Musculoskeletal Science and Practice 42 (2019) 52–59

Contents lists available at ScienceDirect

Musculoskeletal Science and Practice

journal homepage: www.elsevier.com/locate/msksp

Systematic Review

Motor control using cranio-cervical flexion exercises versus other treatments for non-specific chronic neck pain: A systematic review and meta-analysis

Carmen Martin-Gomez[a,1], Rebeca Sestelo-Diaz[a,1], Victor Carrillo-Sanjuan[a,1], Marcos Jose Navarro-Santana[b], Judit Bardon-Romero[a,*,1], Gustavo Plaza-Manzano[c]

[a] Facultad de Medicina y Ciencias de la Salud, Universidad de Alcala, Crta. de Madrid-Barcelona, Km. 33,600, Alcalá de Henares, Madrid, Spain
[b] Rehabilitación San Fernando, Alcala de Henares, Madrid, Spain
[c] Departamento de Radiologia, Rehabilitacion y Fisioterapia, Universidad Complutense de Madrid, Instituto de Investigación Sanitaria del Hospital Clínico San Carlos (IdISSC), Madrid, Spain

ARTICLE INFO

Keywords:
Exercise therapy
Neck pain
Meta-analysis
Motor control exercises

ABSTRACT

Background: Chronic neck pain affects a significant percentage of the adult population. Commonly, the pain is of unknown origin. In those cases, some alterations in motor control (MC) can appear in the deep cervical muscles. The specific training of these muscles could improve muscular function and reduce pain and disability.
Objective: To determine whether MC, using cranio-cervical flexion (CCF), is more effective than other treatments for non-specific chronic neck pain (NSCNP).
Design: Systematic review with meta-analysis.
Methods: A search was done in journals and in a variety of databases, between December 2017 and March 2018. Randomized clinical trials (RCTs) and systematic reviews of RCTs comparing MC with other treatments in adults with NSCNP, regarding pain and disability, were included. Risk of bias was analysed using the Cochrane risk of bias tool. Data was analysed using a random effects model. Heterogeneity was evaluated using the I^2statistic. The quality of the evidence was measured using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.
Results: Ten articles were included for qualitative review; nine were used for a quantitative analysis about the effect of MC on pain and eight for the analysis regarding disability. The meta-analysis comparing MC versus other treatments showed significant differences regarding pain and disability.
Conclusions: MC interventions for NSCNP patients reduces pain and disability. MC seems to be more effective to reduce pain and disability than other treatments.

1. Introduction

Neck pain affects between 12.1 and 71.5% of the world population and is incapacitating in more than 10% of cases (Haldeman et al., 2008). The majority of the cases have a non-specific origin (Childs et al., 2008). Neck pain affects mainly the adult population and it is associated with a decrease in quality of life, affecting activity and mental health (Fernández-de-las-Peñas et al., 2011). In more than half of patients who have experienced neck pain, the pain will return in the following years – for most of them, in the first year (Childs et al., 2008). Due to all of the above, neck pain can be considered a social problem which has a significant impact on patients, their families and companies; as well as the National Health System which has to bear the cost of medication, sick pay and diagnostic testing (Childs et al., 2008; Hoy et al., 2010).

After the first episode of acute neck pain, alterations in MC appear affecting neuromuscular behaviour. The main changes are decrease in strength, range of movement and velocity. These alterations impact high load activities (lifting) without provoking any modifications in less demanding activities. This is possible because in the cervical spine, the same activity can be done by different muscles with similar lines of action (Gizzi et al., 2015). Endurance has been proved to be reduced in situations where the subject is in pain, due to the reduction in the activity of deep flexor and extensor muscles which also produce an increase in superficial muscle tone (Falla and Farina, 2008; Schomacher and Falla, 2013; Brage et al., 2015; O'Leary et al., 2007; Jull et al.,

* Corresponding author. Response Physiotherapy, David Lloyd, Brighton Marina Village, Brighton. BN2 5UF, United Kingdom.
E-mail address: juditbardonromeropt@gmail.com (J. Bardon-Romero).
[1] Physiotherapist, private practice.

https://doi.org/10.1016/j.msksp.2019.04.010
Received 11 September 2018; Received in revised form 12 April 2019; Accepted 16 April 2019

2009). In a recent study where the sensitivity of upper trapezius, splenius capitis and levator scapulae was evaluated, 100% of patients with cervical pain presented hypersensitivity in some of these muscles (Cerezo-Téllez et al., 2016). This process can explain the recurrence of cervical pain over the first year after an acute episode and contribute to its chronicity (Childs et al., 2008; Hoy et al., 2010). Furthermore, it could explain the MC deficits that patients with chronic neck pain present (Falla and Farina, 2008).

Specific training tailoring the deep flexor and extensor muscles increases their activity. As such, it reduces the overactivation of the superficial muscles, reducing pain and disability (Schomacher and Falla, 2013; Brage et al., 2015). Specifically, CCF training improves the activation pattern of the neck muscles (Jull et al., 2009). For that reason, MC has been referred to CCF throughout this paper.

There are several studies which examine this (Brage et al., 2015; O'Leary et al., 2007; Jull et al., 2009; Cerezo-Téllez et al., 2016) and even some systematic reviews (Amiri et al., 2007; Gross et al., 2016) but they do not include many RCTs nor do they conduct a thorough meta-analysis. In light of this, it is necessary to conduct a systematic review and meta-analysis that collects the latest studies about the effectiveness of MC in the adult population with NSCNP. The objective is to determine if MC interventions are more effective regarding pain reduction and disability than other treatments.

2. Methods

This systematic review followed "The Cochrane Handbook for Systematic Review of Intervention" (Higgins and Green, 2011). This systematic review and the Meta-analysis are reported according to Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines (PRISMA) (UrrútiaG, 2010). A formal protocol was developed and submitted to PROSPERO (CRD42018081542).

2.1. Data sources and searches

Indirect sources were consulted. The databases PubMed, PEDro, Cochrane, SCOPUS and Web of Science were searched. The journals "*Fisioterapia*" and "*Cuestiones de Fisioterapia*" were reviewed.

The initial search was done between December 2017 and March 2018, where systematic reviews and RCTs were identified. The articles belonging to the systematic reviews were searched in April and May 2018.

2.1.1. Searching strategy

The strategy used is recommended by The Cochrane Back and Neck Review Group (Furlan et al., 2015). Medical Subject Headings (MeSH) and free text were used and combined according to the requirements of each database. The search algorithm and descriptors used for PubMed can be found on Table 1. This was adapted for the different databases as appropriate.

2.2. Study selection

Title and abstract were screened independently by two reviewers (J.B.R. and V.C.S). All discrepancies were discussed between the reviewers. Only those publications written in English or Spanish were evaluated.

The following inclusion criteria were used. The publications were RCTs or systematic reviews published from 2007. Participants were adults with NSCNP ($\geq$3 months). The treatment of the experimental group had to be MC exercises (using CCF) intended to retrain neuromuscular behaviour. This had to be compared with a different intervention. Validated scales were used to measure pain - the Visual Analog Scale (VAS) (Knop et al., 2001) or the Numeric Rating Scale (NRS) (Jensen et al., 1999) and disability – the Neck Disability Index (Vernon and Mior, 1991).

Studies of patients with specific neck pain were excluded, as well as the studies where the patients had a trauma or cervical surgery prior the commencement of the study. Studies that included patients with neurologic signs were excluded, as were those where the patient had a temporomandibular disorder.

2.3. Data extraction and risk of bias assessment

Data was extracted by two independent reviewers (C.M.G and R.S.D). The reviewers filtered and evaluated the complete text of the studies determining those suitable for revision. They conducted the data extraction. Risk of bias was evaluated using the Cochrane tool following the Updated Method Guideline for Systematic Reviews (Furlan et al., 2015). Discrepancies were discussed between the reviewers and resolved with an independent reviewer if necessary.

2.4. Data synthesis and analysis

Studies with comparable outcomes were included in the qualitative analysis. Studies used 100 mm VAS or 11-point NRS. Disability was measured with NDI (range 0–50). Results were divided into immediate-short term ($\leq$4 weeks after intervention) and short-to medium-term (between 5- and 10-weeks post-intervention).

MC exercises, using CCF, were compared with the control group. Besides, an analysis between subgroups - made regarding the type of intervention, was conducted.

Data was analysed using mean difference (MD) that were converted into a standardized mean difference (SMD) with a confident interval (CI) of 95%. A random effects model was used to determine the effect size. Large effect size was considered to be 0.8 or more; medium between 0.5 and $<$ 0.8; and small when 0.2 to $<$ 0.5 (Ferguson, 2009). Statistical significance was set at $p < 0.05$.

Effect size and its calculation for the outcomes pain and disability were presented using a forest plot. Test of heterogeneity were analysed using the I^2 statistic (Higgins et al., 2003).

The quality of evidence in this meta-analysis was evaluated using the GRADE approach, which has four levels of evidence: very low, low, moderate or high (Ryan and Hill, 2016; Schunemann et al., 2008). To rate the quality of evidence different criteria, such as the presence of study limitations, indirectness of evidence, unexplained heterogeneity or inconsistency of results, imprecision of results, and high probability of publication bias (Austin et al., 2014) were considered.

Studies were blinded and analysed by an independent reviewer. Data was analysed using the software Review Manager 5.3.

Table 1
Search strategy for PubMed.

#1	"Neck pain" (MeSH) and "chronic pain" (MeSH)
#2	"Exercise therapy" (MeSH) **OR** "Exercise" (MeSH) **OR** "Proprioception" (MeSH) **OR** "Motor control" **OR** "Train" **OR** "Exercis*" **OR** "Craniocervical flexion test" **OR** "Craniocervical flexor muscles"
#3	#1 **AND** #2
#4	"Whiplash" (MeSH) **OR** "Neuritis" (MeSH) **OR** "Brachial plexus" (MeSH) **OR** "Temporomandibular joint disorders" (MeSH) **OR** "Pain postoperative" (MeSH)
#5	#3 **NOT** #4

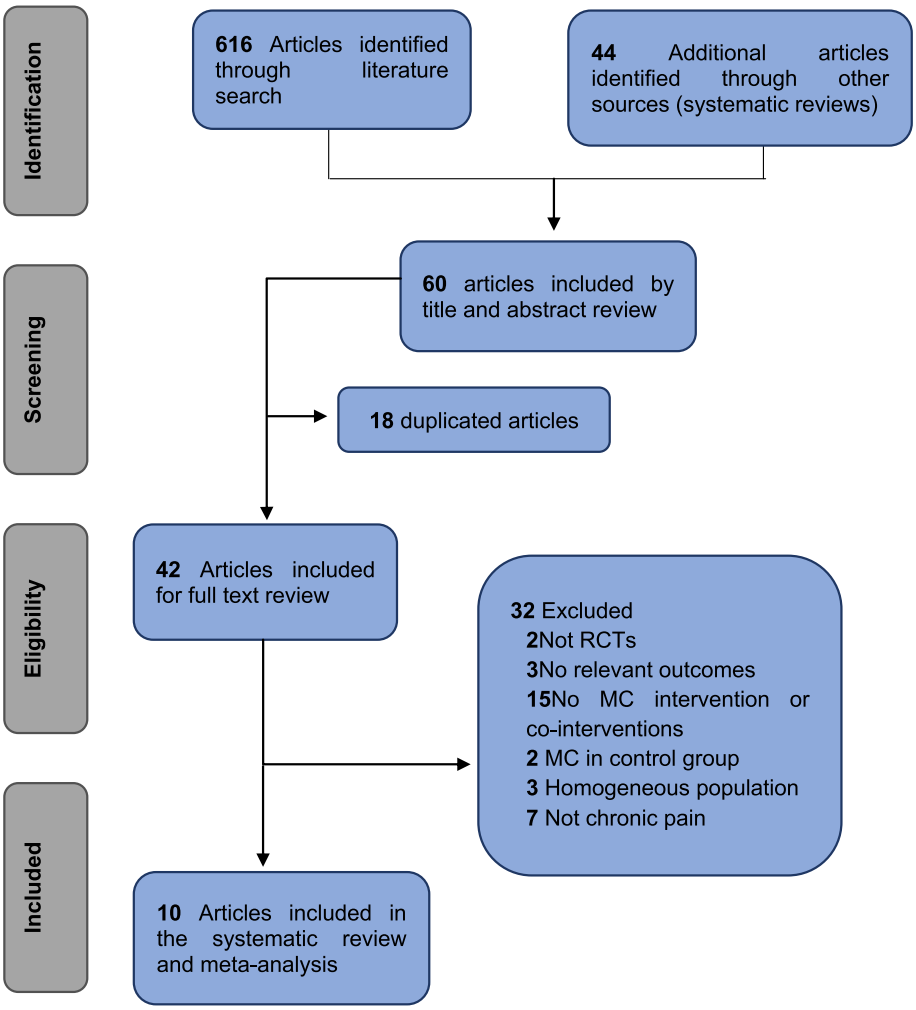

Fig. 1. Literature search, PRISMA Flow diagram.

3. RESULTS

3.1. Study selection

From the searches for systematic reviews and RTCs, 42 articles were fully analysed. After the inclusion and exclusion criteria were applied, 10 articles were included in the systematic review and meta-analysis (Fig. 1).

3.2. Description of the evidence

The studies included, 10 RCTs, measured the effect of MC exercises on pain and disability on adults with NSCNP compared to other treatments. The intervention was based on the protocol described by Jull (Jull et al., 2004, 2009). MC by using CCF was compared to strengthening and endurance exercises for cervical flexion (O'Leary et al., 2007; Jull et al., 2009; Javanshir et al., 2015; Falla et al., 2008; Kim and Kwag, 2016), mobilisations (Lluch et al., 2013; O'Leary et al., 2012; Kwan-Koo and Kim, 2016) or other treatments – proprioceptive exercises (Gallego-Izquierdo et al., 2016) or 'wait and see' (Falla et al., 2013).

Risk of bias was assessed using the Cochrane Handbook tool available in the software Review Manager 5.3. The result of this analysis is presented on Table 2.

The studies included between 18 and 60 patients, with a total of 423 across the RCTs. Four studies only included women to avoid differences caused by gender. The characteristic of the studies included can be found on Table 3.

The quality of evidence included in this meta-analysis was assessed using the GRADE approach. The studies analysed were divided into groups: association with pain immediate-short-term, association with pain short-to medium-term and association with disability short-to medium-term. The results regarding pain and disability showed very low to moderate evidence. The full analysis can be seen on Table 4.

3.3. Association with pain

The studies presented the outcome pain using the VAS scale on six studies and NRS on the remaining four. Three of the studies measured the outcome over the immediate-short term (O'Leary et al., 2007; Kim and Kwag, 2016; Lluch et al., 2013) and seven over the short-to medium-term (Jull et al., 2009; Javanshir et al., 2015; Falla et al., 2008; Kim and Kwag, 2016; O'Leary et al., 2012; Kwan-Koo and Kim, 2016; Falla et al., 2013).

3.3.1. Comparison versus control group

Comparing MC with a control group over the immediate-short term showed no significant greater decrease in pain with a small effect size (SMD -0.33, [95% CI] −0.73 to 0.08, n = 96, p = 0.11 a MD of 0.34, [95% CI] −0.76 to 0.09, p = 0.09) and a null heterogeneity (I^2 = 0%) in both cases. The analysis of the subgroups did not demonstrate any difference between groups and showed a null heterogeneity (I^2 = 0%).

The short-to medium-term comparison (Fig. 2) presented significant pain reduction with a moderate effect size (SMD -0.58, [95% CI] −0.97

Table 2
Risk of bias.

	Random sequence generation (Selection bias)	Allocation concealment (Selection bias)	Blinding of participants and care providers Out: Pain and disability (Performance Bias)	Blinding of outcomes assessors Out: Pain and disability (Detection bias)	Incomplete outcome data Out: Pain and disability. (Attrition bias)	Selective outcome reporting (Reporting bias)	Group similarity at baseline (Selection bias)	Co-interventions (Performance bias)	Timing of outcome assessments (Detection bias)	Other bias
Falla et al., 2008	Low	Low	High	Low	Low	Low	Low	Low	Unclear	Low
Falla et al., 2013	Low	Low	High	Low	Unclear	Low	Low	High	Unclear	Low
Gallego-Izquierdo et al., 2016	Low	Low	High	Low	Low	Low	Low	Low	Low	Low
Javanshir et al., 2015	Low	Unclear	High	Low	Low	Low	Low	Low	Low	Low
Jull et al., 2009	Low	Unclear	High	Low	Low	Low	Low	Low	Low	Low
Kim and Kwag, 2016	Low	Low	High	High	Low	Low	Unclear	Unclear	Low	Low
Kwan-Koo and Kim, 2016	Unclear	Unclear	High	Low	Low	Low	Low	Unclear	Low	Low
Lluch et al., 2013	Low	Unclear	High	Low	Low	Low	Low	Unclear	Low	Low
O'Leary et al., 2007	Low	Low	High	Low	Low	Low	Unclear	Low	Low	Low
O'Leary et al., 2012	Low	Low	High	Low	Low	Low	Unclear	Unclear	Low	Low

to −0.20, n = 349, p = 0.003) a MD of −0.97 ([95% CI] - 2.05 to −0.30, p = 0.0002) and a high heterogeneity (I^2 = 67%) in both cases.

The subgroup analysis indicated significant differences between groups (p = 0.009) and showed a high heterogeneity in the SMD analysis (I^2 = 78.6%). The funnel plot graph showed a likelyrisk of publication bias in terms of the short-medium term analysis (Fig. 3).

One of the studies was not included in the analysis of the MC effect over pain versus a control group because the data could not be combined (Gallego-Izquierdo et al., 2016). This study showed a significant decrease in both groups (MC and proprioceptive exercises) regarding pain after the first treatment session that was maintained after one- and three-months post-intervention.

3.4. Association with disability

Only eight of the ten selected studies for the meta-analysis (Jull et al., 2009; Javanshir et al., 2015; Falla et al., 2008; Kim and Kwag, 2016; O'Leary et al., 2012; Kwan-Koo and Kim, 2016; Gallego-Izquierdo et al., 2016; Falla et al., 2013) had disability as an outcome to compare the effects of MC versus other treatments when measuring the results over the short-to medium-term using the NDI.

3.4.1. Comparison versus control group

This meta-analysis showed a significant reduction in disability when comparing MC exercises with a control group in the short to medium-term (Fig. 4), with a small size effect (SMD -0.44 [95% CI] −0.81 to −0.08, n = 377, p = 0.02) and a high heterogeneity (I^2 = 66%). The MD was −2.31 [95% CI] −4.38; −0.24, p = 0.03 with a high heterogeneity (I^2 = 81%).

No significant differences were found between groups ($p > 0.05$) with a null heterogeneity (I^2 = 0%) in the SDM and MD analysis. A likely publication bias was observed in the funnel plot graph (Fig. 5).

4. Discussion

The objective of this meta-analysis was to assess if a treatment based on MC exercises, using CCF exercises, reduces pain and disability and if this intervention is more effective than other treatments for NSCNP. This is relevant due to an increase of NSCNP in the population, which has a vast social and economic cost (Haldeman et al., 2008; Childs et al., 2008; Fernández-de-las-Peñas et al., 2011; Hoy et al., 2010). A search of the literature from 2007 to 2018 was done and ten articles were finally included.

The results of this systematic review and meta-analysis have demonstrated that MC exercises reduce pain (measured immediate-short term and short-to medium-term) and disability (when measured short-to medium term).

When the effect of MC interventions is compared with other treatments (strengthening and endurance exercises, mobilisations or other treatments – proprioceptive exercises or 'wait and see') the difference in reduction in pain and disability is statistically significant with moderate and small effect size, respectively. When the subgroups are analysed separately regarding pain, only the group other treatments is statistically significant. However, if the analysis concerns disability, the none of the groups are significant.

Therapeutic exercise is recommended (grade B in the Clinical Practice Guidelines) for those patients with chronic neck pain associated with an alteration in movement. It is also recommended (grade C) when the pain is associated with coordination deficits (Blanpied et al., 2017). Moreover, several studies support the use of exercise to treat NSCNP due to the reduction in pain and disability that exercise provokes (Gross et al., 2016). This is also effective when combined with manual therapy (Fredin and Håvard, 2017). A Cochrane review on chronic pain shows similar results regarding general exercise and its effect on pain and disability (Geneen et al., 2017).

Several studies support the use of mobilisations as an effective

Table 3
General characteristics of the studies.

Study	Sample size	Characteristics of participants	Duration and doses of MC	Intervention	Control group	Outcomes	Results
Falla et al., 2008	57 MC: 28 CG: 29	Women with chronic neck pain (> 3 months) and NDI < 15/50	6 weeks: - 30 min sessions once a week - Home exercises twice a day	CCF training supine position with pressure biofeedback. Followed Jull et al., 2004 protocol (Jull et al., 2004)	Strengthening and endurance training of neck flexors during cervical elevation McArdle et al., 1996 protocol (McArdle et al., 2010)	Pain: Average Intensity of Pain (0–10) Disability: NDI (0–50)	Reduction in pain in both groups. Reduction in perceived disability in both groups
Falla et al., 2013	46 MC: 23 CG: 23	Women with chronic neck pain (> 1 year)	8 weeks: - 30 min sessions once a week - Home exercises twice a day	Progressive training of CCF and extensors Jull et al., 2008 protocol (Jull et al., 2009)	Wait and see	Pain: VAS (0–10) Disability: NDI (0–50)	Significant reduction in pain and disability
Gallego-Izquierdo et al., 2016	28 MC: 14 CG: 14	Adults with NSCNP (> 3 months) and NDI ≤15/50	8 weeks: - 6 sessions (45 min) - Home exercises twice a day	CCF training supine position with pressure biofeedback. Jull et al., 2004 protocol (Jull et al., 2004)	Proprioception exercises Oculomotor exercises Revel et al., 1991, 1994 protocol (Revel et al., 1991, 1994)	Pain: VAS (0–10) Disability: NDI (0–50)	Significant reduction in pain and disability on both groups after first session After 1 month significant reduction in pain and after 2 months significant reduction in pain and disability, on both groups
Javanshir et al., 2015	60 MC: 30 CG: 30	Adults with NSCNP (> 3 moths)	10 weeks: - 30 min sessions, 3 times a week - Home exercises 3 times a day	CCF training supine position with pressure biofeedback O'Leary et al., 2007 protocol (O'Leary et al., 2007)	Cervical flexion exercise maintaining neutral the superior cervical O'Leary et al., 2007 protocol (O'Leary et al., 2007)	Pain: NRS (0–10) Disability: NDI (0–50)	Similar reduction in pain and disability in both groups
Jull et al., 2009	46 MC: 23 CG: 23	Adult women with chronic neck pain (> 3 months) and NDI < 15/50	6 weeks: - 30 min sessions once a week	CCF training supine position with pressure biofeedback Jull et al., 2008 protocol (Jull et al., 2009)	Strengthening and endurance training of neck flexors with cervical elevation McArdle et al., 1996 protocol (McArdle et al., 2010)	Pain: NRS (0–10). Disability: NDI (0–50).	Significant reduction in pain and disability in both groups
Kim and Kwag, 2016	30 MC: 15 CG: 15	Adults with chronic neck pain (> 3 months) and NDI < 15/50	4 weeks: - Sessions 3 times a week	CCF training supine position with pressure biofeedback: - 10 repetitions (10–15 s)	Strengthening program. Modified protocol Axen et al., 1992 (Axen et al., 1992): - Isometrics - Stretches in 5 different positions	Pain: NRS (0–10) Disability: NDI (0–50)	MC improves in pain and disability CG only improves NDI scoring 4 weeks after intervention
Kwan-Koo and Kim, 2016	30 MC: 15 CG: 15	Adults with NSCNP (> 3 months) NDI > 20% ROM limited (flexion and cranio-cervical extension)	10 weeks: - 35 min sessions 3 times a week. - 30 min sessions once a week.	CCF training supine position with pressure biofeedback: - 10 repetitions (10 s) - 25 min training and 10 min auto-stretching	Active self-exercise: flexion, extension, side-flexion and rotation during 35 min.	Pain: VAS (0–10) Disability: NDI (0–50)	Both groups improved scoring in pain and disability. Group using MC improved more
Lluch et al., 2013	18 MC: 9 CG: 9	Adults with NSCNP (> 3 months) and NRS ≥3/10	Only 1 session for evaluation and intervention.	Assisted CCF exercises in supine 1 repetition every 2 s during 3 min: - CCF assisted 1 min - CCF active 2 min	3 min of passive mobilisations and assisted CCF: - 2 min of passive mobilisations of cervical spine - 1 min of assisted CCF mobilisation	Pain: NRS (0–10)	Pain was reduced in both groups but more in the exercise group
O'Leary et al., 2007	48 MC: 24 CG: 24	Women with chronic neck pain (> 3 months) and NDI 5–13/50	1 learning session Experimental session and result assessment (after 48 h)	CCF training supine position with pressure biofeedback: - 10 repetitions (10 s)	Endurance exercise: cervical elevation (2 cm) maintaining neutral the superior cervical 3 sets of 10 repetitions	Pain: VAS (10 cm)	Only CCF exercises demonstrated a reduction in pain during active movements
O'Leary et al., 2012	60 MC: 20 CG1: 20 CG2: 20	Adults with mechanic chronic neck pain (> 6 months) and NDI < 15/50	10 weeks: - Home exercises twice a day	CCF training supine position with pressure biofeedback: - 10 repetitions (10 s)	CG1: AROM exercises in a vertical position. Progressing number of repetitions and sets. CG2: endurance exercises for flexor muscles in a vertical position. Isometric exercises according to MVC	Pain: VAS (100 mm) Disability: NDI (0–50)	All three groups reduced pain and disability

MC = motor control. CG: control group. CCF: cranio-cervical flexion. VAS = visual analogue scale. NDI = Neck Disability Index. NSCNP = non-specific chronic neck pain. NRS = Numeric Rating Scale. ROM = range of motion. AROM = active range of motion. MVC = Maximum Voluntary Contraction.

Table 4
GRADE assessment.

Number of Studies	Risk of Bias[a]	Inconsistency[b]	Indirectness of Evidence[c]	Imprecision[d]	Publication Bias[e]	Quality of Evidence	SMD (95%CI)
Association with pain: immediate-short term (0 to 10 weeks)							
Motor Control vs Control Group 3	No	No	No	Very Serious	No	⊕⊕◯◯ LOW	−0.33 (−0.73,0.08)
Motor Control vs Subgroup-Exercise Therapy 2	No	No	No	Very Serious	No	⊕⊕◯◯ LOW	−0.26 (−0.71,0.18)
Motor Control vs Subgroup-Mobilisation 1	No	No	No	Very Serious	No	⊕⊕◯◯ LOW	−0.62 (−1.57,0.33)
Association with pain: short to medium term (5 to 10 weeks)							
Motor Control vs Control Group 8	No	Serious	No	Serious	Serious	⊕◯◯◯ VERY LOW	0.58 (−0.97, 0.2)
Motor Control vs Subgroup-Exercise Therapy 5	No	No	No	Serious	No	⊕⊕⊕◯ MODERATE	−0.25 (−0.50, 0.01)
Motor Control vs Subgroup-Mobilisation 2	No	Very Serious	No	Very Serious	No	⊕◯◯◯ VERY LOW	−1.21 (−2.57, 0.15)
Motor Control vs Subgroup- Other treatments 1	No	No	No	Very Serious	No	⊕⊕◯◯ LOW	−1.23 (−1.87, −0.60)
Association with disability: short- to medium- TERM (5 to 10 weeks)							
Motor Control vs Control Group 9	No	Serious	No	Serious	Serious	⊕◯◯◯ VERY LOW	−0.44 (−0.81, 0.08)
Motor Control vs Subgroup-Exercise Therapy 5	No	No	No	Serious	No	⊕⊕⊕◯ MODERATE	−0.23 (−0.49, 0.02)
Motor Control vs Subgroup-Mobilisation 2	No	Very Serious	No	Very Serious	No	⊕◯◯◯ VERY LOW	−1.44 (−3.58, 0.71)
Motor Control vs Subgroup- Other treatments 2	No	Serious	No	Very Serious	No	⊕◯◯◯ VERY LOW	−0.36 (−1.02, 0.29)

[a] No risk of bias was found in any study.
[b] $I^2 > 40\%$: serious. $I^2 > 80\%$: very serious.
[c] No indirectness of evidence was found in any study.
[d] N < 300: serious. N < 300 and estimated effect little or absent: very serious.
[e] Based on funnel plot analysis.

treatment for NSCNP (Hidalgo et al., 2017; Farooq et al., 2017). In the study conducted by (Lluch et al., 2013) (Lluch et al., 2013) similar results are obtained using mobilisations as an intervention. However, MC exercises also improve outcomes with regards to motor tasks. This can be explained due to the increase in activation velocity achieved in the deep cervical flexor muscles that occurs when training these muscles in isolation, as happens during MC exercises (Boudreau et al., 2010).

The meta-analysis revealed significant differences in the effectiveness of MC reducing pain compared with 'wait and see'. However, no differences were found when compared with "exercise group", "mobilisation group" or proprioceptive exercise to reduce pain and disability. According to the study conducted by Falla et al. (2013)where the effect of an MC intervention versus 'wait and see' was analysed, a significant reduction in pain and disability favouring the MC group was achieved. Furthermore, the study conducted by Gallego-Izquierdo et al. (2016)also showed a significant reduction in pain and disability levels when treated with either MC or proprioceptive exercises. These results confirm the benefits observed when using therapeutic exercises for NSCNP.

It has been shown that those patients with NSCNP can improve when doing different exercise modalities. The load of the exercise

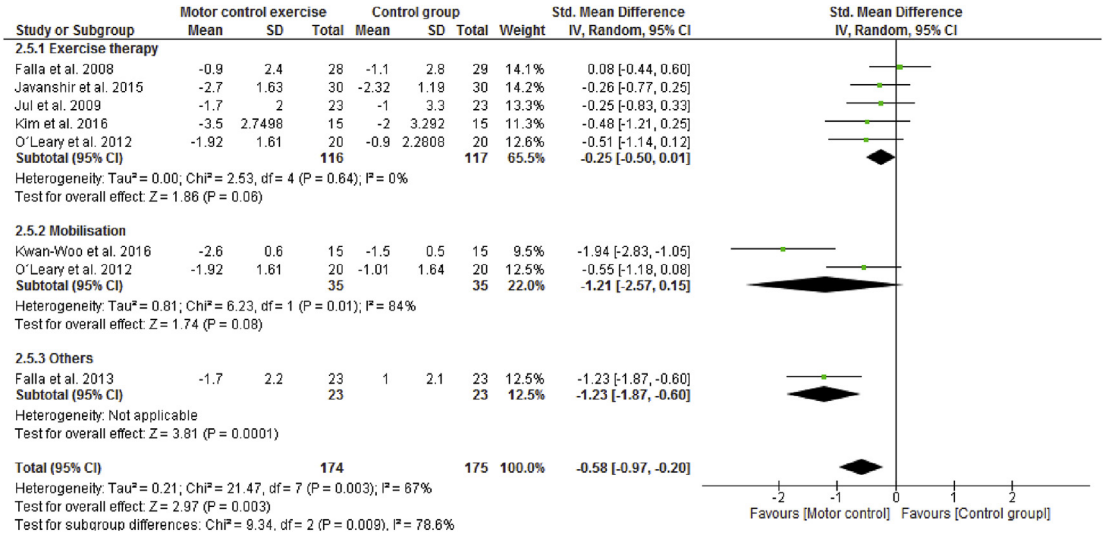

Fig. 2. Effect on pain short-to medium-term (SDM).

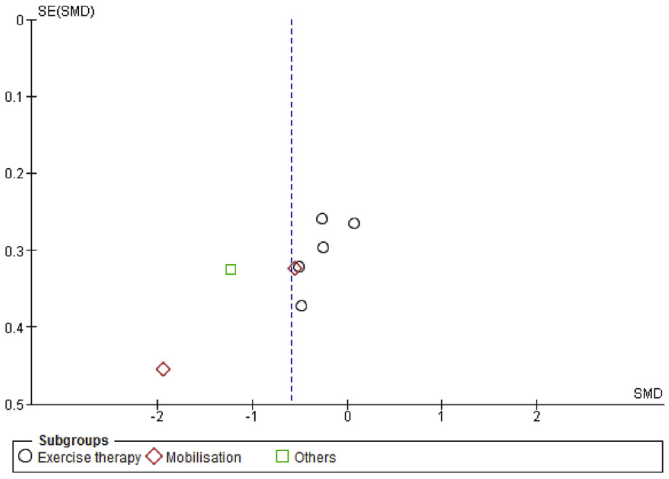

Fig. 3. Funnel plot showing effect on pain short-to medium-term (SMD).

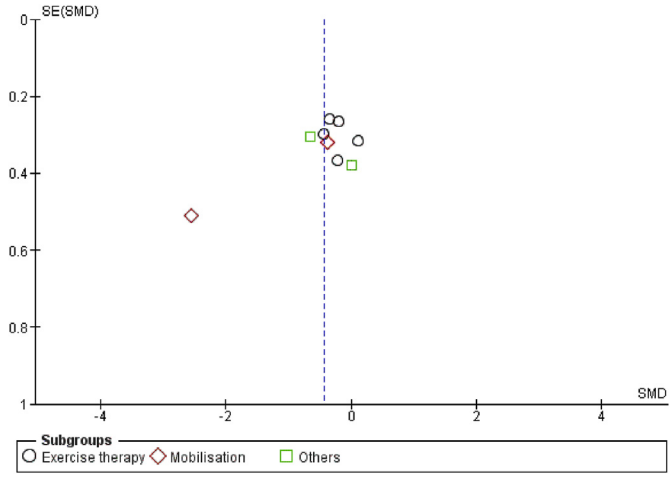

Fig. 5. Funnel plot showing effect on disability short-to medium-term (SMD).

should depend on the extent of the pain or the disability (O'Leary et al., 2009). Recent studies refer to the importance of a good initial assessment of motor tasks to be able to conduct a treatment tailored to those deficits, resulting in a more effective treatment (Falla et al., 2012; Jull et al., 2008). This could be the subject of future studies.

4.1. Strengths and limitations

One of the strengths of this review is that only RCTs were included. Furthermore, the studies included had similar interventions and did not include any co-interventions which could influence the results. To minimise the risk of selection bias, the studies were reviewed independently by two different researchers. Where the merits of an article were a subject of debate, the inclusion or exclusion of the article was discussed between the researchers.

Several limitations can be considered when interpreting the results found in this review. Firstly, selection bias – only articles published in English or Spanish were reviewed and no research of grey literature was done; therefore, it is likely that not all the studies relevant to the discussion were analysed. Secondly, only a few studies were found that met the criteria for this meta-analysis. Thus, there was insufficient data to enable a viable analysis of outcomes regarding disability in the immediate to short-term. Moreover, the analysis in terms of pain outcomes over the immediate to short-term was based on limited data points. Lastly, the heterogeneity was null in the statistical analysis of pain outcomes, but high or moderate for the disability analysis. It is important to consider the influence the study conducted by Kwan-Woo et al. (Kwan-Koo and Kim, 2016) has in the disability analysis. If the results had been analysed excluding that study, the heterogeneity would have been null, and therefore the analysis would have shown a low publication bias.

5. Conclusions

Based on the results of this meta-analysis we can conclude that an intervention based on MC exercises (using CCF) when compared with other treatments (strengthening and endurance exercises tailoring cervical flexion, mobilizations or other treatments – proprioceptive exercises or 'wait and see') shows statistically significant results regarding diminution of pain (VAS or NRS) and disability (NDI) in a population with NSCNP. If we analyse each subgroup separately, the meta-analysis will reveal significant differences in the effectiveness of MC compared with the "other treatment" group to reduce pain.

No systematic reviews that analysed the effect of MC interventions in isolation were found. Nor were meta-analysis that compared MC with other treatment techniques.

The evidence remains ambiguous regarding this subject. Therefore, more high-quality studies that assess the effect of MC exercises versus

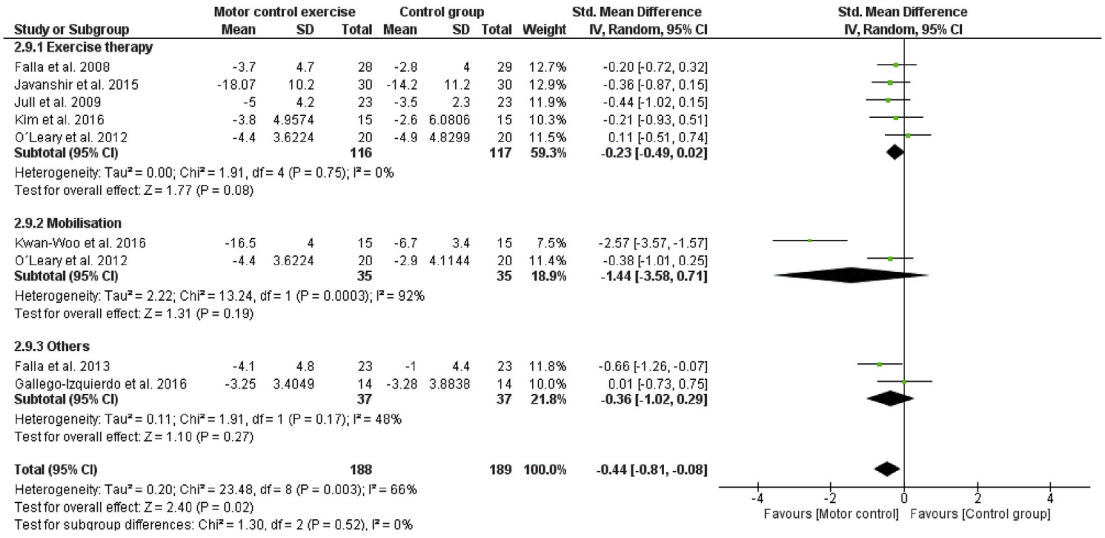

Fig. 4. Effect on disability short-to medium-term (SMD).

other treatment techniques are necessary.

Conflict of interests

Not applicable.

Ethical approval

Not applicable.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sector.

Acknowledgements

This research was supported by the University of Alcala. We thank our colleagues from the University of Alcala who provided insight and expertise that greatly assisted the research.

We thank Gustavo Plaza-Manzano PT, PhD for his guidance throughout the research, Marcos Jose Navarro-Santana PT for his assistance with methodology and John Boothby for his help with the translation into English of this manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2019.04.010.

References

Amiri, S., Mohseni Bandpei, M.A., Javanshir, K., Rezasoltani, A., Biglarian, A., 2007. The effect of different exercise programs on size and function of deep cervical flexor muscles in patients with chronic nonspecific neck pain. Am. J. Phys. Med. Rehabil. 96 (8), 582–588.

Austin, T.M., Richter, R.R., Sebelski, C.A., 2014. Introduction to the GRADE approach for guideline development: considerations for physical therapist practice. Phys. Ther. 94 (11), 1652–1659.

Axen, K., Haas, F., Schicchi, J., Merrick, J., 1992. Progressive resistance neck exercises using a compressible ball coupled with an air pressure gauge. J. Orthop. Sport. Phys. Ther. 16 (6), 275–280.

Blanpied, P.R., Gross, A.R., Elliott, J.M., Devaney, L.L., Clewley, D., Walton, D.M., et al., 2017. Neck pain: revision 2017. J. Orthop. Sport. Phys. Ther. 47 (7), A1–A83.

Boudreau, S.A., Farina, D., Falla, D., 2010. The role of motor learning and neuroplasticity in designing rehabilitation approaches for musculoskeletal pain disorders. Man. Ther. 15 (5), 410–414.

Brage, K., Ris, I., Falla, D., Søgaard, K., Juul-Kristensen, B., 2015. Pain education combined with neck- and aerobic training is more effective at relieving chronic neck pain than pain education alone–A preliminary randomized controlled trial. Man. Ther. 20 (5), 686–693.

Cerezo-Téllez, E., Torres-Lacomba, M., Mayoral-del Moral, O., Sánchez-Sánchez, B., Dommerholt, J., Gutiérrez-Ortega, C., 2016. Prevalence of myofascial pain syndrome in chronic non-specific neck pain: a population-based cross-sectional descriptive study. Pain Med. 17 (12), 2369–2377.

Childs, J.D., Clelandt, J.A., Elliot, J.M., Teyhen, D.S., Wainner, R.S., Whitmam, J.M., et al., 2008. Neck pain: clinical practice guidelines linked to the international classification of functioning, disability, and health from the orthopaedic section of the American physical therapy association. J. Orthop. Sport. Phys. Ther. 838 (9), A34.

Falla, D., Farina, D., 2008. Neuromuscular adaptation in experimental and clinical neck pain. J. Electromyogr. Kinesiol. 18 (2), 255–261.

Falla, Deborah, Jull, Gwendolen, Hodges, Paul, 2008. Training the cervical muscles with prescribed motor tasks does not change muscle activation during a functional activity. Man. Ther. 13 (6), 507–512.

Falla, D., O'Leary, S., Farina, D., Jull, G., 2012. The change in deep cervical flexor activity after training is associated with the degree of pain reduction in patients with chronic neck pain. Clin. J. Pain 28 (7), 628–634.

Falla, D., Lindstrøm, R., Rechter, L., Boudreau, S., Petzke, F., 2013. Effectiveness of an 8-week exercise programme on pain and specificity of neck muscle activity in patients with chronic neck pain: a randomized controlled study. Eur. J. Pain 17 (10), 1517–1528.

Farooq, M.N., Mohseni-Bandpei, M.A., Gilani, S.A., Ashfaq, M., Mahmood, Q., 2017. The effects of neck mobilization in patients with chronic neck pain: a randomized controlled trial. J. Bodyw. Mov. Ther. 22 (1), 24–31.

Ferguson, C.J., 2009. An effect size primer. Prof. Psychol. Res. Pract. 40 (5), 532–538.

Fernández-de-las-Peñas, C., Hernández-Barrera, V., Alonso-Blanco, C., Palacios-Ceña, D., Carrasco-Garrido, P., Jiménez-Sánchez, S., et al., 2011. Prevalence of neck and low back pain in community-dwelling adults in Spain: a population-based national study. Spine 36 (3), E213–E219.

Fredin, K., Håvard, 2017. Manual therapy, exercise therapy or combined treatment in the management of adult neck pain – a systematic review and meta-analysis. Musculoskelet Sci. Pract. 31, 62–71.

Furlan, A.D., Malmivaara, A., Chou, R., Maher, C.G., Deyo, R.A., Schoene, M., et al., 2015. Updated method guideline for systematic reviews in the Cochrane back and neck group. Spine 40 (21), 1660–1673.

Gallego-Izquierdo, T., Pecos-Martin, D., Lluch-Girbés, E., Plaza-Manzano, G., Rodríguez Caldentey, R., Mayor Melús, R., et al., 2016. Comparison of cranio-cervical flexion training versus cervical proprioception training in patients with chronic neck pain: a randomized controlled clinical trial. J. Rehabil. Med. 48 (1), 48–55.

Geneen, L.J., Moore, R.A., Clarke, C., Martin, D., Colvin, L.A., Smith, B.H., 2017. Physical activity and exercise for chronic pain in adults: an overview of Cochrane reviews. Cochrane Database Syst. Rev. 4, CD011279.

Gizzi, L., Muceli, S., Petzke, F., Falla, D., 2015. Experimental muscle pain impairs the synergistic modular control of neck muscles. PLoS One 10 (9), 1–19.

Gross, A.R., Paquin, J.P., Dupont, G., Blanchette, S., Lalonde, P., Cristie, T., et al., 2016. Exercises for mechanical neck disorders: a Cochrane review update. Man. Ther. 24, 25–45.

Haldeman, S., Carroll, L., Cassidy, J., Schubert, J., Nygren, Å., 2008. The bone and joint decade 2000–2010 task force on neck pain and its associated disorders. Eur. Spine J. 17 (S1), 5–7.

Hidalgo, B., Hall, T., Bossert, J., Dugeny, A., Cagnie, B., Pitance, L., 2017. The efficacy of manual therapy and exercise for treating non-specific neck pain: a systematic review. J. Back Musculoskelet. Rehabil. 30 (6), 1149–1169.

Higgins, J.P.T., Green, S., 2011. Cochrane Handbook for Systematic Reviews of Interventions. [updated March 2011] The Cochrane Collaboration Available from: www.cochrane-handbook.org, Version 5.1.0.

Higgins, J.P., Thompson, S.G., Deeks, J.J., Altman, D.G., 2003. Measuring inconsistency in meta-analyses. BMJ 327 (7414), 557–560.

Hoy, D.G., Protani, M., De, R., Buchbinder, R., 2010. The epidemiology of neck pain. Best Pract. Res. Clin. Rheumatol. 24 (6), 783–792.

Javanshir, K., Amiri, M., Mohseni Bandpei, M.A., De las, Penas, Fernandez, Cesar, Rezasoltani, A., 2015. The effect of different exercise programs on cervical flexor muscles dimensions in patients with chronic neck pain. J. Back Musculoskelet. Rehabil. 28 (4), 833–840.

Jensen, M.P., Turner, J.A., Romano, J.M., Fisher, L.D., 1999. Comparative reliability and validity of chronic pain intensity measures. Pain 83 (2), 157–162.

Jull, G.A., Falla, D.L., Treleaven, J.M., Sterling, M.M., O'Leary, S.P., 2004. A therapeutic exercise approach for cervical disorders. In: Jull, G., Boyling, J. (Eds.), Grive's Modern Manual Therapy. Churchill Livingstone-Elsevier Science, Edinburg, UK, pp. 451–470.

Jull, G.A., Sterling, M., Falla, D., Treleaven, J., O'Leary, S., 2008. Whiplash, Headache, and Neck Pain: Research-Based Directions for Physical Therapies, 1 ed. Churchill Livingstone: Elsevier Limited, Edinburgh.

Jull, G.A., Falla, D., Vicenzino, B., Hodges, P.W., 2009. The effect of therapeutic exercise on activation of the deep cervical flexor muscles in people with chronic neck pain. Man. Ther. 14 (6), 696–701.

Kim, J.Y., Kwag, K.I., 2016. Clinical effects of deep cervical flexor muscle activation in patients with chronic neck pain. J. Phys. Ther. Sci. 28 (1), 269–273.

Knop, C., Oeser, M., Bastian, L., Lange, U., Zdichavsky, M., Blauth, M., 2001. Development and validation of the visual analogue scale (VAS) spine score. Unfallchirurg 104 (6), 488–497.

Kwan-Koo, L., Kim, W., 2016. Effect of thoracic manipulation and deep craniocervical flexor training on pain, mobility, strength, and disability of the neck of patients with chronic nonspecific neck pain: a randomized clinical trial. J. Phys. Ther. Sci. 28 (1), 175–180.

Lluch, E., Schomacher, J., Gizzi, L., Petzke, F., Seegar, D., Falla, D., 2013. Immediate effects of active cranio-cervical flexion exercise versus passive mobilisation of the upper cervical spine on pain and performance on the cranio-cervical flexion test. Man. Ther. 19 (1), 25–31.

McArdle, W.D., Katch, F.I., Katch, V.L., 2010. Exercise Physiology, 7[a] ed. Wolters Kluwer Lippincott Williams & Wilkins, Philadelphia, Pa.

O'Leary, S., Falla, D., Elliott, J.M., Jull, G., 2009. Muscle dysfunction in cervical spine pain: implications for assessment and management. J. Orthop. Sport. Phys. Ther. 39 (5), 324–333.

O'Leary, S., Jull, G.A., Kim, M., Uthaikhup, S., Vicenzino, B., 2012. Training mode–dependent changes in motor performance in neck pain. Arch. Phys. Med. 93 (7), 1225–1233.

O'Leary, S., Falla, D., Hodges, P.W., Jull, G., Vicenzino, B., 2007. Specific therapeutic exercise of the neck induces immediate local hypoalgesia. J. Pain 8 (11), 832–839.

Revel, M., Andre-Deshays, C., Minguet, M., 1991. Cervicocephalic kinesthetic sensibility in patients with cervical pain. Arch. Phys. Med. 72 (5), 288–291.

Revel, M., Minguet, M., Gregoy, P., Vaillant, J., Manuel, J.L., 1994. Changes in cervicocephalic kinesthesia after a proprioceptive rehabilitation program in patients with neck pain: a randomized controlled study. Arch. Phys. Med. 75 (8), 895–899.

Ryan, R., Hill, S., 2016. How to GRADE the Quality of the Evidence Version 3.0. Cochrane Consumers and Communication Group Available from: http://cccrg.cochrane.org/author-resources.

Schomacher, J., Falla, D., 2013. Function and structure of the deep cervical extensor muscles in patients with neck pain. Man. Ther. 18 (5), 360–366.

Schunemann, H.J., Oxman, A.D., Brozek, J., Glasziou, P., Bossuyt, P., Chang, S., et al., 2008. GRADE: assessing the quality of evidence for diagnostic recommendations. Evid. Based Med. 13, 162–163.

UrrútiaG, Bonfill X., 2010. Declaración PRISMA: una propuesta para mejorar la publicación de revisiones sistemáticas y metaanálisis. Med. Clin (Barc). 135 (11), 507–511.

Vernon, H., Mior, S., 1991. The Neck Disability Index: a study of reliability and validity. J. Manip. Phys. Ther. 14 (7), 409–415.