Immediate effects of upper cervical translatoric mobilization on cervical mobility and pressure pain threshold in patients with cervicogenic headache: A randomized controlled trial

Miguel Malo-Urriés

José Miguel Tricás-Moreno

Elena Estébanez-de-Miguel

César Hidalgo-García

Andoni Carrasco-Uribarren

Sara Cabanillas-Barea

ABSTRACT

Objective: The purpose of this study was to evaluate the immediate effects of upper cervical translatoric spinal mobilization (UC-TSM) on cervical mobility and pressure pain threshold in subjects with cervicogenic headache (CEH).

Methods: Eighty-two volunteers (41.54 ± 15.29 years; 20 males and 62 females) with CEH participated in the study and were randomly divided into control or treatment group. Treatment group received UC-TSM and the control group remained in the same position and time than UC-TSM group but received no treatment. Cervical mobility (active cervical mobility and flexion-rotation test (FRT)), pressure pain thresholds (PPT) over upper trapezius muscles, C2-C3 zygapophyseal joints and suboccipital muscles and current headache intensity (VAS) were measured before and immediately after the intervention by two blinded investigators.

Results: After the intervention, UC-TSM group presented significant increases in total cervical mobility ($p=0.002$; d=0.16) and FRT ($p<0.001$; d=0.81-0.85). No significant differences were observed between groups for cervical PPTs ($p>0.05$). Nevertheless, UC-TSM group showed a significantly lower intensity of headache ($p=0.039$; d=0.57).

Conclusions: UC-TSM intervention increased upper and showed a tendency to improve general cervical range of motion and induce immediate headache relief in subjects with CEH. To confirm these results, further research considering the limitations of the present clinical trial is required.

Clinical Trial Registration Number: NCT02422862 (clinicaltrials.gov)

Keywords: Cervicogenic Headache; Manual Therapy; Neck; Randomized Controlled Trial

1. INTRODUCTION

Cervicogenic headache (CEH), a secondary headache arising from cervical disorders, is nowadays internationally recognized as a distinct clinical entity.[1] However, for many years, international opinion have disagreed on the acceptance of this condition.[2] In 1860, Hilton was the first to describe the concept of a headache that originates in the cervical region, but it was not until 1983 when Sjaastad coined the term “cervicogenic headache”.[3]

CEH is characterized by unilateral headache with symptoms and signs of neck involvement, including impairment in cervical range of motion and pain on palpation of the neck, especially on the upper cervical spine.[4] Restoration of the upper cervical mobility is usually considered one of the main objectives for the treatment of CEH. Manual therapy interventions seek to restore upper cervical mobility through a wide range of therapeutic procedures including mobilization or manipulation techniques. Previous systematic reviews reported preliminary evidence for the application of upper cervical manual therapy techniques for the management of CEH.[5-7] Although severe harm of the patient after cervical manual therapy procedures are extremely rare,[8-12] there is an international discussion regarding the adoption of safety measures for manual techniques in the cervical spine.

In order to guide the assessment and treatment of the cervical spine region focussing on techniques occurring in end range positions, notably during passive joint mobilization and manipulation, international frameworks have been developed.[13] Upper cervical translatoric spinal mobilization (UC-TSM) techniques have been suggested as a safe alternative that meets international criteria. Translatoric Spinal Mobilization (TSM) is defined as a system of manual techniques using straight-line forces delivered in a parallel or perpendicular direction to an individual vertebral joint or motion segment.[14] An increasing body of evidence supporting the clinical effectiveness[15-18] and safety[19,20] of TSM in the management of patients with cervical impairments has appeared during the last years. Nevertheless, to the best of the authors'

knowledge, no study to date has investigated the immediate effects of UC-TSM in patients with CEH. Therefore, the purpose of this randomized controlled trial was to evaluate immediate effects of UC-TSM on cervical mobility and cervical pressure pain thresholds (PPT) in patients with CEH. The hypothesis was that UC-TSM produces an increase of cervical mobility and PPT in CEH patients.

2. METHODS

The study design was a two-group (parallel) randomized controlled trial with pre- and post-intervention measurements. The allocation ratio was 1:1. The study was conducted in accordance to the Declaration of Helsinki and approved by the local Ethics Committee (CEICA). All participants provided informed consent before their enrolment in the study. This clinical trial was carried out in the facilities of the Faculty of Health Sciences (University of Zaragoza, Spain).

2.1. Subjects / Participants

A convenience sample of eighty-two volunteers (20 male, 62 female), aged 18-80 participated in the clinical trial (Figure 1). The inclusion criteria were to be over 18 years of age and present a diagnosis of CEH according to Sjaastad et al. (1998): subjects had to fulfil both parts I and III of the major criteria (pain aggravated by neck movement, sustained position or external pressure, restricted cervical range of motion and unilateral pain starting in the neck and radiating to the frontotemporal region).[21] These criteria demonstrated moderate to good reliability.[22] Anaesthetic blockades were not used as a criterion for CEH, as the procedure was considered too invasive and is not readily accessible to most clinicians. Participants were excluded if they had received cervical treatment in the previous month, presented red flags for headache or any contraindications to manual therapy, or the current involvement in compensations.

2.2. Procedure / Study protocol

Participants were randomly allocated to control (n=41) or treatment (UC-TSM) (n=41) group using a computer generated sequence of numbers (simple randomisation) using Microsoft Excel 2010 performed by an independent blinded investigator. A second researcher assigned an intervention group to each number. To implement the random allocation sequence, sequentially

numbered opaque sealed envelopes (SNOSE) was used. Participants were recruited by a different researcher who was blinded to the number sequence and intervention assignment. The researcher who had to apply the manual treatment was the one that opened opaque sealed envelopes.

2.3. Measurements

The primary outcome measures that are reported in this study were cervical mobility and cervical PPT. Headache intensity was also used as secondary outcome measure.

Physical tests of the cervical spine included active cervical movements in all cardinal planes for the assessment of the general cervical mobility and flexion-rotation test (FRT) for the assessment of the upper cervical mobility. For active tests, subjects were asked to move their head as far as they could without pain.[23] The FRT was performed in supine according to a previously described method by Hall et al. (2008),[24] which has been shown to be a valid and reliable measurement of upper cervical movement, predominantly at C1-C2.[25] CROM device (Pastimo Airguide, Inc, Buffalo Groove, IL) was used to measure the cervical mobility. CROM device is a reliable and valid method for measuring active and passive cervical mobility.[26] Three measurements of each movement were performed and the mean was used for further analysis.

Cervical PPT was measured using a digital algometer (Somedic AB Farsta) with a round surface area of 1 cm^2, applying the pressure at a rate of 1 $kg/cm^2/s$ perpendicular to the skin. PPT was assessed with the subject in supine lying, over 3 points bilaterally: upper trapezius muscle, C2-C3 zygapophyseal joint and suboccipital muscles. Patients were instructed to press the button of the digital algometer at the precise moment that pressure sensation changed to pain. The mean of 3 trials was calculated over each point and used for the analysis. The reliability of PPT measurement has been found to be high (ICC=0.91-0.97).[27,28]

Finally, current headache intensity was rated on a visual analogue scale (VAS), a valid and reliable tool for measuring pain intensity widely used for pain-related research.[29,30] A continuous vertical line of 10 centimetres, anchored by 2 verbal descriptors ("No Pain" and "Worst Imaginable Pain"), one for each extreme, was used. It has been demonstrated that the minimal clinically important difference (MCID) of VAS depends on baseline pain score, increased with increasing baseline pain score.[31] While a 1-2 point difference at the pre- and post- measures is generally considered for the MCID on a VAS,[32,33] this varies with the baseline pain score (i.e., the value increases with higher baseline pain score).[31] For low baseline VAS scores, the MCID for improvement is about 0.7 units.[31]

Two investigators, with Orthopaedic Manual Therapy specialized training and more than five years of experience, performed the outcome measures before and immediately after the intervention and were blinded to the allocation group of each patient throughout the process. Participants were not informed of the assignment group.

2.4. Intervention

The UC-TSM group received a 30 minutes treatment consisting of 30-seconds series of translatoric mobilizations of the upper cervical spine with 10-seconds rest between sets. For that purpose, the patient was positioned in supine, with the cervical spine in neutral position (Figure 2). The therapist placed a hand dorsally at the level of the vertebral arch of C1 with the metacarpophalangeal and radial border of the index finger. The other hand was placed posteriorly under the occiput, with the shoulder positioned anteriorly on the patient's forehead. The mobilization force was directed dorsally from the shoulder until the therapist felt a marked resistance and then applied slightly more pressure in order to perform a stretching mobilization. No pain was reported by the subjects during the intervention. The control group received no treatment intervention, staying in supine lying during 30 minutes (a similar position and time as the UC-TSM group).

The treatment was applied by one therapist with Orthopaedic Manual Therapy specialized training and more than 5 years of manual therapy experience.

2.5. Statistical analysis

Statistical analysis was conducted with the SPSS 15.0 package. Mean and standard deviations were calculated for each variable. The Kolmogorov-Smirnov test was used to determine a normal distribution of quantitative data ($p>.05$). Intra-group and inter-group differences were analyzed using Student *t* test. For the variables that did not follow a Gaussian distribution, non-parametric analysis was carried out for statistical evaluation using Mann-Whitney *U* test and Wilcoxon signed-rank test. Due to the convenience sample of 82 participants, effect sizes were calculated using Cohen's *d* coefficient.[34] An effect size greater than 0.8 was considered large; around 0.5, moderate; and less than 0.2, small.[34] All subjects enrolled originally were included in the final analysis as planned (no participant was excluded or dropped out). Thus, participants were analyzed as per protocol (i.e., by intention-to-treat). The level of significance was set at $p<.05$.

3. RESULTS

From January 2014 to October 2015, 162 volunteers were recruited. Eighty-two participants (20 males and 62 females; 41.54 years, SD=15.29 years) satisfied all the eligibility criteria and agreed to participate. Forty-one subjects were randomly assigned to each group, receiving the intended treatment and all of them were analysed for the outcomes. The patients' demographic characteristics are presented in Table 1. There were no significant differences between the two groups ($p>.05$) at the pre-treatment measurement, so it could be assumed that both groups were comparable in all variables (Table 1).

General cervical range of motion

A significant increase of general cervical range of motion was observed immediately after the intervention for the UC-TSM group in extension ($p=.004$), left side-bending ($p=.004$), right rotation ($p=.016$), left rotation ($p<.001$) and total range of movement ($p=.002$), however pre-post effect sizes were small ($d<0.20$) (Table 2). In contrast, the control group showed a significant reduction of general cervical range of movement between pre- and post-intervention measurements for flexion ($p<.001$) and total range of movement ($p=.030$) (Table 2). UC-TSM group experienced significant increases of cervical range of movement as compared with those of the control group in flexion ($p=.012$), left rotation ($p=.022$) and total range of movement ($p=.043$) (Table 2). Between-group effect sizes were moderate ($0.33<d<0.56$) after the intervention.

Upper cervical range of motion

A significant increase of upper cervical range of motion was observed immediately after the intervention for the UC-TSM group in FRT ($p<.001$) (Table 3). Pre-post effect sizes were large ($d=0.81$-0.85) for the UC-TSM group. For the control group, there were no statistically significant differences between pre- and post-intervention measurements (Table 3). UC-TSM

group experienced significant increases of upper cervical range of motion as compared with those of the control group in FRT to the right ($p=.006$) and left ($p<.001$) (Table 3). Between-group effect sizes were considered from moderate to large (d=0.74-0.92) after the intervention.

Pressure pain threshold

Immediately after the treatment, there were no statistically significant differences between groups in PPT ($p=.053$-$.610$) (Table 4). There were no statistically significant changes in PPT between pre- and post-intervention measurements in the UC-TSM group (d=0.01-0.12) or in the control group (d=0.00-0.03), except for a significant decline in left upper trapezius PPT in the control group ($p=.012$; d=.12) (Table 4).

Current headache intensity

Immediately after treatment, current headache intensity was significantly lower in the UC-TSM group ($p=.039$) (Table 4). Between-group effect size was large (d=1.26) after the intervention. The UC-TSM group reduced their current headache intensity 0.58 (SD=1.99), from 1.31 (SD=2.25) to 0.72 (SD=1.19), with a moderate pre-post effect size (d=0.57) (Table 4). In contrast, the control group increased 0.45 (SD=0.72), from 1.58 (SD=2.13) to 2.02 (SD=2.40) (Table 4).

No harm or unintended effect derived from the intervention was reported.

4. DISCUSSION

This study showed that a single session of UC-TSM resulted in an immediate increase of upper cervical range in patients with CEH.

Evidence for cervical mobility changes following cervical manual therapy interventions

The present study demonstrate that UC-TSM may be effective for an improvement of general and upper cervical mobility in subjects with CEH. UC-TSM group showed a statistically significant increase in general cervical mobility, however effect sizes were small and in no case reached the minimal detectable change (MDC).[35] Nevertheless, due to the involvement of the upper cervical spine in CEH, especially the C1-C2 segment,[36] quantification of the upper cervical mobility is more important in the assessment of CEH patients. FRT suppose a valid and reliable tool for testing C1-C2 mobility.[24,25] In the present study, increases of FRT in UC-TSM group exceeded the minimal detectable change[37] reaching the clinically relevant improvement for patients with CEH,[38] unlike the control group that reduce FRT mobility. The improvement of FRT mobility obtained in the present study, applying UC-TSM with the cervical spine in neutral position, are comparable to those of previous studies using different cervical manual techniques applied at the end of the cervical rotation, in asymptomatic subjects[39] and patients with neck pain[40] or CEH[41]. These findings supports the efficacy of UC-TSM to increase upper cervical mobility, suggested as a technique in neutral cervical position meeting the international recommendations.[13] Based on the available evidence, these results can be explained by a model in which a mechanical input generated by the UC-TSM triggers a cascade of biomechanical and neurophysiological events, leading to an increase of cervical mobility.[42]

Evidence for hypoalgesic changes following cervical manual therapy interventions

The present study showed that UC-TSM group did not exhibit significant changes in PPT. This result contrast with previous studies, that have demonstrated an increase of cervical PPT after

UC-TSM in patients with cervical[43] and craniofacial pain[44]. Differences in the sample or in the treatment dose could explain these controversial findings, and should be taken into consideration in future studies.

When analyzing headache intensity, results indicated that UC-TSM may be effective for an immediate reduction of headache intensity in patients with CEH, as shown for other manual therapy techniques.[45-50] Nevertheless, pain reduction, although statistically significant ($p<.05$) and with large effect size ($d>0.8$), was small (close to 0.5 on the VAS). The results of the present study should be interpreted with caution. Results for headache intensity did not reach the recommended minimal clinically important difference (MCID) on the VAS of 1-2 points.[32,33] Nonetheless, some have argued that the MCID value varies depending on baseline pain score, with the MCID increasing for higher baseline pain score).[31] In case of low baseline scores as in the current study (mean baseline headache intensity of about 1.5), a difference of 0.5 may be considered a clinically relevant change.[51] In any case, the results of the present study in terms of headache intensity should be interpreted with caution, taking into account the considerations previously described. On the other hand, to the best of the authors' knowledge, no study has investigated immediate effects on current headache intensity in CEH. Most studies recorded headache intensity based on episodes experienced in the preceding week or month.[45-50]

Current evidence suggest that immediate hypoalgesic effects of manual therapy are possibly due to neurophysiological mechanisms activated, in this case, by the mechanical stimulus of the UC-TSM.[52,53] Possible neurophysiological mechanisms include the activation of descendent pain inhibitory systems via corticospinal projections from the periacueductal gray matter (PAG).[54-58] Further studies are needed to determine the mechanisms of hypoalgesic effects of manual therapy interventions in CEH patients.

Limitations

Although a potential strength of the current controlled clinical trial was the inclusion of a control group without receiving any intervention, we should recognize potential limitations that should be considered. First, headache intensity during the procedure was low in both groups (VAS = 1.31 and 1.58), hindering to make meaningful interpretations of headache intensity results because of the occurrence of a floor effect. For this reason, headache intensity was not used as a main study variable. Additionally, this study presents immediate effects of UC-TSM, so short and long term effects should not be inferred. Third, control group did not receive any type of intervention, so placebo effect cannot be ruled out. Significant differences observed in control group (increase of VAS and reduction of total cervical ROM) should be considered when interpreting results. One possibility observed during field work is that evaluation tests used (especially the use of algometry for PPTs) may have irritated participants, increasing their pain and reducing their cervical mobility, which would highlight the improvements achieved in the intervention group. However, authors have to admit that these differences could be the explanation of between-group changes obtained in the present study or indicate that the condition is evolving randomly. These aspects must be especially taken into account and results should be interpreted with great caution. Furthermore, because of clinical conditions, a convenience sample of 82 consecutive patients was used, but no sample size calculation was performed. The results of the present study should be interpreted taking into account this issue, and future studies should consider an adequate sample size. On the other hand, one therapist provided the treatment in the current study, which may limit the generalization of the results. Finally, CEH subject selection was based on clinical criteria, however anaesthetic blockades were not used as a criterion. Further studies should address these issues.

5. CONCLUSION

A single session of UC-TSM showed an immediate improvement of upper cervical mobility. However, for general cervical range of motion and headache intensity, differences were small and likely of limited clinical value. Further research considering the limitations of the present clinical trial is required to confirm the tendency to an immediate increase of general cervical range mobility and a reduction of headache intensity in patients with CEH.

REFERENCES

1. Headache Classification Committee of the International Headache Society (IHS). The International Classification of Headache Disorders, 3rd edition (beta version). Cephalalgia 2013;33(9):629-808.

2. Olesen J, Goadsby PJ, Ramadan NM, Tfelt-Hansen P, Welch KMA, editors. The Headaches. 3rd ed. Philadelphia. Lippincott Williams & Wilkins; 2006.

3. Haldeman S, Dagenais S. Cervicogenic headaches: a critical review. Spine J 2001;1(1):31-46.

4. Bogduk N, Govind J. Cervicogenic headache: an assessment of the evidence on clinical diagnosis, invasive tests, and treatment. Lancet Neurol 2009;8(10):959-68.

5. Vernon H, McDermaid C, Hagino C. Systematic review of randomized clinical trials of complementary/alternative therapies in the treatment of tension type and cervicogenic headache. Complement Ther Med 1999;7:142-55.

6. Fernández-de-las-Peñas C, Alonso C, Cuadrado ML, Pareja JA. Spinal manipulative therapy in the management of cervicogenic headache. Headache 2005;45:1260-3.

7. Chaibi A, Russell MB. Manual therapies for cervicogenic headache: a systematic review. J Headache Pain 2012;13:351-9.

8. Rothwell DM, Bondy SJ, Williams JI. Chiropractic manipulation and stroke: a population-based case-control study. Stroke 2001;32:1054-60.

9. Ernst E. Manipulation of the cervical spine: a systematic review of case reports of serious adverse events, 1995–2001. Med J Aust 2002;176:376-80.

10. Cagnie B, Vinck E, Beernaert A, Cambier D. How are side effects of spinal manipulation and can these side effects be predicted? Man Ther 2004;9:151-6.

11. Cassidy JD, Boyle E, Cote P, He Y, Hogg Johnson S, Silver FL, et al. Risk of vertebrobasilar stroke and chiropractic care results of a population-based case-control and case-crossover study. Spine 2008;33:S176-83.
12. Puentedura EJ, March J, Anders J, Perez A, Landers MR, Wallmann HW, et al. Safety of cervical spine manipulation: are adverse events preventable and are manipulations being performed appropriately? A review of 134 case reports. J Man Manip Ther 2012;20(2):66-74.
13. Rushton A, Rivett D, Carlesso L, Flynn T, Hing W, Kerry R. International framework for examination of the cervical region for potential of dysfunction prior to Orthopaedic Manual Therapy Intervention. Man Ther 2014;19(3):222-8.
14. Krauss JR, Evjenth O, Creighton D. Translatoric spinal manipulation for physical therapists. Rochester (MI):Lakeview Media LLC; 2006.
15. Creighton D, Viti J, Krauss J. Use of translatoric mobilization in a patient with cervical spondylotic degeneration: a case report. J Man Manip Ther 2005;13:12-26.
16. Kondratek M, Creighton D, Krauss J. Use of translatoric mobilization in a patient with cervicogenic dizziness and motion restriction: a case report. J Man Manip Ther 2006;14:140-51.
17. Krauss J, Creighton D, Ely J, Podlewska-Ely J. The immediate effects of upper thoracic translatoric spinal manipulation on cervical pain and range of motion: a randomized clinical trial. J Man Manip Ther 2008;16:93-9.
18. Hidalgo-García C, Tricás-Moreno JM, Lucha-López O, Estébanez-de-Miguel E, Bueno-Gracia E, Malo-Urriés M, et al. Short term efficacy of C0-C1 mobilization in the cervical neutral position in upper cervical hypomobility: A randomized controlled trial. J Int Acad Phys Ther Res 2016;7(1):908-14.

19. Maher S, Kondratek M, Krauss J, Creighton D, Qu X. Postgraduate orthopedic manual physical therapy residents physical responses to peer practice of cervical manipulation. J Phys Ther Educ 2010;24:35–44.

20. Creighton D, Kondratek M, Krauss J, Huijbregts P, Qu H. Ultrasound analysis of the vertebral artery during non-thrust cervical translatoric spinal manipulation. Journal of Manual and Manipulative Therapy 2011;19(2):84-90.

21. Sjaastad O, Fredriksen TA, Pfaffenrath V. Cervicogenic headache: diagnostic criteria. The Cervicogenic Headache International Study Group. Headache 1998;38(6):442-5.

22. Van Suijlekom JA, de Vet HCW, van den Berg SGM, Weber WE. Inter-observer reliability of diagnostic criteria for cervicogenic headache. Cephalalgia 1999;19:817-23.

23. Edmondston SJ, Henne SE, Loh W, Ostvold E. Influence of cranio-cervical posture on threedimensional motion of the cervical spine. Man Ther 2005;10(1):44-51.

24. Hall TM, Robinson KW, Fujinawa O, Akasaka K, Pyne EA. Intertester reliability and diagnostic validity of the cervical flexion-rotation test. J Manipulative Physiol Ther 2008;31:293-300.

25. Takasaki H, Hall T, Oshiro S, Kaneko S, Ikemoto Y, Jull G. Normal kinematics of the upper cervical spine during the Flexion-Rotation Test - In vivo measurements using magnetic resonance imaging. Man Ther 2011;16(2):167-71.

26. Williams MA, McCarthy CJ, Chorti A, Cooke MW, Gates S. A systematic review of reliability and validity studies of methods for measuring active and passive cervical range of motion. J Manipulative Physiol Ther 2010;33(2):138-55.

27. Chesterson LS, Sim J, Wright CC, Foster NE. Inter-rater reliability of algometry in measuring pressure pain thresholds in healthy humans, using multiple raters. Clin J Pain 2007;23:760-6.

28. Jones DH, Kilgour RD, Comtois AS. Test-retest reliability of pressure pain threshold measurements of the upper limb and torso in young healthy women. The Journal of Pain: Official Journal of the American Pain Society 2007;8(8):650-6.

29. Conti PCR, De Azevedo LR, De Souza NVW, Ferreira FV. Pain measurement in TMD patients: evaluation of precision and sensitivity of different scales. J Oral Rehabil 2001;28(6):534-9.

30. Lundeberg T, Lund I, Dahlin L, Borg E, Gustafsson C, Sandin L, et al. Reliability and responsiveness of three different pain assessments. J Rehabil Med 2001;33(6):279-83.

31. Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: visual analog scale for pain (VAS Pain), numeric rating scale for pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP. Arthritis Care Res. 2011;63(S11):S240-S252.

32. McCormack HM, Horne DJ, Sheather S. Clinical applications of visual analogue scales: a critical review. Psychol Med 1988;18:1007-19.

33. Kelly AM. The minimum clinically significant difference in visual analogue scale pain score does not differ with severity of pain. Emerg Med J 2001;18:205-7.

34. Cohen J. Statistical Power Analysis for the Behavioural Sciences. Lawrence Erlbaum Associates, Hillsdale, NJ; 1988.

35. Jørgensen R, Ris I, Falla D, Juul-Kristensen B. Reliability, construct and discriminative validity of clinical testing in subjects with and without chronic neckpain. BMC Musculoskelet Disord 2014;4(15):408.

36. Bogduk N. Cervicogenic headache: Anatomical basis and pathophysiological mechanisms. Journal of Current Pain Headache Report 2001;5:382-6.

37. Hall T, Briffa K, Hopper D, Robinson K. Long-term stability and minimal detectable change of the cervical flexion-rotation test. Journal of Orthopaedic & Sports Physical Therapy 2010;40(4):225-9.

38. Hall T, Robinson K. The flexion-rotation test and active cervical mobility-a comparative measurement study in cervicogenic headache. Man Ther 2004;9(4):197-202.

39. Clements B, Gibbons P, McLaughlin P. The amelioration of atlanto-axial rotation asymmetry using high velocity low amplitude manipulation: is the direction of thrust important? J Osteopath Med 2001;4:8-14.

40. Dunning JR, Cleland JA, Waldrop MA, Arnot CF, Young IA, Turner M, et al. Upper cervical and upper thoracic thrust manipulation versus nonthrust mobilization in patients with mechanical neck pain: a multicenter randomized clinical trial. J Orthop Sports Phys Ther 2012;42(1):5-18.

41. Hall T, Chan HT, Christensen L, Odenthal B, Wells C, Robinson K. Efficacy of a C1-C2 selfsustained natural apophyseal glide (SNAG) in the management of cervicogenic headache. J Orthop Sports Phys Ther 2007;37(3):100-7.

42. Bialosky JE, Bishop MD, Price DD, Robinson ME, George SZ. The mechanisms of manual therapy in the treatment of musculoskeletal pain: a comprehensive model. Manual Therapy 2009;14:531-8.

43. Lluch E, Schomacher J, Gizzi L, Petzke F, Seegar D, Falla D. Immediate effects of active craniocervical flexion exercise versus passive mobilisation of the upper cervical spine on pain and performance on the cranio-cervical flexion test. Manual Therapy 2014;19(1):25-31.
44. La Touche R, París-Alemany A, Mannheimer JS, Angulo-Díaz-Parreño S, Bishop MD, López- Valverde-Centeno A, von Piekartz H, Fernández-Carnero J. Does mobilization of the upper cervical spine affect pain sensitivity and autonomic nervous system function in patients with cervico-craniofacial pain? A randomized-controlled trial. Clin J Pain 2013;29:205-15.
45. Nilsson N. A randomized controlled trial of the eff ect of spinal manipulation in the treatment of cervicogenic headache. J Manipul Physiol Ther 1995;18:435-40.
46. Nilsson N, Christensen HW, Hartvigsen J. The eff ect of spinal manipulation in the treatment of cervicogenic headache. J Manipul Physiol Ther 1997;2:326-30.
47. Haas M, Groupp E, Aickin M, Fairweather A, Ganger B, Attwood M et al. Dose response for chiropractic care of chronic cervicogenic headache and associated neck pain: a randomized pilot study. J Manipulative Physiol Ther 2004;27(9):547-53.
48. Haas M, Spegman A, Peterson D, Aickin M, Vavrek D. Dose response and efficacy of spinal manipulation for chronic cervicogenic headache: a pilot randomized controlled trial. The Spine Journal 2010;10:117-28.
49. von Piekartz H, Ludtke K. Effect of treatment of temporomandibular disorders (TMD) in patients with cervicogenic headache: a single-blind, randomized controlled study. Cranio 2011;29(1):43-56.
50. Bodes-Pardo G, Pecos-Martín D, Gallego-Izquierdo T, Salom-Moreno J, Fernández-de-las-Peñas C, Ortega-Santiago R. Manual treatment for cervicogenic headache and active trigger point in the sternocleidomastoid muscle: a pilot randomized clinical trial. J Manipulative Physiol Ther 2013;36:403-11.

51. Rowbotham MC. What is a ’clinical meaningful’ reduction in pain? Pain 2001;94:131-2.
52. Schmid A, Brunner F, Wright A, Bachmann LM. Paradigm shift in manual therapy? Evidence for a central nervous system component in the response to passive cervical joint mobilisation. Manual Therapy 2008;13:387-96.
53. Nijs J, Van Houdenhove B, Oostendorp RAB. Recognition of central sensitization in patients with musculoskeletal pain: application of pain neurophysiology in manual therapy practice. Manual Therapy 2010;15:135-41.
54. Wright A. Hypoalgesia post-manipulative therapy: a review of a potential neurophysiological mechanism. Man Ther. 1995;1:11-6.
55. Vicenzino B, Collins D, Benson H, et al. An investigation of the interrelationship between manipulative therapy-induced hypoalgesia and sympathoexcitation. J Manipulative Physiol Ther. 1998;21:448-53.
56. 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.
57. Paungmali A, O’Leary S, Souvlis T, et al. Hypoalgesic and sympathoexcitatory effects of mobilization with movement for lateral epicondylalgia. Phys Ther. 2003;83:374-83.
58. Skyba DA, Radhakrishnan R, Rohlwing JJ, et al. Joint manipulation reduces hyperalgesia by activation of monoamine receptors but not opioid or GABA receptors in the spinal cord. Pain. 2003;106:159-68.

	Control Group (n=41)	**UC-TSM Group** (n=41)	***p***
Clinical Features			
Age	40.59±15.10	42.49±15.61	*.498*
Sex	10 ♂. 31 ♀	10 ♂. 31 ♀	*1.000*
Height	1.65±0.08	1.65±0.09	*.905*
Weight	67.71±14.88	68.76±15.25	*.754*
Current headache intensity	1.58±2.13	1.31±2.25	*.584*
PPTs			
Upper trapezius (R)	224.54±172.48	229.10±129.01	*.478*
Upper trapezius (L)	250.39±163.37	235.76±111.48	*.878*
C2-C3 (R)	207.12±108.90	216.44±100.97	*.409*
C2-C3 (L)	209.68±113.20	213.12±87.49	*.578*
Suboccipital (R)	240.98±128.03	253.41±98.63	*.252*
Suboccipital (L)	237.20±131.27	259.71±117.20	*.206*
Upper cervical ROM			
FRT (R)	32.67±9.61	30.06±8.60	*.199*
FRT (L)	36.22±8.06	37.20±8.90	*.602*
FRT-A (R)	13.06±3.55	12.12±2.69	*.181*
FRT-A (L)	12.92±2.90	12.38±3.42	*.329*
UC flexion	-1.38±8.97	-1.69±9.62	*.993*
UC extension	39.80±6.73	41.31±6.57	*.308*
UC side-bending (R)	15.96±3.85	15.67±3.70	*.926*
UC side-bending (L)	13.72±3.92	12.86±3.77	*.311*
General cervical ROM			
Flexion	52.98±52.67	52.38±12.27	*.832*
Extension	57.48±11.68	57.14±13.19	*.846*
Side-bending (R)	35.88±9.06	38.19±9.14	*.253*
Side-bending (L)	37.30±9.59	38.16±9.79	*.688*
Rotation (R)	62.90±9.24	64.18±11.20	*.574*
Rotation (L)	62.40±12.94	64.46±12.43	*.462*
Total	308.39±54.19	314.51±59.23	*.627*

Table 1. Baseline features for both groups.

Outcome / Group	Pre-Treatment	Post-Treatment	Within-group	Between-group
Cervical Flexion				
Control Group	52.98±13.12	47.49±13.00	*p*<.001*	*p*=.012*
			d=0.27	*d*=0.56
UC-TSM Group	52.38±12.27	54.63±12.20	*p*=.096	
			d=0.12	
Cervical Extension				
Control Group	57.48±11.68	55.90±13.03	*p*=.803	*p*=.153
			d=0.12	*d*=0.38
UC-TSM Group	57.14±13.19	60.17±13.79	*p*=.004*	
			d=0.16	
Cervical Side-bending (R)				
Control Group	35.88±9.06	36.07±8.43	*p*=.791	*p*=.069
			d=0.08	*d*=0.38
UC-TSM Group	38.19±9.14	39.56±8.74	*p*=.062	
			d=0.08	
Cervical Side-bending (L)				
Control Group	37.30±9.59	37.86±10.31	*p*=.494	*p*=.209
			d=0.00	*d*=0.33
UC-TSM Group	38.16±9.79	40.52±8.65	*p*=.004*	
			d=0.17	
Cervical Rotation (R)				
Control Group	62.90±9.24	62.48±9.93	*p*=.647	*p*=.065
			d=0.00	*d*=0.44
UC-TSM Group	64.18±11.20	66.53±9.66	*p*=.016*	
			d=0.14	
Cervical Rotation (L)				
Control Group	62.39±12.94	61.50±13.01	*p*=.349	*p*=.022*
			d=0.06	*d*=0.52
UC-TSM Group	64.46±12.43	67.59±10.48	*p*<.001*	
			d=0.19	
Total				
Control Group	308.39±54.19	301.61±57.26	*p*=.030*	*p*=.043*
			d=0.09	*d*=0.46
UC-TSM Group	314.51±59.23	327.77±57.98	*p*=.002*	
			d=0.16	

Table 2. Pre- and post-treatment and differences for general cervical mobility outcomes.

Outcome / Group	Pre-Treatment	Post-Treatment	Within-group	Between-group
FRT (R)				
Control Group	32.67±9.61	31.84±9.83	*p*=.909 *d*=0.08	*p*=.006* *d*=0.74
UC-TSM Group	30.06±8.60	37.43±7.58	*p*<.001* *d*=0.81	
FRT (L)				
Control Group	36.22±8.06	36.53±7.92	*p*=.629 *d*=0.00	*p*<.001* *d*=0.92
UC-TSM Group	37.20±8.90	42.43±6.66	*p*<.001* *d*=0.85	

Table 3. Pre- and post-treatment and differences for upper cervical mobility outcomes.

Outcome / Group	Pre-Treatment	Post-Treatment	Within-group	Between-group
PPT Upper Trapezius (R)				
Control Group	224.54±172.48	219.61±131.39	*p=.402* *d=0.02*	*p=.469* *d=0.14*
UC-TSM Group	229.10±129.01	237.02±132.28	*p=.464* *d=0.04*	
PPT Upper Trapezius (L)				
Control Group	250.39±163.37	225.76±124.38	*p=.012** *d*=0.12	*p=.308* *d*=0.09
UC-TSM Group	235.76±111.48	236.46±108.75	*p=.851* *d*=0.01	
PPT C2-C3 (R)				
Control Group	207.12±108.90	211.12±112.26	*p=.523* *d*=0.03	*p=.475* *d*=0.06
UC-TSM Group	216.44±100.97	218.05±105.02	*p=.692* *d*=0.01	
PPT C2-C3 (L)				
Control Group	209.68±113.20	209.27±93.86	*p=.824* *d*=0.00	*p=.610* *d*=0.11
UC-TSM Group	213.12±87.49	219.54±94.32	*p=.641* *d*=0.05	
PPT Suboccipital (R)				
Control Group	240.98±128.03	240.41±132.32	*p=.788* *d*=0.00	*p=.053* *d*=0.25
UC-TSM Group	253.41±98.63	270.51±108.63	*p=.060* *d*=0.12	
PPT Suboccipital (L)				
Control Group	237.20±131.27	242.98±123.35	*p=.599* *d*=0.03	*p=.250* *d*=0.19
UC-TSM Group	259.71±117.20	264.98±111.29	*p=.605* *d*=0.03	
Headache Intensity (VAS)				
Control Group	1.58±2.13	2.02±2.40	*p<.001** *d*=0.35	*p=.039** *d*=1.26
UC-TSM Group	1.31±2.25	0.72±1.19	*p=.061* *d*=0.57	

Table 4. Pre- and post-treatment and differences for pain-related outcomes.