented together with the exercises of wrist glide in improvement of symptoms and hand function in patients with mild to moderate CTS.

Of the 50 screened patients, 30 subjects were admitted according to specified inclusion and exclusion criteria. Statistically significant improvements in important outcome measures were demonstrated after the intervention (reductions in pain intensity, VAS, $p < 0.001$, increases in grip strength, $p = 0.001$, and better functional outcomes determined by the Symptom Severity Scale, SSS, and Functional Status Scale, FSS, $p < 0.001$). Wrist range of motion (ROM), thumb abduction specifically, also showed an excellent improvement ($p = 0.001$). Although these results suggest the possible therapeutic effect of the intervention, effect sizes (e.g., a VAS reduction of 5.7) must be viewed with caution, since the magnitude of changes in such a small time period can be interpreted as overestimate of its clinical importance without follow-up.

The effects of neurodynamic exercises separately or nerve/tendon gliding exercises have been studied previously. The study by Sheereen et al. (2022) compared the neurodynamic method to carpal bone mobilization therapy, and they noted more favorable results concerning nerve conduction and functions in the former group [18]. According to Sekaringtyas et al. (2021), neurodynamics produced as positive effect as compared to nerve and tendon gliding exercises, but there were no significant differences in grip strength or functional status between the two interventions [17]. In contrast to the previous research, the current study aimed at a synergistic intervention including both neurodynamic and wrist glide interventions, which has a potential to allow both nerve mobility, as well as restrictions of mechanical interface, to occur concomitantly.

Looking at a randomized controlled trial by Talebi et al. (2020) confirmed that functional status and symptoms severity could be improved using either neurodynamic or mechanical interface techniques, and no significant differences were found, thus both of them could be considered a possible non-surgical option [20]. The same results were obtained by Wolny and Linek (2019) who discovered that the use of neurodynamic based manual therapy led to enhanced sensory conduction of the median nerve, maximized grip strength and alleviated pain when compared with electrophysical modalities ($p < 0.01$, $p < 0.05$) [20]. Vaidya and Nariya (2020) demonstrated that neural mobilization elicited more significant improvement in nerve conduction and pain levels compared to nerve and tendon gliding exercises, and their combination, with no significant difference between those interventions in terms of functional outcome [21]. Tendon and nerve gliding were also found to be effective in symptomology relief as well as enhancing improved sensory conduction in an article by Abdolrazaghi et al. (2020), even though functional outcomes were low [22].

The collective works open the path to conservative management of CTS. Nevertheless, a majority of them studied the techniques separately. There is a growing body of evidence regarding the use of both devices in combination, and we contribute to this evidence by examining both sequentially within a structured physiotherapy program, which may have maximum mechanical and neurophysiological effect. This fills a literature gap since little research has been done to assess dual-techniques protocols in moderate CTS and mild CTS inhabitants.

There are, however, some limitations to our study despite these encouraging results. First, there was no control group, which restrains the study in attributing the changes to the intervention only and introduces the probability of a Hawthorne effect. Second, the outcome may have been biased through observers and participants not being blinded. Third, the treatment span was not that long (only four weeks) and the intervention results would not be possible to evaluate and/or the improvement possibilities to continue long term. Fourth, generalizability was low since the sample size was small with middle-aged, right-handed and mild CTS participants. Finally, no follow-up after treatment was performed and thus it is unclear whether the gains will persist with time.

Finally, the study recommends the knee-to-knee combination of neurodynamic wrist exercise and wrist glide that is effective in reducing hand pains and enhancing hand functions in people with moderate and mild CTS. These findings justified their application as a formidable early-intervention in the physiotherapy profession. Future investigations are needed however, to utilize more randomized controlled studies using wider, diverse study populations, low attrition with long-term follow-up and more stringent methodological controls (e.g., blinding to both study and control groups, and controls) to improve evidence and smooth clinical practice recommendations.

Conclusion

The present study showed that the neurodynamic wrist shaking in combination with gliding exercises is effective in decreasing pain, increasing grip strength and thumb range of the motion as well as the overall hand functioning in patients with mild to moderate carpal tunnel syndrome. Outcome assessment with validated measures proved the effectiveness in improvements, through the Symptom Severity Scale (SSS) and Functional Status Scale (FSS), making these methods effective not surgical medications. It is interesting to note that the present study is one of the few to compare the concurrent effect of both the neurodynamic and the wrist glide exercises, thus, filling the gap in current literature. Future studies must ideally use these results constructively by making use of larger and broader types of samples, control groups, and follow-up durations in order to get a clearer idea of the lasting efficacy and the process of improving rehabilitation plans regarding CTS.

Ethical Consideration

This study has been approved by the Ethics Committee of University of Ahliya (Code: CAMS/PTBR/3/131/2024).and The Universal Trial Number (UTN) of world health organization (Code: U1111-1316-5677.Patients provided their informed consent before any collection and the Helsinki declaration of 2008 was followed.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors thank all the patients who participated in the study.

References

1. Genova, A., Dix, O., Saefan, A., Thakur, M., & Hassan, A. (2020). Carpal Tunnel Syndrome: A Review of Literature. *Cureus*, *12*(3), e7333. https://doi.org/10.7759/cureus.7333

2. Rüsch CT, Knirsch U, Weber DM, Rohrbach M, Eichenberger A, Lütschg J, et al. Etiology of Carpal Tunnel Syndrome in a Large Cohort of Children. Children (Basel). 2021 Jul 23;8(8):624. PMID: 34438514; PMCID: PMC8392332.

3. Osiak K, Elnazir P, Walocha JA, Pasternak A. Carpal tunnel syndrome: state-of-the-art review. Folia Morphol (Warsz). 2022;81(4):851-62. PMID: 34783004.

4. Garcia JO, Scott D, Parikh P, Curley KL, Turkmani A. Understanding carpal tunnel syndrome. JAAPA. 2022 Dec 1;35(12):19-26. PMID: 36346923.

5. Wiberg A, Smillie RW, Dupré S, Schmid AB, Bennett DL, Furniss D. Replication of epidemiological associations of carpal tunnel syndrome in a UK population-based cohort of over 400,000 people. J Plast Reconstr Aesthet Surg. 2022 Mar;75(3):1034-40. PMID: 34916160; PMCID: PMC8982328.

6. Cage ES, Beyer JJ, Ebraheim NA. Injections for treatment of carpal tunnel syndrome: A narrative review of the literature. J Orthop. 2023 Mar;37:81-5. PMID: 36000134; PMCID: PMC9389835.

7. Jiménez-Del-Barrio S, Cadellans-Arróniz A, Ceballos-Laita L, Estébanez-de-Miguel E, López-de-Celis C, Bueno-Gracia E, et al. The effectiveness of manual therapy on pain, physical function, and nerve conduction studies in carpal tunnel syndrome patients: a systematic review and meta-analysis. Int Orthop. 2022 Feb;46(2):301-12. PMID: 34862562; PMCID: PMC8782801.

8. Alhusain FA, Almohrij M, Althukeir F, Alshater A, Alghamdi B, Masuadi E, et al. Prevalence of carpal tunnel syndrome symptoms among dentists working in Riyadh. Ann Saudi Med. 2019;39(2):104-11. PMID: 30905925; PMCID: PMC6464669.

9. Wang WL, Hanson T, Fowler JR. A Comparison of 6 Diagnostic Tests for Carpal Tunnel Syndrome Using Latent Class Analysis. Hand (N Y). 2020 Nov;15(6):776-9. PMID: 30854901; PMCID: PMC7850262.

10. Cunha TAL, Oliveira OM, Ribeiro MB. PHALEN TEST POSITIVATION TIME AND ITS CORRELATION WITH ELECTRONEUROMYOGRAPHY. Acta Ortop Bras. 2020;28(3):114-6. PMID: 32536790; PMCID: PMC7269134.

11. Turgut AÇ, Tubbs RS, Turgut M. Paul Hoffmann (1884-1962 AD) and Jules Tinel (1879-1952 AD), and their legacy to neuroscience: the Hoffmann-Tinel sign. Childs Nerv Syst. 2019 May;35(5):733-4. PMID: 29987376.

12. Magni N, Olds M, McLaine S. Reliability and validity of the K-force grip dynamometer in healthy subjects: do we need to assess it three times. Hand Ther. 2023 Mar;28(1):33-9.

13. Alarab A, Unver F. Stretching Exercise Versus Tissue Mobilization Technique in Piriformis Syndrome. EJMED. 2021 Jan 6;2(6). PMID: 32313774; PMCID: PMC7164699.

14. Multanen J, Ylinen J, Karjalainen T, Ikonen J, Häkkinen A, Repo JP. Structural validity of the Boston Carpal Tunnel Questionnaire and its short version, the 6-Item CTS symptoms scale: a

Rasch analysis one year after surgery. BMC Musculoskelet Disord. 2020 Sep 12;21(1):609. PMID: 32919457; PMCID: PMC7488577.

15. Aranceta-Garza A, Ross K, Buhler M, Rameckers E. A Comparative Study of Efficacy and Functionality of Ten Commercially Available Wrist-Hand Orthoses in Healthy Females: Wrist Range of Motion and Grip Strength Analysis. Front Rehabil Sci. 2021;2:687554. PMID: 34286314; PMCID: PMC7611306.

16. Sheereen FJ, Sarkar B, Sahay P, Shaphe MA, Alghadir AH, Iqbal A, et al. Comparison of Two Manual Therapy Programs, including Tendon Gliding Exercises as a Common Adjunct, While Managing the Participants with Chronic Carpal Tunnel Syndrome. Pain Res Manag. 2022;2022:1975803. PMID: 35719196; PMCID: PMC9200595.

17. Wolny T, Saulicz E, Linek P, Shacklock M, Myśliwiec A. Efficacy of Manual Therapy Including Neurodynamic Techniques for the Treatment of Carpal Tunnel Syndrome: A Randomized Controlled Trial. J Manipulative Physiol Ther. 2017 May;40(4):263-72. PMID: 28395984.

18. Wolny T, Linek P. Is manual therapy based on neurodynamic techniques effective in the treatment of carpal tunnel syndrome? A randomized controlled trial. Clin Rehabil. 2019 Mar;33(3):408-17.PMID: 30306805.

19. Vaidya SM, Nariya D.Effect of Neural Mobilisation Versus Nerve and Tendon Gliding Exercises in Carpal Tunnel Syndrome: A Randomised Clinical Trial.J Clin of Diagn Res.2020; 14(6):YC01 YC04. https://www.doi.org/10.7860/JCDR/2020/43320/13779

20. Abdolrazaghi HA, Khansari M, Mirshahi M, Ahmadi Pishkuhi M. Effectiveness of Tendon and Nerve Gliding Exercises in the Treatment of Patients With Mild Idiopathic Carpal Tunnel Syndrome: A Randomized Controlled Trial. Hand (N Y). 2023 Mar;18(2):222-9. PMID: 33855879; PMCID: PMC10035085.