CHANGES IN NECK PAIN AND ACTIVE RANGE OF MOTION AFTER A SINGLE THORACIC SPINE MANIPULATION IN SUBJECTS PRESENTING WITH MECHANICAL NECK PAIN: A CASE SERIES

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ABSTRACT

Objective: Our aim was to report changes in neck pain at rest, active cervical range of motion, and neck pain at end-range of cervical motion after a single thoracic spine manipulation in a case series of patients with mechanical neck pain.

Methods: Seven patients with mechanical neck pain (2 men, 5 women), 20 to 33 years old, were included. All patients received a single thoracic manipulation by an experienced manipulative therapist. The outcome measures of these cases series were neck pain at rest, as measured by a numerical pain rating scale; active cervical range of motion; and neck pain at the end of each neck motion (eg, flexion or extension). These outcomes were assessed pre treatment, 5 minutes post manipulation, and 48 hours after the intervention. A repeated-measures analysis was made with parametric tests. Within-group effect sizes were calculated using Cohen *d* coefficients.

Results: A significant ($P < .001$) decrease, with large within-group effect sizes ($d > 1$), in neck pain at rest were found after the thoracic spinal manipulation. A trend toward an increase in all cervical motions (flexion, extension, right or left lateral flexion, and right or left rotation) and a trend toward a decrease in neck pain at the end of each cervical motion were also found, although differences did not reach the significance ($P > .05$). Nevertheless, medium to large within-group effect sizes ($0.5 < d < 1$) were found between preintervention data and both postintervention assessments in both active range of motion and neck pain at the end of each neck motion.

Conclusions: The present results demonstrated a clinically significant reduction in pain at rest in subjects with mechanical neck pain immediately and 48 hours following a thoracic manipulation. Although increases in all tested ranges of motion were obtained, none of them reached statistical significance at either posttreatment point. The same was found for pain at the end of range of motion for all tested ranges, with the exception of pain at the end of forward flexion at 48 hours. More than one mechanism likely explains the effects of thoracic spinal manipulation. Future controlled studies comparing spinal manipulation vs spinal mobilization of the thoracic spine are required. (J Manipulative Physiol Ther 2007;30:312-320)

Key Indexing Terms: *Neck Pain; Manipulation; Spinal; Thoracic Vertebrae*

Mechanical neck pain affects 45 to 54% of the general population at some time during their lives[1] and can result in severe pain and disability.[2] Further, the economic expense caused by neck disorders is extremely high, second only to low back pain costs in the United States.[3]

The source of symptoms in mechanical neck pain is not completely understood, but has been purported to be related to various anatomical structures, particularly zygapophyseal or uncovertebral joints of the cervical spine.[4,5] Spinal manipulation or mobilization is commonly used in the management of mechanical neck disorders.[6,7] Furthermore, several studies have demonstrated that spinal manipulation aimed at the cervical spine is an effective intervention for patients with mechanical neck pain.[8-13] However, clinicians

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should consider the risk-benefit ratio of these interventions.[14] Although many premanipulative screening procedures have been proposed to predict patients who may be at risk for serious injury, particularly of the vertebral artery, from cervical manipulation,[15-17] little evidence exists to support these decision-making schemes in the ability to accurately identify these patients.[14] Scientific evidence implicates cervical rotation near the terminal range of motion as the primary component for vertebral artery injuries after spinal manipulative procedures.[14]

It has been found that spinal manual procedures could activate descending inhibitory mechanisms resulting in hypoalgesic effects in distant areas.[18-20] Furthermore, some authors have suggested that because of biomechanical, anatomical and nerve relationships between the cervical and thoracic spine, disturbances in the thoracic region could contribute to the maintenance of neck pain.[5,21] For these reasons, it seems possible that therapeutic interventions directed at the thoracic spine may have hypoalgesic or biomechanical effects on the cervical spine.

Preliminary evidence suggests that thoracic spine manipulation may result in an immediate decrease in pain and an increase in cervical range of motion in patients with mechanical neck pain.[22] In a controlled study, Cleland et al[23] demonstrated that patients with mechanical neck pain who received thoracic spine manipulation experienced a significantly immediate improvement ($P < .001$) in neck pain, as compared to a sham-manipulative group. In another study, it was found that patients with whiplash-associated disorders who received thoracic spine manipulation experienced a significantly greater ($P < .003$) reduction in their symptoms than those patients who did not receive the thoracic manipulation.[24]

It seems that thoracic spine manipulation could be effective in decreasing neck pain and increasing cervical range of motion. However, before we conduct a randomized controlled study comparing different manual procedures, we planned to investigate the effects on neck pain at rest, active cervical range of motion, and neck pain at end-range of each cervical motion after a single thoracic spine manipulation in a case series of patients suffering from mechanical neck pain.

Methods

Subjects

Seven consecutive subjects, 2 men and 5 women, from 20 to 33 years old (mean age, 26; SD, 5) who presented with mechanical neck pain and were referred by their primary care physician to the Department of Physical Therapy, Occupation Therapy, Rehabilitation and Physical Medicine, Universidad Rey Juan Carlos in Madrid, Spain, were recruited. For the purpose of this study, mechanical neck pain was defined as generalized neck and/or shoulder pain with mechanical characteristics including symptoms provoked by maintained neck postures, neck movement, or by palpation of the cervical muscles. Patients were excluded if they exhibited any of the following: any contraindication to manipulation, previous history of a whiplash injury, history of cervical spine surgery, diagnosis of cervical radiculopathy or myelopathy determined by their primary care physician, presence of widespread pain (ie, fibromyalgia syndrome),[25] having undergone spinal manipulative therapy in the 2 months before the study, or being younger than 18 years. The clinical history for each patient was solicited from their primary care physician to assess the presence of any exclusion criteria or "red flags," for example, infection and osteoporosis.

Fig 1. *Thoracic spinal manipulation used in this study.*

This study was supervised by the Department of Physical Therapy, Occupational Therapy, Rehabilitation and Physical Medicine, Universidad Rey Juan Carlos, and it was also approved by the local human research committee. All subjects signed an informed consent before their inclusion.

Thoracic Manipulation

The subject lay supine with the arms crossed over the chest and hands passed around the shoulder. The thoracic spine was in neutral position. The hand of the therapist contacted with a neutral hand position over the spinous process of T4 (inferior vertebra of the motion segment). The other hand stabilized the head, neck, and upper thoracic spine of the patient. Gently, flexion of the thoracic spine was introduced until slight tension was palpated in the tissues at the therapists' contact point. Then, a high-velocity, low-amplitude technique downward toward the couch and in a cephalad direction was applied (Fig 1).[26] A cracking or popping sound accompanied all manipulations. If no popping sound was heard on the first attempt, the therapist repositioned the patient, and the therapist performed a second manipulation. A maximum of 2 attempts were performed on each subject.

All patients were treated a by therapist who had a postgraduate background in spinal manipulative therapy and

Table 1. *Preintervention, postintervention, and follow-up data of neck pain and cervical range of motion assessments*

	Preintervention	Postintervention	Follow-up
Neck pain at rest (NPRS)	5.4 ± 1.5	2.9 ± 1.4	2.7° ± 1.5°
Neck mobility			
Flexion	57.8° ± 8.1°	62.1° ± 5.6°	59.7° ± 8.7°
Extension	65.4° ± 14.8°	71° ± 13.9°	71.7° ± 9.7°
Right lateral flexion	35.7° ± 8.3°	39.3° ± 6.1°	37.1° ± 6.9°
Left lateral flexion	38.5° ± 6.9°	41.4° ± 8.5°	40° ± 6.4°
Right rotation	72.8° ± 6.9°	77.8° ± 3.9°	75.7° ± 5.3°
Left rotation	70.7° ± 10.1°	75° ± 5°	77.1° ± 5.6°
Neck pain during neck motion (NPRS)			
Flexion	3.8 ± 2.9	1.6 ± 1.5	0.8 ± 1.2
Extension	2.6 ± 2.5	0.8 ± 1.6	0.3 ± 0.7
Right lateral flexion	2.7 ± 2.9	1 ± 2.2	0.7 ± 1.2
Left lateral flexion	2.7 ± 2.8	1.1 ± 1.6	0.8 ± 1.2
Right rotation	1.4 ± 1.8	0.2 ± 0.4	0 ± 0
Left rotation	0.8 ± 1.5	0 ± 0	0 ± 0

Values are expressed as mean ± SD.

with more than 8 years of clinical experience in the management of neck pain patients with manual procedures.

Outcome Measures

The outcome measures of this case series were neck pain at rest; active cervical range of motion; and neck pain at end-range of each neck motion (eg, flexion or extension, right or left rotation, right or left lateral flexion). Both neck pain at rest and neck pain at the end of each cervical motion were assessed with an 11-point numerical pain rate scale[27] (NPRS; range, 0 [no pain] to 10 [maximum pain]).

Active cervical range of motion was calculated with a cervical goniometric device (Perfomance Attainment Associates, St Paul, Minn). The cervical goniometer has been shown to be a reliable method of measurement[28,29] with an intratester reliability ranging from 0.7 to 0.9 and an intertester reliability ranging from 0.8 to 0.87.[30,31] Neck mobility was assessed in a relaxed sitting position. It was recorded as half-cycles, that is, flexion or extension, and right or left. For this purpose, all subjects were asked to sit comfortably on the chair with both feet flat on the floor, hips and knees positioned at 90° angles, and buttocks positioned against the back of the chair. Then, the goniometer was placed at the top of the head. Once the goniometer was set in neutral position, they were asked to move the head as far as possible in a standard form: forward (flexion), backward (extension), right lateral flexion, left lateral flexion, right rotation, and left rotation. Three measurements were recorded for each type of movement, and the mean was used in further statistical analysis. This protocol has been used in previous studies.[13]

Procedure

Subjects presenting with mechanical neck pain were recruited from the Department of Physical Therapy, Occupational Therapy, Rehabilitation and Physical Medicine, Universidad Rey Juan Carlos in Madrid, Spain. Subjects completed self-report measures and then received a standardized history and physical examination by an experienced physical therapist. Demographic information including age, sex, medical history, and location and nature of symptoms was collected. Only patients who reported bilateral neck pain were included. Patients also completed the Neck Disability Index (NDI) to measure perceived disability.[32] The NDI is scored from 0 to 50, with higher scores corresponding to greater disability. The NDI has been demonstrated to be a reliable and valid assessment of disability in patients with neck pain.[33,34]

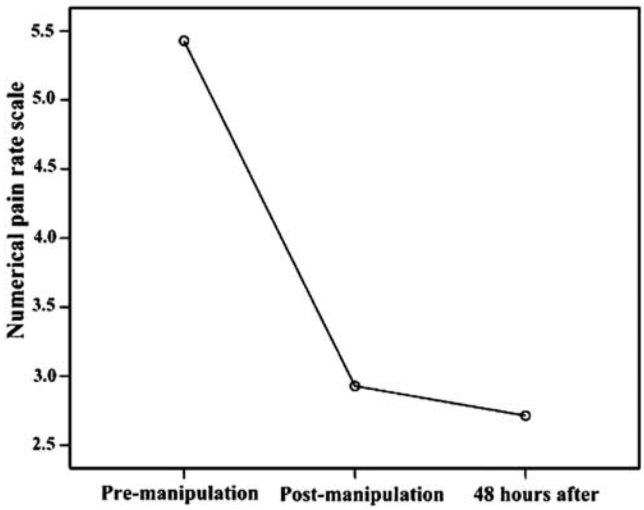

Fig 2. *Evolution of neck pain at rest during the assessments.*

After that, pretreatment measurements were assessed by an external assessor. Subjects reported first their neck pain at rest on a NPRS, and secondly, active cervical range of motion was taken. At the end of range of each cervical

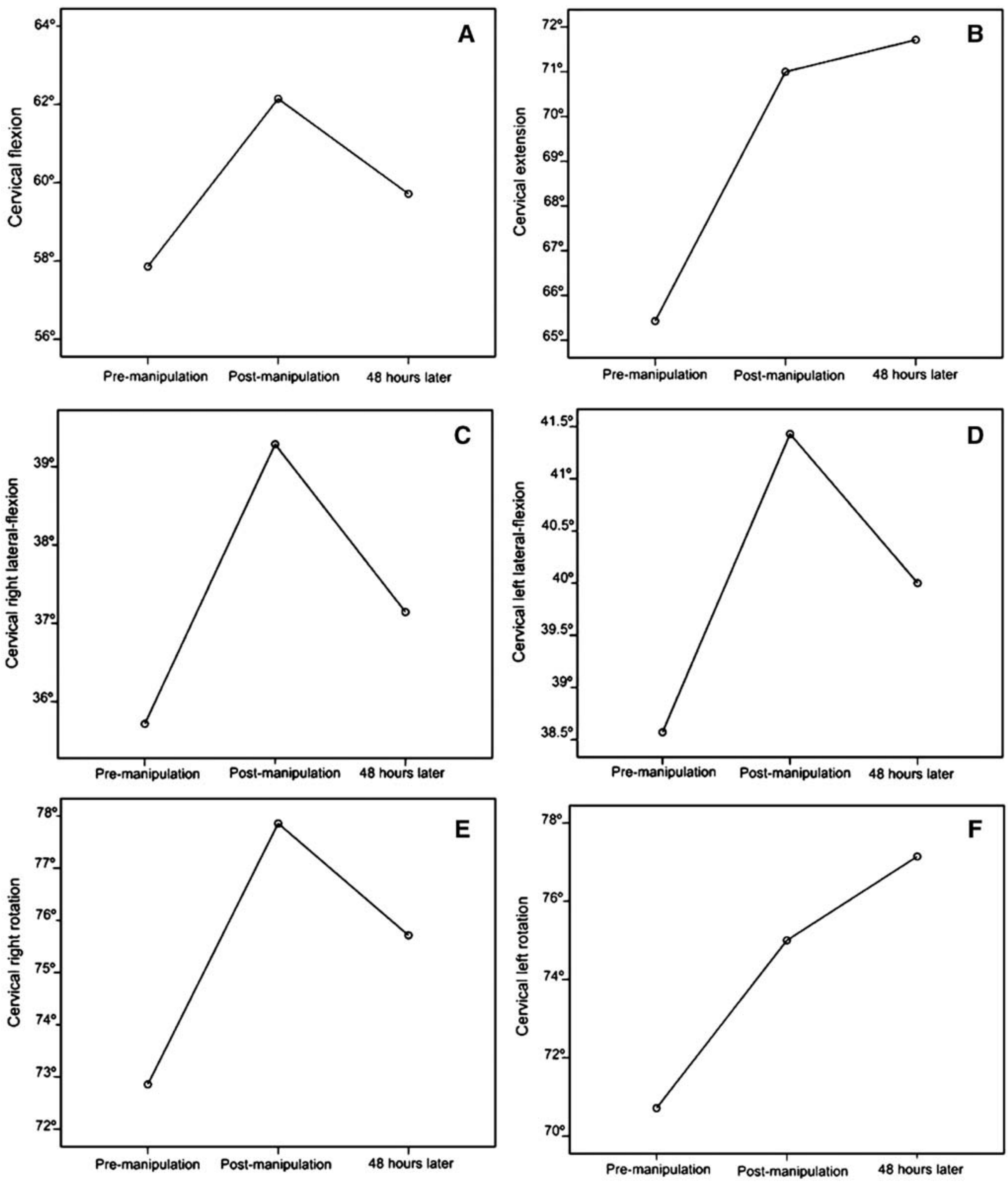

Fig 3. *Evolution of active cervical range of motion during the assessments.*

motion, subjects were asked for neck pain (NPRS) at that point. After pretreatment measurements, subjects received the thoracic manipulation by an experienced manipulative therapist. Postintervention data were assessed 5 minutes and 48 hours after the manipulation by the external assessor, in the same way as in the pretreatment assessment.

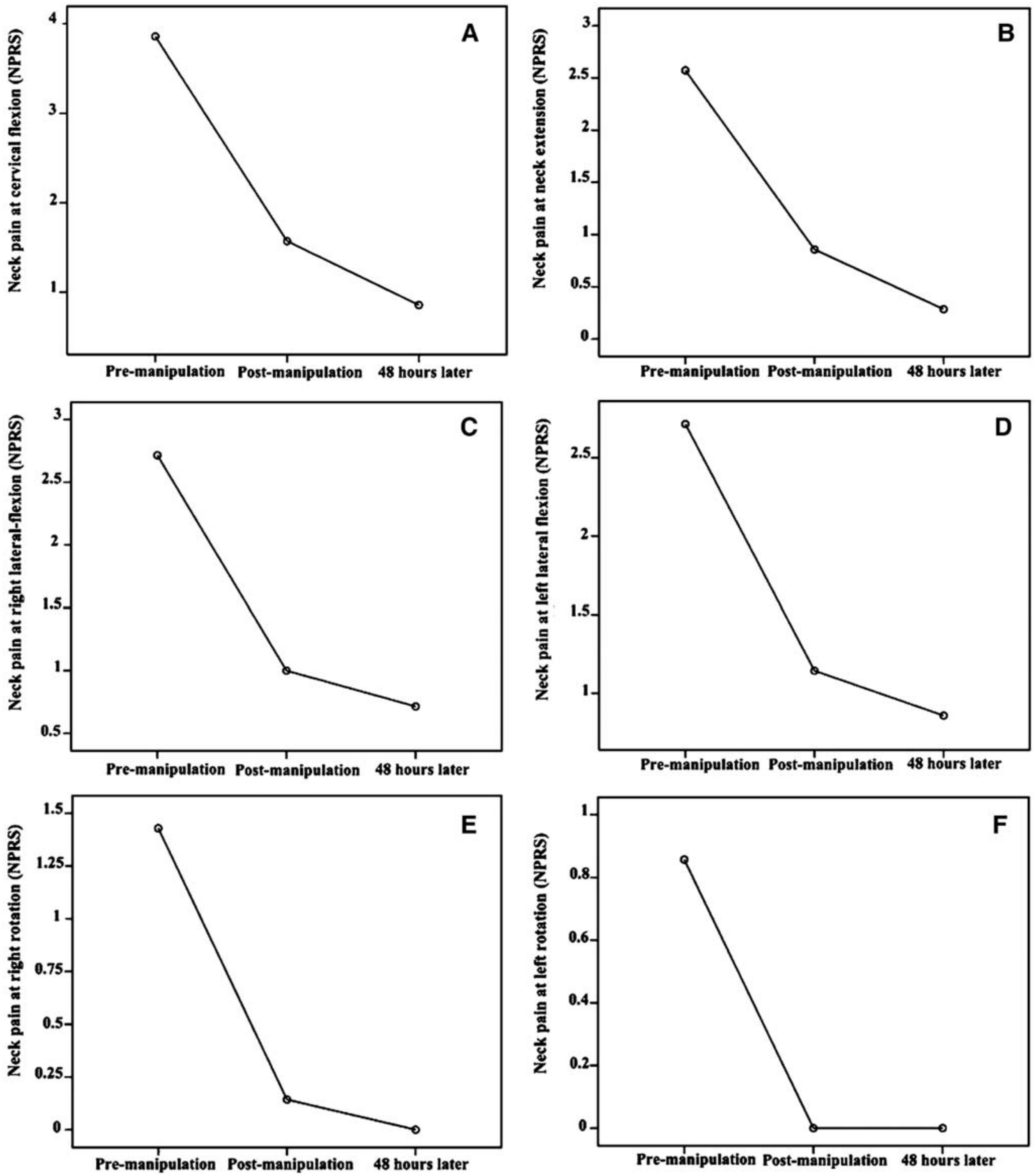

Fig 4. *Evolution of neck pain at end-range of each cervical motion during the assessments.*

Statistical Analysis

Data were analyzed with the SPSS package version 13.0 (SPSS Inc, Chicago, Ill). Results are expressed as mean and SD or [minimum – maximum] in the text. A normal distribution of quantitative data was assessed by means of the Kolmogorov-Smirnov test ($P > .05$). A 1-way analysis

Table 2. *Within-group changes and within-group effect sizes at each assessment of the study*

	Pre − post data	Post − follow-up data	Pre − follow-up data
Neck mobility			
Flexion	4.3° ± 5.3° (*P* = NS); *d* = 0.8	−2.4° ± 6°; (*P* = NS); *d* = 0.4	3.3° ± 5.2° (*P* = NS); *d* = 0.6
Extension	5.6° ± 4.5°; (*P* = NS); *d* = 1.2	0.7° ± 6.7° (*P* = NS); *d* = 0.1	3.4° ± 9.8°; (*P* = NS); *d* = 0.34
Right lateral flexion	3.5° ± 3.7°; (*P* = NS); *d* = 0.9	−2.1° ± 3.9° (*P* = NS); *d* = 0.53	1.4° ± 5.5°; (*P* = NS); *d* = 0.25
Left lateral flexion	2.8° ± 3.9°; (*P* = NS); *d* = 0.7	−1.4° ± 2.4° (*P* = NS); *d* = 0.58	1.4° ± 2.4°; (*P* = NS), *d* = 0.58
Right rotation	4.3° ± 5.3°; (*P* = NS); *d* = 0.8	−2.1° ± 3.9° (*P* = NS); *d* = 0.53	2.8° ± 3.9°; (*P* = NS); *d* = 0.71
Left rotation	4.3° ± 7.3°; (*P* = NS); *d* = 0.57	2.1° ± 4.8° (*P* = NS); *d* = 0.43	6.4° ± 7.4°; (*P* = NS); *d* = 0.86
Neck pain during neck motion (NPRS)			
Flexion	−2.3 ± 2 (*P* = NS); *d* = 1.1	−0.7 ± 1.5 (*P* = NS); *d* = 0.5	−2.6 ± 2.4 (*P* = .02); *d* = 1.1
Extension	−1.7 ± 1.6 (*P* = NS); *d* = 1.1	−0.6 ± 1.5 (*P* = NS); *d* = 0.4	−2.3 ± 1.9 (*P* = NS); *d* = 1.2
Right lateral flexion	−1.7 ± 2.6 (*P* = NS); *d* = 0.65	−0.3 ± 1.2 (*P* = NS); *d* = 0.25	−2 ± 2.5 (*P* = NS); *d* = 0.8
Left lateral flexion	−1.6 ± 2.1 (*P* = NS); *d* = 0.68	−0.3 ± 0.5 (*P* = NS); *d* = 0.6	−1.9 ± 2.2 (*P* = NS); *d* = 0.86
Right rotation	−1.3 ± 1.7 (*P* = NS); *d* = 0.76	−0.1 ± 0.4 (*P* = NS); *d* = 0.25	−1.4 ± 1.8 (*P* = NS); *d* = 0.76
Left rotation	−0.9 ± 1.5 (*P* = NS); *d* = 0.5	0 ± 0 (*P* = NS); *d* = 0	−0.9 ± 1.6 (*P* = NS); *d* = 0.56

Values are expressed as mean ± SD (*P* value); effect sizes (*d*)/positive values indicate increase, and negative values, decrease. *P* values come from the ANOVA test (the Bonferroni correction was used as post hoc analysis). *NS*, Nonsignificant.

of variance (ANOVA) for repeated measures was used to compare the intragroup scores of each variable during postintervention assessments (the Bonferroni correction was used as post hoc analysis). Within-group effect sizes were calculated using the Cohen *d* coefficient.[35] An effect size greater than 0.8 was considered large, around 0.5 was moderate, and less than 0.2 was small.[35] The statistical analysis was conducted at a 95% confidence level. A *P* value less than .025 was considered as statistically significant (Bonferroni correction).

Results

In the present cases series, length of neck pain history ranged from 1 to 5 years (mean, 2.5 ± 1.8 years). All subjects described an insidious onset of neck pain without a trauma or relevant event. Furthermore, no patient had concomitant back pain. The mean intensity of neck pain (Visual Analog Scale) at rest was 5.5 (range, 3-7), whereas the mean NDI was 14.4 (range 11 to 20). There was a trend toward a positive correlation between length of the disease and neck pain at rest (r_s = 0.67; P = .09).

Neck Pain Assessment

A 1-way ANOVA of repeated measures revealed a significant decrease in neck pain at rest after the thoracic spinal manipulation (F = 48.01; $P < .001$). Post hoc testing (Bonferroni) showed the difference to be between preintervention data and both postintervention (immediate and 2 days later) data ($P < .001$) but not between both postintervention assessments ($P > .9$). Furthermore, large within-group effect sizes ($d > 1$) were found between preintervention data and both postintervention assessments but not between the 2 latest assessments (48 hours post intervention; $d = 0.25$). Table 1 and Figure 2 summarize the evolution of neck pain at rest during the study.

Active Cervical Range of Motion Assessment

A 1-way ANOVA of repeated measures revealed a trend toward an increase in all cervical motions (flexion, extension, right or left lateral flexion, and right or left rotation), although the improvement did not reach the significance level ($P > .05$). In addition, medium to large within-group effect sides ($0.2 < d < 1$) were found between preintervention data and both postintervention assessments, depending on each neck motion. Table 1 and Figure 3 summarize the evolution of active cervical motion during the study.

Again, a 1-way ANOVA of repeated measures revealed a trend toward a decrease in neck pain at the end of each cervical motion, being only statistically significant for neck pain during cervical flexion (F = 10.5; $P = .018$), but not for neck pain during the remaining neck motions ($P > .05$). Finally, medium to large within-group effect sizes ($0.5 < d < 1$) were found between preintervention data and both postintervention assessments, depending on each neck motion. Table 1 and Figure 4 summarize the evolution of neck pain at the end of each cervical motion during the study. Table 2 shows within-group changes and within-group effect sizes at each assessment time of the study.

Discussion

The present results demonstrate a statistically significant reduction in pain at rest in this small series of cases with mechanical neck pain immediately and 48 hours after a thoracic manipulation. Although increases in all tested ranges of motion were obtained, none of them reached statistical significance at either posttreatment point. The same was found for pain at the end of range of motion for all tested ranges with the exception of pain at the end of forward flexion at 48 hours. The effect sizes for these changes suggest a moderate-strong clinical effect.

The effectiveness of cervical spinal manipulation in reducing neck pain has been demonstrated in previous studies.[8-13] However, cervical manipulative procedures involving cervical rotation movement are not completely free of risk to the vertebral artery.[14] In the present case series, after a single thoracic manipulation, a mean reduction of 2.5 cm on a Visual Analog Scale for pain at rest was obtained immediately after the procedure, which agrees with the findings of Cleland et al[23] In addition, this improvement was maintained 48 hours after the intervention. According to Kelly, this decrease in neck pain can be considered as a clinically meaningful level of improvement.[36] Because thoracic procedures are free of risk of the vertebral artery, previous[23] and current findings suggest that thoracic spinal manipulation could be used in the management of patients with mechanical neck pain. The effectiveness of thoracic spinal maneuvers is clinically supported by the fact that the thoracic spine is the region of the spine most often manipulated, despite the fact that more patients complain of neck pain.[37]

The neurophysiologic mechanisms by which spinal manipulative therapy is effective in reducing pain are not completely understood. One possible mechanism could be that the manipulative procedure may induce a reflex inhibition of pain or reflex muscle relaxation by modifying the discharge of proprioceptive group I and II afferents.[38] A second mechanism might be a presynaptic inhibition of segmental pain pathways and the activation of the endogenous opiate system.[39] These mechanisms would explain local effects of spinal manipulative procedures but not the distal effects such as those found in our case series. Some studies have found that spinal manual procedures can activate descending inhibitory mechanisms resulting in hypoalgesic effects in distant areas.[18-20] Activation of descending inhibitory mechanisms after the thoracic spinal manipulation would explain the decreased neck pain found in our case series after a distant manipulation (thoracic spine). Nevertheless, it seems that more than 1 mechanism likely explains the effects of spinal manipulative therapy.[40]

We also found that the thoracic manipulation provoked an increase in active cervical range of motion and a decrease in neck pain at the end-range of each cervical movement. These effects could be explained by a possible repercussion of the thoracic intervention on the biomechanics of the cervical spine. The rationale to include thoracic spine maneuvers in the management of patients with neck pain results from the hypothesis that disturbances in joint mobility in the thoracic spine may be an underlying contributor to musculoskeletal disorders in the cervical spine.[5,21] It is suggested that thoracic spinal manipulation may restore the normal biomechanics of this region, potentially lowering mechanical stress and improving the distribution of joint forces in the cervical spine.[41] Some studies found a significant association between decreased mobility in the upper thoracic spine and the presence of subjective complaints associated with neck pain.[42-44] It is possible that spinal manipulative therapy has inherent qualities that can alter the biomechanics of the treated region, that is, the thoracic spine and those segments that are biomechanical related, that is, the cervical region. It is also plausible that the experienced symptomatic improvement after a manipulative procedure influences the range of motion improvement in the entire spine. In that way, the effects on pain modulation rather than direct range of motion effects can lead to changes in active range of motion.

Our case series has several limitations. First, the sample size was small. Future studies with a larger sample size comparing the effects of different manual procedures, such as thoracic manipulation vs mobilization, are required. Secondly, we only examined the short-term effects of spinal manipulative therapy directed at the thoracic spine. That statistically significant changes occurred after spinal manipulation provides impetus for future research in this area. Therefore, further studies are needed to examine long-term effects of thoracic manipulation in neck pain and range of motion or to compare the results of cervical vs thoracic manipulation. Finally, a single manipulative procedure does not represent the common clinical practice because patients are usually treated with several manipulations during their treatment. It would be interesting to analyze if the inclusion of thoracic spinal procedures in clinical practice provokes faster outcome responses.

Conclusions

The present results demonstrated a clinically significant reduction in pain at rest in subjects with mechanical neck pain immediately and 48 hours after a thoracic manipulation. Although increases in all tested ranges of motion were obtained, none of them reached statistical significance at either posttreatment point. The same was found for pain at the end of range of motion for all tested ranges with the exception of pain at the end of forward flexion at 48 hours. More than 1 mechanism likely explains the effects of thoracic spinal manipulation. Future controlled studies comparing spinal manipulation vs spinal mobilization of the thoracic spine are required.

Practical Applications

- A single thoracic spinal manipulation was effective in reducing neck pain at rest, in increasing active cervical range of motion, and in decreasing neck pain at end-range of each cervical motion in a sample of 7 patients with mechanical neck pain.
- The obtained effect sizes suggest a strong-moderate clinical effect.
- More than 1 mechanism likely explains the effects of thoracic spinal manipulation.

References

1. Côte P, Cassidy JD, Carroll L. The factors associated with neck pain and its related disability in the Saskatchewan population. Spine 2000;25:1109-17.
2. Côte P, Cassidy JD, Carroll L. The Saskatchewan health and back pain survey. The prevalence of neck pain and related disability in Saskatchewan adults. Spine 1998;23:1689-98.
3. Wright A, Mayer TG, Gatchel RJ. Outcomes of disabling cervical spine disorders in compensation injuries: a prospective comparison to tertiary rehabilitation response for chronic lumbar spinal disorders. Spine 1999;24:178-83.
4. Bogduk N, Aprill C. On the nature of neck pain, discography and cervical zygapophyseal joint blocks. Pain 1993;54:213-7.
5. Maitland G, Hengeveld E, Banks K, English K. Maitland's vertebral manipulation. 6th ed. London, England: Butterworth Heineman; 2000.
6. Gross AR, Kay T, Hondras M, et al. Manual therapies for mechanical neck disorders: a systematic review. Man Ther 2002;7:131-49.
7. Howing JL, Gross A, Gasner D, et al. A critical appraisal of review articles on the effectiveness of conservative treatment for neck pain. Spine 2001;26:196-205.
8. Vernon HT, Aker P, Burns S, Viljakaanen S, Short L. Pressure pain threshold evaluation of the effect of spinal manipulation in the treatment of chronic neck pain: a pilot study. J Manipulative Physiol Ther 1990;13:13-6.
9. Cassidy JD, Lopes AA, Yong-Hink K. The immediate effect of manipulation versus mobilization on pain and range of motion in the cervical spine: a randomized controlled trial. J Manipulative Physiol Ther 1992;15:570-5.
10. Nansel D, Peneff A, Cremata E, Carlson J. Time course considerations for the effects of unilateral lower cervical adjustments with respect to the amelioration of cervical lateral-flexion passive end-range asymmetry. J Manipulative Physiol Ther 1990;13:297-304.
11. Schalkwyk RV, Parkin-Smith GF. A clinical trial investigating the possible effect of the supine cervical rotatory manipulation and the supine lateral break manipulation in the treatment of mechanical neck pain: A pilot study. J Manipulative Physiol Ther 2000;23:324-31.
12. Pikula JR. The effect of spinal manipulative therapy on pain reduction and range of motion in patients with acute unilateral neck pain: a pilot study. J Can Chiropr Assoc 1999;43:111-9.
13. Martínez-Segura R, Fernández-de-las-Peñas C, Ruiz-Sáez M, López-Jiménez C, Rodríguez-Blanco C. Immediate effects on neck pain and active range of motion following a single cervical HVLA manipulation in subjects presenting with mechanical neck pain: a randomized controlled trial. J Manipulative Physiol Ther 2006;29:511-7.
14. Di Fabio RP. Manipulation of the cervical spine: risks and benefits. Phys Ther 1999;79:50-65.
15. Refshauge KM, Parry S, Shirley D, Larsen D, Rivett DA, Boland R. Professional responsibility in relation to cervical spine manipulation. Aust J Physiother 2002;48:171-9.
16. Barker S, Kesson M, Ashmore J, Turner G, Conway J, Stevens D. Professional issue: guidance for pre-manipulative testing of the cervical spine. Man Ther 2000;5:37-40.
17. Licht PB, Christensen HW, Hoilund-Carlsen PF. Is there a role for pre-manipulative testing before cervical manipulation? J Manipulative Physiol Ther 2000;23:175-9.
18. Vicenzino B, Paungmali A, Buratowski S, Wright A. Specific manipulative therapy treatment for chronic lateral epicondylalgia produces uniquely characteristic hypoalgesia. Man Ther 2001;6:205-12.
19. Paungmali A, O'Leary S, Souvlis T, Vicenzino B. Hypoalgesic and sympathoexcitatory effects of mobilization with movement for lateral epicondylalgia. Phys Ther 2003;83:374-83.
20. Skyba DA, Radhakrishnan R, Rohlwing JJ, Wright A, Sluka KA. Joint manipulation reduces hyperalgesia by activation of monoamine receptors but not opioid or GABA receptors in the spinal cord. Pain 2003;106:159-68.
21. Greenman PE. Principles of manual medicine. 2nd ed. Philadelphia: Lippincott Williams and Wilkins; 1996. p. 24-31.
22. Flynn TW, Wainner RS, Whitman JM. Immediate effects of thoracic spine manipulation on cervical range of motion and pain (abstract). J Man Manipulative Ther 2001;9:164-71.
23. Cleland J, Childs JD, McRae M, Plamer J, Stowell T. Immediate effects of thoracic manipulation in patients with neck pain. Man Ther 2005;10:127-35.
24. Fernández-de-las-Peñas C, Fernández-Carnero J, Plaza-Fernández A, Lomas-Vega R, Miangolarra-Page JC. Dorsal manipulation in whiplash injury treatment: a randomized controlled trial. J Whiplash Rel Disord 2004;3:55-72.
25. Wolfe F, Smythe HA, Yunus MB, et al. The American College of Rheumatology 1990 criteria for classification of fibromyalgia: report of the multicenter criteria committee. Arthritis Rheum 1990;33:160-70.
26. Gibbons P, Tehan P. Manipulation of the spine, thorax and pelvis. Edinburgh: Churchill Livingstone; 2000. p. 68-9.
27. Jensen MP, Turner JA, Romano JM, Fisher L. Comparative reliability and validity of chronic pain intensity measures. Pain 1999;83:157-62.
28. Zachman ZJ, Triana AD, Keating JS, Bolles ST, Braun-Porter L. Inter-examiner reliability and concurrent validity of two instruments for the measurement of cervical ranges of motion. J Manipulative Physiol Ther 1989;12:205-10.
29. Jordan K. Assessment of published reliability studies for cervical spine range of motion measurement tools. J Manipulative Physiol Ther 2000;23:180-95.
30. Peolsson A, Hedlund R, Ertzaard S, Oberg B. Intra- and intertester reliability and range of motion of the neck. Phys Can 2000;52:233-42.
31. Capuano-Pucci D, Rheault W, Aukai J, Bracke M, Day R, Pastrick M. Intratester and intertester reliability of the cervical range of motion device. Arch Phys Med Rehabil 1991;72:338-40.
32. Vernon H, Mior S. The neck disability index: a study of reliability and validity. J Manipulative Physiol Ther 1991;14:409-15.
33. Hains F, Waalen J, Mior S. Psychometric properties of the neck disability index. J Manipulative Physiol Ther 1998;21:75-80.

34. Stratford PW, Riddle DL, Binkley JM, Spadoni G, Westaway MD, Padfield B. Using the Neck Disability Index to make decisions concerning individual patients. Physiother Can 1999;51:107-12.
35. Cohen J. Statistical power analysis for the behavioural sciences. Hillsdale (NJ): Lawrence Erlbaum Associates; 1988. p. 55-65.
36. Kelly A. The minimum clinically significant difference in visual analogue scale pain score does not differ with the severity of pain. Emerg Med J 2001;18:205-7.
37. Adams G, Sim J. A survey of UK manual therapists' practice of and attitudes towards manipulation and its complications. Phys Res Int 1998;3:206-27.
38. Pickar JG. An in vivo preparation for investigating neural responses to controlled loading of a lumbar vertebra in the anesthetized cat. J Neurosci Methods 1999;89:87-96.
39. Haldeman S. Pain physiology as a neurological model for manipulation. Man Med 1981;19:5-11.
40. Pickar JG. Neuro-physiological effects of spinal manipulation. Spine J 2002;2:357-71.
41. Edmondston SJ, Singer KP. Thoracic spine: anatomical and biomechanical considerations for manual therapy. Man Ther 1997;2:132-43.
42. Norlander S, Aste-Norlander U, Nordgren B, Sahlstedt B. Mobility in the cervico thoracic motion segment: an indicative factor of musculo-skeletal neck-shoulder pain. Scand J Rehabil Med 1996;28:183-92.
43. Norlander S, Gustavsson BA, Lindell J, Nordgren B. Reduced mobility in the cervico-thoracic motion segment—a risk factor for musculoskeletal neck-shoulder pain: a two-year prospective follow-up study. Scand J Rehabil Med 1997;29:167-74.
44. Norlander S, Nordgren B. Clinical symptoms related to musculoskeletal neck-shoulder pain and mobility in the cervico-thoracic spine. Scand J Rehabil Med 1998;30:243-51.