ORIGINAL ARTICLES

IMMEDIATE HYPOALGESIC AND MOTOR EFFECTS AFTER A SINGLE CERVICAL SPINE MANIPULATION IN SUBJECTS WITH LATERAL EPICONDYLALGIA

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ABSTRACT

Objective: The purpose of this study is to investigate the immediate effects of a single cervical spine manipulation and a manual contact intervention (MCI) on pressure pain thresholds (PPTs) and thermal pain thresholds over the elbow region and pain-free grip (PFG) force in patients with lateral epicondylalgia (LE).

Methods: A repeated measures, crossover, single-blinded randomized study was done. Ten patients with LE (5 female) aged from 30 to 49 years (mean, 42; SD, 6 years) participated in this study. Subjects attended 2 experimental sessions on 2 separate days at least 48 hours apart. At each session, participants received either a manipulative intervention or MCI assigned in a random fashion. Pressure pain threshold and hot and cold pain thresholds (HPT and CPT, respectively) over the lateral epicondyle of both elbows was assessed preintervention and 5 minutes postintervention by an examiner blinded to the treatment allocation of the patients. In addition, PFG on the affected arm and maximum grip force on the unaffected side were also assessed. A 3-way analysis of variance (ANOVA) with time (pre-post) and side (ipsilateral, contralateral to the intervention) as within-subjects variable and intervention (manipulation or MCI) as between-subjects variable was used to evaluate changes in PPT, HPT, CPT, or PFG.

Results: The ANOVA detected a significant effect for time (F = 37.2, $P < .001$) and a significant interaction between intervention and time (F = 25.1, $P < .001$) for PPT levels. Post hoc revealed that the manipulative intervention produced a greater increase of PPT in both sides when compared with MCI ($P < .001$). The ANOVA did not detect significant effects for time (F = 2.7, $P > .2$), intervention (F = 2.8, $P > .2$), or side (F = 0.9, $P > .4$) for HPT. Again, no significant effects for time (F = 0.8, $P > .4$), side (F = 0.6, $P > .4$), or intervention (F = 0.8, $P > .5$) was found for CPT. Finally, a significant interaction between intervention and time (F = 9.4, $P = .004$) and between time * side * intervention (F = 18.2, $P < .001$) was found for grip force. Post hoc analysis revealed that the cervical manipulation produced an increase of PFG on the affected side as compared with the MCI ($P < .001$).

Conclusions: The application of a manipulation at the cervical spine produced an immediate bilateral increase in PPT in patients with LE. No significant changes for HPT and CPT were found. Finally, cervical manipulation increased PFG on the affected side, but not the maximum grip force on the unaffected arm. Future studies with larger sample sizes are required to examine the effects of thrust manipulation on PPT, HPT, CPT, or PFG. (J Manipulative Physiol Ther 2008;31:675-681)

Key Indexing Terms: *Lateral Humeral Epicondylitis; Neck; Cervical Manipulation*

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Lateral epicondylalgia (LE) is a musculoskeletal disorder characterized by pain and mechanical hyperalgesia at the common extensor origin or lateral epicondyle with pain referring into the dorsal forearm-hand and force attenuation of the wrist extensor muscles. It commonly affects individuals between 35 and 50 years old and usually affects the dominant arm.[1] Although the etiology and pathology of this disorder are under debate, evidence of a tissue-based pathology includes degenerative changes at the common extensor origin consistent with tendinopathy.[2] It has been found that the extensor radial carpi brevis muscle is involved in 64% of patients with LE,[3] whereas the extensor digitorum communis muscle has been found in 35%.[4] Furthermore, it is suggested that this condition is characterized by secondary hyperalgesia because patients with LE exhibit mechanical, but not thermal, hyperalgesia.[5] Nevertheless, the cause of LE is most likely multifactorial, involving local mechanisms as well as generalized impairments in nociceptive mechanisms.

It has been determined that manual mobilization procedures induce mechanical, but not thermal, hypoalgesic effects.[6] This manual therapy–induced hypoalgesia appears to be nonopioid in nature, because it is not reversed by the application of naloxone[7] and does not develop tolerance to repeated application of manual interventions.[8] Furthermore, mechanical hypoalgesia provoked by manual procedures is concurrent with sympathetic nervous system[9,10] or motor system[11] excitation. For instance, some studies found that cervical[10] or elbow[6] nonthrust mobilization not only reduced mechanical pain sensitivity, but also increased pain-free grip (PFG) strength in subjects with LE. Furthermore, Sterling et al[11] found that cervical posterior-anterior nonthrust mobilization decreased pressure sensitivity and reduced overactivity of the superficial neck flexor muscles during the craniocervical flexion test. Finally, based on data from the animal model, nonthrust mobilization-induced analgesia involves serotonin and noradrenaline receptors in the spinal cord.[12] These findings support the hypothesis that manual procedures (at least mobilization techniques) can stimulate descending inhibitory pain systems.[13-15]

It seems that previous studies investigating concomitant hypoalgesic and motor effects of manual therapy in patients with LE have focused on nonthrust mobilization techniques, for example, lateral glide of the cervical spine,[16] posterior-anterior mobilization of the cervical spine,[11] or mobilization-with-movement of the elbow.[6,17] Bolton and Budgell[18] suggested that manipulation may stimulate receptors within deep intervertebral muscles, whereas mobilization techniques most likely affect more superficial axial muscles. Therefore, because the mechanisms of nonthrust mobilization may differ from that of thrust manipulation, further studies are needed to investigate the effects of thrust techniques.

A review of the literature (2000) revealed only a few studies exploring changes in pain/thermal pain sensitivity provoked by spinal manipulative procedures.[19] Fernández-de-las-Peñas et al[20] recently found that a cervical spine thrust manipulation resulted in immediate mechanical hypoalgesia in both elbows in a cohort of healthy subjects. In a follow-up study, it was also identified that the application of a cervicothoracic thrust manipulation induced bilateral hypoalgesic effects over the C5-C6 zygapophyseal joints in healthy subjects.[21] We are not aware of any studies exploring both hypoalgesic and motor effects associated with cervical spine thrust manipulation in patients with LE. Therefore, the aim of the present pilot study was to compare the immediate effects of a cervical spine thrust manipulation and a manual contact intervention (MCI) on pressure and thermal pain thresholds over the elbow region, as well as PFG force in patients with LE.

Methods

A repeated measures, crossover, single-blinded randomized pilot study was used to evaluate the immediate effects of a cervical thrust manipulation on pressure, heat, and cold pain sensitivity over the elbow region, as well PFG force.

Subjects

Ten patients with LE (5 female), aged from 30 to 49 years (mean, 42; SD, 6 years), who responded to a local advertisement were recruited to participate. All subjects were right handed, and the dominant side was the affected in all participants. Subjects were selected for inclusion if, on physical examination, 2 or more of the following criteria were present: (1) pain on palpation over the lateral epicondyle and the associated common extensor unit, (2) pain on gripping a hand dynamometer, and (3) pain with stretching or contraction of the wrist extensor muscles.[22] Patients were excluded if they exhibit any of the following criteria: (1) any contraindication to manipulation, (2) symptoms in the cervical spine, (3) if bilateral upper extremity symptoms were present, (4) previous history of whiplash or cervical surgery, (5) receiving spinal manipulative therapy directed to the cervical or thoracic spine within the past 12 months before the study, or (6) exhibiting positive response during premanipulative testing of the cervical spine.[23] The protocol was approved by local human research committee of the Universidad Rey Juan Carlos, Madrid, Spain. All subjects signed an informed consent form before participation in the study.

Pressure Pain Threshold Assessment

Pressure pain threshold (PPT) is defined as the minimal amount of pressure induced when the pressure first changes to pain.[24] An electronic algometer (Somedic AB, Farsta, Sweden) was used to measure the PPT over the most tender area of the lateral epicondyle. The algometer consists of a 1-cm^2 rubber-tipped plunger mounted on a force transducer. The pressure was applied at a rate of 30 kPa/s. Subjects were instructed to press a switch when the sensation under the probe changed from pressure to pain.[25] Three consecutive

Fig 1. *Assessment of PFG force. The arm of the participant was placed in elbow extension and forearm pronation.*

measurements of the PPT at the lateral epicondyle on both right and left sides at intervals of 30 seconds were obtained by the same assessor (intraexaminer reliability) who was blinded to the treatment allocation of the subject. The mean of these 3 trials was used for data analysis.

Thermal Pain Thresholds

Hot and cold pain thresholds (HPT and CPT, respectively) were tested with a Thermotest System (Somedic AB). The Thermotest System is factory calibrated to ±0.2°C with a control resolution of greater than 0.2°C. A Peltier thermode was applied directly to the lateral epicondyle of either the right or left side. From a baseline of 32° C, the thermode either increased in temperature at a rate of 1°C/s up to a maximum cutout temperature of 50° C (HPT) or decreased in temperature again at a rate of 1°C/s to a cutout temperature of 4.5°C (CPT). Hot pain threshold signals were collected on an IBM-compatible PC. Park et al[26] showed a good reliability of thermal pain thresholds at a site on the volar aspect of the left forearm in healthy subjects. Each participant was instructed to press a hand-controlled switch as soon as the sensation was felt to change from one of heat/cold to one of pain. The mean of 3 trials at each elbow region was calculated and used for data analysis. A rest of 5 seconds occurred between trials.

Grip Strength Assessment

Dynamometric measurement of grip strength is a reliable[27] method of evaluation often used in research investigating elbow disorders.[28,29] In the present pilot study, PFG force was assessed on the affected arm, whereas the maximum grip strength was evaluated on the unaffected side. Pain-free grip is defined as the amount of force each subject is able to generate with an isometric gripping action before eliciting pain.[30] A JAMAR hydraulic hand dynamometer (Sammon Preston, Canada) was used in this study. The dynamometer was adjusted to the hand of each participant. The arm was placed in a standardized position of elbow extension and forearm pronation (Fig 1). On the affected arm, subjects were instructed to squeeze the dynamometer until they first experienced pain, and then to release their grip. On the unaffected side, patients were asked to squeeze the dynamometer to their maximum capacity (maximum grip force [MGF]). The attained force was subsequently recorded. Both tests were repeated 3 times with a 20-second interval, and the mean was used to the analysis.

Fig 2. *Cervical spine manipulation. Gentle ipsilateral side flexion and contralateral rotation to the right side were introduced until slight tension was perceived in the tissues at the contact point. The high velocity low article thrust manipulation was directed upward and medially in the direction of the subject's contralateral eye.*

Intervention conditions

Each participant attended 2 treatment sessions and received either the cervical spine thrust manipulation or a MCI, which were assigned in a random fashion, at each visit. All interventions were administered by a manual physical therapist with more than 5 years of clinical experience in manipulative therapy. The cervical manipulation was directed at the C5-C6 vertebral level and was applied as follows: the subject was supine with the cervical spine in a neutral position. The index finger of the therapist applied a contact over the posterolateral aspect of the zygapophyseal joint of C5 vertebra. The therapist cradled the subject's head with the other hand. Gentle ipsilateral side flexion and contralateral rotation to the targeted side were introduced until slight tension was perceived in the tissues at the contact point (Fig 2). A high-velocity low-amplitude thrust manipulation was directed upward and medially in the direction of the subject's contralateral eye.[31] The therapist monitored for a popping sound accompanying the manipulations. If the audible popping sound was not heard during the first manipulative attempt, the subject was repositioned, and the procedure was

Table 1. *Pre-post data for pressure, thermal pain thresholds, and grip strength outcomes for each intervention condition*

	Manipulative intervention			MCI		
	Pre	Post	Pre-post differences	Pre	Post	Pre-post differences
PPT ipsilateral side (kPa)	282.7 (44.8)	404.2 (60.3)	121.5 (82.4/160.5)	314.4 (11.6)	327.7 (18.6)	13.3 (−4.91/31.4)
PPT contralateral arm (kPa)	420.7 (32.3)	495.1 (80.2)	74.4 (22.2/126.5)	475.2 (78.5)	481.2 (84.6)	6.1 (−36.3/48.4)
HPT ipsilateral side (°C)	41.3 (3.4)	42.5 (4.0)	1.2 (−0.7/3.0)	41.1 (3.4)	41.8 (1.3)	0.7 (−1.1/2.5)
HPT contralateral arm (°C)	43.2 (2.8)	44.7 (2.2)	1.5 (−0.3/2.8)	44.3 (1.5)	43.4 (0.9)	−0.9 (−1.8/0.1)
CPT ipsilateral side (°C)	17.5 (7.5)	17.8 (5.1)	−0.25 (−3.3/2.7)	18.2 (7.4)	19.7 (6.8)	−1.5 (−4.4/1.3)
CPT contralateral arm (°C)	11.1 (6.1)	10.2 (4.5)	0.9 (−0.5/2.8)	11.1 (4.8)	12.1 (6.4)	−1.0 (−3.2/0.6)
PFG affected side (kg)	10.8 (4.4)	14.7 (5.5)	3.8 (1.6/6.0)	14.7 (6.0)	13.6 (6.2)	−1.0 (−2.5/0.4)
MGS unaffected arm (kg)	33.2 (12.2)	32.5 (12.8)	−0.8 (−2.1/0.5)	33.8 (7.9)	33.7 (10.5)	0.1 (−0.8/0.8)

Scores are expressed as mean (SD) for pre- and postintervention data and as mean (95% confidence interval) for pre-post differences.

repeated a second time. For the MCI, the therapist simulated the cervical thrust manipulation (ie, the therapist placed the patient's head in ipsilateral lateral flexion and contralateral cervical rotation), but without any tissue tension or thrust. This position was maintained for 20 seconds. The MCI was applied on the same side as the manipulative procedure.

Study Protocol

Subjects attended a preliminary session for familiarization with the laboratory environment and tests. This study was conducted in the Esthesiology Laboratory of Universidad Rey Juan Carlos, Alcorcón, Spain. (Room controls ensure constant temperature and humidity levels.) Each subject attended 2 sessions scheduled on separated days at least 48 hours apart and at the same time of the day. Subjects were not allowed to take any analgesic or antiinflammatory drug for approximately 24 hours before each session. In addition, any kind of exercise with the upper extremity or the cervical spine was not permitted for the 24 hours before any of the sessions.[32]

At each session, participants received either the manipulative intervention or MCI, which was assigned in random fashion. Each intervention, either thrust manipulation or MCI, was applied to the dominant (right) side of the cervical spine. At each experimental session, the participant was positioned in a supine position. The pretreatment assessment of PPT, HPT, or CPT was taken over both affected and unaffected elbows by an assessor. Pain-free grip force was assessed by the same evaluator. The order of assessment was randomized on each subject and on each session. After pretreatment measurements, the therapist, blinded to pretreatment data, applied one of the interventions (manipulation or MCI) on the right side. Five minutes after the application of the intervention, postintervention testing for PPT, HPT, CPT, and PFG was performed by the same assessor who was blinded to the treatment allocation of the subject.

Statistical Analysis

Data were analyzed with the SPSS package, version 14.0 (SPSS Inc, Chicago, Ill). Mean values, SDs, or 95% confidence interval was calculated for each variable. Normal distribution of the data was assessed by mean values of the Kolmogorov-Smirnov test ($P > .05$). Correlation coefficient (ICC)[1,3] and SEM were calculated to assess intraexaminer reliability of PPT, HPT, CPT, and PFG data. The unpaired Student *t* test was used to assess differences in PPT, CPT, HPT, and PFG preintervention data measured before each intervention (manipulation or MCI). A 3-way ANOVA with time (pre-post) and side (ipsilateral, contralateral to the side of the intervention) as within-subject variable and intervention (manipulation or MCI) as between-subject variable was used to evaluate changes in all the outcomes. Separate ANOVAs were conducted for PPT, HPT, CPT, or PFG. When significant interactions were identified in the ANOVA test, the Bonferroni correction was used for post hoc comparisons. A P value less than .025 was considered statistically significant (Bonferroni correction) for multiple comparisons of pretreatment and posttreatment data for each intervention condition (manipulation or MCI).

Results

Pressure pain threshold values (dominant side, $P = .2$; nondominant, $P = .3$), HPT (dominant side, $P = .8$; nondominant side, $P = .4$), CPT (dominant, $P = .8$; nondominant, $P = .7$), PFG ($P = .3$), and MGF ($P = .9$) before intervention (manipulation or MCI) were not statistically significantly different, so it could be assumed that both interventions were comparable at the start of each experimental session (Table 1).

Intervention Condition and PPT

The intraexaminer reliability (ICC)[1,3] of PPT levels for both sides, which was determined from the 3 trials collected before intervention, was 0.92, suggesting high repeatability of PPT testing. The SEM was 6.4 kPa for the dominant side and 5.4 kPa for the nondominant arm.

The analysis of variance detected a significant effect for time ($F = 37.2$, $P < .001$), but not for side ($F = 2.3$, $P > .2$). Furthermore, a significant interaction between intervention and time ($F = 25.1$, $P < .001$) was found. Post hoc

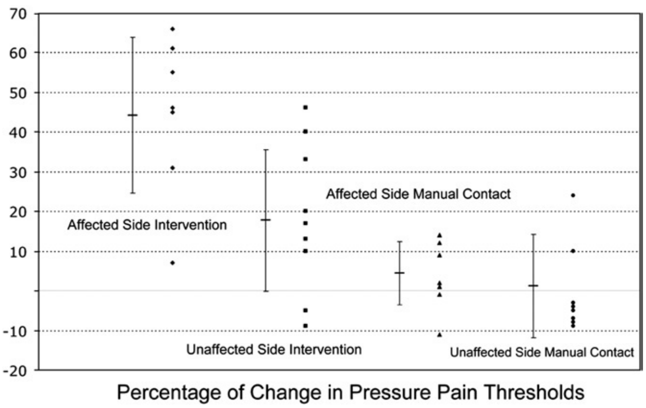

Fig 3. *Percentage of change in PPT levels in both arms after each intervention. *Significant interaction between intervention and time (F = 25.1, P < .001). The manipulative intervention produced a greater increase of PPT in both sides compared with MCI (P < .001).*

revealed that the manipulative intervention produced a greater increase of PPT in both sides compared with MCI ($P < .001$). The PPT (mean ± SEM) increased 44.2% ± 19.0% for the ipsilateral side and 17.7% ± 15.7% for the contralateral arm after the application of the cervical thrust manipulative, which was significantly greater ($P < .001$) than the change of 4.4% ± 8.1% and 1.7% ± 1.2%, respectively, produced by the MCI (Fig 3). Table 1 summarizes within-group pre-post scores of PPT in both arms for each intervention.

Intervention Condition and Thermal Pain Thresholds (HPT, CPT)

The intraexaminer reliability (ICC)[1,3] of HPT and CPT, determined from the 3 trials collected before the intervention, was 0.89 and 0.92, respectively. The SEM was 0.17°C for HPT and 0.11°C for CPT.

The ANOVA did not detect significant effects for time (F = 2.7, $P > .2$), intervention (F = 2.8, $P > .2$), or side (F = 0.9, $P > .4$) for HPT. The HPT (mean ± SEM) increased 2.9% ± 6% on the ipsilateral arm and 3.9% ± 4.1% for the contralateral side after the cervical manipulation, and 2.2% ± 6.7% and 1.9% ± 2.7%, respectively, after the MCI.

The ANOVA did not detect significant effects for time (F = 0.8, $P > .4$), intervention (F = 0.8, $P > .5$), or side (F = 0.6, $P > .4$) for CPT. The CPT (mean ± SEM) increased 9.2% ± 17.2% for the ipsilateral arm and 19.6% ± 18.1% for the contralateral side after the cervical manipulation, and 9.6% ± 17.4% and 3.7% ± 23.0%, respectively, after the MCI. Because no significant effects were detected in the ANOVA, post hoc analysis for HPT and CPT were not conducted. Table 1 summarizes within-group pre-post scores of thermal pain thresholds in both arms for each intervention.

Intervention Condition and Grip Strength

The intraexaminer reliability (ICC)[1,3] of PFG on the affected side was 0.94, whereas the reliability of MGF on the unaffected arm was 0.88. The SEM was 0.5 kg for PFG and 0.7 kg for MGF.

The analysis of variance detected a significant interaction between intervention and time (F = 9.4, $P = .004$), and between time × side × intervention (F = 18.2, $P < .001$). Post hoc analysis revealed that the manipulative intervention produced an increase of PFG on the affected side compared with the MCI ($P < .001$).

The PFG (mean ± SEM) increased 37.8% ± 31.9% on the affected side after the thrust manipulation but decreased 8.5% ± 12.6% after the MCI ($P < .001$). The MGF (mean ± SEM) decreased 3.0% ± 5.9% on the unaffected arm after the cervical manipulation and 0.1% ± 3.7% after the MCI. Table 1 shows within-group pre-post scores for both PFG and MGF in both arms for each intervention.

Discussion

In the current pilot study, we found that the application of a cervical spine thrust manipulation produced an immediate bilateral increase in PPT levels in patients with LE. No significant changes for HPT and CPT were found. In addition, the thrust manipulation increased PFG on the affected side, but not the MGF on the unaffected arm. Current findings are similar to a recent study by Fernández-de-las-Peñas et al[20] that found, after a cervical spine thrust manipulation, asymptomatic individuals exhibited a significant bilateral improvement in PPT over both elbows. Because their study was performed on healthy individuals, it is difficult to generalize to a patient population. The results of our current pilot study further support that perhaps manipulation is more of a neurophysiologic effect rather than strictly a biomechanical one.[19,33]

The hypoalgesic effect that we identified is similar to that identified by other authors who have examined the effects of nonthrust joint mobilizations directed at the cervical spine in patients with LE.[10,16] Vicenzino et al,[16] in a double-blind placebo-controlled repeated measures study, investigated the effects of nonthrust mobilizations directed at the cervical spine and found an improvement in PPT at the elbow in LE. Although the proposed physiologic mechanism by which manual therapy produces its effects is not completely understood, it has been suggested that manual therapy stimulates central control mechanisms (periaqueductal gray area).[14,15] This is speculated to occur through the stimulation of descending inhibitory mechanisms.[12] However, future research is necessary to fully elucidate the mechanisms by which thrust manipulation exerts its effects.

It has been previously reported that manual nonthrust mobilization procedures induce mechanical, but not thermal, hypoalgesic effects.[6] Repeatedly, Vicenzino et al[10,16] showed that one session of cervical lateral glide oscillations are not effective in altering temperature thresholds in a patient presenting with LE. Therefore, we are not surprised that the cervical spine thrust manipulation used in the current study did not alter the temperature thresholds in these subjects with LE. We expect that this is likely due to the result of mobilization/manipulation techniques that stimulate endogenous mechanisms that affect pain but not thermal sensitivity.[10] Nevertheless, Song et al[34] showed that a spinal manipulation applied to L5, L6, or L5-L6 spinous process in an animal model (with induced intravertebral foramen inflammation) significantly reduced the severity and duration of thermal as well as mechanical hyperalgesia, as measured by shortened latency of foot withdrawal to radiant heat and von Frey filament stimulation to the hind paw, respectively. We do not know if the neurophysiologic effects of manipulative therapy may be impacted by the specific segment manipulated.

It is plausible that the reduction of pain in our subjects led to the patients' ability to immediately achieve greater scores for PFG. However, it has been shown that joint manipulation (high-velocity thrust) has resulted in a reduction of inhibition of the biceps muscle in patients presenting with cervical impairments.[35] In addition, a recent study has shown altered cortical motor control of arm muscles after cervical thrust manipulation using transcranial magnetic stimulation,[36] which would support this argument.

In addition, recent studies showed that lumbopelvic thrust manipulation results in immediate improvements in contraction of the transversus and multifidi muscle in patients with low back pain.[37-39] Perhaps thrust manipulation techniques used in this study, which were directed at the cervical spine, resulted in a reduction of reflex inhibition, allowing the muscle to produce a greater force. Perhaps this may be related to the fact that thrust and nonthrust techniques stimulate different axial sensory beds.[18]

Similarly to our findings of improved PFG, several studies have also shown that nonthrust techniques directed at the elbow region result in improved PFG immediately after the technique in patients with LE.[6,17,40] This has led some authors to postulate that patients with LE may be classified into specific subgroups.[41] The overall premise is that patients with greater deficits in PFG force relative to PPT might respond best to techniques directed at the elbow. Patients with greater PPT deficits may respond better to techniques targeted at the cervical spine.[41] This subgrouping was based solely on patient response to nonthrust techniques, and considering the results of our study requires further investigation.

It should be noted that although the PFG improved 3.8 kg and was statistically greater than after the MCI condition, this value does not reach the previously reported clinically important change of 21.5 kg.[42] It may be that repeated sessions of cervical spine thrust manipulation are necessary to achieve an accumulative effect in PFG and reach a clinically important difference. This potentially could be the case with nonthrust techniques as shown by Cleland et al.[43]

Finally, the current study has several limitations. First, it should be recognized that we only assessed immediate effects of cervical thrust manipulation on the outcome measures. Second, it is possible that a joint cracking/popping sound during the thrust manipulation could have created a placebo effect on the participants. Nevertheless, this situation is difficult, if not impossible, to control in a manipulation study. In addition, this pilot study only included a small sample of patients with LE. Future studies are needed to examine the long-term effects of cervical manipulation in a larger sample size.

Conclusion

The application of a thrust manipulation at the cervical spine produced an immediate bilateral increase in PPT in patients with LE. No significant changes for HPT and CPT were found. Finally, cervical manipulation increased PFG on the affected side, but not the MGF on the unaffected arm. Future studies with larger sample sizes are required to further examine the effects of thrust manipulation on PPT, HPT, CPT, or PFG.

Practical Applications

- The application of a manipulation at the cervical spine produced an immediate bilateral increase in PPT levels in LE.
- The application of a manipulation at the cervical spine did not produce changes in thermal pain thresholds in patients with LE.
- The application of a cervical thrust manipulation increased PFG on the affected side, but not the MGF on the unaffected arm.

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