Occipitoatlantoaxial Manipulation for Immediate Increase to Cervical Rotation

Article *in* Alternative therapies in health and medicine · March 2016

5 authors, including:

Maria Alice Mainenti Pagnez
Escuela de Osteopatia de Madrid

Leandro Alberto Calazans Nogueira
IFRJ / UNISUAM, Rio de Janeiro, Brazil

ORIGINAL RESEARCH

Occipitoatlantoaxial Manipulation for Immediate Increase to Cervical Rotation

Maria Silveira Mello, PT; Maria Alice Pagnez, PT; Raíza de Sousa Cabral, PT; Charles Taciro, PhD; Leandro Alberto Calazans Nogueira, PhD

ABSTRACT

Context • The assessment of the range of motion (ROM) of the cervical spine is common in physical therapy practice. An ROM assessment is used as an integral part of a physical examination, both in symptomatic and asymptomatic populations. Spine manipulation has shown several benefits, including an increased range of passive rotation of the upper cervical spine.

Objectives • The study intended to analyze the immediate effects of manipulation of the occipitoatlantoaxial (OAA) joint on the ROM of the cervical rotation and its relationship to an individual's most limited side on Mitchell's test.

Design • The study used a single-subject experimental design.

Setting • The study took place at Hospital Universitário Gaffrée e Guinle in Rio de Janeiro, Brazil.

Participants • A convenience sample of 40 healthy participants with a limited ROM in respect to the rotation of the cervical spine, who were selected in the outpatient physical therapy team (professionals and students).

Intervention • The OAA joint manipulation was performed by an independent therapist on all participants, on the side with the greater ROM restriction only.

Outcome Measures • Cervical rotation using a ROM fleximeter and the Mitchell's test was performed.

Results • At baseline, 25 of the participants (62.5%) had a reduction in movement for the right-side rotation, whereas 15 of the participants (37.5%) had restricted movement for left-side rotation. After the OAA manipulation, the ROM was increased on both sides independent of the side that had the most restriction to movement. The right-side rotation increased by 9.75°, whereas the left-side rotation increased by 8.26°. Despite a bilateral ROM increase, a difference was observed in the magnitude of the changes between the more-restricted sides and the other sides when the Mitchell's tests were considered, with large clinical effects.

Conclusions • The OAA manipulation increased the ROM for bilateral cervical rotation, irrespective of the side of the restriction, and the increase was more pronounced when considering the results of the Mitchell's test. (*Altern Ther Health Med.* 2016;22(2):##-##.)

Maria Silveira Mello, PT, is a monitor at Osteopathy Clinical Practice (OSP), Escola de Osteopatia de Madri (EOM), in Rio de Janeiro, Brazil. Maria Alice Pagnez, PT, is a coordinator at OSP-EOM. Raíza de Sousa Cabral, PT, is a physical therapist at Hospital Universitário Gaffrée e Guinle and a master's student in the postgraduate progam in rehabilitation science at Centro Universitário Augusto Motta (UNISUAM) in Rio de Janeiro, Brazil. Charles Taciro, PhD, is a professor of physiotherapy, Universidade Federal de Mato Grosso do Sul and an invited professor at EOM. Leandro Alberto Calazans Nogueira, PhD, is a professor at EOM, a professor at Instituto Federal do Rio de Janeiro, and a professor in the postgraduate progam of reabilitation science at UNISUAM.

Corresponding author: Leandro Alberto Calazans Nogueira, PhD
E-mail address: leandro.nogueira@ifrj.edu.br

Assessment of the range of motion (ROM) of the cervical spine is often used in the practice of physical therapy[1] and can be used as an important tool for (1) diagnosing musculoskeletal disorders,[1] (2) analyzing the disease's progression,[2] (3) assessing the effects of different treatments,[3] (4) monitoring patients' evolution during rehabilitation,[4,5] and (5) developing a basis for evaluating the effectiveness of therapeutic interventions.[4] Limitations to the cervical ROM can be related to musculoskeletal disorders, traumatic or idiopathic neck pain,[6] headaches,[7] or any dysfunction of the temporomandibular joint and masticatory muscles.[8]

During the analysis of the cervical ROM, the practitioner must consider the existence of a natural variability between individuals and the factors that influence that variability, such as the person's gender and age and the nature of the motion, passive or active.[4] For example, women have a greater ROM than men do,[9] and aging leads to a decrease in ROM[10] of approximately 5° per decade.[11]

The verification of ROM has been used as part of the procedure for a physical examination[12] for cervical dysfunction, both in symptomatic[12] and asymptomatic individuals.[10] Recently, several instruments have been developed for the evaluation of the cervical ROM, from simple devices such as fleximeters[1] to electromagnetic systems of computerized kinematic analysis[2] or 3-dimensional ultrasound equipment.[6] However, in general, those devices have increasingly complex, specific uses for only a segment of patients in a high-cost and, therefore, rarely accessed clinical practice. Thus, instruments like the universal goniometer and the fleximeter stand out as simple alternatives for widespread use at a low cost.

The use of magnetic resonance imaging (MRI) shows that the cervical segment of head rotation occurs mainly at the occipitoatlantoaxial (OAA) joint when the neck is in flexion.[13] The neck region with the OAA joint is where the greatest part of the rotational movement occurs, being between 39° and 45° of the neck's entire rotation,[14,15] whereas in other segments, rotation occurs only between 4° and 8°.[15]

Patients with mechanical cervical pain can benefit from the manipulation of the upper cervical spine (C1/C2). The benefits of manipulation include (1) decreased pain, (2) increased range of passive movement of the upper cervical rotation, (3) improvement in the motor performance of the deep cervical flexor, and (4) improved ability to perform daily activities.[16] The aim of the current study was to analyze the immediate effect of the OAA manipulation on the ROM of the cervical rotation and ts relationship to the side of the more-restricted ROM, as identified by the Mitchell's test.

METHODS

The study used a single-subject experimental design.

Participants

A convenience sample of 40 healthy participants with a limited ROM in respect to the rotation of the cervical spine, who were selected in the outpatient physical therapy team (professionals and students) of the Hospital Universitário Gaffrée e Guinle (Rio de Janeiro, Brazil). Participants eligible for the study had to present an ROM limitation related to the rotation of the cervical spine, and participants meeting that criteria were added irrespective of age, gender, and origin of the restriction.

The following were considered as exclusion criteria: (1) neck pain or a neck-pain history in the month preceding the survey; (2) neurological sequelae; (3) a postoperative cervical spine; (4) tumors, infections, or inflammatory disorders of the spine; (5) a history of fibromyalgia; (6) a history of cervical manipulative therapy less than 2 months; or (7) a diagnosis of radiculopathy cervical.

The study's participants were interviewed by a physiotherapist who explained the clinical protocol. All participants provided informed consent prior to their participation. All procedures conformed to the Declaration of Helsinki.

Procedures

After signing the informed consent form, participants were referred for an initial evaluation by an examiner who assessed the ROM restriction for the cervical rotation using a flexion test for the OAA rotation, in accordance with Mitchell[17] and with the instructions for the fleximeter (Code Research Institute, Guarulhos, São Paulo, Brazil). Then, manipulative therapy was performed by a second therapist who was blinded to the initial evaluation, providing the OAA manipulation only to the participant's side that had the more restricted ROM. After the intervention, the ROM was re-evaluated by the fleximeter.

Intervention

For the OAA manipulation, the participant remained supine, and his or her head was rotated to one side. The therapist stood in front of the head of the stretcher. With the middle and ring fingers of one hand, the therapist contacted the mastoid process. With the palm of the other hand, the therapist then contacted the participant's jaw line and cheek. A slight traction was cranially introduced with both hands. When joint tension was perceived by the therapist, a high-velocity, low-amplitude thrust was performed in the direction of traction, with a gentle rotary force. The OAA manipulation was performed only to the side of the more-restricted ROM.

Outcome Measures

The test for rotation in the flexion of the OAA joint occurred in accordance with Mitchell. Therefore, the patient was positioned supinely, and the therapist was standing in front of the participant's head. The therapist made contact in the occipital region with both hands, supporting the patient's head and causing cervical flexion to the limit. Maintaining that positioning in maximum flexion, the therapist then rotated the patient's head to both sides, up to the limit of each side, and compared the ROM of the 2 rotations, left and right, watching to determine which side showed the most restriction to movement.[17]

The ROM was measured by the fleximeter, which consists of a gravity action inclinometer, which has a precision of 1°, and it is attached to Velcro strap. At the end of each movement, the device was repositioned.

The rotations were measured with the participant in the supine position, with the shoulders aligned with the end of the stretcher. Lima et al[18] found excellent reliability for the fleximeter in assessing cervical rotation (ICC-0.79). Other studies have demonstrated excellent levels of reliability for fleximetry, both for intra- and interrater measurements in adult populations.[5,19] Takasaki et al[13] showed 163° of the total cervical rotation in the neutral position using an MRI in healthy participants. The current research team defined a *restriction of rotation movement* as the participant showing fewer than 80° of rotational ROM for each side.

Statistical Analysis

The data obtained in the evaluation at baseline and the re-evaluation postintervention were used to compare the effects of the intervention. Data were stored in an electronic file using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) and were processed using the Statistical Package for Social Sciences (SPSS), version 17 (International Business Machines, Armonk, NY, USA).

The results were presented in proportional and central-tendency measures, such as the mean and standard deviation. The comparison between the means was performed by student's *t* test. Because of the nature of the nonparametric distribution of the data, a correlation analysis was performed using Spearman's method. The calculation of the effect size was carried out considering the difference between the mean ROM measured by the fleximeter and the positivity of the Mitchell test and by dividing by the standard deviation grouped on each side and in the total population. According to Cohen,[20] effect sizes of 0.20, 0.50, and 0.80 are considered small, medium, and large, respectively. The significance level was established at 5% ($P < .05$).

RESULTS

The study enrolled 40 healthy participants, and all participants completed the study. Twenty-five of the participants (62.5%) had restricted movement for the right-side rotation, whereas 15 of the participants (37.5%) had restricted movement for left-side rotation. The Mitchell's test correctly identified 14 of the 15 participants with a restriction to the left side and 22 of the 25 participants with restriction to the right side.

The average ROM to the right side for all participants at baseline, without respect to their sides of restriction, was 58.60 ± 14.24°, whereas the rotation to the left side was 59.62 ± 13.61° (Table 1).

Table 1. Values Obtained for Range of Motion in Neck Rotation for the Left and Right Sides of All Participants Before and After the Occipitoatlantoaxial Manipulation, Without Respect to the Participants' Sides of Restriction (N = 40)

	Degrees of Rotation		
Side	Before Manipulation Mean ± SD	After Manipulation Mean ± SD	*P* Values
Right	58.60 ± 14.24	68.25 ± 12.22	<.01
Left	59.62 ± 13.61	67.88 ± 11.87	<.01

Abbreviation: SD, standard deviation.

Table 2. Values Obtained for Range of Motion in Neck Rotation for All Participants Before and After Occipitoatlantoaxial Manipulation, With Consideration of the Side of the Restriction in Movement as Found in Mitchell's Test (N = 40)

		Degrees of Rotation		
Side of Restriction in Mitchell's Test	n	Before Manipulation Mean ± SD	After Manipulation Mean ± SD	*P* Values
Right	25			
Right Rotation		55.65 ± 14.33	67.83 ± 12.95	<.01
Left Rotation		64.13 ± 13.03	68.91 ± 12.70	<.01
Left	15			
Right Rotation		62.35 ± 13.59	68.82 ± 11.53	<.01
Left Rotation		53.53 ± 12.22	66.47 ± 10.86	<.01

Abbreviation: SD, standard deviation.

After classifying individuals according to their restricted sides, an initial average of 55.65 ± 14.33° of rotation to the right side for participants with a right-side restriction and of 53.53 ± 12.22° of rotation to the left side for participants with a left-side restriction were observed. The opposite side evidenced a rotation average of 64.13 ± 13.03° for participants with a right-side restriction and 62.35 ± 13.59° of rotation for participants with a left-side restriction (Table 2).

After the OAA manipulation, the ROM significantly increased for all participants on both sides, irrespective of the originally restricted side, both with $P < .01$. The rotation increased by 9.65° on the right side, whereas the left-side rotation increased by 8.26°. A reduction in the difference in the ROM between the 2 sides also occurred after the manipulation. The difference in values on the fleximeter between the right and left sides before the manipulation was 1.02°, and after the intervention, this difference was reduced to 0.37°. None of the participants experienced any adverse events after the OAA manipulation.

A bilateral ROM increase was also observed for all participants, with consideration of the side of restricted movement that was found in Mitchell's test. By analyzing the restriction to the right side, the study found a mean increase of 12.18° for that side after OAA manipulation, whereas the same analysis for restriction to the left side showed an average increase of 12.94° for that side.

Despite a bilateral ROM increase, a difference in the magnitude of the changes was obtained between the more-restricted sides and the other sides when the Mitchell's test was considered, with a large clinical effect. The study showed smaller increases in ROM for the other sides than for the sides with more restriction. An increase was observed of 4.78° for the right side in participants with a left-side restriction as well as an increase of 6.47° for the left side in individuals with a right-side restriction. The effect-size analysis showed that participants who had positive results on the Mitchell's test had the highest gain in ROM to the restricted side after OAA manipulation, with a large clinical effect for the study's entire population (Cohen's $d = 1.18$).

DISCUSSION

Healthy individuals can show a decreased ROM for cervical rotation even without the presence of pain and disability. In the current study, the manipulation of the OAA joint resulted in an increase in the ROM for bilateral cervical rotation, regardless of the side of the restriction that was observed in the Mitchell's test. The increase in the cervical ROM after manipulation of the OAA joint, which was documented in the current study by the use of Mitchell's test and the fleximeter, was clinically significant, even though the study worked with healthy participants.

Another Brazilian study has reported values for healthy individuals similar to the baseline values of participants that have been described in the current study.[7] Other authors have also described a reduction in the ROM for neck rotation in asymptomatic individuals,[4,21,22] using other measuring instruments. The average, asymptomatic individual's neck rotation in India has been shown to be approximately 10° higher than the results at baseline presented in the current study.[4] Population differences and the use of different instruments of measurement can contribute to a difference in the magnitude of the neck-rotation limitation observed, although that limitation in healthy individuals has been a common finding. Symptomatic patients show a greater reduction in the optimal neck-rotation movement.[22]

The mean cervical rotation found in the asymptomatic individuals that have been analyzed in the current study was approximately 60° at baseline. Wainner et al[23] have described a combination of 4 symptoms and signs to identify cervical radiculopathy, one being evidence of cervical rotation to the involved side less than 60°. That neck-rotation limitation has also been observed in patients with mechanical neck pain,[22] individuals with cervical degeneration,[24] and persons with migraines.[7] The results found in the participants in the current study may suggest the potential risk of starting a painful condition in the cervical spine given that the values found by the fleximeter are close to the ROM, which is a risk factor to cervical radiculopathy. Several instruments have shown good reproducibility in the measurement of cervical rotation, being a reliable measure for use as a clinical outcome.[25]

Neck-rotation movement was defined as the clinical outcome that the current study used to examine the benefits of the OAA manipulation. The results showed a significant increase in the ROM of the neck rotation of approximately 10° on each side. Reid et al[26] found an immediate increase in the rotational mobility of patients with cervicogenic dizziness when using the sustained natural apophyseal gliding (SNAG) technique of the Mulligan method in the C1/C2 joint, and the improvement was maintained for 12 weeks. A study investigating the effects of manual therapy that included joint mobilization of the upper cervical spine and of elongation for 12 weeks in patients with cervical pain, observed an increase in the cervical rotational movement in both treated groups.[27]

Some studies have found no improvement in ROM rotation after using manual therapy. The cervical myofascial induction technique has been shown to cause improvements in the flexion, extension, and lateral bending of the cervical spine of healthy individuals, but it did not modify the rotation movement.[28] The same result was described by Fernandez-de-Las-Penas et al,[29] who analyzed the effects of a thoracic-manipulation session on individuals with cervical pain, and by Martinez-Segura et al,[30] who analyzed the effects of a manipulative therapy on the average cervical region. Thus, approaches directed at the upper cervical region should be emphasized to increase the ROM of the cervical rotation.

Previous studies have shown that Mitchell's test evaluates the mobility predominantly of the C1/C2 articulation.[13,31] Hall and Robinson[21] found positive results for the Mitchell's test in 24 of 28 patients with symptomatic cervicogenic headache. The researchers indicated that the more severe the headache was, the greater the restriction was on the Mitchell's test. The validity of the Mitchell's test for identifying individuals with cervicogenic headache has been documented.[15]

The results of the current study support the improvement of cervical-rotation mobility with the use of the OAA manipulation technique, which is recommended for improving the mobility of the upper cervical spine. Other benefits of the OAA technique have been described, such as an increased ROM for the mouth opening,[32,33] an increased pain threshold to pressure on the sphenoid bone[32] and on the masseter and temporalis muscles[33] in patients with neck pain, and a reduction in pain intensity in patients with degeneration of the atlantoaxial joint.[34]

The significant increase in ROM for cervical rotation on both sides as the result of the unilateral OAA manipulation that was observed in the current study corroborates the findings of Clements et al.[35] Those researchers described improvements in ROM regardless of whether the manipulation was performed unilaterally or bilaterally. Therefore, no need exists for the OAA manipulation to be performed bilaterally for benefits in both directions of rotation. That finding supports the hypothesis that the primary benefit of manipulative therapy is related to neurophysiological mechanisms, because an increase in ROM on both sides after a unilateral manipulation has been observed. Review studies on the mechanisms of manual therapy have emphasized the neurophysiological effects of the technique.[36,37] Nevertheless, identification of the ROM limitation in the Mitchell's test assists in making clinical decisions about the direction of the OAA manipulation, because the clinical effects of the manipulation on the side of the restriction are more noticeable.

The main limitation of the present study was the characteristics of the study's sample (ie, the small number of participants and their asymptomatic profiles). The absence of a control or placebo group is also another limitation that should be considered. Studies with larger sample sizes that include participants with pain and disability should be undertaken to confirm the present results.

CONCLUSIONS

OAA manipulation has generated an increase in ROM for bilateral cervical rotation, regardless of the side of the restriction, and the increase was more pronounced when considering the results of Mitchell's test.

REFERENCES

1. Mannion AF, Klein GN, Dvorak J, Lanz C. Range of global motion of the cervical spine: Intraindividual reliability and the influence of measurement device. *Eur Spine J*. 2000;9(5):379-385.
2. Jordan K, Haywood KL, Dziedzic K, et al. Assessment of the 3-dimensional Fastrak measurement system in measuring range of motion in ankylosing spondylitis. *J Rheumatol*. 2004;31(11):2207-2215.
3. Malmström EM, Karlberg M, Melander A, Magnusson M. Zebris versus Myrin: A comparative study between a three-dimensional ultrasound movement analysis and an inclinometer/compass method: Intradevice reliability, concurrent validity, intertester comparison, intratester reliability, and intraindividual variability. *Spine (Phila Pa 1976)*. 2003;28(21):E433-E440.
4. Agarwal S, Allison GT, Singer KP. Reliability of the spin-T cervical goniometer in measuring cervical range of motion in an asymptomatic Indian population. *J Manipulative Physiol Ther*. 2005;28(7):487-492.
5. Tousignant M, Smeesters C, Breton AM, Breton E, Corriveau H. Criterion validity study of the cervical range of motion (CROM) device for rotational range of motion on healthy adults. *J Orthop Sports Phys Ther*. 2006;36(4):242-248.
6. Strimpakos N, Sakellari V, Gioftsos G, et al. Cervical spine ROM measurements: optimizing the testing protocol by using a 3D ultrasound-based motion analysis system. *Cephalalgia*. 2005;25(12):1133-1145.
7. Bevilaqua-Grossi D, Pegoretti KS, Goncalves MC, Speciali JG, Bordini CA, Bigal ME. Cervical mobility in women with migraine. *Headache*. 2009;49(5):726-731.
8. Olivo SA, Bravo J, Magee DJ, Thie NM, Major PW, Flores-Mir C. The association between head and cervical posture and temporomandibular disorders: A systematic review. *J Orofac Pain*. 2006;20(1):9-23.
9. Ferrario VF, Sforza C, Serrao G, Grassi G, Mossi E. Active range of motion of the head and cervical spine: A three-dimensional investigation in healthy young adults. *J Orthop Res*. 2002;20(1):122-129.
10. Sforza C, Grassi G, Fragnito N, Turci M, Ferrario V. Three-dimensional analysis of active head and cervical spine range of motion: Effect of age in healthy male subjects. *Clin Biomech (Bristol, Avon)*. 2002;17(8):611-614.
11. Simpson AK, Biswas D, Emerson JW, Lawrence BD Grauer JN. Quantifying the effects of age, gender, degeneration, and adjacent level degeneration on cervical spine range of motion using multivariate analyses. *Spine (Phila Pa 1976)*. 2008;33(2):183-186.
12. Hoving JL, Pool JJ, van Mameren H, et al. Reproducibility of cervical range of motion in patients with neck pain. *BMC Musculoskelet Disord*. December 2005;6:59.
13. 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):167-171.
14. Amiri M, Jull G, Bullock-Saxton J. Measuring range of active cervical rotation in a position of full head flexion using the 3D Fastrak measurement system: An intra-tester reliability study. *Man Ther*. 2003;8(3):176-179.
15. Ogince M, Hall T, Robinson K, Blackmore AM. The diagnostic validity of the cervical flexion-rotation test in C1/2-related cervicogenic headache. *Man Ther*. 2007;12(3):256-262.
16. Dunning JR, Cleland JA, Waldrop MA, 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.
17. Mitchell FL Jr, Mitchell PK. *Muscle Energy Concepts and Mechanisms, the Musculoskeletal Screen, and Cervical Region Evaluation and Treatment*. East Lansing, MI: MET Press; 1995. The Muscle Energy Manual; vol 1.
18. Lima LA, Gomes S, Goulart F, Dias RC. Reliability of a flexibility instrument in mature adults and elderly individuals [in Portuguese]. *Rev Fisioter Univ São Paulo*. 2004;11(2):83-89.
19. Youdas JW, Carey JR, Garrett TR. Reliability of measurements of cervical spine range of motion—comparison of three methods. *Phys Ther*. 1991;71(2):98-106.
20. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: L Erlbaum Associates; 1988.
21. 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.
22. Assink N, Bergman GJ, Knoester B, Winters JC, Dijkstra PU, Postema K. Interobserver reliability of neck-mobility measurement by means of the flock-of-birds electromagnetic tracking system. *J Manipulative Physiol Ther*. 2005;28(6):408-413.
23. Wainner RS, Fritz JM, Irrgang JJ, Boninger ML, Delitto A, Allison S. Reliability and diagnostic accuracy of the clinical examination and patient self-report measures for cervical radiculopathy. *Spine (Phila Pa 1976)*. 2003;28(1):52-62.
24. Nykänen M, Ylinen J, Häkkinen A. Do cervical degenerative changes in women with chronic neck pain affect function? *J Rehabil Med*. 2007;39(5):363-365.
25. 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):138-155.
26. Reid SA, Callister R, Katekar MG, Rivett DA. Effects of cervical spine manual therapy on range of motion, head repositioning, and balance in participants with cervicogenic dizziness: A randomized controlled trial. *Arch Phys Med Rehabil*. 2014;95(9):1603-1612.
27. Häkkinen A, Salo P, Tarvainen U, Wirén K, Ylinen J. Effect of manual therapy and stretching on neck muscle strength and mobility in chronic neck pain. *J Rehabil Med*. 2007;39(7):575-579.
28. Saíz-Llamosas JR, Fernández-Pérez AM, Fajardo-Rodríguez MF, Pilat A, Valenza-Demet G, Fernández-de-Las-Peñas C. Changes in neck mobility and pressure pain threshold levels following a cervical myofascial induction technique in pain-free healthy subjects. *J Manipulative Physiol Ther*. 2009;32(5):352-357.
29. Fernández-de-las-Peñas C, Palomeque-del-Cerro L, Rodríguez-Blanco C, Gómez-Conesa A, Miangolarra-Page JC. 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. *J Manipulative Physiol Ther*. 2007;30(4):312-320.
30. 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 after a single cervical high-velocity low-amplitude manipulation in subjects presenting with mechanical neck pain: A randomized controlled trial. *J Manipulative Physiol Ther*. 2006;29(7):511-517.
31. Karhu JO, Parkkola RK, Komu ME, Kormano MJ, Koskinen SK. Kinematic magnetic resonance imaging of the upper cervical spine using a novel positioning device. *Spine (Phila Pa 1976)*. 1999;24(19):2046-2056.
32. Mansilla-Ferragut P, Fernández-de-Las Peñas C, Alburquerque-Sendín F, Cleland JA, Boscá-Gandía JJ. Immediate effects of atlanto-occipital joint manipulation on active mouth opening and pressure pain sensitivity in women with mechanical neck pain. *J Manipulative Physiol Ther*. 2009;32(2):101-106.
33. Oliveira-Campelo NM, Rubens-Rebelatto J, Martí N-Vallejo FJ, Alburquerque-Sendí NF, Fernández-de-Las-Peñas C. The immediate effects of atlanto-occipital joint manipulation and suboccipital muscle inhibition technique on active mouth opening and pressure pain sensitivity over latent myofascial trigger points in the masticatory muscles. *J Orthop Sports Phys Ther*. 2010;40(5):310-317.
34. Yu H, Hou S, Wu W, He X. Upper cervical manipulation combined with mobilization for the treatment of atlantoaxial osteoarthritis: A report of 10 cases. *J Manipulative Physiol Ther*. 2011;34(2):131-137.
35. 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(1):8-14.
36. Nogueira LA. Neurophysiology of manual therapy [in Portuguese]. *Fisioter Bras*. 2008;9(5):414-421.
37. Bialosky JE, Bishop MD, Price DD, Robinson ME, George SZ. The mechanisms of manual therapy in the treatment of musculoskeletal pain: a comprehensive model. *Man Ther*. 2009;14(5):531-538.