Title:

Effect of cervical vs. thoracic spinal manipulation on peripheral neural features and grip strength in subjects with chronic mechanical neck pain: a randomized controlled trial

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Abstract

BACKGROUND: Cervical and thoracic spinal manipulative therapy has shown positive impact for relief of pain and improve function in non-specific mechanical neck pain. Several attempts have been made to compare their effectiveness although previous studies lacked a control group, assessed acute neck pain or combined thrust and non-thrust techniques.

AIM: To compare the immediate effects of cervical and thoracic spinal thrust manipulations on mechanosensitivity of upper limb nerve trunks and grip strength in patients with chronic non-specific mechanical neck pain.

DESIGN: Randomized, single-blinded, controlled clinical trial.

SETTING: Private physiotherapy clinical consultancy.

POPULATION: Eighty-eight subjects (32.09±6.05 years; 72.7% females) suffering neck pain (grades I or II) of at least 12 weeks of duration.

METHODS: Participants were distributed into three groups: 1) cervical group (N.=28); 2) thoracic group (N.=30); and 3) control group (N.=30). One treatment session consisting of applying a high-velocity low-amplitude spinal thrust technique over the lower cervical spine (C7) or the upper thoracic spine (T3) was performed, while the control group received a sham-manual contact. Measurements were taken at baseline and after intervention of the pressure pain threshold over the median, ulnar and radial nerves. Secondary measures included assessing free-pain grip strength with a hydraulic dynamometer.

RESULTS: No statistically significant differences were observed when comparing between-groups in any of the outcome measures ($P>0.05$). Those who received thrust techniques, regardless of the manipulated area, reported an immediate increase in mechanosensitivity over the radial (both sides) and left ulnar nerve trunks ($P<0.05$), and grip strength ($P<0.001$). For those in the control group, right hand grip strength and pain perception over the radial nerve also improved ($P\leq0.025$).

CONCLUSIONS: Low-cervical and upper-thoracic thrust manipulation is no more effective than placebo to induce immediate changes on mechanosensitivity of upper limb nerve trunks and grip strength in patients with chronic non-specific mechanical neck pain.

CLINICAL REHABILITATION IMPACT: A single treatment session using cervical or thoracic thrust techniques is not enough to achieve clinically relevant changes on neural mechanosensitivity and grip strength in chronic non-specific mechanical neck pain.

Key words: Brachial plexus - Hand strength - Neck pain - Pain threshold - Musculoskeletal manipulations.

Introduction

Neck pain is a common disorder which it is estimated to affect around 50-67% of the population at some point of their lives, with the subsequent associated costs.[1] Widespread sensory hypersensitivity is a common feature in patients with whiplash-associated disorders,[2] and can also be present in non-traumatic and idiopathic chronic neck pain,[3, 4] suggesting some inconclusive evidence of central sensitization (an increased sensitivity of the nervous system).[4] Lowered pressure pain thresholds, compared to healthy controls, have been observed in patients with chronic non-specific neck pain locally at the cervical spine,[5] and at peripheral nerve trunks (median,[5, 6] radial and cubital nerves).6 Even though no active treatment seems to be distinctly superior to any other for neck pain,[7, 8] spinal manipulation may show a more favorable effect on increasing pressure pain thresholds than other forms of manual therapy and sham interventions, with this effect being consistent also beyond the local region of manipulation.[9] Upper limb neurodynamic tests are used to detect increased mechanosensitivity of the brachial plexus nerve trunks and report a satisfactory level of reliability.[10] Spinal manipulative therapy is widely used, along with exercise, mobilization and soft-tissue techniques, in patients reporting musculoskeletal symptoms of the spine.[11] It has shown a potential clinical efficacy on muscle inhibition,[12] neuromuscular excitability,[13] and functional performance.[14] The use of cervical [15, 16] or thoracic [7, 17, 18] spinal thrust techniques has reported positive results on pain relief, cervical mobility, and self-reported function in non-specific mechanical neck pain. However, recent systematic reviews conclude that there is still insufficient and discrepant evidence to support the use of thoracic or cervical manipulation or mobilization *versus* control intervention for patients with neck pain.[7, 19] Within manual therapies, the presence of adverse events, although benign and transient, appears to be more common in subjects who undergo manipulation.[20] These perceived risks are usually associated with cervical thrust techniques.[21] Therefore, some attempts have been made to compare the effectiveness of cervical and thoracic thrust manipulation on pain perception, disability level,[18, 22] pressure pain sensitivity, and mobility,[23] in neck pain. However, these previous studies lacked a control group,[18, 22, 23] assessed acute neck pain,[18] or combined thrust and non-thrust techniques,[22] thus no definitive conclusions can be drawn in this issue.[7] New research is needed to associate peripheral effects with a possible centrally-mediated response to manipulative techniques.[24]

This study assessed and compared the effectiveness of a spinal thrust manipulation directed to the cervical or the thoracic spine in patients with chronic non-specific mechanical neck pain. To assess treatment efficacy, we primarily evaluated changes on upper limb neural mechanosensitivity and, as secondary goals, we aimed to compare changes on grip strength. Measurements were taken at baseline and immediately after intervention. We hypothesized that spinal manipulation would have a more positive impact on mechanosensitivity and grip strength than a control intervention, but no differences were expected between the manipulative groups.

Materials and methods

The sample consisted of 88 subjects (32.09±6.05 years; 72.7% females) recruited from a private clinical consultancy in L'Horta Sud region, Valencia, Spain. Participants were enrolled if they were aged between 20 and 65 years, diagnosed with neck pain grades Ior II, with or without pain radiating to the head, trunk and/or limbs, lasting for at least 12 weeks according to the Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders,[25] (no signs or symptoms suggesting major structural pathology, with lack of or minor interference with daily life in grade I, and major interference with activities of daily living in grade II). Additional inclusion criteria were a negative response to the Spurling test,[26] and a positive response to the upper limb neurodynamic test of the median nerve in at least one upper extremity (both upper limbs were tested).27 Patients were excluded if they had mechanical neck pain secondary to whiplash, torticollis, rheumatoid arthritis, advanced cervical osteoarthritis and/or myelopathy, a previous history of ischemic episodes, severe trauma or surgery in the upper extremity and/or cervical spine, a clinical diagnosis of carpal tunnel syndrome, hormonal imbalance, diabetes, or cervicobrachial pain associated with herniation or disc protrusion at lower cervical spine (T_1-weighted sagittal and axial MRI images, as assessed by an independent physician). Those who received manual treatment in the eight weeks before data collection, were currently using drugs or medication, or reported any contraindication to spinal manipulation, were also excluded. Ninety-nine subjects were initially selected and 11 were finally excluded. No loss to follow-up was recorded during the data collection or analysis phases (Figure 1). The study was conducted from late April to mid July 2015 in a specialized private clinical center in Valencia.

Study design

A randomized, controlled, single-blinded clinical trial was carried out. After the initial clinical interview conducted by a specialist manual therapist, an external assistant randomly allocated participants into three groups: 1) control group; 2) cervical group; and 3) thoracic group. Randomization was based on a single sequence of random assignments (simple randomization) using the Epidat software v. 3.1 (Consellería de Sanidade, Xunta de Galicia, Spain and Panamerican Health Organization), and was safeguarded by the assistant. Sealed opaque envelopes concealing the group allocation were used to distribute patients into the study groups. This external assistant was blinded to the study objectives and the examiner who collected data remained unaware of study factors and treatment allocation group.

The required sample size was estimated using the ENE software v. 2.0 (GlaxoSmithKline, UK and Universidad Autónoma de Barcelona, Spain). Following previous research in this field,[23] a mean difference of 0.5 kg/cm2 in mechanosensitivity values after intervention, with a standard deviation (SD) of 0.5 kg/cm2 at post-intervention data, was expected. We accepted a level of 0.05, a two-tailed test, and an 80% desired power. For an equal allocation between groups, at least 26 participants per group were necessary. We predicted a 5% lost to follow-up.

All participants were assessed under the same conditions at baseline and immediately after intervention by the same examiner, who had over 10 years of clinical experience. The exposure times were also similar to all groups. The whole protocol was performed in a single session and lasted around 40-45 minutes. The present trial was approved by the Institutional Review Board (Research Ethics Committee of the University of Sevilla, Spain). Before data collection, all subjects agreed to participate by signing an informed consent form. The study procedures were conducted according to the Declaration of Helsinki, and the trial was registered in the Australian New Zealand Clinical Trial Registry (registration no. ACTR N 12615000412538).

Interventions

As in previous studies,[28] the possibility of compromised vertebral artery was tested before intervention to minimize risks, and stringent eligibility criteria were used to ensure a very low risk of possible adverse events. Each patient received a single session of similar duration where participants remained on a treatment table and received the intervention according to the allocated group. The same therapist, with over 9 years of clinical experience in spinal thrust manipulation, was in charge of intervention in all groups.

Cervical spinal thrust

Subjects in this group underwent the thumb-move manoeuver at the low-cervical spine (C7).[29] With the patient in seated position, the thrust was delivered either to the right or left side, based on subject's pain perception and detection of joint hypomobility.[23]

Thoracic spinal thrust

The subject was lying supine with arms crossed over the chest and hands placed over the opposite shoulder. The high-velocity low-amplitude thrust technique was performed as in previous studies,[23] with T3 being the targeted vertebrae.

Control group

Participants in this group were lying supine and received a sham-manual contact in the scalp for three minutes. Therapist's hands were placed over the lateral sides of the cranium, with a "five-finger hold" and with no movement or therapeutic intention.

Assessment

A baseline assessment about clinical and demographic features was conducted. After that, pain perception and grip strength were evaluated before and immediately after intervention.

Mechanosensitivity was assessed with a digital dynamometer (model FM200, PC E Instruments UK Ltd., Southampton, UK). An increasing pressure of 1 $kg/cm^2/s$ was used, with a 30-second resting period between measurements, and taking the mean of three measurements as the reference score. With the subject lying supine, pressure pain threshold was evaluated over the upper limb nerve trunks in the following order: 1) median nerve, at the carpal tunnel site,30 and at the ulnar fossa;2 2) ulnar nerve;2, 30 and 3) radial nerve.2, 30 Pressure algometry has shown a high inter-examiner reliability.[31]

The pain-free grip strength was assessed with an isometric, hydraulic hand dynamometer (model 5030J1, JAMAR ®, Sammons Preston, Bolingbrook, IL , USA). Dynamometry is a reliable, reproducible and easy-to-use tool.[32] The guidelines of the

American Society of Hand Therapists were followed.33 This procedure has shown an excellent test-retest reliability.[32]

Statistical analysis

The statistical processing of the data was conducted using the statistical package PASpasW Advanced Statistics v. 18.0 (SPSS Inc., Chicago, IL , USA). Findings are expressed as the mean with the corresponding SD and/or 95% confidence intervals or as percentage frequencies. Normality of the study variables was assessed with the Shapiro-Wilk test. The between-groups comparison for baseline data was made with the analysis of variance (ANOVA) and the Kruskall-Wallis test for quantitative variables with normal and no-normal distribution, respectively, and the $\chi2$ test for qualitative variables. A separate 2-by-3 mixed-model ANOVA, with time as within-subject variable, and group as between-subject variable, was used to compare the effectiveness of the interventions on the outcome measures. The Bonferroni test was used for post-hoc analysis. The level of significance was set at a P value <0.05.

Results

More than 70% of the sample was female patients. Table I lists the baseline characteristics of the study groups. No baseline differences were observed in the comparison between-groups (P>0.05). All variables followed a normal distribution (P>0.05), except for pressure pain sensitivity over the median (elbow site) (P=0.039), right ulnar ($P=0.046$) and left radial ($P=0.032$) nerve trunks. Table II includes the overall results (baseline and post-intervention values, and mean score changes after intervention) of the outcome measures. When comparing between groups (Table III), the use of spinal manipulation, regardless of the manipulated segment, showed no statistically significant differences with the control placebo intervention in any of the outcome measures ($P>0.05$ in all cases).

For pressure sensitivity to mechanical stimuli, those patients who received cervical or thoracic thrust techniques reported an immediate increase in mechanosensitivity over the radial (right side $P<0.01$; left side $P\leq0.003$), and left ulnar nerves ($P=0.01$) (Table II). Pain perception also improved over left ulnar nerve trunk for those in the control group ($P<0.025$). For free-pain grip strength, spinal manipulative groups reported a significant increase in both hands ($P<0.001$), while patients that underwent the sham-placebo contact also improved, but only in the right hand ($P=0.003$). Nevertheless, in all cases, the observed effect size was small ($d<0.5$) (Table II).

Discussion

In this randomized, controlled trial, the overall present findings suggest that cervical or thoracic thrust manipulation show a similar impact on increasing mechanosensitivity of upper limb nerve trunks and grip strength in patients with chronic non-specific mechanical neck pain. However, all these changes were small and below the threshold considered to be clinically relevant. The placebo intervention reported similar results than spinal manipulation, which does not confirm the initial hypothesis.

Spinal manipulative therapy has been purported to provoke hypoalgesia over the area of treatment, but also at distal sites.[9, 17] The theoretical construct to understand this phenomenon has been defined as "regional interdependence," which supports the idea that a primary complaint may be linked with dysfunction of several body regions or systems.[34] Changes in pain perception after manipulation have been also explained on the basis of peripheral, spinal cord and supraspinal mediated mechanisms.[35] The most updated evidence of the Neck Pain Task Force suggests that manipulation is an effective intervention to manage neck pain and its associated disorders.[36] For acute neck pain episodes, thoracic manipulation is thought to have a higher impact than cervical manipulation to decrease pain.[19] On the contrary, cervical and thoracic thrust techniques have been reported to be equally effective in chronic neck pain,[23] as in the present trial.

In patients with persistent and recurrent neck pain, thoracic manipulation may be no better than an inactive control intervention.[36] The quality of evidence to support the use of cervical manipulation *versus* control is equally low and diverse in chronic neck pain.[19] For pain perception, our findings confirm this idea because no differences on neural mechanosensitivity were found between patients that underwent spinal thrust techniques and those in the control group. Previous research comparing the efficacy of cervical and thoracic manipulation on neck pain has reported promising results.

However, all these studies lacked a control group with no intervention,[18, 22, 23] which made impossible to rule out the potential placebo effect.[23] Placebo has been included as one of many mechanisms involved in the role of manual therapy to relief pain.[37] Our results suggest that this placebo effect may be an important issue since the lack of significant differences in the comparison between-groups could be partly explained because mechanosensitivity levels also increased after intervention in the control group. For instance, in the cervical and thoracic thrust manipulation groups, pressure pain threshold over the radial nerve increased by a 24%, within the 20-25% range considered to be as clinically relevant,[38] but mechanosensitivity over this nerve trunk also improved more than 10% after the sham placebo contact. Immediate changes on pain perception associated with spinal manipulation can be enhanced after audible cavitations,[39] or be influenced by patients' expectations,[40] both factors not being present in the control group. For the median and ulnar nerve trunks, the improvements in the participants that underwent manipulation (between 5% and 10%) were similar to those reported over the median nerve after cervical lateral glide in chronic whiplash associated disorders,[41] and following a multimodal treatment (neurodynamic techniques and soft tissue mobilization) in individuals with carpal tunnel syndrome.[42] The different pathologies, and the heterogeneity of assessed groups and intervention techniques, make impossible the comparison between studies.

Another plausible explanation to understand the differences between this trial and previous research in this field is that the efficacy of spinal manipulation may depend on the intervention that is combined with manual therapy.[36] Only one previous study comparing cervical and thoracic manipulation used this intervention as a single treatment,[23] whereas the other two trials combined manual therapy with an exercise program.[18, 22] This latter approach is more similar to the multimodal treatment usually implemented in clinical practice, and may report better outcomes. Likewise, there appears to be moderate quality evidence to recommend the combined use of manual therapy with exercise, better than manual therapy or exercise alone for chronic neck pain.[43] Finally, it has been stated that the clinical effect linked with high-velocity low-amplitude thrust techniques, especially when these are used alone, is immediate and demonstrate little carry-over in the follow-up.[44]

Concerning free-pain grip strength, it has been concluded that spinal manipulation may influence how the Central Nervous System responds to a functional task.[45] Cervical thrust techniques increase the resting electromyographic activity of the biceps brachii muscle,[46] which may improve elbow flexor strength,[12] and affect grip strength. Immediate changes in grip strength have been observed following spinal manipulation in healthy individuals,[47] and in patients with lateral epicondylalgia,[48] with improvements ranging from 10% to 40% of the baseline value. Contrary to these findings, the changes in our study only represented a 5% improvement of the baseline score, and were below the clinically significant threshold reported for this outcome measure.[49] Therefore, even when spinal manipulation has been suggested to induce neuromuscular,[14] and functional changes in the upper extremity,[45] this present trial does not support the excitatory motor effect attributed to spinal thrust techniques.[13, 48]

Limitations of the study

This is the first randomized trial comparing the effect of cervical and thoracic thrust manipulation in chronic neck pain where a control group with no intervention has been included. The study also adheres to the PEDro checklist for rating quality of randomized controlled trials,[50] and the intervention was performed by a highly trained and qualified physical therapist. Some potential limitations should be noted. First, participants only underwent a treatment session, which consisted of a single manipulation. Second, the findings were only evaluated in an immediate fashion. Future research should include several treatment sessions and a long-term follow-up. Third, the force applied while delivering the thrust techniques was not assessed; hence, the possible differences in dosage remain a matter for future studies. Fourth, interventionist blinding was not possible, which may represent a potential of bias. Finally, although participants were asked about possible minor or major adverse events immediately after thrust manipulation, due to the lack of follow-up, these were not documented in the short (hours), medium (days) or long term (weeks).

Conclusions

A single treatment session of spinal thrust manipulation, directed either to the low cervical or upper thoracic spine, is not effective in order to improve neural mechanosensitivity and pain-free grip strength in patients with chronic non-specific mechanical neck pain.

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Figure 1.— Flowchart diagram of the study subjects.

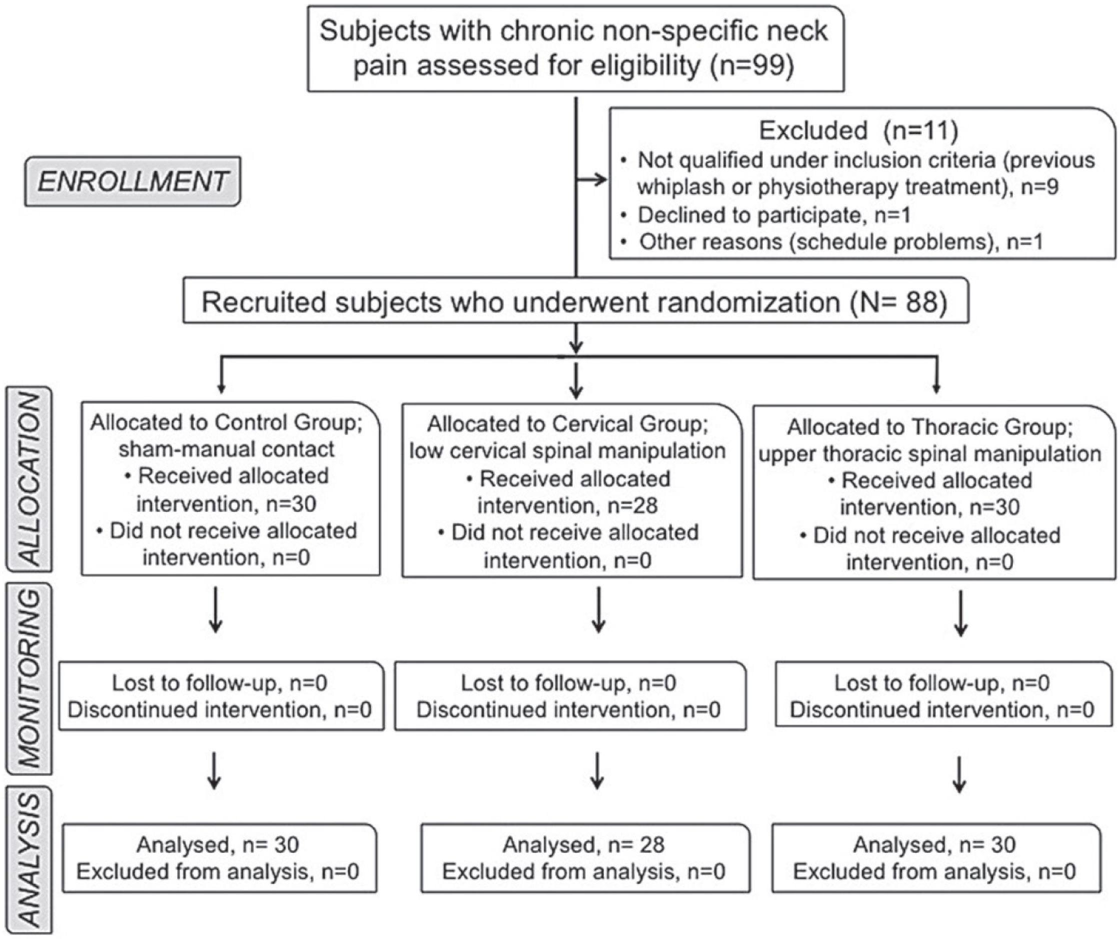

Table I.— Baseline physical characteristics of the subjects in the study groups.

	Total sample (N.=88)	Control group (N.=30)	Cervical group (N.=28)	Thoracic group (N.=30)	P value
Mean age (years)	32.09±6.05	33.36±5.98	31.75±5.99	31.13±6.15	0.341
Sex, female	64 (72.7%)	21 (70%)	21 (75%)	22 (73.3%)	0.812
Height (cm)	167.82±7.82	167.60±8.64	167.85±7.53	168.03±7.46	0.978
Weight (kg)	66.00±12.97	65.83±11.79	65.85±14.12	66.30±13.42	0.988
Hand dominance, right	87 (98.8%)	29 (96.6%)	28 (100%)	30 (100%)	0.979

Data presented as mean ± SD or number (percentage).

Table II .— Overall results of pressure pain threshold (PPT, kg/cm2) and grip strength (kg) for the intervention groups across data points (N.=88).

Outcome measures	Groups	Baseline	Post-intervention	Post- *vs.* pre-intervention	P value; ES
PPT, right medial nerve (wrist)	Control group	6.39±2.91	6.38±3.13	0.00 (-1.23 to 1.22)	0.99; 0.00
	Cervical group	7.05±2.98	7.36±3.59	0.30 (-0.27 to 0.88)	0.29; 0.04
	Thoracic group	6.97±2.91	7.29±3.47	0.31 (-0.22 to 0.86)	0.24; 0.04
PPT, left medial nerve (wrist)	Control group	6.43±3.28	6.33±3.28	-0.10 (-1.50 to 1.34)	0.88; 0.00
	Cervical group	7.05±2.76	7.24±3.11	0.18 (-0.34 to 0.71)	0.48; 0.02
	Thoracic group	6.95±2.71	7.18±3.01	0.23 (-0.27 to 0.73)	0.36; 0.02
PPT, right medial nerve (elbow)	Control group	2.85±1.80	2.83±1.63	-0.02 (-0.43 to 0.38)	0.89; 0.00
	Cervical group	2.88±1.58	3.12±1.87	0.23 (-0.09 to 0.57)	0.15; 0.07
	Thoracic group	2.88±1.56	3.09±1.84	0.20 (-0.10 to 0.51)	0.19; 0.05
PPT, left medial nerve (elbow)	Control group	2.48±1.56	2.64±1.59	0.16 (-0.10 to 0.42)	0.22; 0.04
	Cervical group	3.01±1.87	3.18±2.05	0.17 (-0.04 to 0.40)	0.11; 0.09
	Thoracic group	3.00±1.82	3.20±1.99	0.20 (-0.01 to 0.41)	0.054; 0.12
PPT, right ulnar nerve	Control group	4.05±1.78	4.13±1.91	0.07 (-0.21 to 0.37)	0.58; 0.01
	Cervical group	4.08±1.99	4.41±1.93	0.33 (-0.12 to 0.78)	0.14; 0.07
	Thoracic group	4.03±1.94	4.36±1.87	0.33 (-0.09 to 0.75)	0.12; 0.08
PPT, left ulnar nerve	Control group	3.95±1.66	4.10±1.71	0.15 (-0.08 to 0.39)	0.18; 0.05
	Cervical group	4.09±1.90	4.52±1.87	0.42 (0.09 to 0.76)*	0.01; 0.20
	Thoracic group	4.03±1.89	4.44±1.85	0.40 (0.09 to 0.73)*	0.01; 0.19
PPT, right radial nerve	Control group	3.39±2.04	3.77±2.44	0.37 (0.05 to 0.70)*	0.025; 0.16
	Cervical group	3.38±2.14	4.18±2.50	0.80 (0.38 to 1.22)*	0.001; 0.36
	Thoracic group	3.37±2.07	4.15±2.42	0.78 (0.39 to 1.17)*	<0.01; 0.36
PPT, left radial nerve	Control group	3.42±2.33	3.83±2.56	0.40 (0.11 to 0.70)*	0.009; 0.21
	Cervical group	3.52±2.31	4.39±2.88	0.86 (0.31 to 1.41)*	0.003; 0.28
	Thoracic group	3.50±2.24	4.35±2.81	0.84 (0.33 to 1.35)*	0.002; 0.28
Grip strength (kg) right hand	Control group	31.13±9.22	32.47±9.34	1.34 (0.50 to 2.18)*	0.003; 0.26
	Cervical group	32.58±11.47	33.78±11.70	1.20 (0.54 to 1.85)*	0.001; 0.34
	Thoracic group	32.84±11.27	34.12±11.56	1.27 (0.65 to 1.90)*	<0.01; 0.37
Grip strength (kg) left hand	Control group	28.87±8.87	29.36±8.15	0.48 (0.00 to 0.96)	0.056; 0.12
	Cervical group	30.22±9.63	31.54±9.69	1.32 (0.66 to 1.97)*	<0.01; 0.38
	Thoracic group	30.29±9.33	31.64±9.39	1.34 (0.73 to 1.95)*	<0.01; 0.41

Data presented as mean ± SD or mean (95% CI). ES: effect size. *Statistically significant difference in intra-group comparison (P<0.05).

Table III .— Between-groups differences of the mean pressure pain threshold (PPT, kg/cm2) and grip strength (kg) score changes after intervention.

Outcome measures	Groups	Inter-group differences of mean score changes	P value
PPT, right medial nerve (wrist)	Control *vs.* cervical group	0.30 (-1.10 to 1.75)	0.825
	Control *vs.* thoracic group	0.32 (-1.10 to 1.76)	
	Cervical *vs.* thoracic group	0.01 (-1.44 to 1.77)	
PPT, left medial nerve (wrist)	Control *vs.* cervical group	0.28 (-1.29 to 1.87)	0.852
	Control *vs.* thoracic group	0.33 (-1.22 to 1.88)	
	Cervical *vs.* thoracic group	0.04 (-1.53 to 1.62)	
PPT, right medial nerve (elbow)	Control *vs.* cervical group	0.26 (-0.33 to 0.86)	0.502
	Control *vs.* thoracic group	0.23 (-0.36 to 0.82)	
	Cervical *vs.* thoracic group	-0.03 (-0.63 to 0.56)	
PPT, left medial nerve (elbow)	Control *vs.* cervical group	0.01 (-0.38 to 0.41)	0.956
	Control *vs.* thoracic group	0.04 (-0.34 to 0.44)	
	Cervical *vs.* thoracic group	0.02 (-0.37 to 0.42)	
PPT, right ulnar nerve	Control *vs.* cervical group	0.25 (-0.41 to 0.91)	0.563
	Control *vs.* thoracic group	0.25 (-0.40 to 0.90)	
	Cervical *vs.* thoracic group	0.00 (-0.66 to 0.66)	
PPT, left ulnar nerve	Control *vs.* cervical group	0.27 (-0.23 to 0.78)	0.340
	Control *vs.* thoracic group	0.25 (-0.24 to 0.75)	
	Cervical *vs.* thoracic group	-0.01 (-0.52 to 0.48)	
PPT, right radial nerve	Control *vs.* cervical group	0.42 (-0.21 to 1.06)	0.193
	Control *vs.* thoracic group	0.40 (-0.23 to 1.03)	
	Cervical *vs.* thoracic group	-0.02 (-0.66 to 0.62)	
PPT, left radial nerve	Control *vs.* cervical group	0.45 (-0.32 to 1.23)	0.266
	Control *vs.* thoracic group	0.44 (-0.32 to 1.21)	
	Cervical *vs.* thoracic group	-0.01 (-0.79 to 0.76)	
Grip strength, right hand	Control *vs.* cervical group	-0.14 (-1.36 to 1.07)	0.960
	Control *vs.* thoracic group	-0.06 (-1.26 to 1.13)	
	Cervical *vs.* thoracic group	0.07 (-1.14 to 1.29)	
Grip strength, left hand	Control *vs.* cervical group	0.83 (-0.15 to 1.82)	0.057
	Control *vs.* thoracic group	0.85 (-0.11 to 1.82)	
	Cervical *vs.* thoracic group	0.02 (-0.96 to 1.01)	

Data presented as mean ± SD or mean (95% confidence interval).