The Journal of Physical Therapy Science

Original Article

Effect of thoracic manipulation and deep craniocervical flexor training on pain, mobility, strength, and disability of the neck of patients with chronic nonspecific neck pain: a randomized clinical trial

Kwan-Woo Lee, PT, PhD[1)], Won-Ho Kim, PT, PhD[2)*]

[1)] Department of Physical Therapy, College of Health and Therapy, Daegu Haany University, Republic of Korea
[2)] Department of Physical Therapy, Ulsan College: 101 Bongsuro, Don-gu, Ulsan 682-715, Republic of Korea

Abstract. [Purpose] To investigate the effects of thoracic manipulation and deep craniocervical flexor training on the muscle strength and endurance, range of motion, and the disability index of the neck of patients with chronic nonspecific neck pain. [Subjects and Methods] Forty-six patients with chronic neck pain participated. They received an intervention for 35 minutes a day, three times a week for 10 weeks. Subjects were randomly assigned to one control and two experimental groups: group A (thoracic manipulation combined with deep craniocervical flexor training, n=16), group B (deep craniocervical flexor training, n=15), and group C (active self-exercise as a control group, n=15). Muscle strength and endurance, pain, neck disability index, and range of motion of the cervical and thoracic spine were measured before and after the intervention. [Results] Group A showed significant increases in muscle strength, endurance, and cervical and thoracic range of motion, and significant decreases in the pain and neck disability index, compared with groups B and C. [Conclusion] Although deep craniocervical flexor training is effective at improving neck function, thoracic manipulation combined with deep craniocervical flexor training was a more effective intervention for pain relief and improving the range of motion, muscle function, and neck disability of patients with nonspecific chronic neck pain.
Key words: Thoracic manipulation, Deep craniocervical flexor, Neck pain

(This article was submitted Sep. 16, 2015, and was accepted Oct. 14, 2015)

INTRODUCTION

Neck pain is a musculoskeletal disorder experienced by 48.5–67% of the population at some point in life[1)]. The symptoms of patients with chronic neck problems are pain, stiffness, and limited range of motion (ROM)[2, 3)]. Barnsley et al. reported that limited ROM induces tightness of the muscles surrounding the neck, as well as joint adhesions, resulting in a decrease in biomechanical function of the neck and this leads to chronic neck pain[4)]. In addition, there have been reports of weakness and deficits of motor control of the neck muscles[5, 6)].

Although joint manipulation is one of a variety of treatments for patients with neck pain[7–10)], because the cervical spine is the most sensitive segment of the spinal column, and protects important nerves and blood vessels[11)], manipulation with a rapid velocity of rotation carries the possibility of vertebral artery injury, muscle spasm, and Wallenberg syndrome[12)]. Given the possible risks associated with manipulation of the cervical spine, a thoracic spine approach should be considered[13, 14)].

Motion of the thoracic spine is coupled with the end of motion in the cervical spine in healthy individuals[15]. Cleland et al. suggested a thoracic rather than a cervical spine approach, to decrease the risk of cervical spinal cord injury[16]. Di Fabio[12] and Yang et al.[17] recommended thoracic manipulation (TM) as a useful method for the treatment of patients with neck pain. Many researchers have reported on the effect of TM, as well as TM combined with various techniques for neck pain patients[18–21]. However, the optimal techniques in combination with the manipulation remain unknown[22].

Bronfort et al. reported that spinal manipulation with strengthening of the neck extensors and muscles of the upper extremity were effective for patients with chronic neck pain[23]. Recently, many studies have emphasized the deep craniocervical flexors (DCF) rather than extensors[6, 24]. Among the anterior muscles, it has been argued that the DCF, the longus capitis and longus colli, paly important roles in control of the spinal elements, which cannot be replicated by the more superficial anterior muscles[6]. Javanshir et al. reported that craniocervical flexion exercises increase the cross-sectional area of the longus colli muscle, without altering the sternocleidomastoid muscle, and decrease pain and disability[25].

The effects of TM and DCF training have been reported, but most of the studies involved patients with acute neck pain. The effect of these interventions on patients with chronic neck pain has been inconsistent and is certainly unproven. Therefore, a study on the safety and effectiveness of manipulation combined with active exercise for patients with chronic neck pain would be of value to clinicians. The purpose of this study was to investigate the effects of TM combined with DCF training on the muscle strength and endurance, pain, cervical and thoracic ROM, and neck disability, of patients with chronic nonspecific neck pain.

SUBJECTS AND METHODS

This was a randomized, assessor-blind controlled trial with a pretest-posttest control group design. Patients with chronic neck pain were randomly allocated to one of three groups: group A, group B, and group C. Group A received TM combined with DCF training, and group B received DCF training alone. Group C was a control. Measurements were performed before and after the intervention. This study was approved by the local institutional review board of Ulsan College, and informed consent was obtained from all of the participants.

Forty-six patients with continuous neck pain for at least 3 months completed the study. Patients were recruited if they met the following criteria: diagnosis is of chronic mechanical neck pain, and between the ages of 18 and 60 years; a neck disability index (NDI) score >20%[14]; and limited craniocervical and thoracic flexion and extension ROM. Exclusion criteria were: pain of vascular or neurological system origin; neurological deficits, including nerve root signs; spinal stenosis; previous craniocervical or thoracic spine surgery; or receipt of spinal manipulation therapy within 2 months before the study.

All patients received treatment for 35 minutes a day, 3 days a week for 10 weeks. As outcome measures, strength and endurance of the craniocervical flexors, ROM of the cervical and thoracic spine, pain, and NDI, were assessed immediately before and at the end of the 10-weeks intervention. All measurements were conducted by a therapist with at least 10 years of experience. Fifty-one eligible patients with chronic neck pain were recruited and randomly allocated to one of the three groups. Five of the patients dropped out, and 46 completed the study program. Group A received TM for 10 minutes, DCF training for 15 minutes, and self-stretching of the levator scapulae and upper trapezius muscles as cool-down exercises for 10 minutes. Before TM, a trained therapist confirmed which joints showed hypomobility using a joint play test and a Spinal Mouse device. Patients lay in the supine position, with flexed knee and hip joints, with their hands clasped on the chest. TM was conducted according to the procedures of Krauss et al.[26], with a high-velocity thrust at low amplitude for 10 minutes.

A therapist provided instructions and demonstrations on how to exercise the DCF muscles. The exercise intensity was determined by the patient's status and was increased progressively. Patients were positioned supine, with the knees bent and with a pressure biofeedback unit (PBU) (Chattanooga Group, Hixson, TN, USA) placed suboccipitally, to detect increases in pressure elicited by the gentle nodding action of craniocervical flexion. Visual feedback of the pressure level was provided. Patients were instructed how to perform craniocervical flexion and practiced progressive targeting at five incremental levels (increments of 2 mmHg) between 22 and 30 mmHg[24]. Isometric contraction was performed for 10 seconds, followed by 5 seconds rest in 10 repetitions. Group B received only DCF training for 25 minutes, with self-stretching of the levator scapulae and upper trapezius muscle as a cool-down exercise for 10 minutes. Group C performed active ROM self-exercise (neck flexion, extension, lateral flexion, and rotation without provocation of pain) for 35 minutes.

This study measured the strength and endurance of the DCF muscles using a PBU. Strength was recorded as mmHg and endurance was recorded in seconds. Patients lay supine with their heads in a neutral position. The PBU was then placed under the neck and inflated to 20 mmHg in the suboccipital space. The patients pressed down on the PBU, with maximal craniocervical flexion for the measurement of strength[27]. To measure endurance, under the same conditions as used for muscle strength measurement, patients pressed the PBU with maximal craniocervical flexion. The time that 50% of the maximum pressure could be maintained was measured using a stopwatch[28]. The measurements were repeated three times, and the mean values were recorded. A 0–10 visual analog scale (VAS) was used to assess the intensity of neck pain[29]. Disability was measured with the Korean-Neck Pain Disability Index (K-NDI). This instrument has been widely used and has good reliability[30]. Cervical ROM was assessed using CROM Basic (MedNet-Sites, USA). This instrument has acceptable validity and reliability[29]. Active, cervical flexion and extension, were measured with the patient in a seated position. The mean value of three consecutive readings was used in this study. Thoracic ROM (active flexion and extension) was assessed

Table 1. Changes in strength, endurance, pain, ROM, and NDI after the intervention

Variable		Group A (n=16)	Group B (n=15)	Group C (n=15)
Muscle strength	Pre-test	42.3±5.4	45.3±5.2	45.9±5.8
(mmHg)	Post-test	60.2±4.6	53.0±4.2	47.7±5.5
	Change	14.9±4.4 [a]	7.7±2.5 [b]	1.7±2.0 [c]
	Effect size	2.4	1.1	
Muscle endurance	Pre-test	17.4±2.2	17.3±2.0	18.1±4.2
(seconds)	Post-test	54.1±7.6	38.5±5.8	21.7±3.6
	Change	36.6±7.2 [a]	21.1±6.8 [b]	3.5±2.0 [c]
	Effect size	5.4	3.5	
VAS (cm)	Pre-test	5.2±0.6	5.1±0.6	5.3±0.6
	Post-test	1.4±0.5	2.5±0.5	3.8±0.4
	Change	−3.8±0.6 [a]	−2.6±0.6 [b]	−1.5±0.5 [c]
	Effect size	−5.5	−2.9	
NDI (score)	Pre-test	27.6±4.5	27.2±3.4	27.1±3.9
	Post-test	6.6±2.1	10.7±1.8	20.4±2.5
	Change	−21.0±3.6 [a]	−16.5±4.0 [b]	−6.7±3.4 [c]
	Effect size	−5.9	−4.4	
Cervical	Pre-test	40.5±3.4	40.1±2.5	40.3±4.3
flexion (°)	Post-test	53.3±2.5	49.8±3.1	42.7±4.6
	Change	12.8±3.4 [a]	9.7±1.7 [b]	2.4±2.3 [c]
	Effect size	2.9	1.8	
Extension (°)	Pre-test	45.9±4.5	45.9±4.3	44.9±3.9
	Post-test	61.4±3.1	59.6±3.6	49.6±4.6
	Change	15.5±5.8 [a]	13.7±4.9 [b]	4.7±2.1 [c]
	Effect size	3.1	2.4	
Thoracic	Pre-test	12.2±2.5	12.2±3.3	12.3±2.7
flexion (°)	Post-test	21.4±3.78	12.9±3.9	12.4±2.6
	Change	9.3±3.8 [a]	0.7±4.3 [b]	0.1±0.8 [b]
	Effect size	2.8	0.1	
Extension (°)	Pre-test	17.4±2.8	17.3±2.7	17.1±2.9
	Post-test	24.9±3.0	18.1±2.8	17.1±3.0
	Change	7.6±2.4 [a]	0.8±0.7 [b]	−0.1±0.6 [b]
	Effect size	2.6	0.4	

Values are mean ± standard deviation. Group A (thoracic manipulation + craniocervical deep flexor exercise); Group B (craniocervical deep flexor exercise); Group C (active ROM self-exercise). [a, b, c] Different letters in a raw indicate a statistically significant difference (p<0.05)

using the Spinal Mouse (Idiag, Switzerland). The Spinal Mouse is a hand-held, computer-aided electromechanical device, which is used to measure spinal curvature and mobility. The device is guided along the midline of the spine starting at the spinous process of C7 and finishing at S3. The mean value of three consecutive readings was used in this study.

All data were analyzed using SPSS v. 18.0 (SPSS Korea Inc., Seoul, Korea). The χ^2 test and one-way analysis of variance (ANOVA) were respectively used to examine differences in categorical and continuous variables by group at baseline. The Kolmogorov-Smirnov test was used to identify the normality of the distribution of continuous variables. One-way ANOVA was performed to examine the differences in the mean values of the changes in continuous variables, and, when needed, post hoc analyses were performed. The results of the post-test were not compared because we focused on the change values of the variables measured after treatment by group only. For all analyses, statistical significance was accepted for values of p<0.05. In addition, we calculated the effect size (ES) was calculated using the Cohen d coefficient[31]. ES of main outcomes in groups A and B was calculated by comparison with the change in group C.

RESULTS

The demographic features of patients are presented in Table 1. Pain onset times for groups A, B, and C were 20.7, 19.4, and 11.8 months earlier, respectively. There were no differences in gender, age, height, weight, and onset time at baseline

among the groups (p>0.05). Clinical measurements at baseline were similar: there were no significant differences in ROM of the cervical and thoracic spine, strength and endurance of the DCF, or VAS and K-NDI scores among the groups (p>0.05) (Table 1).

After 10 weeks of treatments, each group showed improvements in all measured variables, and there were significant differences among the intervention (p<0.05) (Table 1). According to the post hoc analysis, the improvements in strength and endurance of the DCF muscles, ROM of the cervical spine, VAS, and K-NDI were more significant in groups A and B than in group C, and more significant in group A than in group B after 10 weeks (p<0.05). The ROM of the thoracic spine showed more improvement in group A than in groups B and C after 10 weeks (p<0.05).

DISCUSSION

This study aimed to investigate the effect of TM combined with DCF training on the strength and endurance of the DCF muscles, cervical and thoracic ROM, pain and neck disability after 10 weeks of treatments conducted for patients with chronic, nonspecific neck pain. We found that in group A, TM + DCF training was more effective than the other approaches at improving ROM, strength, endurance, pain, and NDI. ES in group A ranged from 2.43 (muscle strength) to 5.95 (NDI), when compared with the the change values of group C. In particular, the ES values for muscle endurance, pain, and disability were very large. Vincent et al. reported that the level of evidence was moderate for the short-term effects of upper thoracic manipulation in acute neck pain, limited for long-term effects of neck manipulation, and limited for all techniques in chronic neck pain[32]. This study provides evidence that both manipulation therapy and strengthening of the deep neck flexor muscles help to improve the pain and neck disabilities of chronic neck pain patients.

Group B showed a 16.92% improvement in muscle strength and a 121.92% improvement in muscle endurance after treatment, compared with baseline. There was a 35.8% improvement in muscle strength and a 210.03% improvement in muscle endurance in Group A. Because both group A and B performed DCF muscle training, this may be the natural result of improved strength and endurance. Grimmer and Trot reported that poor endurance of the deep neck flexors was associated with forward head posture and pain[33]. In this study, endurance of the neck flexor muscles was improved more than strength by craniocervical exercise for 10 weeks. In particular, group A showed more improvement in muscle function than group B. It is our opinion that this was due to the effects of manipulation treatment. Manipulation contributes to the facilitation of the deep muscles, and inhibition of the superficial muscles[19]. In addition, strengthening exercise could be actively performed by group A patients, because manipulation has an intermediate pain reduction effect[34, 35].

Previous studies have reported that manual therapy reduces neck pain[18, 19, 22]. In this study, neck pain was reduced to a significantly greater extent in groups A (3.78 VAS points) and B (2.64 VAS points), than in group C. In other words, the percentage of pain relief was 73.39% in group A (d=5.41) and 51.36% in group B (d=2.94) compared with baseline. The apparent hypoalgesic effects of manipulation treatment indicate that manipulation increases the pain threshold via stimulation of mechanical nociceptors, and inhibits pain via facilitation of the dorsal periaqueductal gray area of the midbrain[19, 36].

Manipulation treatment is used to decrease pain and increase ROM. Mobility of the cervical spine is associated with mobility of the high thoracic spine (T1–4)[37]. Patients with neck pain showed decreased motion of the cervical spine coupled with the thoracic spine[38]. This means that treatment of the thoracic spine may be necessary to increase cervical ROM. Many researchers have examined cervical ROM after interventions for patients with neck pain[34, 39], but this study assessed thoracic as well as cervical ROM. Understandably, flexion and extension of the thoracic spine were significantly increased in group A, compared to the other groups. Flexion of the thoracic spine was increased by 75.88% and extension by 43.49%. In addition, all cervical ROM increased by approximately 31–33% after treatment in group A. Although cervical ROM in group B increased significantly more than in group C, the increased ROM of group B was not as great as that of group A. In group A, pain relief, increased neck stabilization, and improvement in the biomechanical relationship between the cervical and thoracic spine may have contributed to increased cervical ROM.

The NDI of groups A and B significantly improved, compared with that of group C. The NDI of group A was reduced by 76.0% (a change of 21 points), and that of group B was reduced by 60.77% (16.53 points). Vernon and Mior suggested that a change of at least 5 points is required to be clinically meaningful, and that "recovery" is represented by an NDI score of less than 4/50, whereupon treatment should cease[40]. The posttest NDI score of group A was 6.63, nearly reaching the "recovery score". Bronfort et al. found that NDI improved 46.6% with manipulation plus exercise, 53.5% with exercise using MedX equipment, and 43.1% with manipulation alone after 11 weeks[23]. Although the study methods differed, the degree of improvement with manipulation plus DCF training in this study was larger than that reported by Bronfort et al.

Miller et al. found that manipulation combined with various exercises produced greater improvement than exercise alone without treatment[22]. However, they did not determine the best exercise to use in combination with manipulation. Although additional well-designed studies should be conducted, we recommend manipulation combined with DCF training to improve cervical function, because this demonstrated excellent effectiveness in the patients with chronic, nonspecific neck pain.

This study had a few limitations. It is difficult to generalize the findings, because the numbers of participants were relatively small. The changes in the dependent variables were not examined at each treatment session, and thus differences among groups were not identified at each session. In addition, the long-term effects following the end of treatment were not investigated. Future study is necessary to examine larger numbers of participants and to implement a protocol for investigat-

ing the long-term effects.

In summary, DCF training was effective at improving neck function, compared with self-exercise in patients with chronic, nonspecific neck pain. Moreover, thoracic manipulation combined with DCF training resulted in greater pain reduction, improvement in muscle strength and endurance, ROM, and NDI, than exercise alone in patients with chronic neck pain. There were no adverse effects reported by any of the participants during the study period.

REFERENCES

1) Cassidy JD, Carroll LJ, Côté P: The Saskatchewan health and back pain survey. The prevalence of low back pain and related disability in Saskatchewan adults. Spine, 1998, 23: 1860–1866, discussion 1867. [Medline] [CrossRef]

2) Sillanpää J, Huikko S, Nyberg M, et al.: Effect of work with visual display units on musculo-skeletal disorders in the office environment. Occup Med (Lond), 2003, 53: 443–451. [Medline] [CrossRef]

3) Kim JH, Lee HS, Park SW: Effects of the active release technique on pain and range of motion of patients with chronic neck pain. J Phys Ther Sci, 2015, 27: 2461–2464. [Medline] [CrossRef]

4) Barnsley L, Lord S, Bogduk N: Comparative local anaesthetic blocks in the diagnosis of cervical zygapophysial joint pain. Pain, 1993, 55: 99–106. [Medline] [CrossRef]

5) Falla D: Unravelling the complexity of muscle impairment in chronic neck pain. Man Ther, 2004, 9: 125–133. [Medline] [CrossRef]

6) Falla D, Rainoldi A, Jull G, et al.: Lack of correlation between sternocleidomastoid and scalene muscle fatigability and duration of symptoms in chronic neck pain patients. Neurophysiol Clin, 2004, 34: 159–165. [Medline] [CrossRef]

7) Jun I, Kim K: A comparison of the deep cervical flexor muscle thicknesses in subjects with and without neck pain during craniocervical flexion exercises. J Phys Ther Sci, 2013, 25: 1373–1375. [Medline] [CrossRef]

8) Simonsen RJ: Principle-centered spine care: McKenzie principles. Occup Med, 1998, 13: 167–183. [Medline]

9) Falla D, Jull G, Russell T, et al.: Effect of neck exercise on sitting posture in patients with chronic neck pain. Phys Ther, 2007, 87: 408–417. [Medline] [CrossRef]

10) Hwangbo PN, Hwangbo G, Park J, et al.: The effect of thoracic joint mobilization and self-stretching exercise on pulmonary functions of patients with chronic neck pain. J Phys Ther Sci, 2014, 26: 1783–1786. [Medline] [CrossRef]

11) Keating L, Lubke C, Powell V, et al.: Mid-thoracic tenderness: a comparison of pressure pain threshold between spinal regions, in asymptomatic subjects. Man Ther, 2001, 6: 34–39. [Medline] [CrossRef]

12) Di Fabio RP: Manipulation of the cervical spine: risks and benefits. Phys Ther, 1999, 79: 50–65. [Medline]

13) Cleland JA, Childs JD, McRae M, et al.: Immediate effects of thoracic manipulation in patients with neck pain: a randomized clinical trial. Man Ther, 2005, 10: 127–135. [Medline] [CrossRef]

14) Cleland JA, Childs JD, Fritz JM, et al.: Development of a clinical prediction rule for guiding treatment of a subgroup of patients with neck pain: use of thoracic spine manipulation, exercise, and patient education. Phys Ther, 2007, 87: 9–23. [Medline] [CrossRef]

15) Ordway NR, Seymour R, Donelson RG, et al.: Cervical sagittal range-of-motion analysis using three methods. Cervical range-of-motion device, 3 space, and radiography. Spine, 1997, 22: 501–508. [Medline] [CrossRef]

16) Cleland JA, Glynn P, Whitman JM, et al.: Short-term effects of thrust versus nonthrust mobilization/manipulation directed at the thoracic spine in patients with neck pain: a randomized clinical trial. Phys Ther, 2007, 87: 431–440. [Medline] [CrossRef]

17) Yang J, Lee B, Kim C: Changes in proprioception and pain in patients with neck pain after upper thoracic manipulation. J Phys Ther Sci, 2015, 27: 795–798. [Medline] [CrossRef]

18) Lopez-Lopez A, Alonso Perez JL, González Gutierez JL, et al.: Mobilization versus manipulations versus sustain apophyseal natural glide techniques and interaction with psychological factors for patients with chronic neck pain: randomized controlled trial. Eur J Phys Rehabil Med, 2015, 51: 121–132. [Medline]

19) Sterling M, Jull G, Wright A: Cervical mobilisation: concurrent effects on pain, sympathetic nervous system activity and motor activity. Man Ther, 2001, 6: 72–81. [Medline] [CrossRef]

20) Casanova-Méndez A, Oliva-Pascual-Vaca A, Rodriguez-Blanco C, et al.: Comparative short-term effects of two thoracic spinal manipulation techniques in subjects with chronic mechanical neck pain: a randomized controlled trial. Man Ther, 2014, 19: 331–337. [Medline] [CrossRef]

21) Evans R, Bronfort G, Schulz C, et al.: Supervised exercise with and without spinal manipulation performs similarly and better than home exercise for chronic neck pain: a randomized controlled trial. Spine, 2012, 37: 903–914. [Medline] [CrossRef]

22) Miller J, Gross A, D'Sylva J, et al.: Manual therapy and exercise for neck pain: a systematic review. Man Ther, 2010, 15: 334–354. [Medline] [CrossRef]

23) Bronfort G, Evans R, Nelson B, et al.: A randomized clinical trial of exercise and spinal manipulation for patients with chronic neck pain. Spine, 2001, 26: 788–797, discussion 798–799. [Medline] [CrossRef]

24) Falla DL, Jull GA, Hodges PW: Patients with neck pain demonstrate reduced electromyographic activity of the deep cervical flexor muscles during performance of the craniocervical flexion test. Spine, 2004, 29: 2108–2114. [Medline] [CrossRef]

25) Javanshir K, Amiri M, Bandpei MA, et al.: The effect of different exercise programs on cervical flexor muscles dimensions in patients with chronic neck pain. J Back Musculoskeletal Rehabil, 2015. [Medline]

26) Krauss JR, Evjenth O: Translatoric spinal manipulation for physical therapists. Minneapolis: Orthopedic Physical Therapy Products, 2006, pp 45–85.

27) Storheim K, Bø K, Pederstad O, et al.: Intra-tester reproducibility of pressure biofeedback in measurement of transversus abdominis function. Physiother Res Int, 2002, 7: 239–249. [Medline] [CrossRef]

28) Jull G, Kristjansson E, Dall'Alba P: Impairment in the cervical flexors: a comparison of whiplash and insidious onset neck pain patients. Man Ther, 2004, 9: 89–94. [Medline] [CrossRef]

29) Martel J, Dugas C, Dubois JD, et al.: A randomised controlled trial of preventive spinal manipulation with and without a home exercise program for patients with chronic neck pain. BMC Musculoskelet Disord, 2011, 12: 41. [Medline] [CrossRef]

30) Lee EW, Shin WS, Jung KS, et al.: Reliability and validity of the neck disability index in neck pain patients. Phys Ther Korea, 2007, 14: 97–103.

31) Cohen J: A power primer. Psychol Bull, 1992, 112: 155–159. [Medline] [CrossRef]

32) Vincent K, Maigne JY, Fischhoff C, et al.: Systematic review of manual therapies for nonspecific neck pain. Joint Bone Spine, 2013, 80: 508–515. [Medline] [CrossRef]

33) Grimmer K, Trott P: The association between cervical excursion angles and cervical short flexor muscle endurance. Aust J Physiother, 1998, 44: 201–207. [Medline] [CrossRef]

34) Martínez-Segura R, De-la-Llave-Rincón AI, Ortega-Santiago R, et al.: Immediate changes in widespread pressure pain sensitivity, neck pain, and cervical range of motion after cervical or thoracic thrust manipulation in patients with bilateral chronic mechanical neck pain: a randomized clinical trial. J Orthop Sports Phys Ther, 2012, 42: 806–814. [Medline] [CrossRef]

35) Suvarnnato T, Puntumetakul R, Kaber D, et al.: The effects of thoracic manipulation versus mobilization for chronic neck pain: a randomized controlled trial pilot study. J Phys Ther Sci, 2013, 25: 865–871. [Medline] [CrossRef]

36) Yu X, Wang X, Zhang J, et al.: Changes in pressure pain thresholds and Basal electromyographic activity after instrument-assisted spinal manipulative therapy in asymptomatic participants: a randomized, controlled trial. J Manipulative Physiol Ther, 2012, 35: 437–445. [Medline] [CrossRef]

37) Knop C, Oeser M, Bastian L, et al.: [Development and validation of the Visual Analogue Scale (VAS) Spine Score]. Unfallchirurg, 2001, 104: 488–497. [Medline] [CrossRef]

38) 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: 243–251. [Medline] [CrossRef]

39) González-Iglesias J, Fernández-de-las-Peñas C, Cleland JA, et al.: Thoracic spine manipulation for the management of patients with neck pain: a randomized clinical trial. J Orthop Sports Phys Ther, 2009, 39: 20–27. [Medline] [CrossRef]

40) Vernon H, Mior S: The Neck Disability Index: a study of reliability and validity. J Manipulative Physiol Ther, 1991, 14: 409–415. [Medline]