Efficacy of Manual Therapy Including Neurodynamic Techniques for the Treatment of Carpal Tunnel Syndrome: A Randomized Controlled Trial

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Abstract

Objective: The purpose of this randomized trial was to compare the efficacy of manual therapy, including the use of neurodynamic techniques, with electrophysical modalities on patients with mild and moderate carpal tunnel syndrome (CTS).
Methods: The study included 140 CTS patients who were randomly assigned to the manual therapy (MT) group, which included the use of neurodynamic techniques, functional massage, and carpal bone mobilizations techniques, or to the electrophysical modalities (EM) group, which included laser and ultrasound therapy. Nerve conduction, pain severity, symptom severity, and functional status measured by the Boston Carpal Tunnel Questionnaire were assessed before and after treatment. Therapy was conducted twice weekly and both groups received 20 therapy sessions.
Results: A baseline assessment revealed group differences in sensory conduction of the median nerve ($P < .01$) but not in motor conduction ($P = .82$). Four weeks after the last treatment procedure, nerve conduction was examined again. In the MT group, median nerve sensory conduction velocity increased by 34% and motor conduction velocity by 6% (in both cases, $P < .01$). There was no change in median nerve sensory and motor conduction velocities in the EM. Distal motor latency was decreased ($P < .01$) in both groups. A baseline assessment revealed no group differences in pain severity, symptom severity, or functional status. Immediately after therapy, analysis of variance revealed group differences in pain severity ($P < .01$), with a reduction in pain in both groups (MT: 290%, $P < .01$; EM: 47%, $P < .01$). There were group differences in symptom severity ($P < .01$) and function ($P < .01$) on the Boston Carpal Tunnel Questionnaire. Both groups had an improvement in functional status (MT: 47%, $P < .01$; EM: 9%, $P < .01$) and a reduction in subjective CTS symptoms (MT: 67%, $P < .01$; EM: 15%, $P < .01$).
Conclusion: Both therapies had a positive effect on nerve conduction, pain reduction, functional status, and subjective symptoms in individuals with CTS. However, the results regarding pain reduction, subjective symptoms, and functional status were better in the MT group. (J Manipulative Physiol Ther 2017;40:263-272)
Key Indexing Terms: *Carpal Tunnel Syndrome; Manual Therapy; Physical Therapy*

Introduction

Carpal tunnel syndrome (CTS) is the most common and most commonly described neuropathy of the peripheral nervous system.[1,2] The reported incidence varies from 1.5% to 3.8%.[3-5] Carpal tunnel syndrome often affects persons of working age and may lead to absences from work and a marked decline in performance.[4] High prevalence and the major socioeconomic impact of CTS are reasons to search for effective, inexpensive treatments.[6]

Both conservative and surgical approaches to treating CTS are used. Conservative medical procedures include splinting the wrist at night, oral pharmacotherapy, and local steroid injections.[7] Physical therapy for CTS usually involves electrophysical modalities or manual therapy, including the use of neurodynamic techniques.[6-8] Alternative treatments, such as yoga, acupuncture, massage, and traditional cupping therapy have also been investigated.[9-12]

The choice of treatment method—both the type and temporal sequence of therapy—is very controversial. Most studies have reported better results for surgical treatment of CTS compared with conservative treatment.[8,13,14] There is a wide range of conflicting opinions regarding the efficacy

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of pharmacologic treatment.[15,16] The efficacy of physical therapy has also been questioned.[17-21] There is some conflicting information about the efficacy of neurodynamic techniques[18,20] and electrophysical modalities[21,22] in the nonsurgical treatment of CTS.

Current CTS treatment protocols may include surgical treatment as well as conservative treatments such as physical therapy. However, to our knowledge, evidence regarding the efficacy of physical therapy is lacking.[23,24] As a result, physical therapy is often ignored in reviews of treatments for CTS.[23] Therefore, it is necessary to establish the efficacy of the various types of physical therapy in order to find optimal therapeutic regimens for use by physical therapists in clinical practice and to reject the use of ineffective techniques.

Low-level laser and ultrasound therapies are often used in the treatment of CTS.[25-27] The mechanism of ultrasound therapy includes thermal and nonthermal effects, which results in pain relief and anti-inflammatory and tissue-stimulating effects.[28] There are some conflicting results on the efficacy of therapeutic ultrasound in the treatment of CTS.[17,26] Several clinical trials have revealed that therapy using ultrasound has positive effects,[26,29] but some reports also have indicated that ultrasound therapy is as effective as placebo.[17,30] In turn, low-level laser therapy has been reported to be effective in increasing mitochondrial ATP production, cellular oxygen consumption, and serotonin and endorphin levels, which lead to pain relief and anti-inflammatory reactions.[27,31] There are also some controversial results regarding the use of low-level lasers in the treatment of CTS.[19,22,25,32] Shooshtari et al[32] and Yagci et al[25] reported positive effects, whereas Irvine et al[19] and Evcik et al[22] reported that low-level laser therapy was no more effective than placebo in CTS treatment. Bakhtiary and Rashidy-Pour[27] compared the efficacy of ultrasound and laser modalities for mild and moderate idiopathic CTS. They reported that ultrasound treatment was more effective than laser therapy in CTS treatment. In contrast to the Bakhtiary and Rashidy-Pour work, in this paper we decided to combine laser and ultrasound modalities, looking for a possible cumulative effect on CTS treatment. As a result, this is the first study to combine these 2 modalities.

In the physical therapy profession, manual therapy is defined as a clinical approach, including diagnosis and treatment, directed at joint structures and soft tissues. The most notable forms of manual therapy are joint manipulation, joint and soft tissue mobilization, and massage.[33,34]

Neurodynamic techniques are a relatively new development in physical therapy, and they are mostly treated as a part of manual therapy.[33,34] To date, the assessment of efficacy of manual therapy treatments in CTS has produced conflicting results.[35] However, their potential value as part of CTS therapy should be studied more extensively in randomized trials. Hence, this is the first study to evaluate the efficacy of manual therapy (functional massage and carpal bone mobilization) including the use of neurodynamic techniques conducted by a physiotherapist in CTS treatment.

The purpose of this study was to evaluate manual therapy including the use of neurodynamic techniques (MT group) compared with electrophysical (laser and ultrasound) modalities (EM group) in the treatment of CTS. We hypothesized that the use of manual therapy including the use of neurodynamic techniques would be more effective in the treatment of CTS than low-level laser and ultrasound modalities.

Methods

Ethics

The study was authorized by the Bioethics Committee for Scientific Studies at the Physical Education College of Katowice on May 31, 2007 (Decision No. 16/2007). All study procedures were performed according to the Helsinki Declaration of Human Rights of 1975 (modified in 1983). The clinical trial registration number is ACTRN12614000367640.

Study Design

This was a multicenter, randomized, controlled, single-blinded, parallel-group design study. The study took place in 2 medical clinics in the Silesia province in Poland from 2007 to 2012. Participants were randomly allocated to the MT group or the EM group. The MT group received 20 treatments of manual therapy including the use of neurodynamic techniques. The EM group received 20 treatments of laser and ultrasound. Therapy was conducted twice weekly for 10 weeks. All patients were informed about what the study would involve and told that they could withdraw at any stage without giving a reason. Written informed consent was obtained from all participants.

Participants

Participants with CTS diagnosed by a physician were enrolled in the study. The selection process did not specify the age of the participants (all were older than 18 years of age). Recruitment was performed in 2 medical clinics in the Silesia province in Poland.

The necessary sample size was assessed based on preliminary results from 20 participants. Calculation of sample size was based on an α of 0.05 and a statistical power of 0.80. Based on this calculation, we aimed to recruit 77 patients for each treatment group.

Protocols

Diagnostic Criteria for CTS. In all cases, CTS was diagnosed by a physician. From all patients who had diagnosed CTS, the main inclusion criterion was the presence of 2 or more

of the following positive symptoms (based on the approach of Chang et al[28]): numbness and tingling in the area of the median nerve; nighttime paresthesia; positive Phalen test; positive Tinel sign; pain in the wrist area radiating to the shoulder.

Additionally, because the gold standard in diagnosis of CTS is the nerve conduction study (NCS),[36] in this work all selected participants (with at least 2 positive tests) underwent NCS. Based on NCSs, only participants who had diminished nerve conduction values (<50 m/s), increased motor latency (>4 m/s), or both were included in the study.

The exclusion criteria were previous surgical treatment, current steroid or nonsteroid pharmacotherapy, cervical radiculopathy, tendon sheath inflammation, rheumatoid diseases, diabetes, pregnancy, past trauma to the wrist, and muscular atrophy of the thenar eminence.

Randomization. Patients diagnosed with mild to moderate CTS (a score of 1 to 3 on the historical-objective scale[37,38]) who met the diagnostic criteria were eligible for the study. Each consecutive patient who met the inclusion criteria and was not excluded was randomly assigned to the MT group or the EM group. Patients were randomly assigned by drawing lots with the group number. Individuals who drew the number 1 were assigned to the MT group, and those who drew number 2 were assigned to the EM group.

Blinding Procedures. The procedure in which the patient drew his or her group number was supervised by a secretary who was not otherwise involved in the study. Next, the patient was directed to a physical therapist who performed a physical examination, and the patient and therapist completed the relevant questionnaires and documentation. The NCS was performed by specialists in an independent, off-site electromyography laboratory. The physical therapy procedures were performed by other physical therapists. The therapists conducting the initial physical examination and delivering the therapy were not members of the research team and knew nothing about the experiment. The specialists who performed the NCS were not aware of the nature of the therapy administered to participants. After the cycle of treatment, participants were reexamined by the physical therapist who had conducted the initial physical examination. Nerve conduction was reassessed by the team of specialists who performed the original assessment, at the same site. The same procedures and record forms were used in the pre- and post-therapy examinations.

Outcome Measures. Nerve conduction studies were prescribed by the treating physician and performed in an electromyography laboratory by experienced personnel. Neuro-Mep (Neurosoft, Ivanovo, Moscow) electrodiagnostic equipment was used to perform the examinations, using an antidromic method with superficial electrodes. To reduce the influence of temperature on nerve conduction, the participant was allowed to become acclimatized to the room in which the examination was performed for 10 to 15 minutes before measurements were made. The temperature in the examnation room was maintained at 24°C to 26°C. The skin temperature in the area in which nerve conduction was assessed was measured by means of a surface thermometer and fluctuated between 32°C and 34°C. Nerve conduction values ≥50 m/s were considered to be normal. Distal motor latency was calculated from motor fibers (values ≤4.0 m/s were considered normal) and standardized by dividing the distal motor latency value by the distance in centimeters between the active and receiving electrodes. The normal standardized latency was ≤0.7 m/s. The latency of the F wave was also evaluated to eliminate the nerve roots (cervical) as a cause of any conduction disorder. Nerve conduction studies were performed at baseline and 1 month after treatment.

Patients used a Numerical Pain Rating Scale (0 = no pain, 10 = maximum pain) to assess current hand pain and the worst pain experienced in the preceding week.[39] The pain in each hand was evaluated separately in patients with bilateral CTS. Pain was assessed at baseline and immediately after treatment.

Symptom severity and physical capacity was evaluated using the Boston Carpal Tunnel Questionnaire (BCTQ).[40] The questionnaire consists of 2 separate scales: the Symptom Severity Scale (SSS) and the Functional Status Scale (FSS). Patients with bilateral CTS completed a separate BCTQ for each hand. All patients completed a BCTQ at baseline and immediately after treatment.

Intervention

Patients in both groups underwent a 10-week cycle of physical therapy. No other forms of treatment were used during this period.

Physical therapy for the MT group was based on manual therapy including the use of neurodynamic techniques directed at the median nerve. Functional massage of the descending part of the trapezius (duration = 3 minutes) and the wrist mobilization techniques described by Shacklock[41] were also used. Three series of 10 wrist mobilizations were used for both techniques. A single mobilization lasted 15 seconds and was followed by a 10-second rest period. Both gliding and tension mobilizations of the median nerve were performed in the median neurodynamic test position (median neurodynamic test 1) with support.[41] One-direction proximal and distal slider mobilizations and 1-direction proximal and distal tension mobilizations were performed.[41] The standard protocol consisted of 3 series of 60 repetitions of glide and tension mobilizations separated by interseries intervals of 15 seconds. A single therapy session included all of the described therapeutic techniques; therapy sessions were performed twice a week for 20 sessions.

Physical therapy for the EM group was based on electrophysical modalities. Laser therapy was performed using a contact method at 3 points on the palmar surface of the wrist in the transverse ligament area.[25] Each procedure

started with a red laser (using a R650/50 probe) emitting 658-nm light at 50 mW; the duration of biostimulation was 1 minute 40 seconds, and the dose was 5 J. Next, an infrared laser (with a IR810/400 probe) emitting 808-nm light at 400 mW was used; the duration of the biostimulation was 1 minute, and the dose was 24 J. Each point was thus stimulated for 2 minutes 40 seconds. The entire procedure lasted 8 minutes. The palmar surface of the hand in the transverse ligament was treated with ultrasound therapy with the following parameters: frequency 1 MHz, intensity of 1.0 W/cm impulse mode with a pulse width factor of 75%. Each procedure lasted 15 minutes.[26] Each therapeutic cycle consisted of 20 therapy sessions delivered at twice-weekly intervals.

Statistical Analysis

The basic parameters were compared between groups using the independent *t* test (age, body mass, height, and body mass index [BMI]) and the χ^2 test (sex distribution, side of hand dominance, side of asymptomatic and symptomatic hand, and the number of affected CTS hands [1 hand or both hands]).

A one-way analysis of variance (ANOVA) for repeated measurements (the independent factor was group: MT group versus EM group; the repeated factor was time: before therapy vs after therapy) was used to evaluate the differences in median nerve parameters (sensory, motor and latency conduction, and standardized latency), pain score, functional status, and symptom severity. For significant differences in the main effect for group, time, or interaction (group × time), Bonferroni's post hoc test was used.

The results are presented as the mean and 95% confidence interval. For all analyses, the threshold of the *P* value considered as significant was set at <.05.

Results

Initially, 236 patients with diagnosed CTS were enrolled in the study; however, 76 of these patients were excluded from the study because of comorbidities. The remaining 160 patients were recruited and randomly assigned to groups, but because of some problems at follow-up, a total of 140 complete patient recordings were obtained at baseline and after 10 weeks of treatment. Of these, 70 received manual therapy, including the use of neurodynamic techniques, and 70 received electrophysical modalities (laser and ultrasound). The study flowchart and details of adherence to treatment and compliance with follow-up are presented in Figure 1.

Baseline characteristics are presented in Table 1. The 2 examined groups were similar with respect to most assessed basic parameters. The only significant difference was in BMI. Mean BMI was higher in the MT group. Analyses indicated that both therapeutic regimes conferred beneficial effects. ANOVA performed on sensory conduction of the median nerve revealed both a group effect ($P < .01$) and a therapy effect ($P < .01$). There was also an interaction between group and therapy ($P < .01$). For the MT group, the mean sensory conduction velocity was 26.2 m/s before therapy and 35.1 m/s after therapy, an improvement of 8.9 m/s (34%). Post-therapy sensory conduction velocity approximated normal values (≥50 m/s). For the EM group, the mean sensory conduction velocity was 38.2 m/s before therapy and 39.2 m/s after therapy, an improvement of only 1.1 m/s (3%). ANOVA performed on motor conduction of the median nerve revealed no group differences ($P = .82$), although there was a therapy effect ($P < .01$) and an interaction between group and therapy ($P = .09$). It should be emphasized, however, that motor conduction values in both groups were within normal limits. After completion of therapy, the mean motor conduction velocity was 3.4 m/s (6%) higher in the MT group and 0.5 m/s (1%) higher in the EM group.

ANOVA revealed no group differences in motor latency of the median nerve ($P = .85$), although a therapy effect ($P < .01$) and a group by therapy interaction effect ($P < .01$) were present. Mean terminal latency in the MT group was 5.6 before therapy and 5.1 after therapy, a decrease of 0.5 (12%) over the course of therapy such that post-therapy values approximated normal values (≤4.0). Mean motor latency in the EM group was 5.4 before therapy and 5.2 after therapy, a decrease of 0.2 (4%). The results of Bonferroni's post hoc tests are shown in Table 2.

ANOVA on reported levels of pain revealed a group difference ($P < .01$), an effect of therapy ($P < .01$), and an interaction between group and therapy ($P < .01$); mean pain score decreased by 4.2 points (290%) in the MT and only 1.7 points (47%) in the EM group. The results of Bonferroni's post hoc tests are shown in Table 3.

ANOVA on SSS scores revealed a group difference ($P < .01$), therapy effect ($P < .01$), and interaction between group and therapy ($P < .01$). Subjective symptoms decreased by 1.2 points (67%) in the MT group and only 0.4 points (15%) in the EM group.

ANOVA on FSS score revealed a group difference ($P < .01$), therapy effect ($P < .01$), and interaction between group and therapy ($P < .01$). FFS scores improved by 0.9 points (47%) in the MT group and by 0.2 points (9%) in the EM group. The results of Bonferroni's post hoc tests are shown in Table 4.

Discussion

The results of our evaluation of the efficacy of manual therapy, including neurodynamic techniques, compared with electrophysical modalities are encouraging and indicate that either of these techniques can be effective in the treatment of CTS.

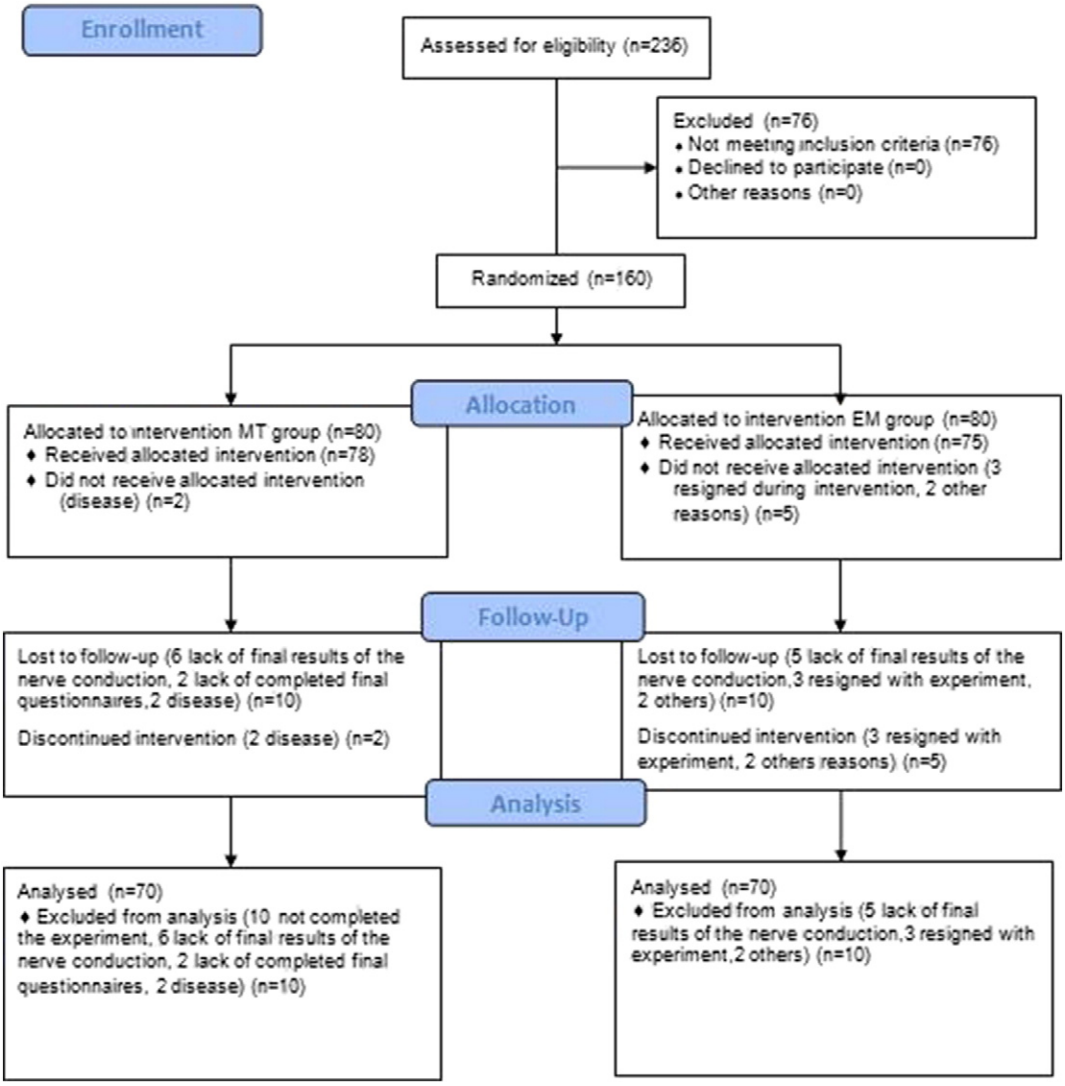

Fig 1. *Flow diagram of phases through clinical trial.*

In both groups, beneficial therapeutic effects were obtained, but slightly better therapeutic results were achieved in the MT group, which received manual therapy including the use of neurodynamic techniques. Baseline sensory conduction velocity was significantly worse in the MT group than in the EM group, but there were no group differences in this parameter after therapy. Looking at significant differences between both groups before therapy and lack of such differences after therapy, it can be stated that the improvement was greater in the MT group and that participants in the MT group benefited more from therapy. After therapy, sensory conduction velocity was 34% faster in the MT group, with a significant improvement, whereas the EM group experienced a nonsignificant 3% increase in speed. Motor conduction velocity was within normal limits in both groups after therapy, but the improvement during therapy was greater for the MT group.

The dissociation between sensory and motor conduction is characteristic of mild and moderate forms of CTS.[42,43] The study by Premoselli et al[43] indicated that therapy for CTS produced improvements in sensory conduction velocity before there were changes in motor conduction velocity. Our results confirm this finding. The pattern we identified—namely, worse sensory conduction velocity than motor conduction velocity before therapy and a greater improvement after a cycle of therapy—may reflect the efficacy of manual therapy including the use of neurodynamic techniques. If nerve conduction is within normal limits, then manual therapy can only produce a very limited improvement, which appears to have been the case in our study with respect to motor conduction velocity.

Both groups experienced a significant reduction in pain, but there was a group difference in the magnitude of the

Table 1. *Group Means and Between-Group Comparisons for Participant Characteristics at Baseline*

	MT Group (n = 70)	EM Group (n = 70)	*P*
Women (%); men (%)	62 (89); 8 (11)	60 (86); 10 (14)	.61 [a]
Age (SD; min-max)	53.1 (8.7; 26-72)	51.5 (10.3; 28-71)	.11 [b]
Body mass (SD; min-max)	72.3 (11.1; 50-97)	69.7 (11.8; 43-105)	.57 [b]
Height, cm (SD; min-max)	164 (6.4; 148-180)	164 (5.9; 144-182)	.19 [b]
BMI (SD; min-max)	26.9 (4.18; 17.9-41.1)	25.5 (3.8; 18.4-39.1)	.03 [b, c]
Dominant hand: right (%), left (%)	65 (93); 5 (7)	69 (98); 1 (1.43)	.95 [a]
Asymptomatic hand: right (%), left (%)	7 (13); 45 (87)	7 (14); 41 (85)	.87 [a]
Symptomatic hand: right (%); left (%)	63 (72); 25 (28)	63 (68); 29 (31)	.64 [a]
Number of carpal tunnels 1/2 (%)	52 (74); 18 (26)	48 (68); 22 (31)	.61 [a]

BMI, body mass index; *EM,* electrophysical modalities; *MT,* manual therapy; *SD,* standard deviation.
[a] χ^2 test.
[b] Student *t* test.
[c] Statistically significant difference.

Table 2. *Group Means, Standard Deviations, and Ranges for Median Nerve Conduction Parameters, Between-Group Comparison, and Effect of Therapy*

	Examination	Pretherapy	Post-Therapy	Effect of Therapy (Mean Difference Between Pre- and Post-Therapy values; 95% CI)
Sensory conduction velocity	MT group	26.2 ± 15.7	35.1 ± 12.1	*P* < .01 [a]
	n = 70	0-59	0-58	(8.9; 6.8-10.9)
	EM group	38.2 ± 11.1	39.22 ± 11.91	*P* = .9859
	n = 70	0-57	0-56	(1.0; −0.9 to 3.1)
	Between-group difference	*P* < .01 [a] (11.9; 6.8-17.1)	*P* = .18 (4.1; −0.9 to 9.3)	Significance level
Motor conduction velocity	MT group	53.2 ± 7.8	56.5 ± 7.8	*P* < .01 [a]
	n = 70	36-84	38-77	(3.4; 1.7-4.9)
	EM group	54.8 ± 5.6	55.3 ± 5.7	*P* = .13
	n = 70	42-69	39-66	(0.5; −1.02 to 2.1)
	Between-group difference	*P* = .68 (1.6; −1.1-4.3)	*P* = .23 (1.2; −1.5 to 3.9)	Significance level
Motor latency	MT group	5.61 ± 1.08	5.02 ± 1.13	*P* < .01 [a]
	n = 70	4.4-8.8	2.2-8.5	(0.6; 0.4-0.7)
	EM group	5.45 ± 1.12	5.24 ± 1.17	*P* = .001 [a]
	n = 70	4-8.9	3-8.5	(0.21; 0.06-0.35)
	Between-group difference	*P* = .33 (0.16; −0.29 to 0.61)	*P* = .21 (0.22; −0.23 to 0.66)	Significance level
Standardized latency	MT group	1.15 ± 0.16	1.01 ± 0.17	*P* < .01 [a]
	n = 70	0.91-1.80	0.70-1.70	(0.13; 0.10-0.17)
	EM group	1.10 ± 0.18	1.06 ± 1.18	*P* = .05 [a]
	n = 70	0.83-1.70	0.70-1.70	(0.04; 0.01-0.07)
	Between-group difference	*P* = .32 (0.05; −0.02 to 0.12)	*P* = .69 (0.04; −0.03 to 0.11)	Significance level

CI, confidence interval; *EM,* electrophysical modalities; *MT,* manual therapy.
[a] Statistically significant difference.

reduction: The mean reduction in pain was 290% for the MT group and 47% for the EM group.

Both groups achieved a similar reduction in symptoms (SSS score) and improvement in function (FSS score). After therapy, symptoms were reduced by 67% and function improved by 47% in the MT group, whereas symptoms were reduced by 15% in the EM group and function improved by 9%; again, these results reflect group differences. The MT group achieved a much greater reduction in pain, combined with a reduction in subjective symptoms and an improvement in function and sensory conduction velocity. This pattern of results suggests that manual therapy, including the use of neurodynamic techniques, may be more effective than electrophysical modalities in treating some CTS symptoms.

Several authors have investigated the efficacy of manual therapy, including the use of neurodynamic techniques, as a conservative treatment for CTS, but the results were not conclusive.

Table 3. *Group Means, Standard Deviations, and Ranges for Pain Score; Between-Group Comparison; and Effect of Therapy*

Examination	Pretherapy	Post-Therapy	Effect of Therapy (Mean Difference Between Pre- and Post-Therapy Pain; 95% CI)
MT group	5.72 ± 1.49	1.47 ± 1.20	$P < .01$ [a]
n = 70	1-10	0-5	(4.25; 3.81-4.69)
EM group	5.25 ± 1.75	3.58 ± 1.93	$P < .01$ [a]
n = 70	2-10	0-10	(1.66; 1.23-2.10)
Between-groups difference	$P = .29$ (0.48; −0.17 to 1.12)	$P < .01$ [a] (2.11; 1.46-2.76)	Significance level

CI, confidence interval; *EM,* electrophysical modalities; *MT,* manual therapy.
[a] Statistically significant difference.

Table 4. *Group Means, Standard Deviations, and Ranges for Symptom Severity and Functional Status; Between-Group Comparison; and Effect of Therapy*

	Examination	Pretherapy	Post-Therapy	Effect of Therapy (Mean Difference Pre- and Post-Therapy; 95% CI)
BCTQ-SSS	MT group	2.97 ± 0.63	1.78 ± 0.47	$P < .01$ [a]
	n = 70	1.54-4.63	1.00-3.09	(1.20; 1.05-1.35)
	EM group	2.94 ± 0.74	2.57 ± 0.77	$P < .01$ [a]
	n = 70	1.00-4.63	1.00-4.27	(0.37; 0.22-0.52)
	Between-group difference	$P = .76$ (0.03; −0.23 to 0.30)	$P < .01$ [a] (0.80; 0.53-1.06)	Significance level
BCTQ-FSS	MT group	2.80 ± 0.94	1.90 ± 0.62	$P < .01$ [a]
	n = 70	1.27-4.62	1.00-3.75	(0.90; 0.78-1.02)
	EM group	2.77 ± 0.94	2.55 ± 0.95	$P < .01$ [a]
	n = 70	1.00-4.88	1.00-4.63	(0.21; 0.10-0.33)
	Between-group difference	$P = .76$ (0.04; −0.29 to 0.36)	$P < .01$ [a] (0.65; 0.32-0.98)	Significance level

BCTQ, Boston Carpal Tunnel Questionnaire; *CI,* confidence interval; *EM,* electrophysical modalities; *FSS,* Functional Status Scale; *MT,* manual therapy; *SSS,* Symptom Severity Scale.
[a] Statistically significant difference.

Tal-Akabi and Rushton[44] studied the efficacy of joint and nerve mobilization in CTS patients. They reported that the group who were subjected to neurodynamic techniques achieved significant pain reduction, motor improvement, and symptom reduction. However, in a comparison of the efficacy of specific nerve mobilization and sham nerve mobilization in CTS patients, Bialosky et al[20] concluded that neurodynamic techniques targeting the median nerve were no more effective than sham techniques.

Rozmaryn et al[18] reported that use of neurodynamic techniques significantly reduced the number of people who had to undergo surgery.

Akalin et al[45] reported that nerve mobilization did not produce significant changes but mentioned a positive effect of neurodynamic techniques in the discussion of results. Bardak et al[21] stated that enriching the standard conservative therapy protocol with neurodynamic techniques may be beneficial. Brininger et al[46] and Horng et al[47] reported that using neurodynamic techniques had no effect, whereas Pinar et al[48] reported significant improvement after the use of neurodynamic techniques.[48]

De-la-Llave-Rincon et al[49] reported a reduction in pain intensity after therapy based on soft tissue mobilization and the "slider" neurodynamic technique.

The advantage of some of these studies was that the therapeutic techniques used were similar to those suggested by Totten and Hunter.[50] Unfortunately, in all the studies cited here, the techniques were implemented as exercises that patients performed on their own at home. Taken together, the results of these studies do not provide conclusive evidence on the efficacy of autotherapy based on neurodynamic techniques.

A novel feature, and a strength of this study, is that manual therapy, including the use of neurodynamic techniques, was delivered by a physiotherapist. A further strength of the study is that we determined that a new therapeutic method was effective in decreasing some CTS symptoms. The large sample size is another important strength. It seems that neurodynamic techniques may have a more beneficial effect when delivered by a physiotherapist than as part of an autotherapy program over which the supervising clinician does not have full control. When a patient is expected to perform unsupervised exercises, there

will always be a question mark over whether they were performed at all and, if they were, whether they were performed systematically, reliably, and according to the prescribed method. Horng et al[47] admitted that lack of control over the implementation of the exercises and inability to monitor whether they were performed correctly were weaknesses of an autotherapy study.

At this stage in the development of neurodynamic techniques for CTS, there are a lot of unknowns and unanswered questions. These results should be treated with caution. It is difficult to compare the efficacy of autotherapy using neurodynamic techniques with the use of neurodynamic techniques by a physiotherapist: in practice, they are different therapeutic techniques and may differ in their impact on the organism and, thus, their therapeutic effect. The extant literature does not include any study in which manual therapy, including the use of neurodynamic techniques, was delivered by a physiotherapist as part of a program of physical therapy. This indicates that further research in this area is needed, something that has already been pointed out by authors of systematic reviews.[51-54] It seems likely that a comprehensive assessment of the utility of neurodynamic techniques will require comparative investigation of different therapeutic programs and separate evaluations of the efficacy of gliding and tension techniques. Coppieters and Butler[6] and Coppieters et al[53] pointed out that different neurodynamic techniques may have different effects on nerve movement, which may in turn produce different biomechanical and neurophysiological effects. Coppieters et al[53] also emphasized that using a technique that is not appropriate to the diagnosis, or even contraindicated, may fail to produce improvement or actually cause deterioration. Trials to assess those techniques in patients with CTS have already been performed, but at the present stage of the experiment, it is difficult to formulate unambiguous conclusions.[54]

To summarize, it should be emphasized that the positive therapeutic effects achieved in this experiment have yet to be replicated. Nevertheless, the promising results obtained using a therapy protocol based on manual therapy, including the use of neurodynamic techniques, suggest that its use in clinical practice should be encouraged.

Limitations

There were several methodological limitations to the study, most importantly that there was no follow-up evaluation; we were therefore unable to draw conclusions about the long-term effects because the improvements that we observed may have been temporary. Both therapy regimes investigated have nevertheless been reported to have substantial beneficial effects on multiple symptoms of CTS. The lack of a no-treatment control group is another limitation, meaning that we were unable to quantify any effect of spontaneous healing in the study. Similarly, the lack of a control group receiving simulated therapy meant that we were unable to quantify any placebo effect in this study. Including a placebo treatment group would have made it possible to estimate the extent to which the therapeutic effects observed simply were due to participation in therapy rather than to the specific therapeutic techniques used. The use of multicomponent therapy regimens is a potential drawback to our study design, meaning that it was not possible to assess the independent contribution of each of the techniques; however, such comprehensive regimens are desirable and typical of clinical practice because they often produce better results.

Conclusions

Both therapies had a positive effect on nerve conduction. After therapy, distal motor latencies were reduced in both groups. The MT group also achieved a significant increase in sensory and motor conduction velocity. Pain was significantly reduced in both groups after completion of therapy, but the effect appeared to be greater in the MT group. Both therapeutic regimens significantly reduced patients' subjective symptoms and improved function, but the MT group had greater effect.

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Contributorship Information

Concept development (provided idea for the research): T.W.
Design (planned the methods to generate the results): T.W., E.S.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): T.W., E.S., P.L., M.S.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): T.W., E.S., P.L.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): T.W., E.S., P.L.
Literature search (performed the literature search): T.W., A.M., P.L.
Writing (responsible for writing a substantive part of the manuscript): T.W.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): T.W., E.S., P.L., M.S., A.M.

Practical Applications

- The therapeutic program based on manual therapy including neurodynamic techniques had a beneficial effect on the improvement of certain symptoms in patients with CTS.
- A considerable reduction of pain and subjective perception of symptoms and improvement of functions, as well as acceleration of sensory conduction and reduction of latency, were achieved.
- Electrophysical modalities used in the conservative treatment of the CTS affect the reduction of patients' subjective and objective symptoms to a lesser extent than manual therapy including neurodynamic techniques.
- Beneficial effects may be achieved by using neurodynamic techniques as a therapy implemented by a physiotherapist.

References

1. Aroori S, Spence RA. Carpal tunnel syndrome. *Ulster Med J.* 2008;77(1):6-17.
2. Lewańska M, Wagrowska-Koski E, Walusiak-Skorupa J. Etiological factors for developing carpal tunnel syndrome in people who work with computers. *Med Pr.* 2013;64(1):37-45.
3. De Krom MC, Knipschild PG, Kester AD, Thijs CT, Boekkooi PF, Spaans F. Carpal tunnel syndrome: prevalence in the general population. *J Clin Epidemiol.* 1992;45(4):373-376.
4. Atroshi I, Gummesson C, Johnsson R, Ornstein E, Ranstam J, Rosén I. Prevalence of carpal tunnel syndrome in a general population. *JAMA.* 1999;282(2):153-158.
5. Tanaka S, Wild DK, Seligman PJ, Behrens V, Cameron L, Putz-Anderson V. The US prevalence of self-reported carpal tunnel syndrome: 1988 National Health Interview Survey data. *Public Health.* 1994;84(11):1846-1848.
6. Coppieters MW, Butler DS. Do 'sliders' slide and 'tensioners' tension? An analysis of neurodynamic techniques and considerations regarding their application. *Man Ther.* 2008; 13(3):213-221.
7. Gerritsen AA, de Vet HC, Scholten RJ, Bertelsmann FW, de Krom MC, Bouter LM. Splinting vs surgery in the treatment of carpal tunnel syndrome: a randomized controlled trial. *JAMA.* 2002;288(10):1245-1251.
8. O'Connor D, Marshall S, Massy-Westropp N. Non-surgical treatment (other than steroid injection) for carpal tunnel syndrome. *Cochrane Database Syst Rev.* 2003;1:CD003219.
9. Field T, Diego M, Cullen C, et al. Carpal tunnel syndrome symptoms are lessened following massage therapy. *J Bodyw Mov Ther.* 2004;8(1):9-14.
10. George JW, Tepe R, Busold D, Keuss S, Prather H, Skaggs CD. The effects of active release technique on carpal tunnel patients: a pilot study. *J Chiropr Med.* 2006;5(4):119-122.
11. Michalsen A, Bock S, Lüdtke R, et al. Effects of traditional cupping therapy in patients with carpal tunnel syndrome: a randomized controlled trial. *J Pain.* 2009;10(6):601-608.
12. Sim H, Shin BC, Lee MS, Jung A, Lee H, Ernst E. Acupuncture for carpal tunnel syndrome: a systematic review of randomized controlled trials. *J Pain.* 2011;12(3):307-314.
13. Badger SA, O'Donnell ME, Sherigar JM, Connolly P, Spence RA. Open carpal tunnel release–still a safe and effective operation. *Ulster Med J.* 2008;77(1):22-24.
14. Hui AC, Wong S, Leung CH, et al. A randomized controlled trial of surgery vs steroid injection for carpal tunnel syndrome. *Neurology.* 2005;64(12):2074-2078.
15. Hagebeuk EE, de Weerd AW. Clinical and electrophysiological follow-up after local steroid injection in the carpal tunnel syndrome. *Clin Neurophysiol.* 2004;115(6):1464-1468.
16. Marshall S, Tardif G, Ashworth N. Local corticosteroid injection for carpal tunnel syndrome. *Cochrane Database Syst Rev.* 2007;2:CD001554.
17. Oztas O, Turan B, Bora I, Karakaya MK. Ultrasound therapy effect in carpal tunnel syndrome. *Arch Phys Med Rehabil.* 1998;79(12):1540-1544.
18. Rozmaryn LM, Dovell S, Rothman ER, Gorman K, Olvey KM, Bartko JJ. Nerve and tendon gliding exercises and the conservative management of carpal tunnel syndrome. *J Hand Ther.* 1998;11(3):171-179.
19. Irvine J, Chong SL, Amirjani N, Chan KM. Double-blind randomized controlled trial of low-level laser therapy in carpal tunnel syndrome. *Muscle Nerve.* 2004;30(2):182-187.
20. Bialosky JE, Bishop MD, Price DD, Robinson ME, Vincent KR, George SZ. A randomized sham-controlled trial of a neurodynamic technique in the treatment of carpal tunnel syndrome. *J Orthop Sports Phys Ther.* 2009;39(10):709-723.
21. Bardak AN, Alp M, Erhan B, Paker N, Kaya B, Onal AE. Evaluation of the clinical efficacy of conservative treatment in the management of carpal tunnel. *Adv Ther.* 2009;26(1): 107-116.
22. Evcik D, Kavuncu V, Cakir T, Subasi V, Yaman M. Laser therapy in the treatment of carpal tunnel syndrome: a randomized controlled trial. *Photomed Laser Surg.* 2007; 25(1):34-39.
23. MacDermid JC. The quality of clinical practice guidelines in hand therapy. *J Hand Ther.* 2004;17(2):200-209.
24. Coppieters MW, Alshami AM. Longitudinal excursion and strain in the median nerve during novel nerve gliding exercises for carpal tunnel syndrome. *J Orthop Res.* 2007; 25(7):972-980.
25. Yagci I, Elmas O, Akcan E, Ustun I, Gunduz OH, Guven Z. Comparison of splinting and splinting plus low-level laser therapy in idiopathic carpal tunnel syndrome. *Clin Rheumatol.* 2009;28(9):1059-1065.
26. Ebenbichler GR, Resch KL, Nicolakis P, et al. Ultrasound treatment for treating the carpal tunnel syndrome: randomized "sham" controlled trial. *BMJ.* 1998;316(7133): 731-735.
27. Bakhtiary AH, Rashidy-Pour A. Ultrasound and laser therapy in the treatment of carpal tunnel syndrome. *Physiother.* 2004; 50(3):147-151.
28. Chang WD, Wu JH, Jiang JA, Yeh CY, Tsai CT. Carpal tunnel syndrome treated with a diode laser: a controlled treatment of the transverse carpal ligament. *Photomed Laser Surg.* 2008;26(6):551-557.
29. Dincer U, Cakar E, Kiralp MZ, Kilac H, Dursun H. The effectiveness of conservative treatments of carpal tunnel syndrome: splinting, ultrasound, and low-level laser therapies. *Photomed Laser Surg.* 2009;27(1):119-125.
30. Armagan O, Bakilan F, Ozgen M, Mehmetoglu O, Oner S. Effects of placebo-controlled continuous and pulsed ultrasound treatments on carpal tunnel syndrome: a randomized trial. *Clinics (Sao Paulo).* 2014;69(8):524-528.

31. Passarella S. He-Ne laser irradiation of isolated mitochondria. *J Photochem Photobiol B.* 1989;3(4):642-643.
32. Shooshtari SM, Badiee V, Taghizadeh SH, Nematollahi AH, Amanollahi AH, Grami MT. The effects of low level laser in clinical outcome and neurophysiological results of carpal tunnel syndrome. *Electromyogr Clin Neurophysiol.* 2008;48(5):229-231.
33. Mintken PE, DeRosa C, Little T, Smith B. AAOMPT clinical guidelines: a model for standardizing manipulation terminology in physical therapy practice. *J Orthop Sports Phys Ther.* 2008;38(3):A1-A6.
34. Gatterman MI, Hansen DT. Development of chiropractic nomenclature through consensus. *J Manip Physiol Ther.* 1994;17(5):302-309.
35. Page MJ, O'Connor D, Pitt V, Massy-Westropp N. Exercise and mobilization interventions for carpal tunnel syndrome. *Cochrane Database Syst Rev.* 2012;6:CD009899.
36. Johnson EW. Diagnosis of carpal tunnel syndrome. The gold standard. *Phys Med Rehabil.* 1993;72(1):1.
37. Giannini F, Cioni R, Mondelli M, et al. A new clinical scale of carpal tunnel syndrome: validation of the measurement and clinical-neurophysiological assessment. *Clin Neurophysiol.* 2002;113(1):71-77.
38. Mondelli M, Giannini F, Giacchi M. Carpal tunnel syndrome incidence in a general population. *Neurology.* 2002;58(2):289-294.
39. Jensen MP, Turner JA, Romano JM, Fisher LD. Comparative reliability and validity of chronic pain intensity measures. *Pain.* 1999;83(2):157-162.
40. Levine DW, Simmons BP, Koris MJ, et al. A self-administered questionnaire for the assessment of severity of symptoms and functional status in carpal tunnel syndrome. *J Bone Joint Surg Am.* 1993;75(11):1585-1592.
41. Shacklock M. Clinical Neurodynamics. A New System of Musculoskeletal Treatment. Toronto, Canada: Elsevier; 2005.
42. Kuntzer T. Carpal tunnel syndrome in 100 patients: sensitivity, specificity of multi-neurophysiological procedures and estimation of axonal loss of motor, sensory and sympathetic median nerve fibers. *J Neurol Sci.* 1994;127(2):221-229.
43. Premoselli S, Sioli P, Grossi A, Cerri C. Neutral wrist splinting in carpal tunnel syndrome: a 3- and 6-months clinical and neurophysiologic follow-up evaluation of night-only splint therapy. *Eura Medicophys.* 2006;42(2):121-126.
44. Tal-Akabi A, Rushton A. An investigation to compare the effectiveness of carpal bone mobilization and neurodynamic mobilization as methods of treatment for carpal tunnel syndrome. *Man Ther.* 2000;5(4):214-222.
45. Akalin E, El O, Peker O, et al. Treatment of carpal tunnel syndrome with nerve and tendon gliding exercises. *Phys Med Rehabil.* 2002;81(2):108-113.
46. Brininger TL, Rogers JC, Holm MB, et al. Efficacy of a fabricated customized splint and tendon and nerve gliding exercises for the treatment of carpal tunnel syndrome: a randomized controlled trial. *Arch Phys Med Rehabil.* 2007;88(11):1429-1435.
47. Horng YS, Hsieh SF, Tu YK, Lin MC, Horng YS, Wang JD. The comparative effectiveness of tendon and nerve gliding exercises in patients with carpal tunnel syndrome: a randomized trial. *Phys Med Rehabil.* 2011;90(6):435-442.
48. Pinar L, Enhos A, Ada S, Güngör N. Can we use nerve gliding exercises in women with carpal tunnel syndrome? *Adv Ther.* 2005;22(5):467-475.
49. De-la-Llave-Rincon AI, Ortega-Santiago R, Ambite-Quesada S, et al. Response of pain intensity to soft tissue mobilization and neurodynamic technique: a series of 18 patients with chronic carpal tunnel syndrome. *J Manip Physiol Ther.* 2012;35(6):420-427.
50. Totten PA, Hunter JM. Therapeutic techniques to enhance nerve gliding in thoracic outlet syndrome and carpal tunnel syndrome. *Hand Clin.* 1991;7(3):505-520.
51. Goodyear-Smith F, Arroll B. What can family physicians offer patients with carpal tunnel syndrome other than surgery? A systematic review of nonsurgical management. *Ann Fam Med.* 2004;2(3):267-273.
52. Muller M, Tsui D, Schnurr R, Biddulph-Deisroth L, Hard J, MacDermid JC. Effectiveness of hand therapy interventions in primary management of carpal tunnel syndrome: a systematic review. *J Hand Ther.* 2004;17(2):210-228.
53. Coppieters MW, Hough AD, Dilley A. Different nerve-gliding exercises induce different magnitudes of median nerve longitudinal excursion: an in vivo study using dynamic ultrasound imaging. *J Orthop Sports Phys Ther.* 2009;39(3):164-171.
54. Wolny T, Halicki Ł, Saulicz E, Kuszewski M, Myśliwiec A, Kokosz M. Wpływ terapii opartej o neuromobilizacje napięciowe i ślizgowe na stan kliniczny pacjentów z Zespołem Cieśni Nadgarstka—doniesienie wstępne. *Fizjoterapia Polska.* 2011;11(Suppl 1):81-82.