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Effects of Neurodynamic Mobilizations on Pain Hypersensitivity in Patients With Hand Osteoarthritis Compared to Robotic Assisted Mobilization: A Randomized ~~Clinical~~ Trial

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Objective. To evaluate the effectiveness of the neurodynamic mobilization techniques compared with passive robotic physiologic movement in patients with hand osteoarthritis (OA).

Methods. We conducted a randomized controlled trial. A total of 72 patients (mean ± SD age 71 ± 11 years) with dominant symptomatic hand OA were randomized in 2 groups, and both received 12 treatment sessions over 4 weeks. The experimental group received neurodynamic mobilization of the median, radial, and ulnar nerves, and the control group received robotic-assisted passive movement treatment. Both groups also participated in a program of hand stability exercises. Outcome measures included pain intensity, pressure pain thresholds (PPTs), and strength measurements. Group-by-time effects were compared using mixed-model analyses of variance.

Results. After the intervention, the experimental group had statistically significant, higher PPTs than the control group at the thumb carpometacarpal joint by 0.7 kg/cm^2 (95% confidence interval [95% CI 0.6, 0.8]), the median nerve by 0.7 kg/cm^2 (95% CI 0.6, 0.7), and the radial nerve by 0.5 kg/cm^2 (95% CI 0.3, 0.6); however, the difference was not statistically significant at 3 months postintervention. Although mean values in the experimental group were higher than in the control group at all PPT sites at both assessments, these differences were not statistically significant. The experimental group experienced a statistically significantly reduction in pain immediately postintervention, but this was not present at the 3-month follow-up. There were no statistically significant differences in pinch or grip strength between groups.

Conclusion. We found that neurodynamic mobilizations decreased hypersensitivity in patients with hand OA immediately after the intervention; however, differences were no longer present at 3 months. The results suggest that these techniques may have some limited value in the short term but do not have lasting effects.

INTRODUCTION

The prevalence of symptomatic osteoarthritis (OA) of the hand is ~67% in the general population (1). The carpometacarpal (CMC) joint of the thumb is most commonly affected by OA, followed by the interphalangeal (IP) joints (2,3). The magnitude of damage or inflammation present in OA is not directly correlated to the pain intensity reported by individuals with OA, particularly those with chronic pain. In individuals with chronic OA pain, the experience is more likely related to central nervous system (CNS) involvement (4,5), and recent studies suggest that OA is a mixed pain state and that in some individuals, CNS factors play an important role (6,7).

For example, individuals with hand OA who underwent functional magnetic resonance imaging analysis showed increased activation in the thalamus, cingulate, and the frontal and somatosensory cortex, which are the brain's pain processing centers and have been implicated in central sensitization (8). Chronic OA pain may also lead to allodynia, in which nonpainful stimuli may produce the sensation of pain, or a painful stimulus may be perceived

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SIGNIFICANCE & INNOVATIONS

- Neurodynamic mobilizations (sliding techniques) immediately decreased hypersensitivity in patients with hand osteoarthritis (OA). This effect was not maintained at the 3-month follow-up.
- The results suggest that these techniques may be useful in the short term for patients with hand OA.

as more intense compared to the experience in asymptomatic individuals (8,9). To examine the presence of this sensitivity, assessing pressure pain threshold (PPT) (i.e., tenderness to palpation) has been shown to be a reliable and valid method for identifying individuals with central sensitization (10).

The European League Against Rheumatism published a systematic literature review that summarized the current nonpharmacologic, pharmacologic, and surgical approaches for the management of hand OA (11). The review identified 28 studies that evaluated nonpharmacologic treatments of hand OA, including exercise, joint protection, splints, assisted devices, and combinations of the interventions (11). However, none of the reviewed studies considered interventions that specifically targeted reducing pain sensitivity (11). Identifying nonpharmacologic interventions to reduce local and widespread pain sensitivity in hand OA could address a missing component of management for individuals who present with signs and symptoms of nervous system sensitization.

Neurodynamic mobilization techniques are a form of manual therapy aimed at influencing the neural structures through positioning and movement of multiple joints to reduce pain (12). Numerous studies by Wolney and Linek have shown that neurodynamic mobilization have been effective in reducing pain and improving functional status and nerve conduction velocity when compared to both a control group and a sham (13–15). However, a limited number of studies have examined the effects of neurodynamic techniques on individuals with joint pathology in the hand. Previous work (16) has shown that neurodynamic mobilization techniques may modify PPTs by potentially reducing pain sensitivity in individuals with hand OA and might potentially be an appropriate management strategy in the presence of central sensitization. Considering that neurodynamic techniques have been beneficial for individuals with carpal tunnel syndrome, and that preliminary evidence suggests that they may be beneficial for patients with OA of the CMC thumb joint, further research is warranted to determine the clinical effectiveness of these techniques compared to other interventions (13–15,17,18).

Additionally, robotic physiologic movements have recently been introduced as a method to assist with the completion of exercise (19,20). Recent technologies have developed robots to serve to assist patients in the rehabilitation process, thus maximizing patient outcomes (21). Actually, the focus of research using robotic devices has been on interventions to improve upper extremity functionality in neurologic populations, particularly patients with a history of stroke (22). To our knowledge, robotic physiologic movement in orthopedic patients has not been well explored in clinical research beyond passive movement after joint arthroplasty, although it has already demonstrated beneficial effects on the CNS and sensorimotor deficits in neurologic patients (23,24). These robotic tools assist the patient with carrying out exercise protocols. Among these devices, the glove provides computer-controlled, repetitive and passive mobilization of the fingers with multisensory feedback (25). However, the effects of robotic physiologic movement have not been compared to neural mobilization in a patient population with hand OA. Therefore, the aim of the current study was to evaluate the effectiveness of the neurodynamic mobilization techniques compared with passive robotic physiologic movement in patients with hand OA.

SUBJECTS AND METHODS

Study design. We conducted a randomized ~~clinical~~ trial. Informed consent was obtained from all patients, and procedures were conducted according to the Declaration of Helsinki and approved by a local ethics committee. The study was registered at ClinicalTrials.gov (NCT02701335). The IRCCS Fondazione Don Carlo Gnocchi Ethics Committee approved the study on February 24, 2016. All participants gave written informed consent before data collection began.

Subjects. From July 2016 to April 2018, all patients presenting to the IRCCS Fondazione Don Carlo Gnocchi clinic in Italy and diagnosed with dominant hand OA were screened for eligibility. Inclusion criteria for the study were ages between 50 and 90 years and symptoms of OA in the dominant hand; only the dominant hand received the treatment intervention. OA was confirmed by the treating physician and by radiographic findings (OA severity of 3 to 4 on the Kellgren/Lawrence scale). Exclusion criteria were subjects scoring >6 points on the Beck Depression Inventory or >30 points in the State-Trait Anxiety Inventory. Patients with a medical history of carpal tunnel syndrome, surgical interventions to the hand, or DeQuervain's tenosynovitis, and those with degenerative or nondegenerative neurologic conditions in which pain perception could be altered, were also excluded.

Randomization. Participants were randomly assigned to either neurodynamic mobilization or passive robotic physiologic movements using simple randomization with a random number generator created by an individual not involved in subject recruitment. Randomization was conducted using a random sequence generator program (http://www.random.org).

An assessor blinded to the patients' allocated group obtained measurements at baseline, immediately after the 4-week treatment period, and at 3 months after the treatment. Interventions in both groups were applied by the same physical therapist, who

had 3 years of experience in manual therapy and the management of musculoskeletal pain disorders. Both groups were provided with the same instructions regarding effectiveness of the treatment.

Interventions. *Neurodynamic intervention group (NIG).* The experimental group received a neurodynamic nerve slider technique targeted to the median, radial, and ulnar nerves of the symptomatic extremity for 12 sessions over a 4-week timeframe (26). The technique was applied with the physiotherapist standing and the patient positioned in supine. These techniques aim to produce neural sliding in relation to adjacent tissues (12). In order not to produce pain, speed and amplitude of movements were adjusted. These movements were alternated at a rate of ~2 seconds per cycle (1 second into extension, and 1 second into flexion). At each session, the techniques were applied 3 times for 3 minutes separated by 1-minute rest periods. These techniques originated from the work of Shacklock and Butler (27).

Median nerve technique. The patient was placed in the following position prior to performing the median nerve slider technique: shoulder girdle depression; glenohumeral abduction and external rotation; supination of the forearm; and wrist, thumb, and finger extension. The neurodynamic technique for the median nerve consisted of the following alternating movements: the combination of elbow extension (which increases tension) and wrist flexion (which decreases tension) movement with the combination of elbow flexion (decreasing tension) and wrist extension (increasing tension) movement (28).

Radial nerve technique. The patient was placed in the following position prior to the performance of the radial nerve slider technique: shoulder girdle depression; glenohumeral internal rotation; pronation of the forearm; elbow extension; and wrist, thumb, and finger flexion. The neurodynamic technique for the radial nerve involved alternating the following movements: the combination of elbow flexion–wrist flexion (unloads the radial nerve) with elbow extension–wrist extension (loading) (16,29).

Ulnar nerve technique. For the ulnar nerve, the wrist was placed in extension, the elbow was flexed, and the shoulder abducted. The slider neurodynamic technique for the ulnar nerve involved alternating the following movements: elbow flexion (unloads the ulnar nerve) and shoulder abduction (loads the ulnar nerve) was alternated with elbow extension (loading) and shoulder adduction (unloading) throughout the sliding technique; the wrist was maintained in 60° extension and the forearm in supination (30).

Passive physiologic movement group. Participants received half an hour of robotic passive movement treatment using a Gloreha Workstation (Idrogenet) for 12 sessions over 4 weeks. The patients wore a glove, and every finger was attached to individual thimbles connected through a nylon thread to a device interfaced with a hybrid system (compressed air and oil) that performed the passive movement of flexion–extension of the fingers (Figure 1). Further details of the intervention are available elsewhere (31). Patients in both groups also received additional standardized exercises, as described by Villafañe et al (32).

Outcome measures. Pain intensity was assessed using a visual analog scale (VAS; 0 = no pain, 10 = maximum pain) for 3 separate pain status conditions: 1) level of pain while executing a key pinch between the thumb and index finger; 2) average level of pain over the last 24 hours; and 3) average level of pain over the last week (31).

The PPT test is a quantitative sensory test of tissue sensitivity, and it is defined as the minimal amount of pressure where the sense of pressure changes to pain. An electronic algometer (Algomed) was used to measure the PPTs (33). The validity and reproducibility of algometry has been described, with higher PPTs indicating lower pain sensitivity. PPTs near the pathologic site are thought to represent the degree of peripheral nociception, whereas decreased PPTs distal to the pathology are markers of hyperexcitability of the CNS (34). An assessor blinded to the patient's group assessed PPT bilaterally over the hand (thumb CMC at the center of the anatomic snuffbox and unciform apophysis of the hamate bone), the C5–C6 zygapophyseal joint, and the median, radial, and ulnar nerves. We assessed widespread pain sensitivity given the evidence for central sensitization in individuals with OA and the recommendations for examining sensitivity at multiple sites. The tested nerve sites were chosen based on the accessibility of the nerve. The median nerve was palpated distally at the wrist between the palmaris longus and flexor carpi radialis longus; the nerve was accessed after moving the tendons laterally. The radial nerve was palpated in the anatomic snuffbox, and the ulnar nerve in the cubital tunnel at the elbow (35). Assessment of PPT in individuals with hand OA has been shown to be very reliable (36), with scores for minimal detectable change (MDC) as follows: C5–C6 joint (95% confidence interval [95% CI] 0.3–0.5 kg/cm^2), thumb CMC joint (95% CI 0.3–0.5 kg/cm^2), hamate bone (95% CI 0.2–0.4

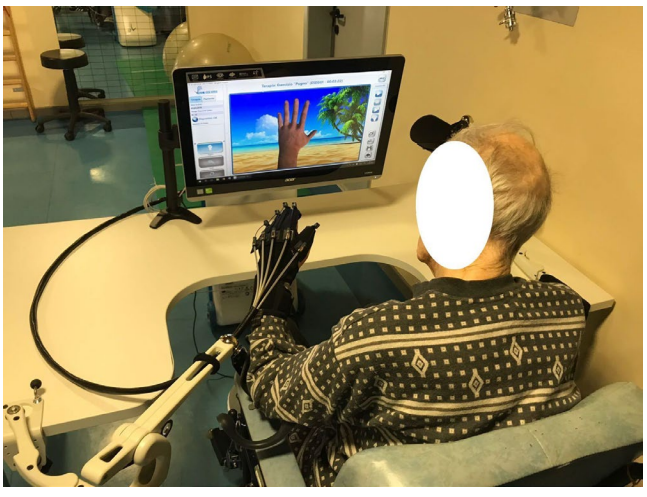

Figure 1. Robotic passive mobilization treatment.

kg/cm^2), median nerve (95% CI 0.3–0.6 kg/cm^2), radial nerve (95% CI 0.2–0.8 kg/cm^2), and ulnar nerve (95% CI 0.2–0.4 kg/cm^2).

Grip strength measurements were obtained with a grip dynamometer (Baseline), which has a precision of ±3%. The grip dynamometer has 5 settings representing grip spans; however, position 2 was used during this study because it has been shown to be the most reliable for reporting maximal grip strength for both clinical and research purposes (37). Pinch strength was measured with a mechanical pinch gauge (Baseline). The reliability of the procedure to measure pinch strength has been shown to be 0.93 (38). Patients, placed in a seated position, with elbow flexed to 90°, forearm in neutral resting on the arm of the chair, and wrist in neutral, were instructed to compress the dynamometer with maximal isometric contractions for 3 seconds. The reported strength value was the average of the 3 trials measured (with a 1-minute rest period between each measurement).

Sample size determination. The sample size and power calculations were performed with ENE 3.0 software (GlaxoSmithKline, Universidad Autónoma). The calculations were based on detecting the mean difference of a 2-cm, minimum clinically important difference (MCID) (39) on a 10-cm VAS, ~~assuming an SD of 2 cm, a 2-tailed test, an α level of 0.05, and a desired power of 90%~~. The estimated desired sample size was 30 individuals per group. To accommodate expected dropouts before study completion, a total of 36 participants were included in each group.

Statistical analysis. Data were analyzed using SPSS for Windows, version 24, conducted following an intent-to-treat analysis using the last-value-forward method. The results are expressed as means, SDs, and/or 95% confidence intervals (95% CIs). A Kolmogorov-Smirnov test showed a normal distribution of the data. Separate 2 × 2 × 3 mixed-model analyses of variance (ANOVAs), with group (experimental, control) as the between-subjects factor and side (ipsilateral, contralateral to the hand with OA) and time (baseline, postintervention at 4 weeks, and at 3-months follow-up) as within-subject factors, were conducted to examine the effects of the intervention on VAS score, PPT, and pinch and grip strength as the dependent variables. The main hypothesis of interest was group × time interaction. Post hoc comparisons were conducted using Bonferroni correction. Between-groups effect sizes were calculated using Cohen's *d* coefficient. We considered an effect size >0.8 large, ~0.5 moderate, and <0.2 small (40). The statistical analysis was conducted at a 95% CI, and *P* values less than 0.05 were considered significant.

RESULTS

Demographic and clinical data on patients. A total of 74 consecutive patients were screened, and 72 patients (32 men and 40 women, ages 74–90 years) were eligible and agreed to participate. Figure 2 shows the recruitment and retention of

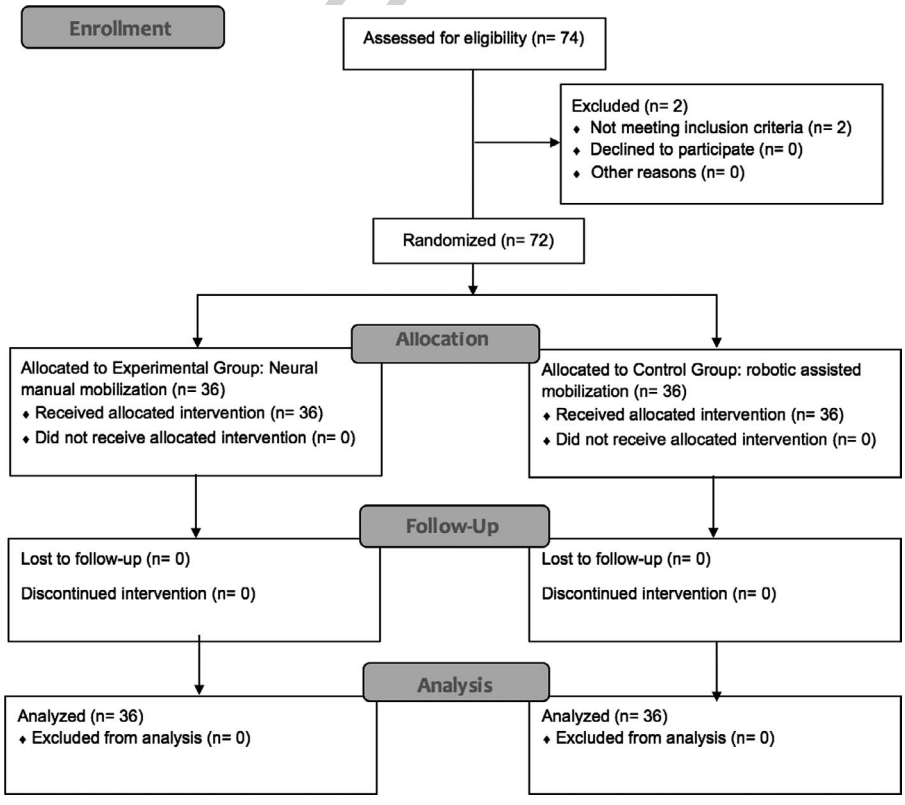

Figure 2. Consort flow chart.

patients through the trial. Baseline characteristics of the patients in each group are presented in Tables 1 and 2.

Response to treatment. *Pain intensity of the hand.* For average VAS during pinch strength testing, over the last 24 hours and over the last week, the ANOVA revealed no significant group × time × side, group × side, or side × time (all $P > 0.05$) interactions. There was also no significant main effect for side. There was a significant main effect of group × time for pain intensity in VAS score over the last 24 hours ($F = 5.47$, $P = 0.02$) but not in VAS score during pinch strength testing ($F = 0.56$, $P = 0.46$) or VAS score over the last week ($F = 0.19$, $P = 0.66$). Post hoc analysis indicated that patients with hand OA receiving the NIG intervention experienced a significant reduction in pain immediately postintervention (experimental group mean 1.4 [95% CI –1.8, –0.9]; control group mean 0.6 [95% CI –1.1, –0.1]; mean difference between groups 0.8 [95% CI –1.1, –0.5]; all $P < 0.01$) but not at 3-months follow-up for the dominant side (VAS score over the last 24 hours). Between-groups effect sizes were moderate at posttreatment and follow-up periods ($d < 0.2$).

PPTs. PPT data for the 5 sites are presented in Table 2. The ANOVA revealed no statistically significant group × time × side, side × time, or group × side (all $P > 0.05$) interactions. The ANOVA did reveal significant group × time interactions for PPT over the ipsilateral thumb CMC joint ($P = 0.044$), median ($P < 0.001$), and radial ($P = 0.005$) nerves for the experimental group, and group × side interactions for PPT of the median nerve ($P = 0.001$) for the experimental group.

The post hoc testing revealed increases in PPT at the thumb CMC joint and the median and radial nerves in the experimental group immediately after intervention as compared with baseline data (experimental group mean 0.7 [95% CI 0.6, 0.8]; control group mean 0.2 [95% CI 0.1, 0.4], experimental group mean 0.7 [95% CI 0.6, 0.7]; control group mean 0.1 [95% CI 0.2, 0.4] and experimental group mean 0.5 [95% CI 0.3, 0.6]; control group mean 0.2 [95% CI 0.1, 0.4], respectively; all $P < 0.02$) but not at 3-month follow-up. The post hoc testing also revealed a significant difference between groups in PPT on the median nerve on both sides (dominant side mean 1.5 [95% CI 2.2, 0.9]; nondominant side mean 1.1 [95% CI 1.8, 0.4]; $P = 0.01$) but not at 3-month follow-up. Between-groups effect sizes were small to moderate (between $d = 0.09$ and $d = 0.25$) and small ($d < 0.2$) at between-sides after the intervention.

Pinch and grip strength. For key pinch strength, the ANOVA revealed no significant group × time × side ($F = 1.49$, $P = 0.23$), group × time ($F = 0.01$, $P = 0.99$), side × time ($F = 0.06$, $P = 0.81$), or group × side ($F = 0.46$, $P = 0.50$) interactions. For grip strength, the ANOVA revealed no significant group × time × side ($F = 2.71$, $P = 0.11$), group × time ($F = 0.02$, $P = 0.89$), side × time ($F = 3.35$, $P = 0.07$), or group × side ($F = 0.33$, $P = 0.57$) interactions (Table 2).

Table 1. Characteristics of patients at baseline*

Characteristics	Exp. (n = 36)	Con. (n = 36)
Age, years	71 ± 11	69 ± 12
Female sex, no. (%)	21 (58)	19 (52)
BDI score	2.7 ± 1.2	3.0 ± 1.7
STAI score	22.9 ± 3.4	23.8 ± 3.1
Q-DASH score	22 ± 15	19 ± 12
Right hand		
VAS score, strength†	2.4 ± 1.5	2.5 ± 1.4
VAS score, 24 hours‡	3.0 ± 2.2	3.0 ± 1.6
VAS score, 1 week§	2.5 ± 1.5	2.8 ± 1.4
Left hand		
VAS score, strength†	1.2 ± 0.6	1.0 ± 0.1
VAS score, 24 hours‡	1.6 ± 1.3	1.2 ± 0.5
VAS score, 1 week§	1.5 ± 1.1	1.2 ± 0.5

* Values are the mean ± SD unless indicated otherwise. BDI = Beck Depression Inventory; Con. = control group; Exp. = experimental group; Q-DASH = Quick Disabilities of the Arm, Shoulder, and Hand; STAI = State-Trait Anxiety Inventory; VAS = visual analog scale.
† VAS score while executing a grip strength.
‡ VAS score over the last 24 hours.
§ VAS score over the last week.

DISCUSSION

Our results showed significantly heightened PPTs (indicating lower pain sensitivity) over the thumb CMC joint and median and radial nerves immediately after neurodynamic mobilizations but not after passive movement. There was also a significant decrease in pain intensity over the past 24 hours in the dominant hand of the NIG intervention group. However, these effects were not maintained at 3 months postintervention.

These results are similar to those of previous work investigating the effects of neurodynamic mobilization on individuals with OA of the CMC thumb joint. For example, Villafañe et al (28) found in a series of 15 patients with OA of the CMC thumb joint receiving neurodynamic mobilizations changes in PPT over the carpal bones immediately following the techniques. In a follow-up clinical trial, the same group found radial nerve mobilizations to be superior to placebo for improving PPT and pinch strength (29). Furthermore, a clinical trial examining the effects of radial mobilization also found that nerve techniques were superior to placebo for improving sensory deficits (16). However, those studies only examined the effects of a single intervention, radial nerve-biased mobilization. The current study is the first to examine effects of median and ulnar nerve–biased techniques in individuals with hand OA.

The presence of widespread hyperalgesia to pressure in individuals with OA of the CMC thumb joint has been reported previously (41). Clinically, a reliable way to assess pain sensitivity in the hands and arms of patients with OA is by applying firm pressure over several IP joints of each hand and over the adjacent phalanges, and then proximally to include firm palpation of the muscles of the forearm, including the lateral epicondyle region, to assess overall pain threshold (4). If the individual is tender in many of these areas, or in just the muscles of the forearm, he or she is likely

Table 2. Mean ± SD for outcomes at all study visits for each group (n = 36), mean ± SD difference within groups (n = 36), and mean (95% confidence interval) difference between groups (n = 72)*

Outcome	Pre-group dominant		Pre-group nondominant		Post-group dominant		Post-group nondominant		Within-group difference, post minus pre, dominant		Within-group difference, post minus pre, nondominant		Between-group difference, dominant†	Between-group difference, nondominant†
	Exp.	Con.	Exp.	Con.	Exp.	Con.	Exp.	Con.	Exp.	Con.	Exp.	Con.		
VAS score, strength	2.4 ± 1.5	2.5 ± 2.5	1.4 ± 1.3	1.1 ± 0.3	1.4 ± 0.6	1.7 ± 0.8	1.2 ± 0.7	1.0 ± 0.1	−1.0 ± 0.2	−0.8 ± 0.2	−0.2 ± 0.1	−0.1 ± 0.1	−0.3 (−0.8, 0.1)	0.2 (−0.1, 0.5)
VAS score, 24 hours	3.0 ± 2.2	3.0 ± 1.6	1.6 ± 1.3	1.2 ± 0.5	1.6 ± 0.9	2.4 ± 1.3	1.4 ± 0.8	1.1 ± 0.3	−1.4 ± 0.2‡	−0.6 ± 0.2	−0.2 ± 0.1	−0.1 ± 0.1	−0.8 (−1.4, −0.2)	0.3 (−0.1, 0.6)
VAS score, 1 week	2.5 ± 1.5	2.8 ± 1.4	1.5 ± 1.1	1.2 ± 0.5	1.2 ± 0.5	1.2 ± 0.5	1.7 ± 0.8	2.0 ± 1.0	−1.3 ± 0.3	−1.6 ± 0.3	0.2 ± 0.2	0.8 ± 0.3	0.1 (−0.2, 0.4)	−0.3 (−0.8, 0.2)
Thumb CMC joint PPT, kg/cm^2	4.0 ± 1.6	4.0 ± 1.3	4.3 ± 1.3	4.3 ± 1.2	4.7 ± 1.4	4.3 ± 1.3	4.5 ± 1.3	4.3 ± 1.2	0.7 ± 0.1‡	−0.3 ± 0.1	0.2 ± 0.1	0.0 ± 0.1	0.4 (−0.6, 1.0)	0.2 (−0.6, 0.9)
Hamate PPT, kg/cm^2	4.3 ± 1.6	3.9 ± 1.4	4.6 ± 1.5	4.2 ± 1.1	4.6 ± 1.5	4.2 ± 1.2	4.6 ± 1.4	4.3 ± 1.2	0.3 ± 0.1	0.3 ± 0.1	0.0 ± 0.1	0.1 ± 0.1	0.4 (−0.4, 1.2)	0.3 (−0.4, 1.1)
Median nerve PPT, kg/cm^2	5.2 ± 1.4	4.0 ± 1.1	5.5 ± 1.2	4.4 ± 1.0	5.9 ± 1.3	4.3 ± 1.1	5.6 ± 1.3	4.5 ± 1.1	0.7 ± 0.1‡	0.3 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	1.5 (0.9, 2.2)‡	1.1 (0.4, 1.8)‡
Radial nerve PPT, kg/cm^2	4.4 ± 1.2	4.6 ± 1.3	4.7 ± 0.9	4.8 ± 1.0	4.9 ± 1.1	4.8 ± 1.0	4.8 ± 0.9	4.7 ± 1.0	0.5 ± 0.1‡	0.2 ± 0.1	0.1 ± 0.1	−0.1 ± 0.1	0.1 (−0.5, 0.7)	0.1 (−0.4, 0.7)
Ulnar nerve PPT, kg/cm^2	5.0 ± 1.3	4.7 ± 1.0	5.4 ± 1.3	5.2 ± 1.0	5.2 ± 1.3	5.0 ± 1.0	5.5 ± 1.3	5.3 ± 1.0	0.2 ± 0.1	0.3 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.2 (−0.4, 0.9)	0.2 (−0.4, 0.9)
Key pinch strength, kg	6.7 ± 3.2	5.4 ± 2.2	7.1 ± 3.0	6.0 ± 2.0	7.5 ± 2.9	6.0 ± 1.8	7.6 ± 3.0	6.7 ± 2.0	0.8 ± 0.4	0.6 ± 0.2	0.5 ± 0.2	0.7 ± 0.4	1.5 (0.2, 2.9)	0.9 (−0.4, 2.4)
Grip strength, kg	7.4 ± 3.1	7.0 ± 2.8	8.0 ± 2.3	7.6 ± 2.3	8.2 ± 2.7	7.6 ± 2.5	8.2 ± 2.3	8.2 ± 2.5	0.8 ± 0.3	0.6 ± 0.3	0.2 ± 0.2	0.6 ± 0.2	0.6 (−0.8, 2.1)	0.0 (−1.4, 1.4)

* CMC = carpometacarpal (joint); Con. = control group; Exp. = experimental group; PPT = pressure pain threshold; VAS = visual analog scale.
† Exp. minus Con.
‡ Significant difference between group ($P < 0.05$).

diffusely tender (i.e., has a low central pain threshold) (4), whereas patients who exhibit sharp local tenderness or pain distal to the joint with OA may exhibit CNS hypersensitivity (34).

We agree with previous recommendations that clinicians should take into account the presence of central sensitization and widespread pressure pain hypersensitivity in patients with hand OA by not limiting their intervention to the affected area (18). We used the neurodynamic sliding techniques in our study. Alternative neurodynamic methods (e.g., tensioning techniques) exist that are proposed to affect intraneural pressure, thereby affecting function (12). However, we specifically used sliding techniques to allow large amplitude movements to be performed. This may present the movement in a novel way to the brain, uncoupling previously learned expectations of pain with movement (12). It has also been suggested that the larger-range sliding movements may decrease the fear of movement, assisting in cortical remapping (12) and decreasing sensitivity, as generally seen in the current study. Specifically, we identified improvements in PPT at the median and radial nerves; however, we didn't see the same effect at the ulnar nerve. Therefore, the true physiologic mechanisms by which sliding techniques alter PPT at the median and radial nerves require further scientific investigation.

In our prior work (36), we identified MDC values for PPT in individuals with hand OA across many of the regions tested in the current study. Changes in PPT that exceeded the MDC were identified for the thumb CMC joint and over the radial and median nerves in this study. What is not known is the MCID for individuals with hand OA. The MCID has been established in patients with hip and knee OA, with a status of "much better" as a reduction of 33%, while 15% reduction was considered "slightly better" (42) for changes in sensitivity measures (i.e., PPT). Our study found that changes in the PPTs of the thumb CMC joint and median and radial nerves ranged from 11% to 13% in the arthritic hand. Although not reaching the benchmark of 15–33% for lower extremity OA, the changes found in the current study surpassed 10% and may potentially be clinically relevant.

Our study did have some limitations. We only used 1 testing measure to determine the presence of pain sensitivity (i.e., PPT). It would be useful to use multiple testing measures to adequately assess pain-processing alterations in hand OA. Also, we assessed outcomes at 4 weeks and then again at 3 months. It would be useful to have a longer follow-up period. Despite the conflicting evidence for the effect of neurodynamic mobilization on nerve conduction velocity, performing such testing bilaterally might also have provided insight into any changes in central and peripheral neural function. Also, it was impossible to blind the patients to the treatment that they received, although all patients received the same information regarding the efficacy of the treatment. Both groups received a program of hand stability exercises as well. This may be a confounding variable if the combination of treatments (i.e., NIR and exercise) was more important for outcome than the treatments without exercise. Additionally, 1 physical therapist performed all treatment techniques, which may limit the generalizability. Another limitation is that we did not assess all outcome domains recommended in the Outcome Measures in Rheumatology–Osteoarthritis Research Society International core sets for outcome measurement in hand OA trials (43); specifically, physical function and health-related quality of life. Consequently, we are unable to comment on the impact of observed changes in the proxy measures of sensitization (i.e., PPT) in these areas. Future studies should also consider incorporating a graded motor imagery program, which may provide better insight into the role of peripheral versus central input in the maintenance of sensitization in this disorder.

In conclusion, we found that neurodynamic mobilizations (sliding techniques) and exercise decreased hypersensitivity in patients with hand OA to a greater extent than passive movement combined with exercise immediately after the intervention. We are unable to calculate the effect of the neurodynamic mobilization without the influence of the exercise program. These results were not maintained at the 3-month follow-up. Therefore, future studies should continue to examine the effects of neural mobilization in individuals with hand OA to determine if any true benefits exist.

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AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be submitted for publication. Dr. Villafañe had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study conception and design. Villafañe.
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