



## Short-term effects of manipulative treatment versus a therapeutic home exercise protocol for chronic cervical pain

*A randomized clinical trial*

Galindez-Ibarbengoetxea, Xabier; Setuain, Igor; Ramírez-Velez, Robinson; Andersen, Lars L.; Izquierdo, Mikel; Jauregi, Andoni; Izquierdo, Mikel

*Published in:*

Journal of Back and Musculoskeletal Rehabilitation

*DOI (link to publication from Publisher):*

[10.3233/BMR-169723](https://doi.org/10.3233/BMR-169723)

*Publication date:*

2018

*Document Version*

Version created as part of publication process; publisher's layout; not normally made publicly available

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*

Galindez-Ibarbengoetxea, X., Setuain, I., Ramírez-Velez, R., Andersen, L. L., Izquierdo, M., Jauregi, A., & Izquierdo, M. (2018). Short-term effects of manipulative treatment versus a therapeutic home exercise protocol for chronic cervical pain: A randomized clinical trial. *Journal of Back and Musculoskeletal Rehabilitation*, 31(1), 133-145. <https://doi.org/10.3233/BMR-169723>

### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

### Take down policy

If you believe that this document breaches copyright please contact us at [vbn@aub.aau.dk](mailto:vbn@aub.aau.dk) providing details, and we will remove access to the work immediately and investigate your claim.

# Short-term effects of manipulative treatment versus a therapeutic home exercise protocol for chronic cervical pain: A randomized clinical trial

Xabier Galindez-Ibarbengoetxea<sup>a</sup>, Igor Setuain<sup>b,c</sup>, Robinson Ramírez-Velez<sup>d</sup>, Lars L. Andersen<sup>e,f</sup>, Miriam González-Izal<sup>b</sup>, Andoni Jauregi<sup>a,g</sup> and Mikel Izquierdo<sup>b,\*</sup>

<sup>a</sup>International School of Osteopathy, Bilbao, Spain

<sup>b</sup>Department of Health Sciences, Public University of Navarra, Navarra, Spain

<sup>c</sup>Clinical Research Department, Orthopaedic Surgery and Advanced Rehabilitation Centre, Spain

<sup>d</sup>Centre for Studies on Measurement of Physical Activity, School of Medicine and Health Sciences, Universidad del Rosario, Bogotá, D.C, Colombia

<sup>e</sup>National Research Centre for the Working Environment, Copenhagen, Denmark

<sup>f</sup>Department of Health Science and Technology, Aalborg University, Aalborg, Denmark

<sup>g</sup>University of Deusto, Bilbao, Spain

## Abstract.

**BACKGROUND:** While both manipulative treatment and physical exercises are used to treat cervical pain, it remains unclear which is most effective.

**OBJECTIVE:** To compare the short-term effect of high-velocity, low-amplitude manipulation techniques (MT) with those of home-exercise (HE) with stretching and low intensity (10% of max) isometric contractions on pain and function.

**METHODS:** Single-blind randomized clinical trial was performed. A total of 27 asymptomatic subjects were randomly assigned to 2 groups: manipulation techniques (MT,  $n = 13$ ) and home exercise (HE,  $n = 14$ ). The visual analogue scale (VAS); neck disability index (NDI); pressure pain thresholds; cervical spine range of motion and electromyography during the cranio-cervical flexion test was measured before and one week after the intervention.

**RESULTS:** After the intervention, both groups showed improved ( $P < 0.05$ ) NDI and VAS scores and flexion in both rotation ranges compared with the pre-intervention values. For the NDI, pain intensity, and neck flexion, the effects sizes were large; for the majority of the other measurements, the effect sizes were small to moderate. The MT group showed significantly better results than the HE group for 2 out of 17 tests.

**CONCLUSIONS:** Both interventions improved function and pain after one week, with only marginal between-group differences in favor of MT.

Keywords: Spinal manipulation, neck pain, cervical vertebrae, thoracic vertebrae, electromyography

## 1. Introduction

Neck pain is defined as pain experienced from the base of the skull (the occiput) to the upper part of the back and extending laterally to the outer and superior bounds of the shoulder blade (scapula) [1]. Neck pain

\*Corresponding author: Mikel Izquierdo, Department of Health Sciences, Public University of Navarra (Navarra), Spain. Campus of Tudela Av. de Tarazona s/n. 31500 Tudela (Navarra), Spain. Tel.: +34 948 417876; E-mail: mikel.izquierdo@gmail.com.

is one of the most prevalent complaints in the general population and is a major cause of disability [2]. In the United States of America, neck pain is the third most common chronic pain condition [3], and its prevalence is higher among young female adults [4]. In the general population, the prevalence has been reported to be greater than 70% [5], while in young adults, the prevalence of neck pain is reported to be between 12 and 34% [6]. It is important to consider the public health and financial implications of neck pain as neck pain patients use the health care system twice as often as the rest of the population [1].

A wide variety of treatment protocols for neck pain are available. However, the most effective management remains an area of debate. Manipulation techniques (MT) and home exercises are commonly used to manage neck pain, and spinal manipulative therapy plus home exercise and advice have yielded better clinical outcomes and lower total societal costs compared with other treatments [7]. In the literature, at least one study has found that a multi-segmental approach to spinal manipulation improved neck pain more than articular manipulation alone [8]. The biomechanical relationship between the TMJ and the cervical complex and the most recent research results recommend the inclusion of that segment in the management of neck pain [9–12]. Considering this findings, in our study manipulations were performed on the upper thoracic spine, the cervical spine and the temporomandibular joint (TMJ).

There are different exercise protocols that can be performed to reduce neck pain, a high-quality randomized clinical trial found that an intervention consisting of several elements, including strength training and stretching, produced results that were superior to those of an intervention that focused mostly on stretching [13], for this reason, the studied protocol included the performance of specific cervical flexor exercises, stretching, isometric exercises, general mobilizations and crania-cervical flexion endurance exercises [14–18]. In the present study, we did not include nonspecific aerobic exercise because although some authors have found an association between such exercise and a moderate decrease in pain [19], this improvement was not as important because it could be achieved through analytical strength exercise of the muscles involved in neck pain [20].

In our study, young adult women with chronic neck pain who volunteered to participate were included, both because they comprise the most common population with neck pain [4] and because compared with

elderly people, young people have shown lower levels of sternocleidomastoid (SCM) activity in the crania-cervical flexion test (CCFT) [21]. This test relates the activation of superficial neck flexors during the CCFT with neck pain [22].

There is lack of evidence to support any conclusions regarding the effectiveness of MT versus HE for relieving mechanical neck pain. Therefore, this study will add to the growing body of knowledge regarding whether these two techniques yield comparable outcomes or one technique is superior to the other and which should be the therapy of choice. This study was performed to compare the short-term effects of an MT protocol and an HE protocol on the neck disability index (NDI), the visual analogue scale (VAS), pressure pain thresholds (PPT), cervical spine ROM and EMG activation of the sternocleidomastoid muscle (SCM) during the crania-cervical flexion test (CCFT) in young adult women with chronic neck pain.

## 2. Methods

### 2.1. Study design

A single-blind randomized clinical trial was performed. One research spinal physical therapist registered in Spain conducted patient recruitment and screening at the Osteopathic Clinic and the Sports Medicine Investigation Center of Pamplona. The study was performed in accordance with the Declaration of Helsinki (2000) and was approved by the local office for Medical Research Ethics Committee of The Public University of Navarra. A written consent form was signed by the participants, and the procedure was explained by the investigator. No formal sample size calculation was performed.

### 2.2. Participants

Social networks and word-of-mouth were used to recruit twenty-seven women with chronic idiopathic neck pain. The participants were enrolled between April and August 2016 and were randomly allocated to either the manipulation group (MT,  $n = 13$ ) group or the home exercise group (HE,  $n = 14$ ) (Fig. 1).

Women were included if they were between 18 and 50 years old with a history of neck pain for 3 months during the last year and a pain intensity at rest in the week before the study of 30/100 on a VAS and somatic dysfunction in temporo-mandibular joint, cervi-

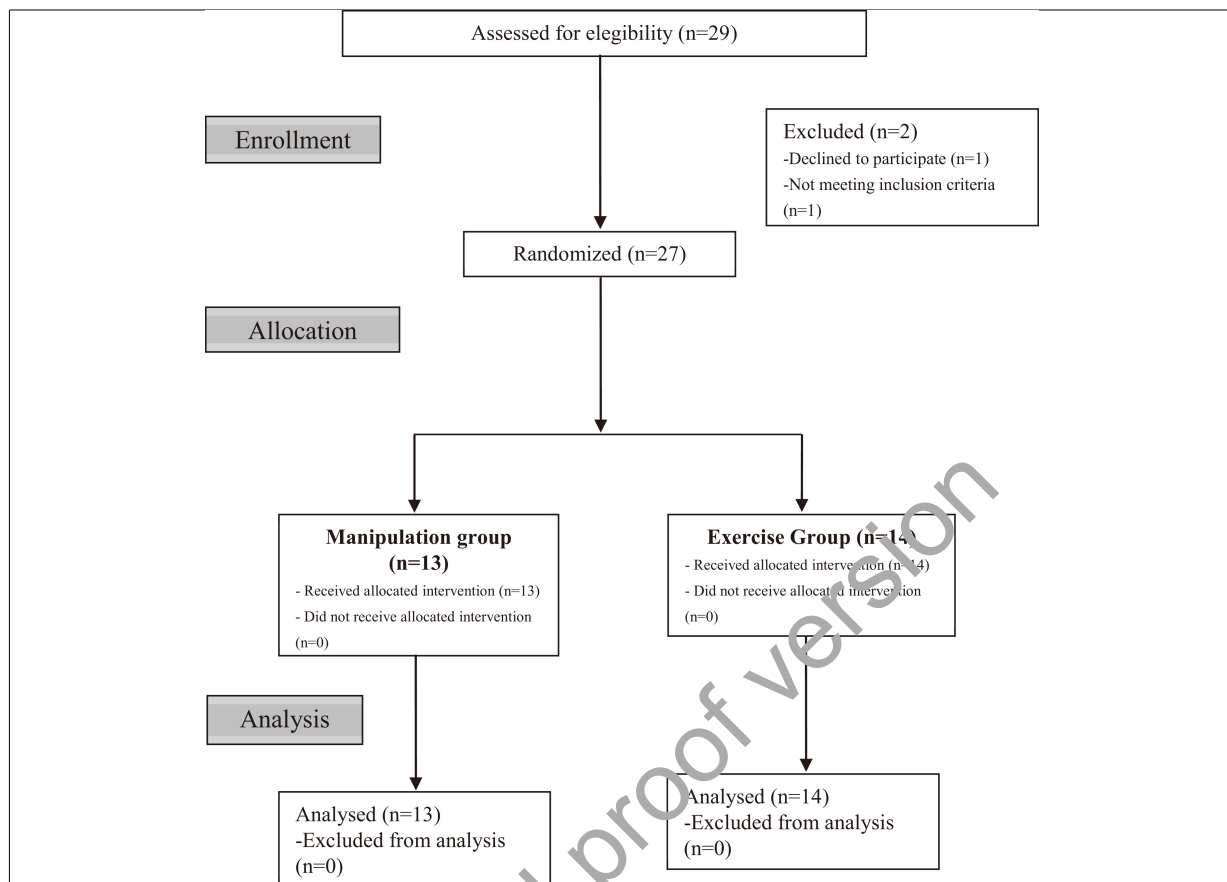


Fig. 1. Flow of participants through the study.

cal spine and upper thoracic spine. The exclusion criteria were any type of cranio-cervical trauma during the last two years, including whiplash; pain radiating to the limbs; neurological alterations in the upper limbs; neurological alterations of the central nervous system; diagnosed vertebral disc injury; degenerative, rheumatologic and/or inflammatory pathologies; pregnancy; previous cervical spine surgery; psychiatric pathologies; spine fractures; dislocation; or positive vertebral artery test [18]. The risks were minimized by ruling out contraindications to the testing protocols via a health history and a thorough physical examination prior to the manipulation session.

### 2.3. Procedure

The individuals who met the inclusion criteria were randomly allocated to the MT group or the HT group using a computer-generated method ([www.randomizer.org](http://www.randomizer.org)) without replacement. The allocation was conducted by the primary investigator prior to the base-

line assessment. At each visit, after entering informed consent was given and prior to the start of data collection, an external researcher who was blinded to the study researchers opened the two sealed envelopes and put two index cards inside them, and the participants choose one of them. In this manner, the risk of bias was reduced, and randomization was ensured.

### 2.4. Data collection and outcome measures

A physical therapist with five years of experience in osteopathic medicine and ten in manual therapies performed the measurement protocol. Each group followed the same measurement protocol. The order of assessments was NDI, VAS at rest, CROM, PPT and EMG during the CCFT before the intervention and one week later.

#### 2.4.1. Neck disability index

This questionnaire evaluates pain intensity, personal care, lifting weights, reading, headache, concentration,

102  
103  
104  
105  
106  
107  
108  
109  
110  
111  
112  
113  
114  
115  
116  
117  
118  
119  
120  
121  
122  
123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138

139 hard work, driving, sleep and leisure activities [23]. A  
140 Spanish version of the NDI validated by Andrade et al.  
141 was used [24].

#### 142 2.4.2. VAS at rest

143 Neck pain at rest was measured using a VAS both  
144 before and one week post intervention. The patient  
145 placed a vertical mark on a continuous 10-cm line to  
146 indicate her pain levels, ranging from no pain (0) to the  
147 worst pain possible [10]. The reliability and validity  
148 of the VAS as a measure of pain has been established  
149 previously [25,26].

#### 150 2.4.3. Cervical spine ROM

151 All of the patients were evaluated for cervical mo-  
152 bility using a CROM goniometer (Performance Attain-  
153 ment Associates, St. Paul, MN, USA). This device has  
154 been validated in several studies and offers a mod-  
155 erate intra-examiner intraclass correlation coefficient  
156 ( $> 0.69$ ) and a good inter-examiner intraclass cor-  
157 relation coefficient ( $> 0.75$ ) [27,28]. The CROM go-  
158 niometer has three inclinometers whose scales range  
159 from two to two degrees. These inclinometers are at-  
160 tached to a frame similar to eyeglasses. The CROM de-  
161 vice was mounted over the subject's nose bridge and  
162 ears and secured to the head with a strap. The frontal  
163 and lateral gravity-dependent inclinometers measured  
164 side bending and flexion/extension, respectively. While  
165 a third, magnetic-dependent inclinometer required the  
166 use of a magnetic necklace to measure rotation. At the  
167 start of the measurement, the participants were seated  
168 and relaxed with their feet flat on the floor, their knees  
169 and ankles at  $90^\circ$  of flexion, and their hands supported  
170 on their thighs. The researcher instructed each subject  
171 to move her head correctly before the test. The mea-  
172 surement protocol study included active cervical ROM  
173 flexion, extension, right side bending, left side bend-  
174 ing, right rotation and left rotation. Three consecutive  
175 measurements were obtained, and the mean of these 3  
176 trials was used for data analysis.

#### 177 2.4.4. Pressure pain thresholds (PPT)

178 The pressure pain threshold is defined as the mini-  
179 mal amount of pressure at which the sensation of pres-  
180 sure changes to a sensation of pain [29]. A mechan-  
181 ical pressure algometer (Force Dial FDK 20, Wagner  
182 Instruments, Greenwich, CT, USA) was used in this  
183 study. This device consists of a round metal disk (area,  
184  $1 \text{ cm}^2$ ) attached to a pressure (force) gauge. The gauge  
185 displays values in kilograms. Because the surface of  
186 the device is  $1 \text{ cm}^2$ , the readings are expressed in kilo-

187 grams per square centimeter. The range of the algome-  
188 ter is 0 to 10 kg in 0.1 kg increments. Previous articles  
189 have reported good inter-examiner reliability with a  
190 mean intra-class correlation coefficient (ICC) of 0.75;  
191 furthermore, intra-examiner reproducibility was excel-  
192 lent (mean ICC = 0.84) [30–32].

193 Before the PPT measurement, the patients were in-  
194 structed to say “stop” when the sensation changed from  
195 pressure to pain. The PPT was measured posterolater-  
196 ally, between the lower border of the occiput and the  
197 horizontal level of the spinous process of C2, over the  
198 C5/6 zygapophyseal joint, and the middle of the front  
199 edge of the upper trapezius fibers). We also used a trig-  
200 ger point within the gluteus medius muscle as a re-  
201 gional control point, given its segmental distance from  
202 the manipulated segment [33]. The PPT was assessed  
203 on the most painful side indicated by the patient. When  
204 both sides were reported as equally painful, the right  
205 side was selected. Three measurements were recorded  
206 for each PPT and the mean was used for the statistical  
207 analyses.

#### 208 2.4.5. Measurement of the efficiency of the cervical 209 deep flexor muscles (cranio-cervical flexion 210 test)

211 An EMG-USB Multichannel Bioelectrical Ampli-  
212 fier (Bioelectronica, Torino, Italy) device, which dis-  
213 played information in real time and stored it on a  
214 personal computer, was used. The surface EMG was  
215 recorded with 24-mm-diameter round adhesive bipolar  
216 connector electrodes (Spes Medica, Battipaglia, Italy).  
217 The participant's skin was cleaned with water before  
218 electrode placement.

219 The sEMG signals were recorded at a sample rate of  
220 2048 Hz and were post-processed offline using MAT-  
221 LAB (Mathworks, Inc.). The sEMG signals were band-  
222 pass filtered between 10 Hz and 500 Hz, and the am-  
223 plitude RMS value was obtained for each muscle.

224 To measure of the efficiency of the cervical deep  
225 flexor muscles, SCM activity was assessed by perform-  
226 ing the cranio-cervical flexion standard clinical pro-  
227 tocol described in previous studies [22,34,35]. These  
228 studies showed the relationship between neck pain, the  
229 inhibition of cervical deep flexor muscles (the longus  
230 capitis and longus colli muscles) and the increased  
231 EMG activity of the SCM. During this protocol, the  
232 patient was in the supine position with the neck in  
233 a neutral position, such that the line of the face was  
234 horizontal and a line bisecting the neck longitudinally  
235 was horizontal to the testing surface. The layers of a  
236 pressure sensor were inflated to 20 mmHg and placed

below the neck (Stabilizer, Chattanooga Group Inc., USA). First, the operator instructed the patient to perform five incremental contractions of 10 seconds each. The participants practiced targeting the five test levels between 22 and 30 mmHg in two practice trials before the electrodes were applied. During the first contraction, the patient was asked to produce enough pressure to raise the pressure device to 22 mmHg; in the second, the device was to reach 24 mmHg; in the third, the target was 26 mmHg; in the fourth, it was 28 mmHg; and in the fifth, the target was 30 mmHg. Between contractions, the patient rested for 30 seconds. After training, the operator placed the electrodes on the sternal portion of the SCM [36] to assess its activity. To obtain the activation value of the SCM during the cranio-cervical flexion test, an average between the maximum and the five sub-maximum values was determined. Following the application of the electrodes, the participants performed a standardized maneuver for EMG normalization (reference voluntary contraction). This reference voluntary contraction involved a head lift (cervical and cranio-cervical flexion) just clear of the bed that was maintained for 10 s, during which EMG data were recorded. A one-minute rest period was allowed before the participants performed the experimental CCFT measurement during which the EMG data were recorded.

## 2.5. Interventions

### 2.5.1. Manipulation group (MT)

In the MT group, after the measurement protocol assessment, joint dysfunction was evaluated. The method chosen for the evaluation was exclusively manual, based on a study by *Jul* in 1998 that showed high reliability for assessing dysfunctions using manual methods [37]. In our study, we used passive mobility tests and tests of anterior-posterior and lateral pressure. These tests have been validated with radiographic studies of the cervical spine and have shown high inter- and intra-examiner reliability as well as a good relationship between manual diagnosis and hypomobility [38,39]. For the upper thoracic spine, the operators used anterior-posterior pressure tests and passive mobility tests [40]. Also tenderness, tissue texture changes and asymmetry were assessed [41]. The patient was evaluated in the flexion, extension and neutral positions to find a FRS, ERS or NSR dysfunctions [40–42]. To correct the cervical dysfunction a HVLA manipulation was performed, the patients were positioned in supine, however to manipulate the upper

thoracic spine the subjects were positioned in prone, these techniques have been commonly used in research studies and were safe and effective [43,44]. The operator adapted the technique to the diagnosed dysfunction; all of them are perfectly detailed in Greenman, Ward and Gibbons textbooks [40–42]. After manipulation, the operator repeated the measurement protocol.

To correct the TMJ dysfunctions, TMJ mobilizations (caudal and ventro-caudal traction, ventral and mediolateral translation) were used [41], these techniques achieved a successful effects in the management of temporomandibular joint disorders [45].

The participants were instructed to contact the principal researcher if adverse events such as pain, headache, dizziness or other symptoms occurred in the week after the study.

### 2.5.2. Home exercise group (HE)

On the first day, the patients in the HE group received personal instruction and supervision by an experienced physiotherapist to ensure that they performed the exercises correctly. All of the subjects were given an exercise diary and a telephone and email contact. The exercise lasted no longer than 10–20 minutes once per day. The exercises were to be performed without provoking neck pain.

The HE protocol consisted of a general range of motion movements, specific stretching of the bilateral upper trapezius and cervical extensor muscles, CCF and submaximal isometric exercises.

First, while the participant was in a sitting position, general range of motion movements of the neck (flexion, rotation and side bending) were achieved 10 times in each direction. The movements were performed gently, with the goal of trying to go a little further during each repetition.

The stretching exercises were performed with the participant in a sitting position. To stretch the right upper trapezius, the subjects fixed the right shoulder with the left hand and then performed a left lateral flexion, right rotation and slight anterior flexion of the head and neck. The left trapezius was then stretched in the same manner. The cervical extensor muscles were stretched using neck and head flexion; to aid the stretch, the hands were placed at the occipital bone. The stretch position was maintained for 30 seconds. Each exercise was repeated 3 times [14,15].

In the supine position, the subjects performed a CCF exercise for 10 repetitions of 10 seconds' duration, with a 10-second rest interval between each contraction (total contraction time: 100 seconds, to-

tal time of session: 190 seconds). The correct movement was first guided by a physical therapist to activate the deep cervical flexor muscles with minimal activity of the superficial cervical flexors. To monitor the correct movement and contraction intensity, a pressure biofeedback device (Stabilizer; Chattanooga Group, Inc., Chattanooga, TN, USA) was used. The participants were instructed to maintain pressure sensor levels between 22 and 30 mmHg comfortably and with no pain during contraction [16,17]. When performing the exercises at home, the patients placed a towel under the neck and then placed one hand gently on the front of the neck to feel the superficial muscles during the cranio-cervical flexion movement. The patients were instructed to stop the contraction if they felt that the muscles were beginning to harden.

Finally, submaximal isometric contractions were performed. In sitting position, the patients achieved a five-second contraction using only 10% effort. The contractions were performed 5 times in each direction (rotation, flexion, extension and lateral flexion in both directions) [18].

Additional outcomes of this study were participant adverse events (such as: pain, headache, dizziness or other symptoms) occurred in the next week after the study.

### 3. Statistical analysis

The statistical analysis was performed by a statistician who was blinded to the randomization, measurement and intervention protocol. Statistical analyses were conducted using SPSS Statistics 20 for Windows (SPSS, Inc., Chicago, IL, USA). The demographic data and initial assessment results were compared using *t*-tests. The statistical distribution of the data was analyzed using the Shapiro Wilks *W* test. For parametric data, the *t*-test for paired samples was used to compare the results of the assessment before and after treatment; for nonparametric data, the Wilcoxon signed-rank test was used. The independent *t*-test for parametric data or the Mann-Whitney *U* Test for non-parametric data was used to compare the difference (change score) from pre to post treatment between groups. Finally, to calculate the effect size, Cohen's *d* was used. A small effect was identified by a Cohen's *d* score of approximately 0.2, a moderate effect was defined as a Cohen's *d* score of approximately 0.5, and a score of approximately 0.8 identified a large effect. The alpha level was set at 0.05.

Table 1  
Baseline characteristics of the subjects included in the study

	MT group	HE group	<i>P</i> value
Sex (% females)	100% (13/13)	100% (14/14)	–
Age (years) (mean ± SD)	32.15 (1.87)	34.35 (1.71)	0.393
Weight (kg) (mean ± SD)	64.71 (5.99)	67.10 (4.72)	0.756
Height (cm) (mean ± SD)	1.64 (0.01)	1.65 (0.01)	0.779
BMI (mean ± SD)	23.91 (2.05)	24.58 (1.62)	0.802

Pre and post values were expressed as mean (SE) two groups and all variables. Significant group interaction ( $P < 0.05$ ).

## 4. Results

### 4.1. Subjects

Of the 28 patients deemed eligible for inclusion, 96% (27 of 28) were enrolled and randomly divided into 2 groups: the MT group ( $n = 13$ ) and the HE group ( $n = 14$ ); (Fig. 1). There were no significant differences in the subjects' baseline characteristics (Table 1) between the two groups. No adverse events were reported, and all of the participants who were randomly assigned to a group completed the study.

### 4.2. Neck disability index

After one week, both interventions (manipulation and home exercises), showed significant ant differences ( $p = 0.000$  in both cases), and the changes were not significantly better in the manipulation group ( $-43.4\% \pm 21.82$ ) than in the home exercise group ( $-39.72 \pm 22.68$ ). Additionally, the Cohen's *d* showed large effects ( $d = 1.36; 0.61-2.03$ ) in both the manipulation and the exercise group ( $d = 1.43; 0.70-2.09$ ); however, no differences were observed between the groups ( $p = 0.909$ ) (Table 2) (Figs 2 and 3).

### 4.3. Visual analogue scale

Significant changes were observed in both groups between the pre- and post-intervention measurements ( $p = 0.001$  in both cases), and the effect size was large ( $d = 1.11; 0.39-1.77$  in the manipulation group and  $1.52; 0.77-2.17$  in the home exercise group), but no differences were observed between the groups ( $p = 0.908$ ) (Table 2) (Figs 2 and 3).

	Baseline	Post intervention	Cohen's <i>d</i> effect size 95% CI	Within-group <i>p</i> value	Between-group <i>p</i> value
<b>NDI</b>					
MT group ( <i>n</i> = 13)	13.07 (1.09)	7.46 (1.19)	1.36 (0.61 to 2.03)	0.000	0.909
HE group ( <i>n</i> = 14)	14.14 (1.15)	8.35 (0.99)	1.43 (0.70 to 2.09)	0.000	–
<b>VAS</b>					
MT group ( <i>n</i> = 13)	48.23 (4.30)	25.84 (6.61)	1.11 (0.39 to 1.77)	0.001	0.958
HE group ( <i>n</i> = 14)	53.85 (3.64)	31.85 (4.10)	1.52 (0.77 to 2.17)	0.001	–

Pre and post values were expressed as mean (SE) two groups and all variables. Significant group interaction ( $P < 0.05$ ). Effect sizes were expressed as Cohen's *d* (95% Confidence Interval), and an effect size greater than 0.8 was considered large, an effect size of approximately 0.5 was considered moderate, and an effect size of less than 0.2 was considered small.

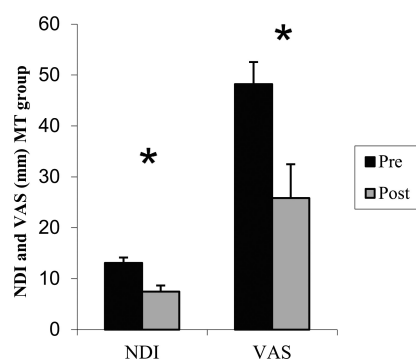


Fig. 2. NDI and VAS results, MT group. Pre and post values were expressed as mean (SE) two groups and all variables. \* denotes  $p$  value  $< 0.05$  within – group interaction.

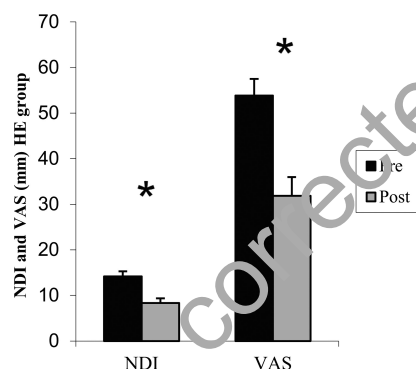


Fig. 3. NDI and VAS results, HE group. Pre and post values were expressed as mean (SE) two groups and all variables. \* denotes  $p$  value  $< 0.05$  within – group interaction.

#### 4.4. Cervical range of motion data

One week after the interventions, no significance differences were observed in extension or left and right side bending range between the two intervention groups. However, the changes in flexion, right rotation and left rotation range in the MT and HE groups were significant ( $p = 0.004$ ,  $p = 0.006$  and  $p = 0.000$ , respectively, in the MT group and  $p = 0.016$ ,  $p = 0.016$

and  $p = 0.006$ , respectively, in the HE group). Furthermore, in the MT group, the effect size was considered large for flexion ( $d = 1.25$ ; 0.51–1.91), right rotation ( $d = 0.94$ ; 0.25–1.58), and left rotation ( $d = 0.99$ ; 0.27–1.64); however, in the HE group, only the flexion effect size was large ( $d = 1.25$ ; 0.51–1.91). Regarding the between-group interaction, only the extension range differences were considered significant ( $p = 0.037$ ) (Table 3) (Figs 4 and 5).

#### 4.5. Pressure pain thresholds

No significant changes were observed in any of the measured PPTs from pre to post intervention or between groups; however, the effect size in the MT group was considered moderate for the upper trapezius PPT ( $d = 0.48$ ; –0.19–1.12), which had a decrease of 11.24%. No differences were observed between the two groups (Table 4).

#### 4.6. Cranio-cervical flexion test

No significant differences were observed between the pre- and post-intervention RMS of the SCM during the five stages of the cranio-cervical flexion test for the two groups. However, the statistical analysis showed a tendency toward a decreased SCM signal in the first stage of CCFT in the exercise-group interaction ( $p = 0.062$ ), with a moderate effect size ( $d = 0.57$ , –0.12–1.22). Additionally, in the MT group, the SCM signal decreased 29% and 34% in the first and fifth stage, respectively, showing a moderate effect size in both stages ( $d = 0.40$ , –0.31–1.08 and 0.46; –0.23–1.13, respectively). No significant differences were observed between the groups (Table 5).

## 5. Discussion

To our knowledge, our study is the first to compare

	Baseline	Post intervention	Cohen's <i>d</i> effect size 95% CI	Within-group <i>p</i> value	Between-group <i>p</i> value
<b>Flexion</b>					
MT group ( <i>n</i> = 13)	34.02 (3.47)	47.69 (2.53)	1.25 (0.51 to 1.91)	0.004	0.700
HE group ( <i>n</i> = 14)	35.07 (2.54)	46.52 (3.31)	1.04 (0.35 to 1.66)	0.016	–
<b>Extension</b>					
MT group ( <i>n</i> = 13)	56.46 (3.38)	60.30 (2.65)	0.35 (–0.31 to 0.99)	0.092	0.037
HE group ( <i>n</i> = 14)	64.66 (3.60)	61.85 (2.41)	0.24 (–0.39 to 0.86)	0.214	–
<b>Right side bending</b>					
MT group ( <i>n</i> = 13)	39.38 (1.79)	40.50 (1.94)	0.17 (–0.51 to 0.84)	0.324	0.965
HE group ( <i>n</i> = 14)	39.71 (1.64)	40.80 (2.06)	0.16 (–0.47 to 0.77)	0.463*	–
<b>Left side bending</b>					
MT group ( <i>n</i> = 13)	37.84 (1.90)	38.10 (1.72)	0.04 (–0.61 to 0.68)	0.899	0.974
HE group ( <i>n</i> = 14)	39.38 (1.90)	39.57 (1.71)	0.03 (–0.59 to 0.65)	0.789*	–
<b>Right rotation</b>					
MT group ( <i>n</i> = 13)	56.30 (1.84)	63.02 (2.11)	0.94 (0.25 to 1.58)	0.006	0.488*
HE group ( <i>n</i> = 14)	59.90 (3.37)	65.80 (2.04)	0.57 (–0.09 to 1.20)	0.016*	–
<b>Left rotation</b>					
MT group ( <i>n</i> = 13)	53.89 (2.31)	62.25 (2.38)	0.99 (0.27 to 1.64)	0.006	0.189
HE group ( <i>n</i> = 14)	56.38 (2.40)	61.66 (1.90)	0.65 (0.00 to 1.27)	0.006	–

Pre and post values were expressed as mean (SE) two groups and all variables. Significant group interaction ( $P < 0.05$ ). Effect sizes were expressed as Cohen's *d* (95% Confidence Interval), and an effect size greater than 0.8 was considered large, an effect size of approximately 0.5 was considered moderate, and an effect size of less than 0.2 was considered small. \**p*-values were drawn from nonparametrical tests.

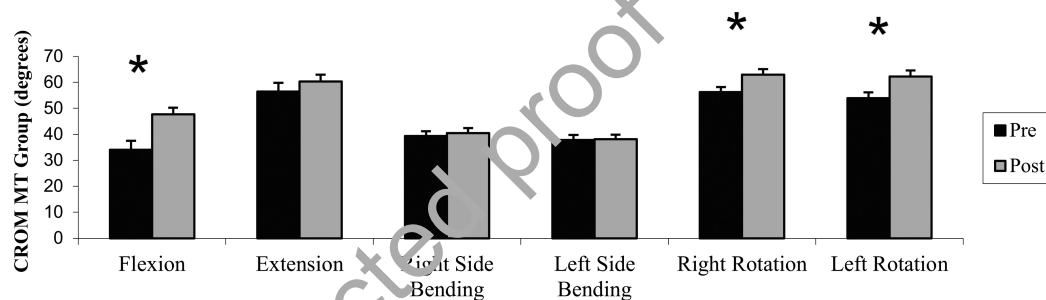


Fig. 4. CROM results, MT Group. Pre and post values were expressed as mean (SE) two groups and all variables. \* denotes  $p$  value  $< 0.05$  within – group interaction.

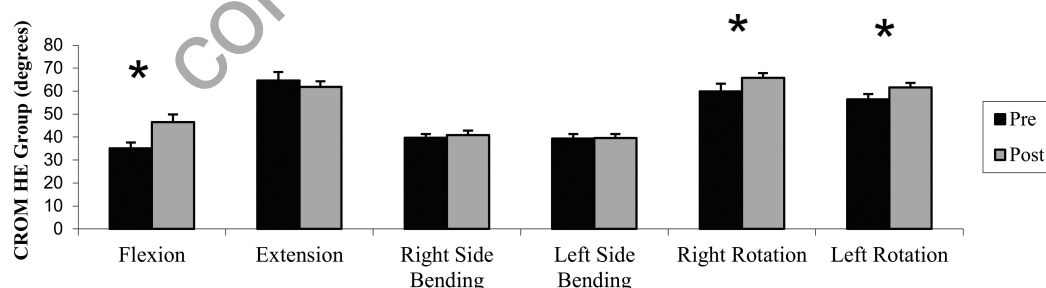


Fig. 5. CROM results, HE Group. Pre and post values were expressed as mean (SE) two groups and all variables. \* denotes  $p$  value  $< 0.05$  within – group interaction.

the short-term effects of an MT protocol with those of an HE protocol in women with chronic neck pain. The main finding was that both interventions improved function and pain, with only marginal between-group

differences in favor of MT group, manipulation was more effective than exercise for only 2 out of 17 measures.

After one week, both interventions showed an im-

	Baseline	Post intervention	Cohen's <i>d</i> effect size 95% CI	Within-group <i>p</i> value	Between-group <i>p</i> value
<b>PPT C1</b>					
MT group ( <i>n</i> = 13)	1.33 (0.04)	1.30 (0.06)	0.11 (−0.54 to 0.75)	0.759	0.863
HE group ( <i>n</i> = 14)	1.24 (0.06)	1.23 (0.07)	0.03 (−0.60 to 0.65)	0.885	–
<b>PPT C5</b>					
MT group ( <i>n</i> = 13)	1.30 (0.06)	1.43 (0.12)	0.38 (−0.29 to 1.01)	0.231	0.818
HE group ( <i>n</i> = 14)	1.28 (0.06)	1.38 (0.10)	0.31 (−0.32 to 0.93)	0.236	–
<b>PPT upper trapezius</b>					
MT group ( <i>n</i> = 13)	1.24 (0.05)	1.34 (0.05)	0.48 (−0.19 to 1.12)	0.162	0.737
HE group ( <i>n</i> = 14)	1.23 (0.06)	1.30 (0.05)	0.28 (−0.35 to 0.90)	0.315	–
<b>PPT gluteus medius</b>					
MT group ( <i>n</i> = 13)	2.22 (0.16)	2.27 (0.16)	0.08 (−0.60 to 0.75)	0.937*	0.487
HE group ( <i>n</i> = 14)	2.25 (0.17)	2.40 (0.13)	0.26 (−0.37 to 0.88)	0.150	–

Pre and post values were expressed as mean (SE) two groups and all variables. Significant group interaction ( $P < 0.05$ ). Effect sizes were expressed as Cohen's *d* (95% Confidence Interval), and an effect size greater than 0.8 was considered large, an effect size of approximately 0.5 was considered moderate, and an effect size of less than 0.2 was considered small. \**p*-values were drawn from nonparametrical tests.

	Baseline	Post intervention	Cohen's <i>d</i> effect size 95% CI	Within-group <i>p</i> value	Between-group <i>p</i> value
<b>First stage</b>					
MT group ( <i>n</i> = 13)	11.59 (2.78)	10.30 (3.15)	0.12 (−0.57 to 0.78)	0.935	0.376
HE group ( <i>n</i> = 14)	15.38 (3.58)	9.49 (2.20)	0.57 (−0.12 to 1.22)	0.62	–
<b>Second stage</b>					
MT group ( <i>n</i> = 13)	22.61 (6.01)	14.33 (6.22)	0.40 (−0.31 to 1.08)	0.488	0.346
HE group ( <i>n</i> = 14)	12.36 (2.56)	13.21 (3.84)	0.07 (−0.60 to 0.74)	0.848	–
<b>Third stage</b>					
MT group ( <i>n</i> = 13)	24.96 (6.56)	20.63 (6.66)	0.16 (−0.82 to 0.47)	0.461	0.583*
HE group ( <i>n</i> = 14)	19.00 (2.23)	23.75 (5.89)	0.29 (−0.35 to 0.90)	0.380	–
<b>Fourth stage</b>					
MT group ( <i>n</i> = 13)	30.64 (7.57)	25.29 (7.97)	0.20 (−0.48 to 0.87)	0.379	0.566
HE group ( <i>n</i> = 14)	21.94 (3.18)	19.20 (4.61)	0.18 (−0.46 to 0.81)	0.299	–
<b>Fifth stage</b>					
MT group ( <i>n</i> = 13)	36.91 (5.14)	25.00 (9.12)	0.46 (−0.23 to 1.13)	0.151	0.362
HE group ( <i>n</i> = 14)	28.35 (3.98)	24.93 (7.08)	0.17 (−0.49 to 0.81)	0.508	–

Pre and post values were expressed as mean (SE) two groups and all variables. Significant group interaction ( $P < 0.05$ ). Effect sizes were expressed as Cohen's *d* (95% Confidence Interval), and an effect size greater than 0.8 was considered large, an effect size of approximately 0.5 was considered moderate, and an effect size of less than 0.2 was considered small. \**p*-values were drawn from nonparametrical tests.

461 important decrease in NDI and VAS scores. The manip-  
 462 ulation protocol decreased the NDI 43.48% (6.05) and  
 463 the VAS 50% (6.06). The NDI changes in the MT  
 464 group may be similar to those found in previous stud-  
 465 ies. For example, Saavedra and cols [8] found patients  
 466 with chronic mechanical neck pain showed greater re-  
 467 duction in NDI scores after manipulations of the cer-  
 468 vical and thoracic spine than after manipulation of the  
 469 cervical spine alone. The short-term effects on pain  
 470 could be different if, like Pires and cols [46], these au-  
 471 thors did not find significant differences in VAS scores  
 472 48–72 hours before manipulating T1. These conclu-  
 473 sions seem to reinforce the belief that multisegment  
 474 manipulation treatment improves the effects on neck  
 475 pain more than isolated manipulation. Our protocol

also included the temporo-mandibular joint; because of  
 its relationships with the neck and cervical pain and  
 biomechanics [9,10,47], including the TMJ in treat-  
 ment yields more effective results. The physiologi-  
 cal mechanism by which CSM produces analgesic ef-  
 fects is still unknown. Some authors studied a chemi-  
 cal response, while others examined biomechanical  
 effects or neurophysiological relationships [48–50].  
 More studies investigating the mechanism behind these  
 effects are needed.

In our study, the HE group showed decreases of  
 39.72% (6.06) in the NDI value and 37.37% (10.72)  
 in the VAS score. These results are similar to those  
 of other authors, such as Karlsson [16,51]; however,  
 our study differs in that it investigated the short-term

491 effects of the treatments and that our HE protocol  
492 was a combined strength and stretching program. The  
493 analgesic effect of the home exercise protocol studied  
494 seems to be related to various aspects; on the one hand,  
495 the motor unit recruitment during isometric contractions  
496 elicits a significant hypoalgesic response [19],  
497 while on the other hand, cranio-cervical flexion exercise  
498 improves the motor control activation of the deep  
499 flexors [17].

500 Regarding ROM, significant changes were found in  
501 flexion and in both directions of rotations in the MT  
502 group. The HE group also showed similar changes,  
503 but only the flexion effect size was considered large  
504 in this group ( $d = 1.25$ ;  $0.51-0.91$ ). The results in  
505 the MT group were similar to other studies [52,53]. A  
506 study by Saavedra and cols of a manipulation protocol  
507 also concluded that MT resulted in significant improvement  
508 in ROM and functional status. For the HE group, our  
509 results are in accordance with the Freimann and cols  
510 study [54]. While no significant changes were observed  
511 in either group in side-bending range, the non-improvement  
512 may be due to the pre-intervention measures (39.38 (1.79)  
513 and 37.84 (1.90) for right and left, respectively, in the  
514 MT group and 39.71 (1.64) and 39.38 (1.90) for right  
515 and left, respectively, in the HE group), which were  
516 already similar to normal [55]. At any rate, the  
517 between-groups differences observed in these movements  
518 were not significant.

519 Regarding the PPT investigation, no significant differences  
520 between the pre- and post-intervention results were  
521 found in any of the measured PPTs between groups. In  
522 the MT group, these results differ from those of another  
523 study of the short-term effects of manipulation [52];  
524 however, in that study, the short-term effect was  
525 measured 20 minutes post-intervention. Similarly, for  
526 the HE group, Lluch and cols [16,56] found immediate  
527 effects on the suboccipital and C5/6 PPTs, but it is  
528 possible that in that study the immediate effects did  
529 not persist over time because the last home exercise  
530 protocol repetition was performed several hours before  
531 assessment. Regardless, although the performance of  
532 cranio-cervical flexion exercise for 6 weeks demonstrated  
533 reductions in pain and the NDI, no changes in the  
534 PPTs over the upper trapezius and at other locations  
535 were found [57].

536 Among the studied subjects, only those in the MT  
537 group showed a moderate effect size ( $d = 0.48$ ;  
538  $-0.19-1.12$ ) for the upper trapezius PPT was found.  
539 This is consistent with the findings of Camargo and  
540 cols [58], who also found a moderate effect size for  
541 upper trapezius PPT change after C5/6 manipulation. No  
542 differences were observed between the two groups.

543 Patients with chronic cervical pain often present a  
544 significant correlation between pain intensity and superficial  
545 muscle activity during cranio-cervical flexion tests, a  
546 finding that could explain altered neuromuscular function  
547 [16]. In the exercise group, after one week, statistical  
548 analysis showed a decreasing trend in the SCM signal  
549 during the first stage of the CCFT with a moderate effect  
550 size ( $d = 0.57$ ;  $-0.12-1.22$ ). This result was not  
551 consistent with those of previous studies [56], which  
552 showed immediate, significant changes during the third  
553 and fifth stage; however, our findings were in the same  
554 line as those of Gallego and cols [59], who found  
555 significant changes in the long term but not immediately  
556 or one month after the intervention. In the MT group,  
557 at the first and fifth stages, the SCM signals decreased  
558 by 29% and 34%, respectively, showing moderate effect  
559 sizes for both stages ( $d = 0.40$ ;  $-0.31-1.08$  and  
560  $0.46$ ;  $-0.23-1.13$ , respectively). These findings were  
561 in with those of other studies [60,61], but while  
562 Sterling and cols found significant changes in the first,  
563 second and third stage after grade III C5/6 mobilization,  
564 Moraleida and cols only found significant differences  
565 in the first stage based on ultrasonography results.  
566 Other authors, such as Pires and cols [46], did not  
567 find significant short-term changes in motor control of  
568 the neck; however, a different motor control test was  
569 used. In the authors' opinion, the SCM signal decrease  
570 in the fifth stage could be explained because the  
571 temporomandibular joint manipulation had an effect on  
572 cranio-cervical biomechanics [9,11,12]; however, this  
573 conclusion should be affirmed by an exhaustive investigation.  
574

575 These findings did not explain the excellent results  
576 on the NDI and VAS; however, in the authors' opinion  
577 and in agreement with other investigators, multiple  
578 factors could contribute to altered motor function in  
579 individuals with chronic mechanical neck pain [16].

580 Some limitations of this study should be considered.  
581 First, the investigator who performed the measurement  
582 protocol was not blinded to the intervention. Second,  
583 although we attempted to control for adherence to the  
584 home exercises through telephone contact, it was  
585 impossible to determine whether the exercises were  
586 being performed correctly. Third, the VAS and NDI are  
587 self-reported measures of pain, not objective measures.  
588 Fourth, the study did not have a control group. Fifth,  
589 there may have been an interaction between the  
590 treatment effects of the HE and MT protocols; therefore,  
591 the results may have demonstrated only the relative  
592 effectiveness of the two protocols. Another limitation  
593 is that the present HE protocol did not include strength train-

ing, only stretching and low-intensity isometric contractions. Additionally, the statistical analyses were not adjusted for multiple comparisons; because the significance level was set at 5%, some of the significant differences may have occurred by chance (statistical type I error). Conversely, a number of potentially significant differences may not have been significant because the sample size was small (statistical type II error). Lastly, the outcome assessor was not blinded, which might have led to measurement bias. More studies with larger sample sizes comparing the short-term effects of an HVLA manipulation protocol and a home exercise protocol are needed. We suggest a longer duration of treatment with more sessions to maximize the treatment effect. Only female with chronic neck pain were included in this study, this fact limited the findings to the female population.

## 6. Conclusions

Both interventions decreased the NDI and VAS in patients with chronic neck pain; additionally, flexion and both rotation directions improved after one week. The between-group differences were marginal, and MT showed significantly better results than HE in only 2 out of 17 tests.

The effect size in the MT group was considered moderate for the C5 and upper trapezius PPT. Similarly, the manipulation protocol group showed a moderate decrease in the first and fifth stage of CCFT in the SCM signal. A moderate decrease during the first stage was also found for the HE group.

## Acknowledgments

To Oscar Moja MsC and Jorge Galino PhD, for the advice in writing this manuscript.

## Conflict of interest

None declared.

## References

- [1] Green BN. A literature review of neck pain associated with computer use: Public health implications. *J Can Chiropr Assoc* 2008 Aug; 52(3): 161-7.

- [2] Hoy DG, Protani M, De R, Buchbinder R. The epidemiology of neck pain. *Best Pract Res Clin Rheumatol* 2010 Dec; 24(6): 783-92.
- [3] Johannes CB, Le TK, Zhou X, Johnston JA, Dworkin RH. The prevalence of chronic pain in United States adults: Results of an Internet-based survey. *J Pain* 2010 Nov; 11(11): 1230-9.
- [4] Cote P, Cassidy JD, Carroll LJ, Kristman V. The annual incidence and course of neck pain in the general population: A population-based cohort study. *Pain* 2004 Dec; 112(3): 267-73.
- [5] Tsao JY, Jang Y, Du CL, Liang HW. Incidence and risk factors of neck discomfort: A 6-month sedentary-worker cohort study. *J Occup Rehabil* 2007 Jun; 17(2): 171-9.
- [6] Cagnie B, Danneels L, Van Tiggelen D, De Loose V, Cambier D. Individual and work related risk factors for neck pain among office workers: A cross sectional study. *Eur Spine J* 2007 May; 16(5): 679-86.
- [7] Leininger B, McDonough C, Evans R, Tosteson T, Tosteson AN, Bronfort G. Cost effectiveness of spinal manipulative therapy, supervised exercise, and home exercise for older adults with chronic neck pain. *Spine J* 2016 Jun 23.
- [8] Saavedra-Hernandez M, Arroyo-Morales M, Cantarero-Villanueva I, Fernandez-Lao C, Castro-Sanchez AM, Puente-dura EJ, et al. Short-term effects of spinal thrust joint manipulation in patients with chronic neck pain: A randomized clinical trial. *Clin Rehabil* 2013 Jun; 27(6): 504-12.
- [9] Roccaforte M. Biomechanical relationship of the cranial, cervical, and hyoid regions. *J Craniomandibular Pract* 1983 Jun-Aug; 1(3): 61-6.
- [10] von Piekartz H, Hall T. Orofacial manual therapy improves cervical movement impairment associated with headache and features of temporomandibular dysfunction: A randomized controlled trial. *Man Ther* 2013 Aug; 18(4): 345-50.
- [11] Armijo-Olivo S, Fuentes JP, da Costa BR, Major PW, Warren S, Thie NM, et al. Reduced endurance of the cervical flexor muscles in patients with concurrent temporomandibular disorders and neck disability. *Man Ther* 2010 Dec; 15(6): 586-92.
- [12] Armijo-Olivo S, Silvestre R, Fuentes J, da Costa BR, Gadotti IC, Warren S, et al. Electromyographic activity of the cervical flexor muscles in patients with temporomandibular disorders while performing the craniocervical flexion test: A cross-sectional study. *Phys Ther* 2011 Aug; 91(8): 1184-97.
- [13] Ylinen JJ, Takala EP, Nykanen MJ, Kautiainen HJ, Hakkinen AH, Airaksinen OV. Effects of twelve-month strength training subsequent to twelve-month stretching exercise in treatment of chronic neck pain. *J Strength Cond Res* 2006 May; 20(2): 304-8.
- [14] Ylinen J, Kautiainen H, Wiren K, Hakkinen A. Stretching exercises vs manual therapy in treatment of chronic neck pain: A randomized, controlled cross-over trial. *J Rehabil Med* 2007 Mar; 39(2): 126-32.
- [15] Peterson F, Kendall E, Geise P, McIntyre M, Anthony W, editors. *Múscles, testing and function, with posture and pain*. 5th ed. Lippincot Williams & Wilkins 2007.
- [16] O'Leary S, Falla D, Hodges PW, Jull G, Vicenzino B. Specific therapeutic exercise of the neck induces immediate local hypoalgesia. *J Pain* 2007 Nov; 8(11): 832-9.
- [17] Jull GA, Falla D, Vicenzino B, Hodges PW. The effect of therapeutic exercise on activation of the deep cervical flexor muscles in people with chronic neck pain. *Man Ther* 2009 Dec; 14(6): 696-701.
- [18] Jull G, Sterling M. *Whiplash injury recovery booklet* 2011.
- [19] Naugle KM, Fillingim RB, Riley JL. A meta-analytic re-

- view of the hypoalgesic effects of exercise. *J Pain* 2012 Dec; 13(12): 1139-50.
- [20] Andersen LL, Kjaer M, Sogaard K, Hansen L, Kryger AI, Sjo-gaard G. Effect of two contrasting types of physical exercise on chronic neck muscle pain. *Arthritis Rheum* 2008 Jan 15; 59(1): 84-91.
- [21] Uthaikhup S, Jull G. Performance in the craniocervical flexion test is altered in elderly subjects. *Man Ther* 2009 Oct; 14(5): 475-9.
- [22] 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 (Phila Pa 1976)* 2004 Oct 1; 29(19): 2108-14.
- [23] Vernon H, Mior S. The neck disability index: A study of reliability and validity. *J Manipulative Physiol Ther* 1991 Sep; 14(7): 409-15.
- [24] Andrade J, Damián A, Almécija R. Validación de una versión española del Índice de Discapacidad Cervical. *Med Clin* 2007; 130(3): 85.
- [25] Price DD, McGrath PA, Rafii A, Buckingham B. The validation of visual analogue scales as ratio scale measures for chronic and experimental pain. *Pain* 1983 Sep; 17(1): 45-56.
- [26] Sriwatanakul K, Kelvie W, Lasagna L, Calimlim JF, Weis OF, Mehta G. Studies with different types of visual analog scales for measurement of pain. *Clin Pharmacol Ther* 1983 Aug; 34(2): 234-9.
- [27] Youdas JW, Carey JR, Garrett TR. Reliability of measurements of cervical spine range of motion – comparison of three methods. *Phys Ther* 1991 Feb; 71(2): 98, 104; discussion 105-6.
- [28] Florencio LL, Pereira PA, Silva ER, Pegoretti KS, Goncalves MC, Bevilaqua-Grossi D. Agreement and reliability of two non-invasive methods for assessing cervical range of motion among young adults. *Rev Bras Fisioter* 2010 Mar-Apr; 14(2): 175-81.
- [29] Fischer AA. Pressure algometry over normal muscles. Standard values, validity and reproducibility of pressure threshold. *Pain* 1987 Jul; 30(1): 115-26.
- [30] Antonaci F, Sand T, Lucas GA. Pressure algometry in healthy subjects: Inter-examiner variability. *Scand J Rehabil Med* 1998 Mar; 30(1): 3-8.
- [31] Kinser AM, Sands WA, Stone NH. Reliability and validity of a pressure algometer. *J Strength Cond Res* 2009 Jan; 23(1): 312-4.
- [32] Sciotti VM, Mittak VL, DiMarco L, Ford LM, Plezbert J, Santipadri E, et al. Clinical precision of myofascial trigger point location in the trapezius muscle. *Pain* 2001 Sep; 93(3): 259-66.
- [33] Srbely JZ, Vernon H, Lee D, Polgar M. Immediate effects of spinal manipulative therapy on regional antinociceptive effects in myofascial tissues in healthy young adults. *J Manipulative Physiol Ther* 2013 07; 36(6): 333-341.
- [34] Chiu TT, Law EY, Chiu TH. Performance of the craniocervical flexion test in subjects with and without chronic neck pain. *J Orthop Sports Phys Ther* 2005 Sep; 35(9): 567-71.
- [35] Jull GA, O'Leary SP, Falla DL. Clinical assessment of the deep cervical flexor muscles: The craniocervical flexion test. *J Manipulative Physiol Ther* 2008 Sep; 31(7): 525-33.
- [36] Barbero M, Merletti R, Rainoldi A. Atlas of muscle innervation zones. Italy: Springer-Verlag 2012.
- [37] Jull G, Bogduk N, Marsland A. The accuracy of manual diagnosis for cervical zygapophysial joint pain syndromes. *Med J Aust* 1988 Mar 7; 148(5): 233-6.
- [38] Fernandez-de-las-Penas C, Downey C, Miangolarra-Page JC. Validity of the lateral gliding test as tool for the diagnosis of intervertebral joint dysfunction in the lower cervical spine. *J Manipulative Physiol Ther* 2005 Oct; 28(8): 610-6.
- [39] Rey-Eiriz G, Albuquerque-Sendin F, Barrera-Mellado I, Martin-Vallejo FJ, Fernandez-de-las-Penas C. Validity of the posterior-anterior middle cervical spine gliding test for the examination of intervertebral joint hypomobility in mechanical neck pain. *J Manipulative Physiol Ther* 2010 May; 33(4): 279-85.
- [40] Greenman P. *Principios y Práctica de la Medicina Manual*. 3ª Edición ed. Buenos Aires: Médica Panamericana 2005.
- [41] Ward R. *Fundamentos de Medicina Osteopática*. Buenos Aires – Argentina: Médica Panamericana 2006.
- [42] Gibbons P, Tehan P. *Manipulación de la columna, el torax y la pelvis: Una perspectiva osteopática*. 2002nd ed. Edinburgh: MCGRAW-HILL.
- [43] Fernandez-de-las-Penas C, Perez-de-Heredia M, Brea-Rivero M, Miangolarra-Page JC. Immediate effects on pressure pain threshold following a single cervical spine manipulation in healthy subjects. *J Orthop Sports Phys Ther* 2007 Jun; 37(6): 325-9.
- [44] Fernandez-de-las-Penas C, Alonso-Blanco C, Cleland JA, Rodriguez-Blanco C, Albuquerque-Sendin F. Changes in pressure pain thresholds over C5-C6 zygapophysial joint after a cervicofascial junction manipulation in healthy subjects. *J Manipulative Physiol Ther* 2008 Jun; 31(5): 332-7.
- [45] Tuncer AB, Ergun N, Tuncer AH, Karahan S. Effectiveness of manual therapy and home physical therapy in patients with temporomandibular disorders: A randomized controlled trial. *J Bodyw Mov Ther* 2013 Jul; 17(3): 302-8.
- [46] Pires PF, Packer AC, Dibai-Filho AV, Rodrigues-Bigaton D. Immediate and short-term effects of upper thoracic manipulation on myoelectric activity of sternocleidomastoid muscles in young women with chronic neck pain: A randomized blind clinical trial. *J Manipulative Physiol Ther* 2015 Oct; 38(8): 555-63.
- [47] Ciancaglini R, Testa M, Radaelli G. Association of neck pain with symptoms of temporomandibular dysfunction in the general adult population. *Scand J Rehabil Med* 1999 Mar; 31(1): 17-22.
- [48] Pickar JG. Neurophysiological effects of spinal manipulation. *Spine J* 2002 Sep-Oct; 2(5): 357-71.
- [49] Pickar JG, Bolton PS. Spinal manipulative therapy and somatosensory activation. *Journal of Electromyography and Kinesiology* 2012 10; 22(5): 785-94.
- [50] Molina-Ortega F, Lomas-Vega R, Hita-Contreras F, Manzano GP, Achalandabaso A, Ramos-Morcillo AJ, et al. Immediate effects of spinal manipulation on nitric oxide, substance P and pain perception. *Man Ther* 2014 Oct; 19(5): 411-7.
- [51] Karlsson L, Takala EP, Gerdl B, Larsson B. Evaluation of pain and function after two home exercise programs in a clinical trial on women with chronic neck pain – with special emphasises on completers and responders. *BMC Musculoskeletal Disord* 2014 Jan 8; 15: 6. 2474-15-6.
- [52] Casanova-Mendez A, Oliva-Pascual-Vaca A, Rodriguez-Blanco C, Heredia-Rizo AM, Gogorza-Arroitaonandia K, Almazan-Campos G. Comparative short-term effects of two thoracic spinal manipulation techniques in subjects with chronic mechanical neck pain: A randomized controlled trial. *Man Ther* 2014 Aug; 19(4): 331-7.
- [53] Saavedra-Hernandez M, Castro-Sanchez AM, Arroyo-Morales M, Cleland JA, Lara-Palomo IC, Fernandez-de-Las-Penas C. Short-term effects of kinesio taping versus cervical

- 825 thrust manipulation in patients with mechanical neck pain:  
826 A randomized clinical trial. *J Orthop Sports Phys Ther* 2012  
827 Aug; 42(8): 724-30.
- 828 [54] Freimann T, Merisalu E, Paasuke M. Effects of a home-  
829 exercise therapy programme on cervical and lumbar range of  
830 motion among nurses with neck and lower back pain: A quasi-  
831 experimental study. *BMC Sports Sci Med Rehabil* 2015 Dec  
832 4; 7: 31. 015-0025-6. eCollection 2015.
- 833 [55] Youdas JW, Garrett TR, Suman VJ, Bogard CL, Hallman HO,  
834 Carey JR. Normal range of motion of the cervical spine: An  
835 initial goniometric study. *Phys Ther* 1992 Nov; 72(11): 770-  
836 80.
- 837 [56] Lluch E, Schomacher J, Gizzi L, Petzke F, Seegar D, Falla  
838 D. Immediate effects of active cranio-cervical flexion exercise  
839 versus passive mobilisation of the upper cervical spine on pain  
840 and performance on the cranio-cervical flexion test. *Man Ther*  
841 2014; 19(1): 25-31.
- 842 [57] Lluch E, Arguisuelas MD, Coloma PS, Palma F, Rey A,  
843 Falla D. Effects of deep cervical flexor training on pressure  
844 pain thresholds over myofascial trigger points in patients with  
845 chronic neck pain. *J Manipulative Physiol Ther* 2013 Nov-  
846 Dec; 36(9): 604-11.
- [58] de Camargo VM, Albuquerque-Sendin F, Berzin F, Stefanelli  
847 VC, de Souza DP, Fernandez-de-las-Penas C. Immediate ef-  
848 fects on electromyographic activity and pressure pain thresh-  
849 olds after a cervical manipulation in mechanical neck pain:  
850 A randomized controlled trial. *J Manipulative Physiol Ther*  
851 2011 May; 34(4): 211-20.
- [59] Gallego Izquierdo T, Pecos-Martin D, Lluch Girbes E, Plaza-  
853 Manzano G, Rodriguez Caldentey R, Mayor Melus R, et al.  
854 Comparison of cranio-cervical flexion training versus cervical  
855 proprioception training in patients with chronic neck pain: A  
856 randomized controlled clinical trial. *J Rehabil Med* 2016 Jan;  
857 48(1): 48-55.
- [60] Sterling M, Jull G, Wright A. Cervical mobilisation: Concur-  
859 rent effects on pain, sympathetic nervous system activity and  
860 motor activity. *Man Ther* 2001 May; 6(2): 72-81.
- [61] Jesus-Moraleida FR, Ferreira PH, Pereira LS, Vasconcelos  
862 CM, Ferreira ML. Ultrasonographic analysis of the neck  
863 flexor muscles in patients with chronic neck pain and changes  
864 after cervical spine mobilisation. *J Manipulative Physiol Ther*  
865 2011 Oct; 34(8): 514-21.  
866

corrected proof version