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The effectiveness of mobilization with movement on patients with mild and moderate carpal tunnel syndrome: A single-blinded, randomized controlled study

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ABSTRACT

Study design: Single-blinded, randomized controlled study.
Introduction: Carpal Tunnel Syndrome (CTS) causes pain and loss of function in the affected hand. The mobilization with movement (MWM) technique is a manual therapy method applied to correct joint movement limitation and to relieve pain and functional disorders.
Purpose of the study: This study aimed to examine the effectiveness of MWM technique on pain, grip strength, range of motion, edema, hand reaction, nerve conduction, and functional status in patients with CTS.
Methods: A total of 45 patients enrolled in the study. The MWM group (n = 18) completed a 4-week combined conservative physiotherapy and MWM program, whereas the control group (n = 18) received only the 4 weeks of conservative physiotherapy. Pain severity according to the numerical rating scale was used as primary outcome.
Results: We found an improvement within the subjects in resting pain (MWMG:5.1 ± 3.6 vs 1.1 ± 2.4, Effect Size (ES)=1.3; CG:4.5 ± 3.3 vs 1.0 ± 2.2, ES=1.1), in activity pain (MWMG:6.5 ± 3.7 vs 1.1 ± 2.4, ES=1.5; CG:4.8 ± 3.4 vs 2.2 ± 2.3, ES=1) and in night pain (MWMG:5.9 ± 3.2 vs 1.8 ± 2.5, ES=1.2; CG:5.3 ± 4.2 vs ± 2.3 ± 3.5, ES=0.9). For between the groups, a statistical difference was found for the activity pain, Disabilities of the Arm Shoulder and Hand Questionnaire score (MWMG:52.2 ± 23.8 vs 27 ± 24.7, ES=1.3; CG:47.0 ± 24.8 vs 41.5 ± 22.1, ES=0.2), Michigan Hand Outcomes Questionnaire (MHQ-1), (MWMG:44.4 ± 23.7 vs 74.7 ± 24.5, ES=1.3; CG:44.8 ± 17.4 vs 57.4 ± 21.7, ES=0.9) and MHQ-5 (MWMG:68.8 ± 13.1 vs 82.5 ± 11.5, ES=0.9; CG:63.4 ± 26.7 vs 59.3 ± 25.8, ES=0.1) parameters in favour of MWM group.
Discussion: This study showed that MWM compared to conservative physiotherapy might be more effective in reducing perceived symptoms in mild and moderate CTS patients.
Conclusions: MWM produced a small benefit to recovery of activity pain and upper extremity functionality level outcomes of patients with mild to moderate CTS when added to a traditional CTS physical therapy program.

Introduction

CTS is the most common entrapment neuropathy of the upper extremity, affecting approximately 3% of the general population.[1] Pain and tenderness over the palmar side of the hand, numbness and tingling in the distribution of the median nerve and nocturnal complaints are the main characteristics.[2] The condition relates to a

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history of excessive and repetitive stress that has strained the intrinsic muscles of the hand.[3] Risk factors include pregnancy, being female, advanced age, obesity, acute trauma, and repetitive wrist work, among others.[4]

Various treatment modalities have been studied including medication, steroid injection, wrist orthotics, manual therapy techniques, nerve gliding, as well as surgical treatment to treat CTS.[5-8] In several studies, groups that integrated joint mobilization performed better than the control group in pain reduction, subjective symptoms, and functional status.[9,10] Cadaveric studies discovered that neurodynamic techniques are effective on fluid dispersion in the median nerve at the level of the carpal tunnel, with no difference between sliding and tensioning.[11] Compared to other interventions, corticosteroid injections shows better outcome to splint alone at 6 weeks[12] and injection and splint shows better outcome than splint alone.[13] However, there is no universally accepted treatment option for CTS, and discussions in this area seem set to continue.[14] Surgery continues to be the treatment approach most commonly used for CTS.[15] The meta-analysis by Shi and MacDermid [16] concluded that both approaches were similarly effective at 3 months but that surgery was superior to nonsurgical treatment at 6 and 12 months for improving pain and function, with moderate between-group effect sizes (.22 < weighted mean difference < .56). According to the literature, CTS decompression surgery may result in numerous serious complications, leading in some cases to permanent loss of function. Neuhaus et al. reported that treatment failure and complications such as hematoma, infection or skin necrosis, and intraoperative iatrogenic injuries, persistence and recurrence are encountered in 1% to 25% of CTS decompression surgeries.[17] Therefore, the conservative treatment techniques should be considered primarily, especially in the mild to moderate severity of CTS. Manual therapy is 1 of the conservative applications used in the rehabilitation of patients with CTS.[8,18] Especially when using joint mobilization techniques, it seeks to increase range of motion and also to reduce pain.[19]

MWM is an active joint mobilization technique and it has been suggested that MWM amends an incorrectly positioned joint that occurs following injury,[20] by repositioning the joint so that it tracks normally and pain-free.[21,22] In the study conducted by Büyükturan et al., it was reported that applying the MWM in older adults with neck pain has positive effects on pain, range of motion ROM, functional level, kinesiophobia, depression, and quality of life.[23] In randomized controlled studies examining the effect of MWM technique in patients with lateral epicondylitis, [24] rotator cuff syndrome [25] and hip osteoarthritis ,[26] it has been reported that this technique reduces pain and increases ROM and functionality.

The most common symptoms usually experienced by patients with CTS include pain and paresthesia in areas innervated by the median nerve. Symptoms can be worse during activities involving the hand/wrist but also at night.[27] A study was to investigate the morphology of small unmyelinated as well as myelinated sensory axons in CTS reported that ratings of the Pain Catastrophizing Scale had significantly higher ratings on the Insomnia Severity Index, which is in accordance with sleep impairment as a cardinal sign of carpal tunnel syndrome.[28] Therefore, sleep disorders caused by pain seen in CTS also affect daily activities and impair quality of life. In order to break this vicious circle, methods that relieve pain as soon as possible are needed. The goal of MWM is to achieve immediate pain relief possibly by regulation of the nonopioid pain sensory pathways and by correction of micropositional faults.[29] The most frequent reported effect is that of an immediate and substantial pain reduction accompanied by improved function.[30] However, studies in the literature about MWM are mostly related to neck, elbow, shoulder, hip region diseases. To the best of our knowledge, the literature contains no prior studies that have examined the effects of MWM in CTS patients. Therefore, the current study aimed to examine the effects of MWM technique on pain, range of motion, muscle strength, edema, upper extremity functionality, hand reaction, nerve conduction velocity, and quality of life in patients diagnosed with CTS.

Methods

Trial design

The study design was a randomized, single-blinded 1:1 parallel-group study, and was conducted at the School of Physiotherapy and Rehabilitation of Kırşehir Ahi Evran University Training and Research Hospital in Turkey between April and December of 2020. The study proposal was approved by the local ethics committee, and conducted in accordance with the Declaration of Helsinki principles. Patients were called from the clinics waiting list, and prior to the study, written and oral consent was taken from each participant. The authors confirm that all ongoing and related trials for this study were registered, although due to an error of omission, the trial was registered retrospectively, but before the data was analyzed (ClinicalTrials.gov Identifier: NCT04733209).

Participants

A total of 36 participants diagnosed with CTS were included in the study. Inclusion criteria were the presence of paresthesia-pain and vasomotor symptoms in the area associated with the median nerve for a period exceeding 6 weeks, positive provocative test, and neurophysiological evaluation of the median nerve lesion severity recorded as mild to moderate. Patients were excluded based on; (1) any sensory and/or motor deficit in either the ulnar or radial nerve, (2) aged over 65 years, (3) previously underwent surgery or received steroid injections, (4) received multiple diagnoses on the upper extremity, (5) any upper extremity trauma, (6) systemic disease causing CTS, (7) comorbid musculoskeletal medical condition, or (8) pregnancy.

Interventions

Control Group (CG)

Traditional physiotherapy methods were applied to the control group's participants. These methods consisted of Transcutaneous Electrical Nerve Stimulation (TENS), Ultrasound (US), tendon gliding exercises, night orthosis, median nerve stretching, and hand-strengthening exercises. Exercises including tendon gliding, nerve gliding and strengthening exercise were supervised. Patients came for supervised physiotherapy program 3 times per week for 4 weeks.

TENS: The patients were sat in a chair positioned next to a treatment table. The hand to be treated was placed on the treatment table with the forearm in the supine position. Electrodes were then placed on the transverse carpal ligament and palmar surface of the hand. Conventional TENS was applied, with the current transition time set to 50-100 μs, and performed at a frequency of 100 Hz for a period of 20 minutes at an amplitude that did not cause muscle contraction or any feeling of numbness or tingling.[31]

US: Each patient sat in a chair positioned next to a treatment table. The hand to be treated was placed on the treatment table with the forearm in the supine position. Continuous ultrasound type was then applied using the full contact technique. Ultrasound treatment was applied over the transverse carpal ligament in the wrist with circular movements towards the proximal and distal at

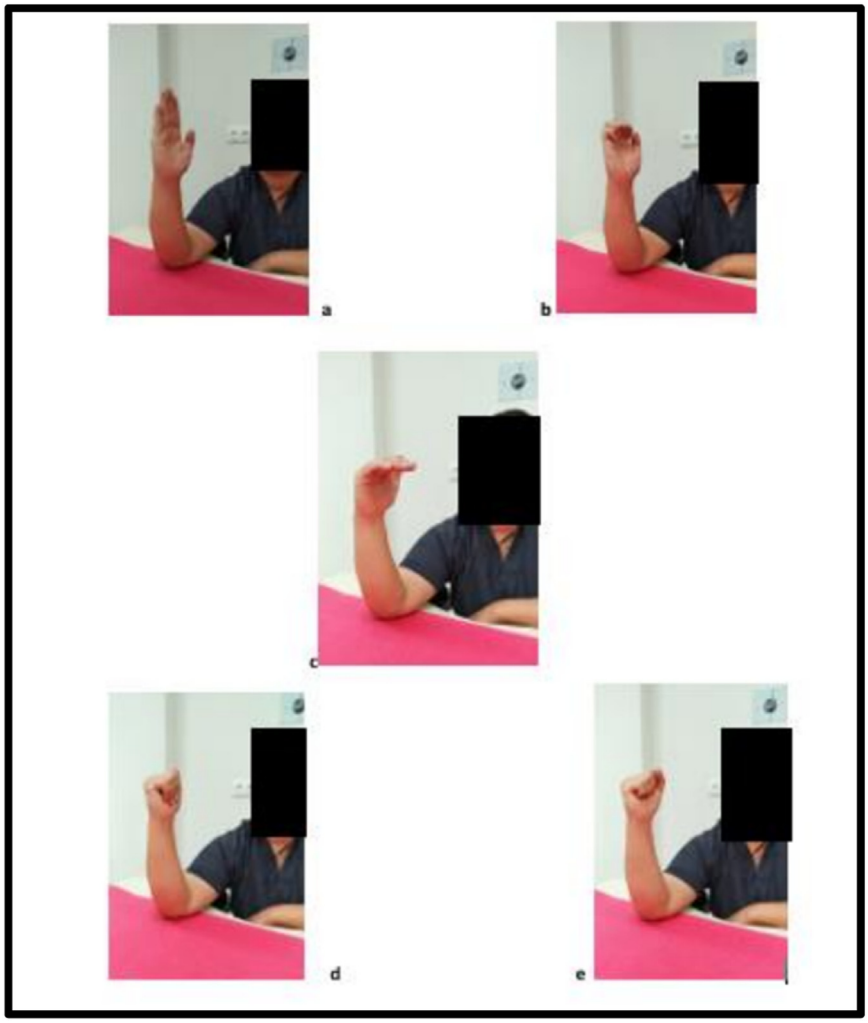

Fig. 1. Tendon gliding exercises.

a speed of 1-2.5 cm per second at a dose of 1 W/cm^2 for 6 minutes with a frequency of 3 Mhz.[32]

Tendon gliding exercises: The patients were instructed to perform nerve and tendon gliding exercises developed by Totten and Hunter.[33] In the starting position, the extremity was positioned with the shoulder joint in adduction and 30° of flexion, the elbow joint at 90° of flexion, the forearm in neutral, the wrist in neutral, and the metacarpophalangeal (MP) joints and finger joints in extension. This exercise involved 5 movements of the fingers, beginning first with full extension followed second by full flexion of the fingers. The third movement was to extend the distal interphalangeal (DIP) joints, whereas the MP joints and proximal interphalangeal (PIP) joints were kept in full flexion. In the fourth movement, all the PIP joints were extended, whereas the MP were in flexion and DIP joints maintained in extension. Finally, all MCP joints were extended in the fifth movement, and all PIP joints and DIP joints were fully flexed (Fig. 1). Patients were then tasked with completing 10 repetitions of each of these movements 3 times daily.

Orthosis: The wearing of an orthosis to maintain the wrist in a neutral position (Fig. 2) was recommended to each patient.[34,35] They were allowed to remove them for 1 hour each day. Orthosis adjustments were applied accordingly if the patient experienced any discomfort.[36]

Fig. 2. CTS orthosis.

Strengthening exercises: The supervised exercises were performed by the patients in a seated position. Strengthening exercises were performed with both hands by means of Digi-Flex hand exerciser (IMC Products Corp, Hicksville, New York), modeling mass and elastics. The patients were tasked with performing these exercises 10 times in each session and 3 times daily.[37]

Median nerve gliding exercise: The patients were tasked with performing 90° of abduction and external rotation to the shoulder joint, extension to the elbow joint, extension to the wrist and lateral flexion to the opposite side of the cervical region in the standing position, and to maintain this position for 5 seconds. For those patients who experienced difficulty performing this exercise from the standing position, they were tasked to perform the same pattern from a seated position. The patients were tasked with performing the exercise once daily with 5 repetitions.[38]

MWM Group

In this group, the MWM was applied in addition to the treatment program applied to the CG group. Mulligan's MWM technique was applied to patients in the MWM Group (MWMG) by a certified physiotherapist (I.C.) with 2 years' experience in applying MWM. Mobilization with movement is a concurrent application of sustained accessory mobilization applied by a physiotherapist and an active physiological end-of-range movement applied by the patient.

In this study, the patients were tasked with actively flexing and extending their wrist with the forearm in neutral whilst sat at a treatment table; this enables the pain direction to be accurately determined (Fig. 3, a1-a2). Each participant was tested with sustained manual glides in each of the possible directions during active wrist flexion and extension from the seated position. For the lateral glide, the therapist stabilises the lateral aspect of the distal radius using the first web-space. And glides the proximal row of carpal bones laterally (towards the thumb) using the first web-space of the other hand, following the joint line. For the medial glide, the therapist stabilises the medial aspect of the distal ulna using the first web-space. And glides the proximal row of carpal bones medially (away from the thumb) using the first web-space of the other hand, following the joint line. Both lateral and medial frontal plane glides were tested (Fig. 3, b1-b2, respectively). The glide direction that reduced the participant's pain and improved their ROM the most was selected as that participant's glide for the MWM technique. After the painless mobilization direction had been determined, while the patient was actively moving in this direction, sustained glide was simultaneously applied to the wrist joint manually by the therapist (Fig. 3, c1-c2). At the end of the movement, the patient applied some passive end-of-range overpressure using their free hand (Fig. 3, d1-d2). If the pain was shown to be in both flexion and extension, sustained glide was applied in both directions. All of these techniques were applied in 3 sets of 10 repetitions. These techniques are each described in detail in a textbook on MWM.[20]

The interventions were performed by the participants of both groups 3 days each week over a 4-week period, and with sessions lasting 50-60 minutes on average. Participants from both study groups were also instructed on how to position the affected side whilst resting, how to avoid overloading the hand, and how to perform functional activities in the safest way.

Data collection

Descriptive characteristics regarding their gender sex, age, body-mass index, dominant side, affected side, occupation, educational status, status as a tobacco smoker, and their CTS symptom severity were recorded during the baseline assessment.

Outcomes

Patients from both groups were assessed in terms of pain severity, grip strength, pinch strength, range of motion of the wrist joint, edema, hand reaction, neurophysiological status, and functional status of the upper extremity.

All outcomes were assessed both prior to and following the treatment.

Primary outcome. *Visual Analogue Scale (VAS).* As a simple and commonly applied method, VAS is considered to be both valid and reliable in measuring patient pain intensity. The patients in the current study were each asked with indicating the intensity of their pain experienced within the past 24 hours by marking on a 10-cm line scale, where 0 = "No pain" and 10 = "Maximum pain."[39] The participants' pain was measured according to 3 different parameters; night-pain, resting-pain, and activity-pain.

Secondary outcomes. *Joint Range of Motion (ROM).* Wrist active and passive flexion and extension ROMs, were recorded in degrees by using a universal goniometer for each group.[40] The goniometer was placed on the dorsal surface for flexion and on the volar surface for extension.

Electromyography assessment (EMG). Assessments were performed at room temperature by an experienced researcher using surface electrodes. The amplitude, latency, and conduction velocity of the median nerve sensory nerve action potential were obtained using a ring electrode positioned on the second finger and then recording from the wrist antidromically. Combined muscle action potential amplitude, latency, and conduction velocity were obtained by stimulation from the wrist and the antecubital fossa through the superficial electrode placed on the abductor pollicis brevis muscle. Results of the median palmar assessments were considered abnormal if the amplitude of the nerve action potential was less than 50 μV, the distal latency exceeded 2.3 ms, or the median-to-ulnar palmar latency difference exceeded 0.3 ms where the palmar latency was less than or equal to 2.2 ms. Finally, the results of the median motor assessments were considered abnormal if the amplitude of the thenar compound muscle action potential was less than 4 mV or the distal latency was greater than 4.5 ms.[41]

Edema. The figure-of 8 method is used to measure the edema over the hand. Using the figure-of8 method, the participants were sat in a chair positioned next to a treatment table for the edema evaluation. The participant's forearm was set to rest on the treatment table, with the forearm pronated and the hand extending over the end of the table. Tape was then wrapped across the ventral surface of the wrist to the most distal point of the radial styloid. Next, tape was placed diagonally across the dorsum of the hand to the fifth metacarpophalangeal (MCP) joint. The tape was then wrapped across the ventral surface to the second MCP joint. The final step involved placing the tape diagonally across the dorsum of the back of the hand to the starting point. Measurements were made bilaterally, and the results recorded in cm.[42]

Grip strength. The participants were first asked to sit upright in a chair with their feet supported. The arm to be tested was then positioned on a table with the shoulders slightly abducted and neutrally rotated, the elbow in 90° of flexion, the forearm at 0° between pronation and supination, and the wrist in a neutral resting position. The participants were then instructed to maintain that position during the test. Each participant was measured in a standard procedure as recommended by the American Society of Hand Therapists.[43] The grip strength of both hands were measured using the Jamar Hand Dynamometer (Patterson Medical, Warrenville, IL) and the outcome was expressed in kg.[44]

Pinch strength. Participants were seated at a table on which the dynamometers were positioned. The tested arm was positioned on a table with the shoulders slightly abducted and neutrally rotated, the elbow in 90° of flexion, the forearm in 0° between pronation and supination, and the wrist in neutral resting position. The participants were then instructed to maintain that position during the test. The pinch strength of both hands was measured using the

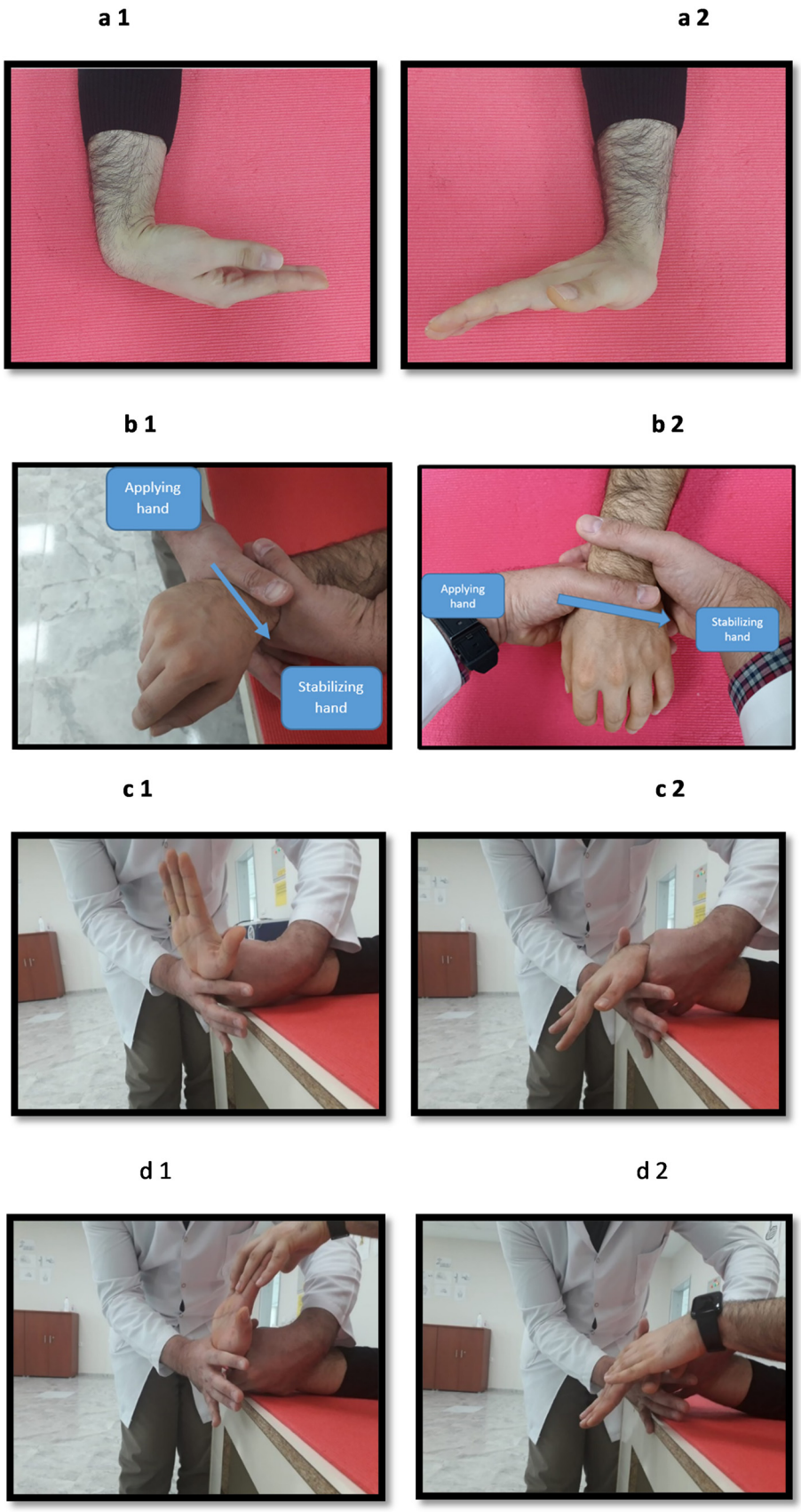

Fig. 3. Mobilization with Movement (MWM). Determination of painful direction (a1: flexion, a2: extension). MWM using sustained glide (b1: lateral glide, b2: medial glide). MWM using sustained glide to improve wrist movement (c1: extension, c2: flexion). Passive end-of-range overpressure applied by patient at the end of the movement (d1: extension, d2: flexion).

Jamar Pinch meter (Patterson Medical, Warrenville, IL) and the outcome was expressed in kg.[45]

Ruler drop test. To measure the hand reaction (HR), the ruler drop test (RDT)[46] was used. Prior to the test, the subject group members watched a video demonstration concerning the RDT and two practices were conducted. During the test, each subject had to sit with an angle of 90° elbow flexion, while the other arm/elbow was laid on a flat horizontal surface. The tested hand was held open and positioned at the edge of the surface. A ruler was then positioned vertically by the examiner in such a way that its lower verge was located across 50 mm between the web space of the subject's hand. The ruler was then dropped by the examiner and the subject had to grab it as quickly as possible. To record the distance passed by the ruler during the test, the mark against the dominant index finger lateral border was used, and the outcome was expressed as the measured cm.

Disabilities of the Arm, Shoulder and Hand Questionnaire (DASH). The functional status of the upper extremity was evaluated using the valid and reliable Turkish adaptation of the DASH questionnaire.[47]

Michigan Hand Outcomes Questionnaire (MHQ). The valid and reliable Turkish adaptation of the MHQ was used to measure the overall hand function, activities of daily living, work performance, pain, esthetics, and patient satisfaction with their hand function.[48]

Boston Carpal Tunnel Questionnaire (BCTQ). The valid and reliable Turkish adaptation of the BCTQ was applied to measure both the symptoms severity score (SSS) and functional status score (FSS).[49]

Sample size

To determine the sample of the study, version 3.1.9.4 of the G-Power program (HeinrichHeine-Universitat Dusseldorf, Germany) was used[50] to measure grip strength.[51] To obtain 80% statistical power ($1 - \beta$ error probability) with an α error level probability of .05, we performed repeated measure analysis of variance (ANOVA) both within and between interactions, used a medium effect size of .30 to consider the 2 groups, and used 2 measurements for the primary outcome. This approach yielded a sample size of 36 participants for the study, with 18 in each group. A flowchart of the study is presented in Figure 4.

Randomization

A randomization process was performed to divide the 36 CTS patients randomly between the 2 study groups (MWMG and CG), using matched-pairs randomization based on their age and sex. Matched-pairs randomization was performed with numbers sorted using the Research Randomizer program on the www.randomizer.org website.[52]

Blinding

At the baseline and after application of the 4-week treatment period, all assessments were evaluated by the investigator, who was blinded to the groups throughout the study (Ö.B.).

Statistical methods

Descriptive statistics were presented as mean ± standard deviation (*SD*) or number and frequency. For comparison of the demographic and subject characteristics between the 2 groups, the chi-square test was used for the categorical variables, whilst *t*-test was used for the continuous variables. A 2-way, mixed-model analysis of variance (ANOVA) was used to examine the effects of the treatment on outcome measures within each group (MWMG and CG) as the between-patient variable and time (baseline, final), and as the within-patient variable. Additionally, pairwise comparisons, known as Bonferroni correction, were performed in order to examine differences between the groups from the baseline to the final treatment session so as to investigate if any between-group differences in change scores were statistically significant. Data analysis was conducted using IBM's SPSS Statistics program Version 26.0 (IBM Corporation, Armonk, NY).

Table 1
Sociodemographic and clinic baseline characteristics of groups.

		MWM-group Mean ± *SD*	CG Mean ± *SD*	*P*
Age (y)		45.9 ± 11.1	47.2 ± 8.5	.69
BMI (kg/m^2)		29.6 ± 3.4	29.8 ± 3.8	.89
Sex (n)	Female	12	14	.84
	Male	4	4	
CTS grade (n)	Mild	6	6	.80
	Moderate	10	12	
Hand domination (n)	Right	14	15	.73
	Left	2	3	
Educational status (n)	Primary school	8	14	.17
	High school	2	2	
	University	6	2	
Occupation (n)	Housewife	8	16	.03
	Teacher	6	2	
	Worker	2	0	
Affected side (n)	Right	8	9	1
	Left	8	9	
Dominant side (n)	Right	14	15	.73
	Left	2	3	
Smoking status (n)	Smoker	2	4	.45
	Non-smoker	14	14	

SD = standard deviation; BMI = body mass index; MWM-Group = mobilization with movement – Group; CG = control group; kg = kilogram; m = meter.
*$P < .05$.

Results

The flow chart of this study shown in Figure 4. A total of 45 patients were enrolled into the study. Nine of them excluded because; did not meet inclusion criteria ($n = 7$) and declined to participate ($n = 2$). Among the 18 patients from the study group, there were 2 dropouts; 1 patient had transportation difficulties and 1 patient dropped because of residence change. In the control group, there was no drop out. Finally, 16 patients from the study group and 18 patients from the control group completed the 4 week follow-up of the study. Data from total 34 patients were analyzed with effect sizes and its 95% confidence intervals.

The sociodemographic and clinic characteristics data of the participants are presented in Table 1.

There was a significant decrease in VAS rest, VAS activity and VAS night measurements after treatment compared to pretreatment measurements for both MWM and control groups. While the highest decrease occurred in the VAS activity value of the MWM group ($P = .001$, t= 6.17, Cohen's d= 1.5), the least decrease was in the VAS night value of the control group ($P = .002$, t= 3.69, Cohen's d= 0.9), (Table 2).

There were reductions in DASH, BCTQSSS, and BCTQFSS after treatment based on pre-treatment measures for both the MWM and control groups. While the highest decrease in the measurements of these parameters occurred in the DASH measurements of the MWM group ($P = .001$, t= 5.22, Cohen's d= 1.3), the lowest decrease was in the control group DASH ($P = .373$, t= 0.91, Cohen's d= 0.2) . While there was a very large increase in the effect for the MHQ1, MHQ2, MHQ4 and MHQ5 parameters of the individuals in the MWM group receiving Mulligan treatment (respectively t: 5.13-5.74-5.04-3.61) for the control group, the same can be

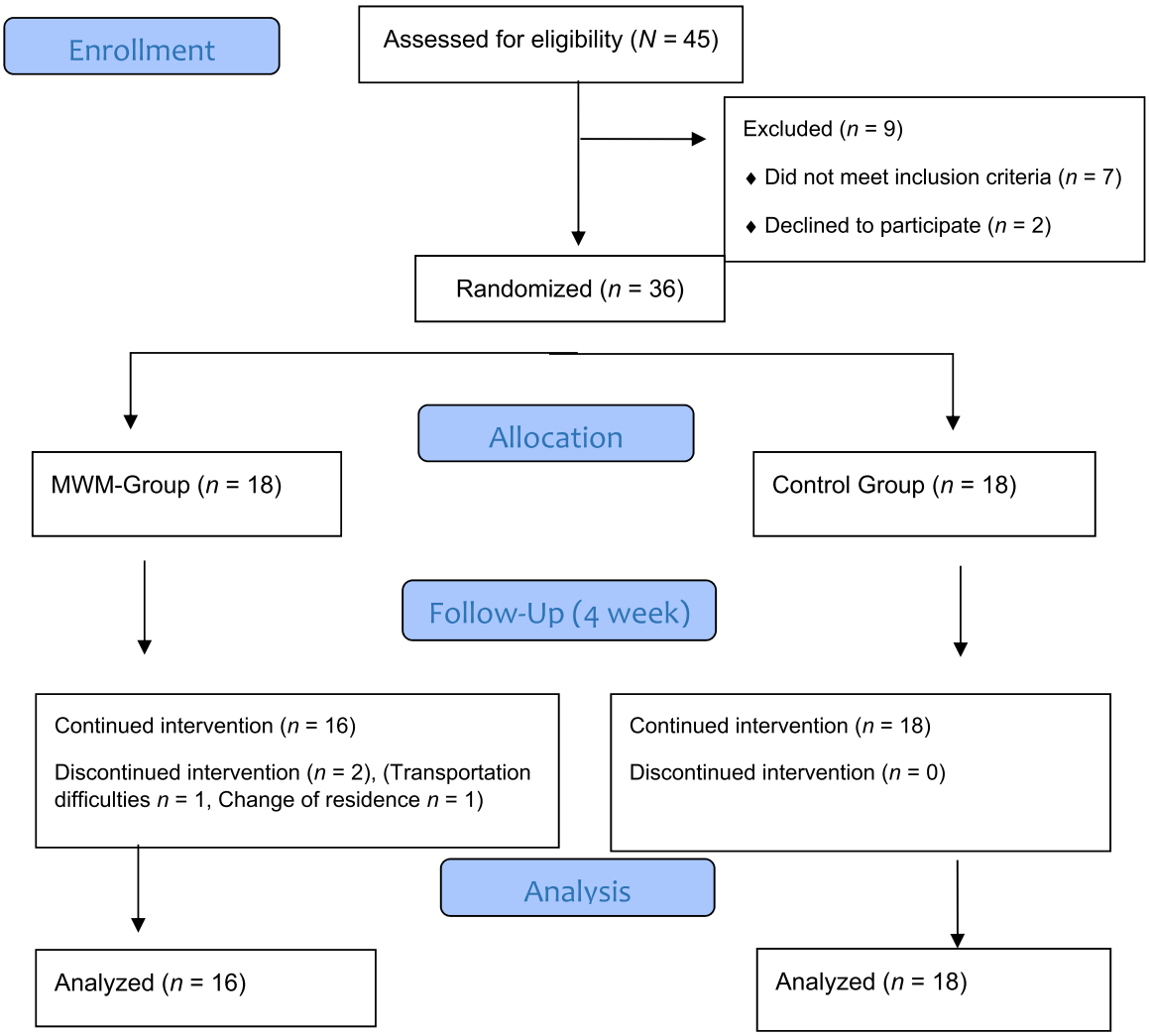

Fig. 4. Study flowchart.

said only for the MHQ6 parameter (t:5.56), (Table 2).As a result of the ROM data analysis, the highest increase occurred in the passive wrist flexion value of the MWM group (P = .007, t= 3.10, Cohen's d= 0.8), while the least increase occurred in the passive wrist extension value of the MWM group (P = .216, t= 1.29, Cohen's d= 0.3). While the highest increase in grip strength and pinch strength measurements occurred in the grip measurements of the control group (P = .004, t= 3.37, Cohen's d= 0.8), the least increase was in the pinch strength value of the control group (P = .695, t= 0.39, Cohen's d= 0.1). In terms of edema measurement, the effect size of the MWM group is higher than the control group (P = .497, t= 0.69, Cohen's d= 0.2). When NERT data were analyzed, although there was an increase in post-treatment measurements compared to pre-treatment measurements for both MWM (P = .184) and control (P = .292) groups, no significant difference was found. When the parameters were examined, there was a significant decrease in post-treatment EMG motor latency measurements compared to pre-treatment measurements for both MWM (P = 0.007) and control (P = 0.007) groups. In the EMG sensory latency measurement, there was a significant decrease only for the MWM group (P = 0.023). There was a significant increase in EMG sensory NCV measurements in terms of MWM group (P = 0.001). There was a great increase in the effect of EMG sensory NCV measurements of individuals in the MWM group, in which MWM treatment was applied (Cohen's d= 1.2). In all parameters, the MWM group was found to be superior in terms of effect width. (supplemental files Table 4).

The 2-way, mixed-model ANOVA of the resting pain (F = 0.217, P = .645, η_p^2 = .007), and night pain (F = 0.979, P = .330, η_p^2 = .030) indicated no significant group-by-time interaction, whereas the 2-way, mixed-model ANOVA of activity pain (F = 7.032, P = .012, η_p^2 = .180) indicated a significant group-by-time interaction. Individuals with CTS in the MWMG experienced greater improvements in activity pain than those in the CG. In addition, a comparison of change scores between the MWMG and CG demonstrated a between-group difference of 0.5 cm (95%CI: 0.3-0.7) on the VAS during activity (Table 3).

Group-by-time analysis of the active wrist flexion (F = 2.634, P = .114, η_p^2 = .076), active wrist extension (F = 0.022, P = .883, η_p^2 = .001), passive wrist flexion (F = 2.462, P = .126, η_p^2 = .071), and passive wrist extension (F = 0.043, P = .838, η_p^2 = .001) motions indicated no significant interaction (Table 2). Also the grip strength (F = 3.357, P = .076, η_p^2 = .095), pinch strength (F = 2.557, P = .120, η_p^2 = .074), edema (F = 0.601, P = .444, η_p^2 = .018), and NHRT (F = 0.127, P = .724, η_p^2 = .004) indicated no significant group-by-time interaction (supplemental files Table 5).

Both BCTQSSS (F = 0.004, P = .950, η_p^2 = .001) and BCTQFSS (F = 0.168, P = .684, η_p^2 = .005) scores improved, but indicated no

Table 2
Paired samples t test.

Variables	Groups	Baseline Mean±*SD*	Post-intervention Mean ± *SD*	t	*P*	Cohen's d	$d_{95\%\ CI}$
VAS rest (cm)	MWM	5.1 ± 3.6	1.1 ± 2.4	5.35	.001*	1.3	(0.6, 2.0)
	Control	4.5 ± 3.3	1.0 ± 2.2	4.58	.001*	1.1	(0.5, 1.7)
VAS activity (cm)	MWM	6.5 ± 3.7	1.1 ± 2.4	6.17	.001*	1.5	(0.8, 2.3)
	Control	4.8 ± 3.4	2.2 ± 2.3	4.44	.001*	1.0	(0.5, 1.6)
VAS night (cm)	MWM	5.9 ± 3.2	1.8 ± 2.5	4.72	.001*	1.2	(0.5, 1.8)
	Control	5.3 ± 4.2	2.3 ± 3.5	3.69	.002*	0.9	(0.3, 1.4)
DASH	MWM	52.2 ± 23.8	27 ± 24.7	5.22	.001*	1.3	(0.6, 2.0)
	Control	47.0 ± 24.8	41.5 ± 22.1	0.91	.373	0.2	(0.3, 0.7)
MHQ 1	MWM	44.4 ± 23.7	74.7 ± 24.5	5.13	.001*	1.3	(0.6, 1.9)
	Control	44.8 ± 17.4	57.4 ± 21.7	3.62	.002*	0.9	(0.3, 1.4)
MHQ 2	MWM	47.6 ± 21.3	72 ± 24.6	5.74	.001*	1.4	(0.7, 2.1)
	Control	44.4 ± 17.0	58.9 ± 19.8	3.33	.004*	0.8	(0.2, 1.3)
MHQ 3	MWM	43.1 ± 27.3	61.3 ± 25.1	2.46	.026	0.6	(0.1, 1.1)
	Control	46.0 ± 19.0	59.8 ± 18.2	2.41	.027	0.6	(0.1, 1.1)
MHQ 4	MWM	27.2 ± 17.0	61.3 ± 22.2	5.04	.001*	1.3	(0.6, 1.9)
	Control	39.1 ± 16.3	64.1 ± 26.1	3.11	.006*	0.7	(0.2, 1.2)
MHQ 5	MWM	68.8 ± 13.1	82.5 ± 11.5	3.61	.003*	0.9	(0.3, 1.5)
	Control	63.4 ± 26.7	59.3 ± 25.8	0.56	.581	0.1	(0.3, 0.6)
MHQ 6	MWM	40.8 ± 31	80.1 ± 22	4.70	.001*	1.2	(0.5, 1.8)
	Control	38.9 ± 15.8	61.1 ± 22	5.56	.001*	1.3	(0.7, 1.9)
BCTQSSS	MWM	2.8 ± 0.8	1.9 ± 0.7	4.2	.001*	1.1	(0.4, 1.7)
	Control	3.3 ± 0.8	2.4 ± 0.9	3.9	.001*	0.9	(0.4, 1.5)
BCTQFSS	MWM	2.7 ± 1.0	2 ± 1.2	3	.009	0.8	(0.2, 1.3)
	Control	3.5 ± 0.8	2.7 ± 0.9	3.31	.004*	0.8	(0.2, 1.3)

SD = standard deviation; MWM-Group = mobilization with movement group; CG = control group; DASH = disabilities of the arm, shoulder and hand questionnaire; MHQ = michigan hand outcomes questionnaire; BCTQSSS = boston carpal tunnel questionnaire symptom severity scale (SSS); BCTQFSS = boston carpal tunnel questionnaire functional status scale (FSS); VAS = visual analogue scale; cm = centimetre.
95% confidence interval.
* $P < .05$.

significant group-by-time interaction, whereas the 2-way, mixed-model ANOVA of the DASH score indicated a significant group-by-time interaction ($F = 6.427$, $P = .016$, $\eta_p^2 = .167$). The MWMG experienced significantly greater improvements in disability than the CG. The comparison of change scores between the MWMG and CG revealed a between-group difference of 1.1 points (95%CI: 0.3-1.3) or the DASH value. In terms of MHQ-2 ($F = 2.642$, $P = .114$, $\eta_p^2 = .076$), MHQ-3 ($F = 0.217$, $P = .645$, $\eta_p^2 = .007$), MHQ-4 ($F = 0.726$, $P = .400$, $\eta_p^2 = .022$), and MHQ-6 ($F = 3.665$, $P = .065$, $\eta_p^2 = .103$) scores, group-by-time interaction indicated no significant improvement, whereas the 2-way mixed-model ANOVA of the MHQ-1 ($F = 7.026$, $P = .012$, $\eta_p^2 = .180$) and MHQ-5 ($F = 4.367$, $P = .045$, $\eta_p^2 = .120$) scores indicated a significant group-by-time interaction. The MWMG experienced significantly greater improvements in disability than the CG in terms of both the MHQ-1 and MHQ-5 scores. A comparison of score change between the MWMG and CG revealed a between-group difference of 0.4 points (95%CI: 0.3-0.5) for MHQ-1 and 0.8 points (95%CI: 0.0-0.9) for MHQ-5 (Table 3).

In addition the EMG motor latency ($F = 1.244$, $P = .273$, $\eta_p^2 = .037$), EMG sensory latency ($F = 0.648$, $P = .414$, $\eta_p^2 = .021$), EMG motor NCV ($F = 0.008$, $P = .931$, $\eta_p^2 = .000$), and EMG sensory NCV ($F = 3.537$, $P = .069$, $\eta_p^2 = .100$) motions indicated no significant group-by-time interaction (supplemental files Table 5).

Discussion

In this study both groups had improvements in pain, grip strength, range of motion, edema, hand reaction, nerve conduction, and functional status at 4 weeks after commencing treatment, suggesting that the exercise protocol that we utilized might be useful in mild and moderate CTS. However, those in the MWM group scored significantly better on the activity pain and upper extremity functionality scales, compared to the control group at 4 weeks.

The literature suggests that CTS is a multidetermined condition with a wide range of associated risk factors. Specifically, several occupational, social, and psychological risk factors were found to be related to CTS.[53] Female sex, age, and obesity have been consistently linked with CTS. A literature review reported that the BMI was found to be significantly higher in patients diagnosed with CTS than in control groups and the threshold for BMI as a risk factor has not yet been determined.[3] In a large case–control study cases were patients with a diagnosis of CTS and included 3,391 cases, of which 2,444 (72%) were women, with a mean age at diagnosis of 46 (range 16-96) years.[54] In our study, the age and BMI ratios of the participants were high, which is consistent with the literature. Also, female sex dominance was 26/8.

Although a variety of diagnostic tests are available, identifying cases of CTS remains a challenge both in the workplace and the clinic. Clinical tests may focus on the nature of the symptoms, provocation of symptoms, or sensorimotor nerve evaluation.[55] In systematic review synthesized 12 clinical studies reporting on 13 diagnostic tests used to screen workers for CTS. Across the studies, hand diagrams, provocative maneuvers, sensorimotor and questionnaires were evaluated, with the Kamath and Stothard questionnaire and the Katz hand symptom diagrams having the best overall sensitivity and specifity.[53] In our study for clinical examination we used provocative test, and neurophysiological evaluation. According to literature findings [53] this tests had conflicting evidence and potentially limited diagnostic accuracy.

Conflicting results concerning manual therapy have been published for CTS treatment.[14] A recent systematic review assessed the effect of neurodynamic techniques and found no clinically important benefit in pain or the BCTQ symptom severity score when they pooled data from trials with various control treatments.[56] In a randomized sham-controlled trial Bialosky et al., ($n = 40$) found no difference in pain or the DASH score between the sham and real treatment.[57] Shem et al. (2020) investigated a self-stretching

Table 3
Independent samples t Test and repeated measures of ANOVA.

Variables	Groups	Baseline Mean±SD	Post-intervention Mean ± SD	F	**P	η_p^2	Between-Group Difference in Change Scores*
VAS Rest (cm)	MWM	5.1 ± 3.6	1.1 ± 2.4	0.217	.645	.007	0.2 (0.1-0.3)
	Control	4.5 ± 3.3	1 ± 2.2				
	*P	.639	.937				
VAS Activity (cm)	MWM	6.5 ± 3.7	1.1 ± 2.4	7.032	**.012**	.180	0.5 (0.3-0.7)
	Control	4.8 ± 3.4	2.2 ± 2.3				
	*P	.183	.182				
VAS Night (cm)	MWM	5.9 ± 3.2	1.8 ± 2.5	0.979	.330	.030	0.3 (0.2-0.4)
	Control	5.3 ± 4.2	2.3 ± 3.5				
	*P	.614	.621				
DASH	MWM	52.2 ± 23.8	27 ± 24.7	6.427	**.016**	.167	1.1 (0.3-1.3)
	Control	47 ± 24.8	41.5 ± 22.1				
	*P	.536	.08				
MHQ 1	MWM	44.4 ± 23.7	74.7 ± 24.5	7.026	**.012**	.180	0.4 (0.3-0.5)
	Control	44.8 ± 17.4	57.4 ± 21.7				
	*P	.949	**.037**				
MHQ 2	MWM	47.6 ± 21.3	72 ± 24.6	2,642	.114	.076	0.6 (0.5-0.8)
	Control	44.4 ± 17	58.9 ± 19.8				
	*P	.632	.095				
MHQ 3	MWM	43.1 ± 27.3	61.3 ± 25.1	0.217	.645	.007	0.0 (0.0-0.0)
	Control	46.0 ± 19.0	59.8 ± 18.2				
	*P	.722	.851				
MHQ 4	MWM	27.2 ± 17	61.3 ± 22.2	0.726	.400	.022	0.6 (0.4-0.7)
	Control	39.1 ± 16.3	64.1 ± 26.1				
	*P	**.046**	.739				
MHQ 5	MWM	68.8 ± 13.1	82.5 ± 11.5	4.367	**.045**	.120	0.8 (0.0-0.9)
	Control	63.4 ± 26.7	59.3 ± 25.8				
	*P	.476	**.002**				
MHQ 6	MWM	40.8 ± 31	80.1 ± 22	3.665	.065	.103	0.1 (-0.2- 0.1)
	Control	38.9 ± 15.8	61.1 ± 22				
	*P	.818	**.017**				
BCTQSSS	MWM	2.8 ± 0.8	1.9 ± 0.7	0.004	.950	.001	0.2 (0.0-0.2)
	Control	3.3 ± 0.8	2.4 ± 0.9				
	*P	.062	.080				
BCTQFSS	MWM	2.7 ± 1.0	2 ± 1.2	0.168	.684	.005	0.0 (0.0-0.0)
	Control	3.5 ± 0.8	2.7 ± 0.9				
	*P	**.011**	.054				

SD = standard deviation; MWM-Group = mobilization with movement group; CG = control group; DASH = disabilities of the arm, shoulder and hand questionnaire; michigan hand outcomes questionnaire; BCTQSSS = boston carpal tunnel questionnaire symptom severity scale (SSS); BCTQFSS = boston carpal tunnel questionnaire; FSS = functional status scale;VAS = visual analogue scale; cm = centimetre.

* *p*: Independent samples t test.

** p: Repeated measures of ANOVA.

protocol of carpal tunnel and did not find any difference in any variable.[58] In a long-term randomized controlled trial ($n = 120$) reported that manual therapy consisting of manual therapies including desensitization maneuvers of the central nervous system and surgery combined with a tendon and nerve gliding exercise program at home resulted in similar outcomes on pain and function in women with CTS at 1- and 4-year follow-up periods. [8] Unlike these studies, others reported improvement in CTS with manual therapy. Recently, 2 randomized controlled trials have shown that immediately after 10 weeks of treatment (20 sessions), patients who received manual therapy based on neurodynamic techniques had significant improvement immediately after therapy.[59,60] Wolny and Linek showed that neurodynamic techniques positively influenced outcomes, such as nerve conduction, pain, subjective symptoms (SSS) and functional state (FSS) BCTQ, and the perception of two-point discrimination.[59,60] In a pilot randomized controlled study individuals with CTS were randomly allocated into a 4-week home-based neuromobilization exercise group or a standard care group while awaiting surgery. And reported that individuals with CTS who engaged in the proposed neuromobilization exercise program would display greater improvement before and after carpal tunnel decompression surgery when compared with their counterparts.[61] In a randomized, single-blinded clinical trial, Fernández-de-las-Peñas et al.[62] compared manual therapy interventions to carpal tunnel decompression surgery in a long-term follow-up study. At 1 and 3 months post treatment, the manual therapy group reported greater pain reduction (MD, –3.4 vs –1.5 and MD, –3.7 vs –2.4, respectively), with a large effect size (ES) favoring manual therapy (1.1 greater than standardized MD greater than 1.8). CTQ-FS scores at 1 month and 3 months also favored the manual therapy group, with standardized MD of 1.2 (large ES) and 0.8 (medium ES), respectively. Recently, 2 randomized controlled trials have shown that Kinesio tape provided additional improvement in pain and function as compared to sham taping and the standard approach in CTS patients.[63,64] Regarding this results, a hypothesis claimed that immediate and substantial pain reduction provided by MWM might improve pain and upper-extremity functionality in patients with mild and moderate CTS. Although some studies[14,65] have reported conflicting results as to whether surgery or manual therapy effective in CTS treatment, according to the findings of the current study, a statistically significant improvement was revealed in both pain level and disability scores. Other studies have found that conservative physiotherapy modalities are deemed useful for pain alleviation and addressing sensory complaints in patients with mild-to-moderate CTS.[14,34] conservative since the results of the current study have shown that applying the MWM technique combined with conservative physiotherapy can significantly improve clinical measurements over the application of conservative physiotherapy

alone, it may be said that the MWM technique can activate an immediate and stronger analgesic mechanism when compared to conservative physiotherapy alone being applied.

Pain is one of the most frequent symptoms experienced by patients with CTS.[14] For the majority of patients, night pain and subsequent daytime dysfunction are the impetus to seek medical intervention.[66] The goal of MWM is to achieve immediate pain relief possibly by regulation of the non-opioid pain sensory pathways and by correction of micropositional faults.[29] The most frequent reported effect is that of an immediate and substantial pain reduction accompanied by improved function.[30] In the current study, when all the parameters were examined, a significant decrease and large effect size in within group analyses was found in favor of MWM group VAS rest (ES:1.3), VAS activity (ES:1.5), and VAS night (ES:1.2) when compared to pre-treatment measurements. Randall et al.[67] propose Minimal clinically important differences (MCID) values in the range of 2.2 to 2.6 for the VAS-pain instrument in a nonshoulder hand and upper extremity postoperative population. We assessed a difference that can be considered as clinically significant in comparison with MCID [67] in MWM group VAS rest (4 point), VAS activity (5.4 point), and VAS night (4.1 point). In our study, we think that the reason for the dramatic decrease in the VAS score was due to the mobilization applied in the correct position of the joint. Providing an intervention, such as MWM, for mild to moderate CTS allows individuals to continue participation in meaningful occupations of self-care, work, and leisure with decreased pain and increased function.

In a clinical practice guide published by the American Academy of Orthopedic Surgeons in 2010 for CTS treatment, BCTQ, DASH, and MHQ were all recommended for functional evaluation in CTS research,[68] and all 3 questionnaires were applied in the current study. Although improvement was observed in both groups in all MHQ, BCTQ, and DASH scores, a significant improvement was revealed in the DASH, MHQ 1, and MHQ 5 scores in favor of the MWM group. One of the our secondary outcome consisted of changes at the 4-week follow-up in self-reported function, which was measured with the functional status subscale (FSS) of the BCTQ. MCID of 0.74 points in the functional status subscale and 1.14 points in the symptom severity subscale (SSS) have been reported.[69] Also the minimal detectable change (MDC) was reported 0.86 and 0.75 for SSS and FSS, respectively.[70] In the current trial, the BCTQ functional status subscale was 0.7 points in MWM group and 0.8 points in control group. And for symptom severity subscale 0.9 points in MWM group and 0.9 points in control group. According to this point it was concluded that both groups had effective difference according to MDC and MCID scores size but MWM group not superior to the control group. We attribute the absence of results in favor of the MWM group in BCTQ values in the intergroup analysis to the short follow-up period in our study.

Reaction time can be defined as the time elapsed between a stimulus being applied and any subsequent reaction.[71] It has been reported that changes in reaction time may be a predictor of musculoskeletal pathologies.[72] When the NHRT data were examined, there was an increase seen in the post-treatment measurements for both the MWM and control groups, although there was no significant difference found between the groups. In recovery conditions, a decrease in post-treatment measurements at reaction time is expected compared to pre-treatment. However, in the findings in our study, the treatment applied to both groups showed no positive effect on hand reaction.

In a single-blinded randomized cohort study,[73] it was reported that subjective edema in the hand with CTS was an important prognostic and diagnostic symptom in the evaluation and treatment of CTS, while another study[74] reported there being no relationship between CTS and objective edema. In the current study, according to the post-treatment edema measurements, there was a decrease recorded in edema measurements for the MWM group, but no change was detected in the control group.

In a randomized placebo-controlled double-blinded study that examined the effects of manual therapy in individuals with carpal tunnel syndrome, sham therapy and manual therapy were compared, with pain, grip strength, symptom severity, and EMG findings measured at baseline and also at 6 weeks post-treatment. Findings from this study suggest that manual therapy may improve sensation, strength, and overall symptom severity. However, there was no significant change detected in nerve conduction studies after 6 weeks of manual therapy.[58] Similarly, although the current study revealed an improvement in motor latency, sensory latency, and NCV measurements from pre- to post-treatment, no significant results were obtained between the 2 patient groups. Longer follow-up periods may therefore be required for neurophysiological sensory and motor recovery. It is thought that the effect of group-by-time interaction was not significant for these parameters due to the short follow-up period in the current study.

Although some studies have reported that manual therapy (neurodynamic techniques,[57] self-stretching protocol,[58] desensitization maneuvers [8]) has no clinically important benefit in outcomes on pain and function in CTS treatment, according to current study MWM produced a small benefit to recovery of activity pain and upper extremity functionality level outcomes of patients with CTS. According to the main explanation provided for the pain-reducing effect of the MWM, mobilization movements correct positional faults in the bony structure and hence reduce pain.[29]

In a 2015 study conducted with CTS patients and healthy individuals that examined hand grip pattern and grip strength, it was reported that the grip pattern and coordination between fingers showed impairment in individuals with CTS compared to healthy subjects. The reason put forward for this deterioration was explained by the loss of sensation in the nervus medianus sensory area seen in patients with CTS.[75] In the current study, hand grip strength and pinch strength increased in post-treatment measurements compared to pre-treatment in both groups. This increase was in favor of the control group for hand grip strength, and the MWM group for pinch strength. The time between the pre-treatment and post-treatment measurements was 4 weeks in the current study. As known, longer processes are required in order to achieve the full increase in muscle strength.[76] In addition, it is thought that different percentages of sensory loss in CTS patients may prevent standard forms of measurement due to a disruption of proprioceptive input during grasping.[75]

Limitations

Our study has the limitations of being a small single center study, and the follow-up time was relatively short. We believe that longer follow-up would not have changed the direction of our results; there is general consensus that CTS outcomes are known to be static by 6 months.[8,77] However, with a longer follow-up time, we might detect the neurophysiologic status and muscle strength more accurately. This may be the reason why there was no significant difference in neurophysiologic status and muscle strength in our study. In addition as an another limitation, 3 functional scale (BCTQ, DASH, and MHQ) were used for functional evaluation in our study. This leads to confusion in the analysis and interpretation of data. Therefore, we believe that it would be more appropriate if to use only the BCTQ, which is specific to this disease.

There are some next steps needed in this area of research:

- This study lacked participation from people with severe CTS, because they were particularly excluded for indication. The ef-

fectiveness of MWM technique in this subgroup of patients can be explored in future studies.
- In the current study MWM group the positive effect obtained in the early period especially with regard to pain and upper-extremity functionality. However, pain and functionality measurements are subjective measurements based on patient statements. Therefore, the use of objective measurement methods such as x-ray scopy and ultrasound imaging that can simultaneously measure the mechanical effect of the MWM technique in future studies will strengthen the level of evidence.

The addition of MWM technique to a conservative program of physiotherapy for patients with mild and moderate carpal tunnel syndrome generates better results for pain and functional status than a standard physiotherapy program alone. Based on our experience from this study, MWM was not associated with any undesirable effects, but it provided small additional benefits compared to routine physiotherapy approaches in patients with mild and moderate CTS. MWM can be used as an adjunct to routine rehabilitation and may increase the motivation of patients for faster functional recovery compared to conservative methods.

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Supplementary materials

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Quiz: # A06

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1. All subjects received
   a. median nerve stretching
   b. tendon gliding
   c. night splinting
   d. all of the above
2. The study design is
   a. qualitative
   b. case series
   c. single-blinded RCTs
   d. double-blinded RCTs
3. The primary outcome was the measure of
   a. pain
   b. ROM
   c. grip strength
   d. all of the above
4. The study included
   a. all normals
   b. two different groups of actual patients
   c. one group of actual patients and one group of normals
   d. all actual patients who had received carpal tunnel release surgery
5. The authors found that MWM was modestly successful in the management of less than severe CTS
   a. false
   b. true

When submitting to the HTCC for re-certification, please batch your JHT RFC certificates in groups of 3 or more to get full credit.