LITERATURE REVIEWS

Individuals With Chronic Neck Pain Have Lower Neck Strength Than Healthy Controls: A Systematic Review With Meta-Analysis

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ABSTRACT

Objective: The aim is to verify whether there is difference in neck strength between healthy individuals and individuals with chronic neck pain.

Methods: The PubMed, Embase, and Scopus databases were searched. Two independent reviewers selected relevant full articles comparing neck strength between healthy individuals and individuals with chronic neck pain. Two independent reviewers extracted the data from the full articles selected. A meta-analysis was used to assess standardized mean differences in neck strength based on a random-effects model (Prospero number CRD42017081502).

Results: The search returned 3554 results; 15 articles were included. The chronic neck pain group showed lower neck strength compared with healthy individuals. The standardized mean difference was -0.90 (95% confidence interval [CI] = -1.13 to -0.67) for flexion, -0.79 (95% CI = -0.99 to -0.60) for extension, -0.74 (95% CI = -1.03 to -0.45) for right lateral flexion, and -0.75 (95% CI = -1.04 to -0.46) for left lateral flexion.

Conclusion: Based on this meta-analysis with a 3a level of evidence, individuals with chronic neck pain have lower neck strength for flexion, extension, and the lateral flexion of the neck than healthy controls. (J Manipulative Physiol Ther 2019;42:608-622)

Key Indexing Terms: *Neck Pain; Muscle Strength; Kinetics; Meta-Analysis*

INTRODUCTION

Several functional changes in the musculoskeletal tissue can be identified as causes or consequences of neck pain.[1] Authors have suggested that there is a decrease in cervical spine range of motion on all planes of movement in individuals with chronic neck pain compared with healthy control participants.[2] Regarding neck muscles' morphology, there is some evidence that morphological changes occur in the neck musculature in individuals with chronic neck pain, such as a reduction of the cross-sectional area in most of the neck's muscles.[3] In addition to these morphological changes, decreases in the electromyographic activity of the deep neck flexors during the craniocervical flexion test,[4] deficits in the neck joint position sense,[5] postural control, and gait[1] have also been associated with neck pain.

Associated with these functional and morphological changes in individuals with neck pain, it is possible that neck strength decreases in individuals with neck pain. Even though there are already suggestions that there is an improvement in the strength and resistance of the neck musculature after an intervention with neck exercises in individuals with neck pain,[6-8] it remains unclear whether this improvement in strength and resistance can be effectively relevant for clinical practice and neck function.

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This uncertainty exists because some studies have shown a decrease in the neck strength of individuals with neck pain compared to healthy individuals,[9-11] whereas other studies do not show these reductions.[12-14] With this in mind, there is a doubt if there are significant changes in the neck strength of individuals with neck pain.

In addition to identifying whether there is a difference in neck strength in individuals with neck pain compared to those without pain, it is also important to quantify this possible difference and promote better interventions to increase neck strength in individuals with neck pain because neck strength and resistance may be associated with improvement of pain and neck disability.[6-8] The aim of this systematic review was to verify if there is a difference in neck strength between healthy individuals and individuals with chronic neck pain and to quantify this difference. We hypothesize that individuals with neck pain have lower neck strength than healthy controls.

Methods

Protocol and Registry

This study is a systematic review; it was previously registered in Prospero under protocol number CRD42017081502. We also followed the Meta-analyses Of Observational Studies in Epidemiology recommendations for systematic reviews and meta-analyses of observational studies[15] and the *Cochrane Handbook for Systematic Reviews* (hereafter, *Cochrane Handbook*) recommendations.[16]

Eligibility Criteria

Articles included for review all compare neck strength or torque between healthy individuals and individuals with chronic neck pain. Articles were included regarding the following patient, exposure, outcomes, and study type criteria[15]:

- Population: Individuals with nontraumatic chronic neck pain with no age or sex restrictions; moreover, the population should not belong to any specific population group with greater chances for neck pain (eg, military pilots or high-performance athletes);
- Exposure: People who have had their neck strength or torque assessed with any instruments, such as dynamometric instruments (isokinetics, load cells, handheld dynamometers, and multi-cervical units, among others) that assess isometric, isokinetic, or dynamic neck strength or torque;
- Outcome: Neck strength or torque;
- Study type: Observational studies comparing healthy individuals and individuals with neck pain.

Only full articles published in English, Portuguese, or Spanish were included in the study. Articles that evaluated neck strength or torque with biomechanical models or cadaveric models were excluded from this review. Further, studies that did not present an abstract in the searched databases, or for which it was not possible to find the full article text even after direct contact with the author, were also excluded.

Methodological quality questions
1. Was the case definition adequate? (selection bias)
2. Was the control definition adequate? (selection bias)
3. Was there an adequate description of the inclusion and exclusion criteria? (selection bias)
4. Was the measurement procedure description adequate? (information bias)
5. Was a reproducible test used? (information bias)
6. Was the outcome assessment blinded to the exposure status? (information bias)
7. Were the possible intervening variables presented? (information bias)
8. Was a sample size estimation conducted in order to calculate the minimum number of participants? (sampling bias)

Fig 1. *Assessment of methodological quality.*

Information Sources

The search was performed in a systematic way according to the recommendations of the *Cochrane Handbook*.[16] We searched the PubMed, Embase, and Scopus databases and conducted a manual search of the references lists from retrieved articles to locate additional relevant publications.

Search Strategy

The search strategy was carried out respecting the structured vocabularies according to each of the databases and using synonyms during October 2017. These words were derived from the patient, exposure, outcomes, and study type research question. The search strategies for each database can be viewed in Supplementary Material A.

Study Selection

Two independent researchers (I.F.M., E.S.W.N.) selected the potentially relevant studies by screening the titles and abstracts and, when these were insufficient for selection purposes, by reading the full article. After selecting and reading the studies, discordant cases were resolved by consensus or by a third researcher (J.F.L.).

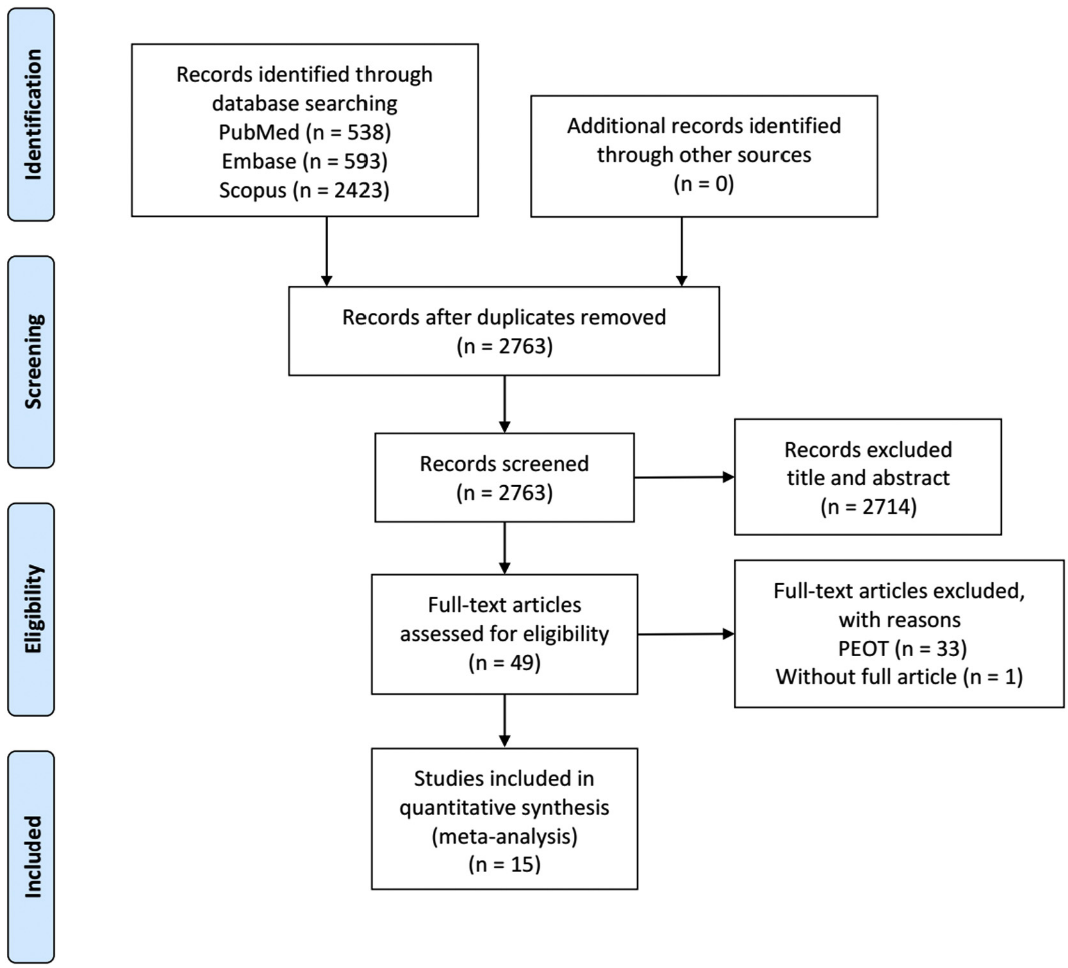

Fig 2. *Study selection flow diagram.* PEOT, *patient, exposure, outcomes, and study type.*

Data Extraction

The data extracted from the studies consisted of general study information, characteristics of the neck pain sample, characteristics of the control sample, characteristics of the evaluation process, results, and authors' conclusions. After 2 researchers (I.F.M., G.A.B.) completed their extractions independently, they compared information to identify possible extraction errors. Discordant cases were solved by consensus or by a third evaluator (J.F.L.).

Outcomes

The primary outcomes of this study deal with isometric, isokinetic, or dynamic neck strength or moment in any plane of motion.

Assessment of Methodological Quality

Two independent researchers (I.F.M., W.D.) evaluated the individual studies' methodological quality. Based on the assumption that it is recommended that researchers customize tools for the evaluation of methodological quality to focus on the context of the study of interest,[16,17] a checklist based on the Newcastle-Ottawa scale[18] and following the recommendations of the *Cochrane Handbook*[16] was used.

For the methodological quality assessment, the following criteria were used: selection bias, performance bias, detection bias, and sampling bias (Fig 1). The 8 items of this tool were categorized as low risk of bias or high risk of bias. Question 1 is associated with the description of the neck pain group in duration of pain and assessment scales used. Question 2 described the control group as being healthy and pain free and was related to the assessment scales used. Question 3 related to the inclusion and exclusion criteria and whether they were adequately described. Question 4 asked if the neck strength assessment was described properly, if the participants were in a proper position during the evaluation, and if the assessment was equal in both groups. Question 5 addressed whether the values of the

Table 1. *Characteristics of Included Studies (Descending Chronological Order of Publication Date)*

Author/Year	Neck Pain Group	Healthy Control Group	Measurement Instrument	Results	Authors' Conclusion
Lopez-de-Uralde-Villanueva et al 2017[27]	Chronic neck pain N: 44 Age: 40.48 ± 13.97 y Height: 165 ± 9 cm Weight: 66.59 ± 12.71 kg VAS: 3.25 ± 2.08 cm NDI: 12.48 ± 6.54	Asymptomatic N: 31 Age: 39.32 ± 13.85 y Height: 169 ± 9 cm Weight: 66.35 ± 14.32 kg VAS: 0.43 ± 0.84 cm NDI: 1.68 ± 1.37	Handheld dynamometer	Flexion NP: 6.85 ± 3.34 kg; HC: 10.25 ± 3.7 kg Extension NP: 9.04 ± 3.74 kg; HC: 13.86 ± 4.43 kg Lateral flexion (average of left and right) NP: 6.44 ± 2.64 kg; HC: 9.7 ± 3.53 kg	Only the chronic nonspecific neck pain group with moderate to severe disability showed cervical motor function impairment and respiratory muscle weakness, compared with the asymptomatic group.
Dimitriadis et al 2013[9]	Chronic neck pain N: 45 (32 F, 13 M) Age: 35.9 ± 14.5 y Height: 165.8 ± 9.2 cm Weight: 71.6 ± 16 kg BMI: 25.9 ± 4.5 NDI: 10.6 ± 5.2 Current pain: 19.3 ± 19.1 mm Usual pain: 45.5 ± 18.8 mm Physical activity BQHPA: 7.9 ± 1.3 Pain chronicity: 69.6 ± 57.6	Healthy controls N: 45 (32 F, 13 M) Age: 35.4 ± 14 y Height: 167.1 ± 8.7 cm Weight: 72.3 ± 15.2 kg BMI: 25.8 ± 4.4 Physical activity BQHPA: 7.6 ± 1.4	Custom-made isometric neck dynamometer	Flexion NP: 10.1 ± 5.8 kg; HC: 11.3 ± 5.8 kg Extension NP: 15.4 ± 8.6 kg; 18.4 ± 7 kg Flexion/extension ratio NP: 0.67 ± 0.15; HC: 0.62 ± 0.16	The patients with chronic neck pain were also found to have reduced strength of the neck extensors, reduced ROM in all movement planes, and reduced endurance of the deep neck flexors ($P < .05$).
Lindstroem et al 2012[26]	Chronic neck pain N: 34 (34 F) Age: 40.5 ± 7.9 y Height: 169.3 ± 6.4 cm Weight: 70 ± 15 kg NDI: 17.5 ± 6.5 VAS: 3.8 ± 2.2 VAS past 4 wk: 4.9 ± 1.8	No neck pain N: 14 (14 F) Age: 37.2 ± 7.6 y Height: 168.1 ± 5.9 cm Weight: 67.7 ± 13.2 kg	Multi-cervical unit (strain-gauge)	Flexion NP: 97.9 ± 31.9 N; HC: 118.3 ± 36.9 N Extension NP: 179.1 ± 48.6 N; HC: 218.5 ± 46.3 N Right lateral flexion NP: 119.3 ± 39 N; HC: 166.0 ± 54.5 N Left lateral flexion NP: 123.7 ± 36.4 N; HC: 164.9 ± 55.8 N Mean of movements NP: 130.0 ± 34.9 N; HC: 166.9 ± 43.8 N	The average MVC was significantly lower for the neck pain patients compared with the controls.
Shahidi et al 2012[11]	Chronic neck pain NPTF—grade I or II N: 19 (9 F, 10 M) Age: 34.9 ± 9.9 y Height: 173 ± 10 cm Weight: 72.13 ± 21.37 kg NDI: 14.4 ± 7.3	Volunteers without neck pain N: 20 (10 F, 10 M) Age: 34.0 ± 10.4 y Height: 176 ± 9 cm Weight: 65.61 ± 20.85 kg NDI: 0.6 ± 1.2	Handheld dynamometer (FPIX 100-kg load cell, Wagner Instruments, Greenwich, Connecticut)	Flexion NP: 10.6 ± 1.1 kgF; HC: 10.3 ± 0.9 kgF Right lateral flexion NP: 14.7 ± 0.9 kgF; HC: 17.5 ± 1.3 kgF Left lateral flexion NP: 13.3 ± 1.0 kgF; HC: 16.8 ± 1.4 kgF Extension NP 15.9 ± 1.3 kgF; HC: 19.8 ± 1.6 kgF	Observations confirmed the presence of strength deficits for the cervical extensors ($P = .036$) and lateral L side bend ($P = .038$), but not the cervical flexors ($P = .737$) or R side bend ($P = .106$) in a larger sample of patients with chronic neck pain than examined in previous studies.

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Table I. *(continued)*

Author/Year	Neck Pain Group	Healthy Control Group	Measurement Instrument	Results	Authors' Conclusion
Muceli et al 2011[29]	Chronic neck pain N: 9 (9 F) Age: 40.4 ± 3.5 y Height: 171.1 ± 10.6 cm Weight: 73.4 ± 10.6 kg NDI: 14.8 ± 8.6 VAS: 4.4 ± 1.7	Healthy volunteers N: 9 (9 F) Age: 38.9 ± 10.5 y Height: 165.4 ± 8.2 cm Weight: 63.6 ± 10.7 kg	Multi-cervical unit (strain-gauge) (Aalborg University, Aalborg, Denmark)	Flexion NP: 46.3 ± 37 N; HC: 109.5 ± 31.4 N	The patient group exerted lower maximal cervical flexion force compared to the controls (exp 1: patients 46.3 ± 37.0 N, controls 109.5 ± 31.4 N, $P < .05$).
Falla et al 2010[30]	Chronic neck pain N: 9 (9 F) Age: 40.4 ± 3.5 y Height: 170.8 ± 5.5 cm Weight: 73.7 ± 10.1 kg NDI: 16.5 ± 8.8 VAS: 4.3 ± 1.5	Volunteers without neck or shoulder pain N: 9 (9 F) Age: 35.4 ± 7.5 y Height: 164.8 ± 7.7 cm Weight: 65 ± 12.3 kg	Multi-cervical unit (strain-gauge) (Aalborg University, Aalborg, Denmark)	Flexion NP: 102.3 ± 39.7 N; HC: 151.8 ± 37.6 N Extension NP: 193.7 ± 77.2 N; HC: 243.4 ± 56.6 N Right lateral flexion NP: 129.6 ± 47.1 N; HC: 168.8 ± 58.5 N Left lateral flexion NP: 125.2 ± 46.5 N; HC: 175.1 ± 48.5 N	The patient group exerted lower force across all directions compared to the control participants ($F = 4.7$, $P = .045$).
Rezasoltani et al 2010[33]	Chronic neck pain N: 10 (10 F) Age: 37.2 ± 6.0 y Height: 159.1 ± 4.9 cm Weight: 64.2 ± 4.8 kg BMI: 25.4 ± 2.0	Healthy volunteers N: 10 (10 F) Age: 32.6 ± 6.4 y Height: 161.0 ± 5.2 cm Weight: 57.1 ± 5.0 kg BMI 22.0 ± 1.9	Load cell against occipital bone and forehead	Flexion NP: 46.2 ± 7.2 N; HC: 62.2 ± 16.1 N Extension NP: 73.4 ± 9.8 N; HC: 127.2 ± 23.2 N Flexion/extension ratio NP: 0.63 ± 0.11; HC: 0.5 ± 0.15 Flexion/weight NP: 0.7 ± 0.1; HC: 1.1 ± 0.2 Extension/weight NP: 1.2 ± 0.2; HC: 2.2 ± 0.4	Isometric strength of the neck extensor and flexor muscles were significantly lower in patients than in the controls ($P < .001$, $P < .05$, respectively).
Scheuer and Friedrich 2010[25]	Chronic neck pain (at least for 12 wk) N: 53 (39 F, 14 M) Age: 49.72 ± 10.74 y Height: 168.13 ± 8.76 cm Weight: 71.32 ± 14.39 kg	Volunteers without spinal pain in the last 12 mo N: 42 (30 F, 12 M) Age: 48.71 ± 12.02 y Height: 168.24 ± 8.08 cm Weight: 71.31 ± 12.36 kg	Dynamometer (The Back Check 607)	Flexion NP: 6.5 ± 3.3 kg; HC: 10.3 ± 5.2 kg Extension NP: 10.4 ± 5.0 kg; HC: 14.8 ± 6.2 kg Right lateral flexion NP: 8.5 ± 4.2 kg; HC: 11.7 ± 5.5 kg Left lateral flexion NP: 7.8 ± 3.8 kg; HC: 10.6 ± 5.6 kg	Patients with chronic neck pain showed strength deficits in all measured regions.
Cagnie et al 2007[32]	Chronic neck pain N: 30 F Age: 32.9 y Height: 166.3 cm Weight: 62.7 kg	Volunteers without pain for 1 year and neither strain necks or shoulders in the past 6 mo N: 96 (48 M, 48 F) Age: 20-59 y Height: 179 ± 8 cm male 167 ± 7 cm female Weight: 79.3 ± 8.2 kg M 63.8 ± 10.4 kg F	System 3 isokinetic dynamometer	Flexion NP: 16.7 ± 3.3 Nm; HC: 16.6 ± 3.6 Nm Extension NP: 22.3 ± 5.6 Nm; HC: 26.5 ± 6.2 Nm Extension/flexion ratio NP: 1.35 ± 0.29; HC: 1.59 ± 0.38	Women with chronic neck pain have lower neck muscle strength in extension than those in the healthy female group.

		BMI: 24.7 ± 2.5 M 23.0 ± 3.1 F			
Ylinen et al 2004 [31]	Chronic neck pain N: 21 F Age: 44 ± 6 y Height: 166 ± 6 cm Weight: 68 ± 10 kg BMI: 25 ± 3 NDI: 13 ± 5 VAS: 54 ± 22 mm	Volunteers without neck pain in the last 6 mo N: 21 F Age: 44 ± 8 y Height: 165 ± 5 cm Weight: 69 ± 13 kg BMI: 25 ± 4	Multi-cervical unit (Kuntovaline Inc, Helsinki, Finland)	Flexion NP: 53.8 ± 18.3) N; HC: 75.7 ± 23.5 N Extension NP: 132.1 ± 38.5 N; HC: 187.1 ± 39.2 N Right rotation NP: 5.8 ± 1.2 Nm; HC: 8.0 ± 2.4 Nm Right rotation NP: 6.1 ± 1.6 Nm; HC: 7.4 ± 2.3 Nm	Neck strength in all directions was significantly lower in patients with neck pain than in controls.
Chiu and Lo 2002 [24]	Mechanical neck pain N: 20 (12 F, 9 M) Age: 27 ± 9.5 y	Healthy volunteers without neck pain in the last year N: 25 (10 F, 15 M) Age: 22.1 ± 3.9 y	Multi-cervical unit (Hanoun Medical Inc, Ontario, Canada).	Flexion NP: 56.7 ± 24.5 N; HC:74.5 ± 19.6 N Extension NP: 67.4 ± 27.3 N; HC: 93.3 ± 34 N Right lateral flexion NP: 52.4 ± 21.2 N; HC: 65.7 ± 19.2 N Left lateral flexion NP: 50.6 ± 22.9 N; HC: 66.9 ± 16.4 N Protraction NP: 52.9 ± 26.1 N; HC: 74.8 ± 17.6 N Retraction NP: 51.7 ± 21.5 N; HC: 78.9 ± 21.5 N	There was a significant difference in the isometric neck muscle strength between the healthy and symptomatic groups.
Jordan et al 1997 [34]	Chronic neck pain N: 119 Pain (0-30): 13 ± 27 (median ± range)	Active volunteers without neck pain in the past 12 mo N: 80	Strain gauge dynamometer (Neck Exercise Unit, Follo Futura, Ås, Norway)	Flexion NP: 12.5 ± 6 Nm; HC: 32.6 ± 4 Nm Extension NP: 14.5 ± 5 Nm; HC: 56.1 ± 8 Nm	The main findings include a clinically important and statistically significant reduction in maximal isometric contraction values, particularly affecting the extensor muscles.
Barton and Hayes 1996 [36]	Chronic neck pain with headache N: 10 (7 F, 3 M) Age: 42.5 ± 12.2 y Height: 167.8 ± 9.2 cm Weight: 72.5 ± 12.5 kg	Healthy control participants N: 10 (7 F, 3 M) Age: 27.4 ± 7.9 y Height: 169.2 ± 8.5 cm Weight: 66.9 ± 8.9 kg	Shaevitz force transducer	Flexion NP: 22.4 ± 13.1 N; HC: 45.3 ± 17.6 N	All force values were significantly lower in the neck pain population compared with the controls.
Jordan and Mehlsen 1993 [35]	Chronic cervicobrachialgia N: 18 Age: 41 (28-55) y [a] Height: 169 (163-178)‡ cm Weight: 64 (5-76) [a] kg	Healthy volunteers N: 18 Age: 41 (28−55) [a] y Height: 171 (162−183)‡ cm Weight: 67 (55−80) [a] kg	Strain gauge dynamometer	Flexion NP: 8 (3.75) kp; HC: 11 (2.25) kp* Extension NP: 12 ± 5.75 kp; HC: 16 ± 5 kp* Flexion lateral NP: 8 ± 3.75 kp; HC: 11 ± 2.75 kp*	MVC was reduced in all directions in patients with CBS, and the reduction was more pronounced during dorsal flexion than during the other types of movement.

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Table I. *(continued)*

Author/Year	Neck Pain Group	Healthy Control Group	Measurement Instrument	Results	Authors' Conclusion
Silverman et al 1991[28]	Chronic neck pain N: 30 (20 F, 10 M) Age: 43 ± 12.1 y	No pain or injury in the neck region N: 30 (15 F, 15 M) Age: 32 ± 5.5 y	MicroFET handheld dynamometer that used 3 integrated strain gauges (Hoggan Health Industries Inc, Draper, Utah)	Flexion NP: 1.16 ± 0.49 N × kg^{-1}; HC: 1.71 ± 0.42 N × kg^{-1} Left rotation NP: 1.01 ± 0.52 N × kg^{-1}; HC: 1.47 ± 0.41 N × kg^{-1} Right rotation NP: 0.99 ± 0.46 N × kg^{-1}; HC: 1.43 ± 0.43 N × kg^{-1}	All measures were significantly different ($P < .05$) when comparing the neck pain group to the control group.

Data are mean ± SD unless otherwise indicated.
BMI, body mass index; *BQHPA*, Baecke questionnaire of habitual physical activity; *CBS*, cerviocobrachial syndrome; *F*, female; *HC*, health controls; *kgF*, kilograms force; *L*, left; *M*, male; *MVC*, maximum voluntary contraction; *N*, Newtons; *Nm*, Newton × meters; *NDI*, Neck Disability Index; *NP*, neck pain; *NPTF*, Neck Pain Task Force; *QTF*, Quebec Task Force; *R*, right; *ROM*, range of motion; *VAS*, visual analog scale; *WAD*, whiplash-associated disorder.
[a] Mean (min-max).

precision of the neck strength evaluation were presented, whether the precision values were evaluated during the study, or if the values were cited in the studies that conducted the precision evaluations. Question 6 asked if the neck strength assessors were blinded. Question 7 investigated if it is possible that intervening variables, such as each group's weight, height, age, or head circumference, were presented. Question 8 was concerned with whether a sample size estimation was performed in the study.

To define the methodological quality of the study, and consequently the risk of bias, a cutoff point equal to 6 or more points was arbitrarily adopted as the classifier for a low risk of bias. A study scoring below 6 points was considered to have a high risk of bias. No weights were applied among the criteria, and each item classified as low risk of bias received 1 point. Discordant cases were resolved by consensus or through a third-party evaluator (J.F.L.).

Data Synthesis and Meta-Analysis

A quantitative approach was used to analyze the data using neck strength or torque as a continuous outcome. Because there are several measures and instruments for strength and torque, the effect measure used was the standardized mean difference. The analysis was done with a 95% confidence interval (CI) using a random-effects model and considering the possibility of unexplained heterogeneity. Heterogeneity was evaluated via the inconsistency test (I^2). The percentage values in the inconsistency (I^2) are defined as "low" heterogeneity at around 25%, "medium" around 50%, and "high" at 75%.[19] The data for each study were analyzed using Review Manager 5.3 and plotted in a forest plot.

Heterogeneities above 50% were explained by sensitivity analysis. Sensitivity analysis was completed excluding outlier studies or studies that presented important clinical or methodological discrepancies from the others. For the outliers' evaluations, we performed an exploratory analysis on the effect measures of each included study using a box plot in SPSS 22.0 software (IBM Corp, Armonk, New York). Therefore, studies that were located 1.5 times the interquartile range of the nearest quartile were considered outliers.[20]

Additional Analyses

Additional analyses were completed only on studies that used strength measures force units (such as Newtons or kilograms converted to Newtons) to quantify the neck strength of individuals with chronic neck pain and healthy control participants. For this task, both meta-analyses and sensitivity analyses were performed in the same way described previously; however, we used the mean difference as a measurement effect of the mean difference. Thus, it was possible to quantitatively discern, in Newtons, the difference in neck strength between individuals with chronic neck pain and healthy control participants.

Results

Study Selection

Our systematic search yielded 3554 studies. After removing duplicate studies and reading all titles and abstracts, a total of 49 potential studies were read in their entirety; all were published in English. After reading the full articles, 29 studies were removed based on eligibility criteria (eg, congress abstract, letter to editor, sample with military pilots, individuals with whiplash-associated disorders, duplicated data, unhealthy participants in control group) and another study was removed because it was not possible to find its full-text version, even after contacting the authors. Three studies with some specific head movements (craniocervical flexion, dorsal head force, and sternocleidomastoid force)[12,21,22] were excluded from the meta-analysis owing to insufficient number of studies. Because only 1 longitudinal study was found, it was excluded from the meta-analysis.[23] In total, 15 studies were evaluated quantitatively (Fig 2). Furthermore, no study was included based on our manual searches.

Study Characteristics

Population. Of the 471 neck pain participants evaluated, 291 were identified by sex (80% female and 20% male). The average age of the participants ranged from 27 (9.5)[24] to 49.7 (10.7)[25] years, and the mean neck disability of the neck pain group ranged from 10.6 (5.2)[9] to 17.5 (6.5).[26]

In all studies, members of the control groups were classified as healthy, without neck pain, asymptomatic, or without neck pain for a certain period (3 months to 2 years). The average age of participants in the control groups ranged from 22.1 (3.9)[24] to 48.71 (12.02)[25] years. All studies that used the Neck Disability Index to classify the control group were classified as having no disability or values less than or equal to 4 on a scale of 0 to 50 points (Table 1). All studies included in quantitative analysis were aged-matched.

Measurements. Several instruments with several means of evaluations were used in these 15 studies. Three studies used a handheld dynamometer[11,27,28]; 5 used a multi-cervical unit, a commonly used instrument to assess neck strength[24,26,29-31]; and only 1 study used an isokinetic dynamometer from Biodex Corp[32] (Shirley, New York). The other studies used nonspecific devices with dynamometers[9,33-36] or other types of instruments.[25] Most of the instruments used underwent a validation process, either in the study itself or as cited in another study.

Outcomes. The evaluation was isometric in all 15 studies. The main neck strength outcome was measured in force followed by moment (Table 1). The isometric evaluation of the neck is greatly dependent on the position of the dynamometer on the participant's head. So, it was assumed that the dynamometer was positioned in the same position for both groups (neck pain and healthy) and in all articles. Most of the studies performed the evaluations in several planes of movement (flexion, extension, lateral flexion, rotation, head protraction, and retraction), and flexion-extension was performed in most studies. The main outcomes were found in Newtons, kilograms, Newton-meters, or normalized by weight. We also found studies that measured the ratio between flexion/extension and extension/flexion.[9,32,33]

Assessment of Methodological Quality

Of the 15 studies evaluated, 4 were considered to have a low risk of bias (Table 2). Most of them (73%) adequately described the neck pain group, and 100% adequately described the control group (items 1 and 2). The precision of the measurements was shown, referenced, or evaluated in the study itself in 73% of the studies (item 5). None of the studies had blinded the assessor, and the sample size estimation was provided in only 20% of the studies. A statistical analysis was made for the agreement between the researchers in the methodological quality analysis and for the final score of the study; the agreement was high ($\kappa = 0.92$, 95% CI, 0.77-1.0, $P < .05$).

Flexion

The flexion movement chronic neck pain group had lower neck strength than the control group, -1.03 (95% CI = -1.60 to -0.46; $I^2 = 93\%$) (Fig 3).

Extension

For extension, 12 of 15 studies were analyzed quantitatively. Significantly lower neck strength was found among the chronic neck pain group in comparison to the healthy control group, -1.57 (95% CI = -2.41 to -0.73; $I^2 = 96\%$) (Fig 4).

Lateral Flexion

Five studies evaluated the neck lateral flexion strength, which was found to be reduced in individuals with chronic neck pain compared with the healthy control group, -1.05 (95% CI = -1.62 to -0.48) and -1.17 (95% CI = -1.82 to -0.52) with $I^2 = 73\%$ and 79%, respectively (Figs 5 and 6).

Sensitivity Analysis

For the sensitivity analysis of individuals with chronic neck pain, 3 studies on the flexion and extension movement, and 1 study on right and left lateral flexion movements were not analyzed because they were statistically classified as outliers[11,33,34] (plus or minus 1.5 interquartile range), or as a result of methodological differences in measurements between the studies (extension movement assessed against gravity[11] and flexion assessed with an isokinetic dynamometer[32]).

All movements had an I^2 below 35%, allowing us to conclude these meta-analyses. Therefore, for the sensitivity

Table 2. *Individual Studies' Methodological Quality Assessments*

Study	Patient Group	Control Group	Selection Bias	Exposure	Test Precision	Blinded	Confounders	Power Analysis	Risk of Bias
Lopez-de-Uralde-Villanueva et al 2017[27]	L	L	L	L	L	H	L	L	Low
Dimitriadis et al 2013[9]	L	L	H	H	L	H	L	L	High
Lindstroem et al 2012[26]	L	L	L	L	H	H	L	H	High
Shahidi et al 2012[11]	L	L	L	L	L	H	L	H	Low
Muceli et al 2011[29]	L	L	L	L	H	H	L	H	High
Falla et al 2010[30]	L	L	L	L	H	H	L	H	High
Rezasoltani et al 2010[33]	H	L	L	L	L	H	L	H	High
Scheuer and Friedrich 2010[25]	L	L	L	H	L	H	L	H	High
Cagnie et al 2007[32]	H	L	L	L	L	H	L	H	High
Ylinen et al 2004[31]	H	L	L	L	L	H	L	H	High
Chiu and Lo 2002[24]	H	L	H	L	L	H	H	L	High
Jordan et al 1997[34]	L	L	L	L	L	H	L	H	Low
Barton and Hayes 1996[36]	L	L	L	L	L	H	L	H	Low
Jordan and Mehlsen 1993[35]	L	L	H	H	H	H	L	H	High
Silverman et al 1991[28]	L	L	L	L	L	H	H	H	High

H, high risk of bias; *L*, low risk of bias.

analysis, we found lower neck strength among individuals with chronic neck pain, varying from -0.90 (95% CI = -1.13 to -0.67) for flexion (Fig 2) and -0.79 (95% CI = -0.99 to -0.60) for extension (Fig 4) to -0.74 (95% CI = -1.03 to -0.45) for right lateral flexion and -0.75 (95% CI = -1.04 to -0.46) for left lateral flexion (Figs 3-6).

Additional Analysis

Considering the same sensitivity analysis for this additional analysis, we found a lower neck strength for individuals with chronic neck pain, varying from -27.17 N (95% CI = -34.04 to -20.30, I^2 = 45%) for flexion and -40.03 N (95% CI = -48.80 to -31.25, I^2 = 0%) for extension to -27.12 N (95% CI = -43.28 to -10.97, I^2 = 48%) for right lateral flexion and -25.52 N (95% CI = -38.27 to -12.77, I^2 = 27%) for left lateral flexion (Supplementary Material B).

Discussion

Chronic pain has serious effects on people's lives, reducing the quality of life, impairing performance in daily activities, causing psychological illness, and even impairing performance at work.[37] For this reason, it is crucial to identify the functional changes that chronic neck pain can cause and to develop better treatments and intervention actions. With this perspective in mind, the present study found with a 3a level of evidence,[38] despite the interference of methodological variability related to neck strength assessment, individuals with chronic neck pain have lower neck strength than healthy controls for flexion, extension, and lateral flexion.

In the quantitative analysis, both neck force and torque studies were included. To analyze mainly the studies with force measurement, we assumed that the assessments were equal for both groups. If the assessment had been different between groups, the force measurements may have been overestimated or underestimated.

Considering the main forces involved during the neck strength assessment, and considering the isometric assessment for the extension movement, for example (Fig 7), there must be an equality between the extensor moment (Me), produced by the neck extensor muscles, and the flexor moment, produced by the resistance of the instrument, for example, by a handheld dynamometer (*F*) and by the weight of the head (*W*). Subsequently, using Newton-Euler's[39] equations of motion, if the moment

Study or Subgroup	Neck Pain Mean	Neck Pain SD	Neck Pain Total	Health Control Mean	Health Control SD	Health Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.1.1 Flexion CNP								
BARTON and HAYES1996	22.4	13.1	10	45.3	17.6	10	6.0%	-1.41 [-2.42, -0.41]
CAGNIE, et al.2007	16.7	3.3	30	16.6	3.6	96	7.1%	0.03 [-0.38, 0.44]
CHIU and LO2002	56.7	24.5	20	74.5	19.6	25	6.8%	-0.80 [-1.41, -0.19]
DIMITRIADIS, et al.2013	10.1	5.8	45	11.3	5.8	45	7.1%	-0.21 [-0.62, 0.21]
FALLA, et al.2010	102.3	39.7	9	151.8	37.6	9	6.0%	-1.22 [-2.25, -0.19]
JORDAN and MEHLSEN1993	8	3.75	18	11	2.25	18	6.7%	-0.95 [-1.64, -0.26]
JORDAN, et al.1997	12.5	6	119	32.6	4	80	7.0%	-3.79 [-4.26, -3.31]
LINDSTROEM, et al.2012	97.9	31.9	34	118.3	36.9	14	6.8%	-0.60 [-1.24, 0.03]
LOPEZ-DE-URALDE-VILLANUEVA, et al.2017	6.85	3.34	44	10.25	3.7	31	7.0%	-0.96 [-1.45, -0.48]
MUCELI, et al.2011	46.3	37	9	109.5	31.4	9	5.7%	-1.75 [-2.88, -0.63]
REZASOLTANI, et al.2010	46.2	7.2	10	62.2	16.1	10	6.1%	-1.23 [-2.20, -0.25]
SCHEUER and FRIEDRICH2010	6.5	3.3	53	10.3	5.2	42	7.1%	-0.89 [-1.31, -0.46]
SHAHIDI, et al.2012	10.6	1.1	19	10.3	0.9	20	6.8%	0.29 [-0.34, 0.92]
SILVERMAN, et al.1991	1.16	0.49	30	1.71	0.42	30	6.9%	-1.19 [-1.74, -0.64]
YLINEN, et al.2004	53.8	18.3	21	75.7	23.5	21	6.8%	-1.02 [-1.67, -0.37]
Subtotal (95% CI)			**471**			**460**	**100.0%**	**-1.03 [-1.60, -0.46]**
Heterogeneity: Tau² = 1.14; Chi² = 194.23, df = 14 (P < 0.00001); I² = 93%								
Test for overall effect: Z = 3.56 (P = 0.0004)								
1.1.2 Flexion CNP Sensibility Analisys								
BARTON and HAYES1996	22.4	13.1	10	45.3	17.6	10	4.3%	-1.41 [-2.42, -0.41]
CAGNIE, et al.2007	16.7	3.3	30	16.6	3.6	96		Not estimable
CHIU and LO2002	56.7	24.5	20	74.5	19.6	25	9.0%	-0.80 [-1.41, -0.19]
DIMITRIADIS, et al.2013	10.1	5.8	45	11.3	5.8	45	14.0%	-0.21 [-0.62, 0.21]
FALLA, et al.2010	102.3	39.7	9	151.8	37.6	9	4.1%	-1.22 [-2.25, -0.19]
JORDAN and MEHLSEN1993	8	3.75	18	11	2.25	18	7.6%	-0.95 [-1.64, -0.26]
JORDAN, et al.1997	12.5	6	119	32.6	4	80		Not estimable
LINDSTROEM, et al.2012	97.9	31.9	34	118.3	36.9	14	8.6%	-0.60 [-1.24, 0.03]
LOPEZ-DE-URALDE-VILLANUEVA, et al.2017	6.85	3.34	44	10.25	3.7	31	11.9%	-0.96 [-1.45, -0.48]
MUCELI, et al.2011	46.3	37	9	109.5	31.4	9	3.5%	-1.75 [-2.88, -0.63]
REZASOLTANI, et al.2010	46.2	7.2	10	62.2	16.1	10	4.5%	-1.23 [-2.20, -0.25]
SCHEUER and FRIEDRICH2010	6.5	3.3	53	10.3	5.2	42	13.7%	-0.89 [-1.31, -0.46]
SHAHIDI, et al.2012	10.6	1.1	19	10.3	0.9	20		Not estimable
SILVERMAN, et al.1991	1.16	0.49	30	1.71	0.42	30	10.3%	-1.19 [-1.74, -0.64]
YLINEN, et al.2004	53.8	18.3	21	75.7	23.5	21	8.4%	-1.02 [-1.67, -0.37]
Subtotal (95% CI)			**303**			**264**	**100.0%**	**-0.90 [-1.13, -0.67]**
Heterogeneity: Tau² = 0.05; Chi² = 16.71, df = 11 (P = 0.12); I² = 34%								
Test for overall effect: Z = 7.72 (P < 0.00001)								

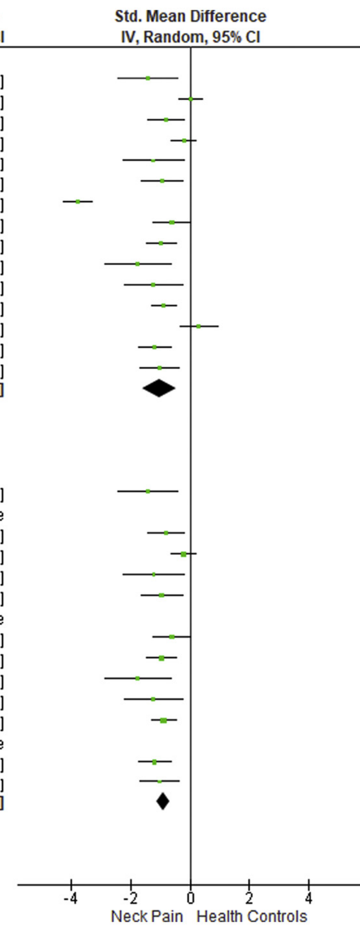

Fig 3. *Chronic neck pain group versus health control group: flexion.* CI, *confidence interval;* CNP, *chronic neck pain;* SD, *standard deviation.*

arm of the force *F* (dF) decreases as the dynamometer approaches the rotational axis, our equality between the moments will only be achieved if the value of the force *F* increases to maintain the isometry (because *W* is constant); consequently, we will acquire a greater measure of force than recorded by the dynamometer (Fig 7). Therefore, considering the additional analysis (Supplementary Material B), the results should be viewed with caution because, among the studies, they do not present a normalization of the position of the dynamometer on the head, making it difficult to quantify the force difference between them.

The greatest neck strength is shown in the extension movement. This greater strength can be attributed to the greater internal moment generated by the extensor muscles, resulting from a greater moment arm, in a neutral head position, and greater physiological cross-sectional area of the extensor compared with the flexor muscles.[40,41] Moreover, the greatest difference between the chronic neck pain and healthy control groups was found for flexion (-0.90 [95% CI = -1.13 to -0.67, I^2 = 34%]) and extension (-0.79 [95% CI = -0.99 to -0.60, I^2 = 14%]) movements. The reduced neck strength of the chronic neck pain group is similar for all movements; clinically, strength gains can improve the symptom pain[6-8] and, consequently, neck exercises may also improve the quality of life and disability level[8] of these individuals. In this way, rehabilitation professionals should be aware of the need to increase neck strength for all planes of movement of the neck because the reduction of neck strength is associated with individuals with chronic neck pain.

Several mechanisms may explain this reduction of neck strength for individuals with chronic neck pain compared to healthy control participants. The first mechanism can be explained with a behavioral analysis of pain. There is evidence that, because of the mechanisms of fear of movement (kinesiophobia), the presence of chronic neck pain may cause individuals to avoid daily activities, which may lead to a decrease in neck strength due to disuse of the neck musculature. Chronic pain could then lead to a vicious cycle where a catastrophizing pain would lead to kinesiophobia, hypervigilance of the region, disuse, and ultimately more pain and more chronicity.[42,43]

Another possible mechanism is due to morphological changes in which there is a reduction of the physiological cross-sectional area of the neck musculature in individuals

	Neck Pain			Health Control				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
1.2.1 Extension CNP								
CAGNIE, et al.2007	22.3	5.6	30	26.5	6.2	96	8.7%	-0.69 [-1.11, -0.27]
CHIU and LO2002	67.4	27.3	20	93.3	34	25	8.5%	-0.82 [-1.43, -0.20]
DIMITRIADIS, et al.2013	15.4	8.6	45	18.4	7	45	8.7%	-0.38 [-0.80, 0.04]
FALLA, et al.2010	193.7	77.2	9	243.4	56.6	9	7.9%	-0.70 [-1.66, 0.26]
JORDAN and MEHLSEN1993	12	5.75	18	16	5	18	8.4%	-0.73 [-1.40, -0.05]
JORDAN, et al.1997	14.5	5	119	56.1	8	80	8.3%	-6.50 [-7.21, -5.80]
LINDSTROEM, et al.2012	179.1	48.6	34	218.5	46.3	14	8.4%	0.81 [1.45, 0.16]
LOPEZ-DE-URALDE-VILLANUEVA, et al.2017	9.04	3.74	44	13.86	4.43	31	8.6%	-1.18 [-1.68, -0.68]
REZASOLTANI, et al.2010	73.4	9.8	10	127.2	23.2	10	7.2%	-2.89 [-4.22, -1.56]
SCHEUER and FRIEDRICH2010	10.4	5	53	14.8	6.2	42	8.7%	-0.78 [-1.21, -0.36]
SHAHIDI, et al.2012	15.9	1.3	19	19.3	1.6	20	8.2%	-2.28 [-3.10, -1.45]
YLINEN, et al.2004	132.1	38.5	21	187	39.2	21	8.4%	-1.39 [-2.07, -0.71]
Subtotal (95% CI)			**422**			**411**	**100.0%**	**-1.57 [-2.41, -0.73]**
Heterogeneity: Tau² = 2.06; Chi² = 260.74, df = 11 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 3.68 (P = 0.0002)								
1.2.2 Extension CNP Sensibility Analisys								
CAGNIE, et al.2007	22.3	5.6	30	26.5	6.2	96	17.0%	-0.69 [-1.11, -0.27]
CHIU and LO2002	67.4	27.3	20	93.3	34	25	9.0%	-0.82 [-1.43, -0.20]
DIMITRIADIS, et al.2013	15.4	8.6	45	18.4	7	45	17.1%	-0.38 [-0.80, 0.04]
FALLA, et al.2010	193.7	77.2	9	243.4	56.6	9	3.9%	-0.70 [-1.66, 0.26]
JORDAN and MEHLSEN1993	12	5.75	18	16	5	18	7.5%	-0.73 [-1.40, -0.05]
JORDAN, et al.1997	14.5	5	119	56.1	8	80		Not estimable
LINDSTROEM, et al.2012	179.1	48.6	34	218.5	46.3	14	8.2%	-0.81 [-1.45, -0.16]
LOPEZ-DE-URALDE-VILLANUEVA, et al.2017	9.04	3.74	44	13.86	4.43	31	12.8%	-1.18 [-1.68, -0.68]
REZASOLTANI, et al.2010	73.4	9.8	10	127.2	23.2	10		Not estimable
SCHEUER and FRIEDRICH2010	10.4	5	53	14.8	6.2	42	16.9%	-0.78 [-1.21, -0.36]
SHAHIDI, et al.2012	15.9	1.3	19	19.3	1.6	20		Not estimable
YLINEN, et al.2004	132.1	38.5	21	187	39.2	21	7.5%	-1.39 [-2.07, -0.71]
Subtotal (95% CI)			**274**			**301**	**100.0%**	**-0.79 [-0.99, -0.60]**
Heterogeneity: Tau² = 0.01; Chi² = 9.34, df = 8 (P = 0.31); I² = 14%								
Test for overall effect: Z = 7.94 (P < 0.00001)								

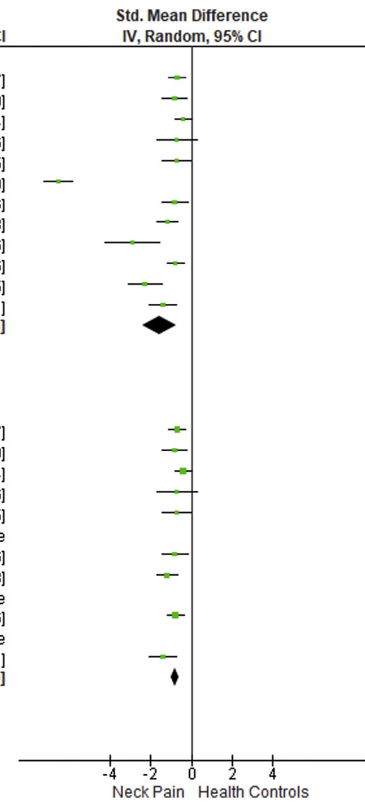

Fig 4. *Chronic neck pain group versus health control group: extension.* CI, *confidence interval;* CNP, *control neck pain;* SD, *standard deviation.*

with chronic neck pain, perhaps for the same reasons of disuse owing to kinesiophobia.[3] This reduction of the physiological cross-sectional area of the neck musculature can cause lower neck strength, since the cross-sectional area is one of the determining factors of muscle strength. In addition, the reduction in the cross-sectional area is associated with a reduction in the number of parallel sarcomeres, the structures responsible for the capacity to produce muscle strength.[44] Another possible biomechanical mechanism for this lower neck strength can be credited to changes in the electromyographic activity of the neck muscles.[4] Although these electromyographic changes do not directly represent muscle strength, they may represent muscle imbalance and, consequently, lower neck strength.[45]

The reduction of the neck strength may also be related to neurophysiological aspects. Because the nociception caused by dysfunctions in the neck region alter the excitatory threshold of the mechanoreceptors,[46] and the neck area of the spine contains a high concentration of mechanoreceptors,[47] it is possible to affirm that changes in the mechanoreceptors owing to the nociception can lead to a change in the sensorimotor integration[48-50] and, consequently, lower neck strength.

Regardless of the mechanisms that may have caused the reduction of neck strength, the findings of the present study encourage the evaluation of strength in clinical practice because it might have a reduction of strength for this population. Therefore, considering this possibility, it is fundamental to evaluate and manage these deficits, regardless of which muscle group is affected.

Of the included studies, only 23% were considered to be at low risk of bias, and none had blinded the assessor to the participant group. This represents a bias in this type of study.[34] Another important factor is that only 20% of the studies performed a sample calculation, even though there were enough studies in the literature to estimate a sample, thus avoiding sampling bias.[16]

Considering the high risk of bias estimated for the included studies, it is recommended that future studies be more methodologically rigorous, to reduce bias. In addition, other neck pain classifications, such as acute, subacute, and whiplash, should be evaluated to identify whether the reduction of neck strength found in the present study can also be found in different levels of injury time and neck pain classifications. The assessment of neck strength in the specific population of pilots with and without neck pain is a chapter apart and also needs attention.

Limitations

It is possible that unpublished studies have not been included because we made no searches of the

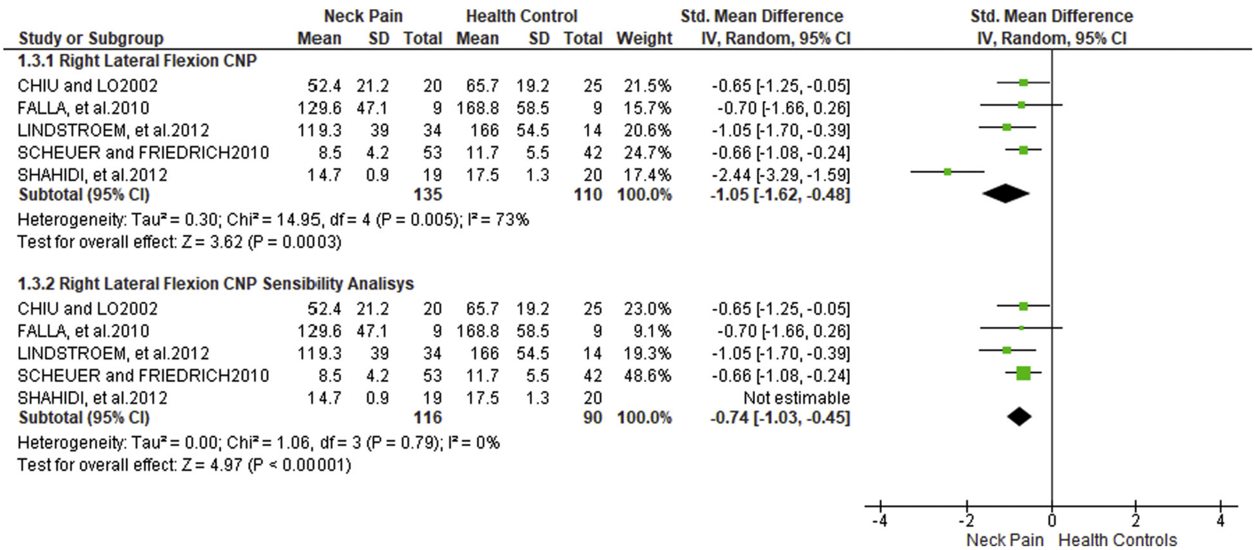

Fig 5. *Chronic neck pain group versus health control group: right lateral flexion.* CI, *confidence interval;* CNP, *chronic neck pain;* SD, *standard deviation.*

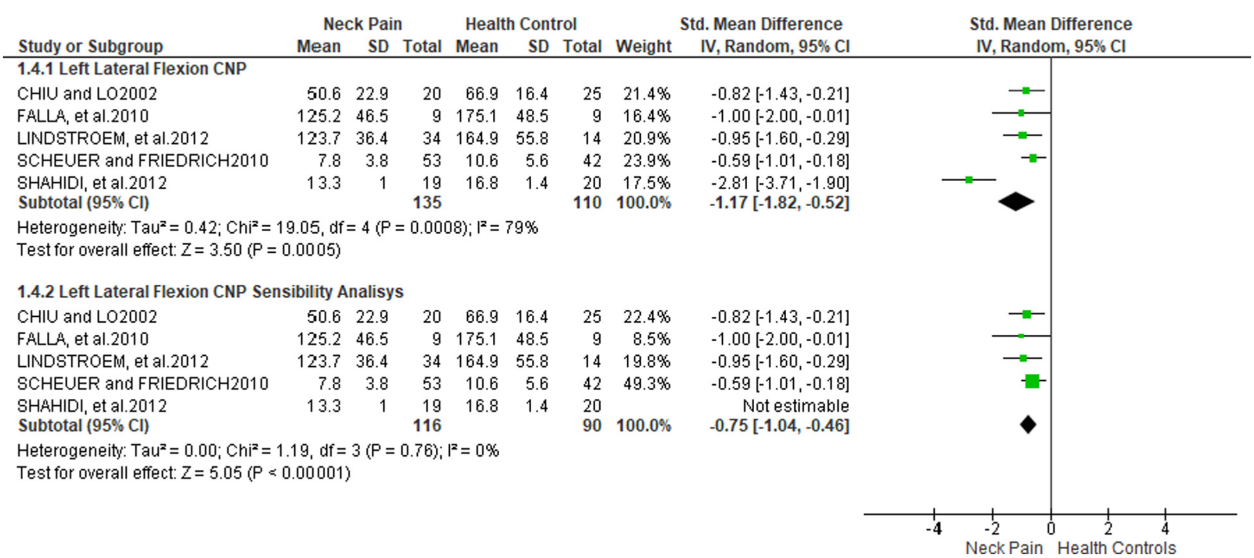

Fig 6. *Chronic neck pain group versus health control group: left lateral flexion.* CI, *confidence interval;* CNP, *chronic neck pain;* SD, *standard deviation.*

gray literature. An adapted tool from the Newcastle-Ottawa scale[18] was used for assessment of the risk of bias, and it was not validated previously. However, it was used to better meet the type of included studies in this review,[16] since Newcastle-Ottawa does not evaluate information and sampling bias. In addition, the Newcastle-Ottawa scale[51] has low reproducibility among reviewers, and there is abundant discussion in the literature owing to the large number[52] of tools for the methodological analysis of observational studies. Owing to these factors, the adopted strategy was to adapt a methodological analysis tool, which was "this strategy was already performed in a previous study."[2] These changes in the neck strength for those individuals are a functional change in chronic neck pain. Based on this study alone, we cannot conclude that these changes are causal factors for the development of chronic neck pain because there is an insufficient number of prospective studies, and we can only infer that there is an association between lower neck strength and individuals with chronic neck pain. To infer that these adaptations precede chronic neck pain and are causal factors, more longitudinal studies must be done because fewer than 2 studies were found. In addition, it has been suggested that lower neck strength is not a causal factor or risk factor for the development of neck pain, but instead a consequence due to neck pain.[23]

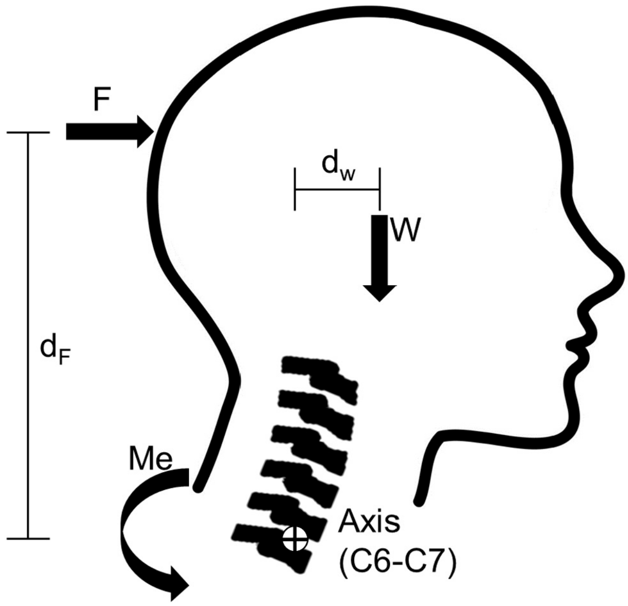

Fig 7. *Free body diagram of the neck. Motion equation:* $Me = F \times d_F + W \times d_W$. d_F*: F moment arm;* d_W*: weight moment arm;* F*, dynamometer force;* Me*: extensor moment;* W*: head weight.*

Conclusion

Our findings suggest that based on the quantitative analyses of this meta-analysis with a 3a level of evidence, individuals with chronic neck pain have lower neck strength for flexion, extension, and lateral flexion of the neck than healthy control participants; however, we could not conclude if this is a cause or consequence of neck pain owing to the lack of longitudinal studies.

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Contributorship Information

Concept development (provided idea for the research): I.F.M.

Design (planned the methods to generate the results): I.F.M., E.S.W.N., J.F.L.

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): I.F.M., J.F.L.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): I.F.M., E.S.W.N., W.D., G.A.B.

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): I.F.M., E.S.W.N., W.D., G.A.B., J.F.L.

Literature search (performed the literature search): I.F.M., E.S.W.N.

Writing (responsible for writing a substantive part of the manuscript): I.F.M

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): I.F.M., E.S.W.N., W.D., G.A.B., J.F.L.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jmpt.2018.12.008.

Practical Applications

- Individuals with chronic neck pain have lower neck strength than healthy individuals.
- Neck exercises may be important for the treatment of individuals with chronic neck pain.
- Owing to a lack of longitudinal studies, we cannot conclude that this is a causal effect.

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