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Systematic Review

Cervical musculoskeletal impairments in migraine and tension type headache: A systematic review and meta-analysis

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ABSTRACT:

Aims: Neck pain is common in migraine and tension type headache (TTH). This review aimed to examine the evidence for cervical musculoskeletal impairments in these headaches.

Methods: Databases PubMed (Medline), EMBASE, CINAHL, SCOPUS, and Web of Science were searched from inception to December 2018. Observational studies using a comparator group were included. Risk of bias was assessed using the Appraisal tool for Cross-Sectional Studies. Results were pooled using random effects meta-analysis. Level of evidence for each outcome was assigned based on risk of bias, consistency of results and magnitude of difference between participants with headache and controls. (PROSPERO registration: CRD42018083683).

Results: Of 48 studies included, the majority were rated moderate risk of bias due to possible confounding influences. In total, 17 cervical outcomes were assessed, with confidence in findings ranging from very low to moderate levels. Compared to controls, participants with TTH had greater forward head posture (FHP) (MD = −6.18°, 95% CI [-8.18°, −4.18°]) and less cervical range of motion (ROM) (greatest difference transverse plane MD = −15.0°, 95% CI [-27.7°, −2.3°]. Participants with migraine demonstrated minimally reduced cervical ROM (greatest difference sagittal plane MD = −5.4°, 95% CI [-9.9°, −0.9°]. No differences presented in head posture, strength, craniocervical flexion test performance or joint position error between migraineurs and controls.

Conclusions: TTH presented with more findings of cervical musculoskeletal impairments than migraine however levels of confidence in findings were low. Future studies should differentiate episodic from chronic headache, identify coexisting musculoskeletal cervical disorders, and describe neck pain behaviour in headache.

1. Introduction

Neck pain commonly accompanies migraine and tension type headache (TTH) (Ashina et al., 2014; Plesh et al., 2012; Calhoun et al., 2010; Hagen et al., 2002), and patients often seek treatment of the neck as part of headache management (Adams et al., 2013; Moore et al., 2017). Evidence supporting such treatment is limited (Côté et al., 2019). It is therefore important to understand the mechanisms underlying neck pain in primary headache to direct interventions. As primary afferent input from both trigeminal and upper cervical (C1-3) nerves converge in the trigeminocervical nucleus (Bogduk, 2014), neck pain in headache may be a referred pain and part of the headache symptomatic complex. Alternatively, nociception from upper cervical structures can result in local neck pain and may also refer pain to the head, contributing to headache pathogenesis as in cervicogenic headache (CEH) (Headache Classification Committee, 2018). Neck pain may result from a comorbid musculoskeletal cervical disorder that is unrelated to headache. Each of these scenarios have different implications for headache management.

Identifying cervical musculoskeletal impairments is important for understanding mechanisms of neck pain in headache. This is challenging because sensitisation of head afferents in the trigeminocervical nucleus can increase neck muscle activity (Hu et al., 1995), which may masquerade as a cervical impairment. That is, augmented neck muscle tension or electromyographic activity observed at rest in headache patients may reflect central sensitisation and occur independently of any local neck dysfunction (Bartsch, 2005). Similarly, myofascial trigger points are often present in TTH and migraine and frequently regarded as evidence of cervical musculoskeletal dysfunction (Sohn et al., 2010; Luedtke et al., 2018). Yet they can stem from central

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sensitisation (Srbely et al., 2010), and are also found in non-musculoskeletal conditions such as endometriosis (Jarrell, 2008; Stratton et al., 2015) and chronic prostatitis (Anderson et al., 2009). Therefore trigger points may not always indicate a musculoskeletal disorder, even though they are sensitive areas in muscle or connective tissue. In order to delineate musculoskeletal dysfunction from headache-mediated sensitisation mechanisms, impairments uniquely associated with musculoskeletal cervical disorders need to be identified in migraine and TTH. These are typically reduced neck motion, articular signs, cervical neuromuscular and sensorimotor dysfunction (Kristjansson and Treleaven, 2009; de Zoete et al., 2017).

Features of neck pain also provide insight into mechanisms underlying neck pain in primary headache. Frequent and intense neck pain associated with marked cervical impairments supports a cervical musculoskeletal cause. Conversely, frequent and intense neck pain accompanied by mild or isolated cervical impairment does not typify cervical musculoskeletal disorders and may indicate a dominance of sensitisation mechanisms due to the migraine or TTH. To date, no review has attempted to collect and report on neck pain characteristics in conjunction with musculoskeletal impairments in both migraine and tension type headache.

This review aims to identify cervical musculoskeletal and sensorimotor impairments in migraine and TTH, as compared to healthy controls or individuals with CEH. This review will also study any available data to determine if neck pain characteristics of headache individuals relate to the presence of cervical impairments.

2. Methods

A priori protocol for this systematic review was registered with PROSPERO (CRD42018083683).

2.1. Identification and selection of studies

Inclusion criteria are presented in Box 1. Measures not unique to cervical musculoskeletal disorders including trigger points, soft tissue palpation, pressure algometry, and non-cervical impairments were excluded. If a study measured cervical musculoskeletal impairments in addition to any of the above exclusions, the study was included but only data regarding cervical impairments was extracted.

PubMed (Medline), EMBASE, CINAHL, SCOPUS, and Web of Science electronic bibliographic databases were searched from inception to December 2018. Initial searches of PubMed and CINAHL were performed to identify keywords and terms used in titles and abstracts of relevant articles. A combination of all relevant Medical Subject Headings and keywords identified were used in searches across the five databases. Initial keywords and an example of the search strategy is provided (Appendix A). The “related articles” and “cited by” links of databases and Google Scholar were used to identify relevant grey literature and studies citing the included papers. Reference lists were perused, and relevant trial and study registries were searched to identify any unpublished studies.

After removing duplicates, titles and abstracts of studies retrieved were screened independently by two reviewers (ZL and OG). Authors of potentially eligible unpublished studies were contacted to obtain full details of their research. Full texts of potential studies were independently assessed by two reviewers. The other review members were consulted when there was disagreement.

2.2. Assessment of study characteristics

Data were independently extracted by two review members using a standardized, pre-piloted form. Study characteristics extracted included: research design, study setting, recruitment methods, sample size, method of headache diagnosis, inclusion/exclusion criteria, and measurement methods. Participant data extracted included: demographics, headache features and neck pain characteristics. Findings for all impairments were individually and systematically tabulated. Authors were contacted if information regarding selection criteria, blinding or results were missing or unclear.

Risk of bias assessment was performed independently by two reviewers using the Appraisal tool for Cross-Sectional Studies (AXIS) (Downes et al., 2016) (Appendix B). By examining 20 components of each study, this tool assesses risk of bias across various domains. Items relating to selection, measurement, reporting and confounding biases were determined a priori to be weighted more heavily for the purposes of this review. To supplement the AXIS tool, three other questions relating to potential confounders, suitability of comparators and examiner blinding were assessed in each study. Each reviewer gave each study an independent overall rating for risk of bias. This process was pre-trialed to ensure parity in interpretation and judgement. Disagreements in judgement were resolved through discussion and in consultation with other review members. Agreement between reviewers was calculated using Cohen's Kappa in SPSS version 25 (Statistics for M, 2017). Results for risk of bias assessment were summarized into the five key domains of bias (selection, measurement, reporting, confounding and assessor blinding) and overall ratings were used to stratify findings from the studies included.

2.3. Data analysis

Trends across participant characteristics and study findings were identified. Due to methodological heterogeneity across studies, there was partial scope for meta-analysis. For measures assessed similarly in three or more studies with low or moderate risk of bias, results were pooled using a random-effects model (DerSimonian and Laird, 1986) and heterogeneity assessed using I^2 statistic. Group differences between migraine or TTH and controls were calculated as standardized mean

Box 1
Inclusion criteria.

Design

- Observational study aimed at investigating cervical musculoskeletal impairment

Participants

- Diagnosed with migraine or tension type headache
- Comparator group of either no headache or cervicogenic headache

Outcome measures

- Cervical musculoskeletal impairments unique to musculoskeletal neck disorders differences or mean differences (MD), 95% confidence intervals. If results were reported for more than one test condition, or in more than one patient subgroup, the result which gave the greatest mean difference was used in analyses. Subgroup and sensitivity analyses were performed whenever appropriate data were available from three or more studies. Wherever there was sufficient data, funnel plots of means were inspected for possible publication bias. Analyses and output figures were produced using Review Manager version 5.3 (2014).

2.4. Confidence in cumulative evidence

Using guidelines by the American Academy of Neurology (Gronseth et al., 2017), the level of evidence for each cervical musculoskeletal impairment was assessed in individual studies and collectively across domains of risk of bias, consistency of results, effect size and sample size. When substantial risk of bias was present in several studies, level of evidence was up-rated for non-significant findings and down-rated for significant findings since plausible confounders/biases would create a spurious effect (Guyatt et al., 2011). Level of evidence was also rated down for significant findings where there was substantial unexplained heterogeneity based on dissimilarity in point estimates, low extent of overlap in confidence intervals and/or I^2 values ≥ 50%. Additionally, evidence was also rated down where effect size was small or unlikely to be clinically relevant, or when sample size was limited. Based on these assessments, the body of evidence for each measure was awarded one of four levels: High, moderate, low or very low.

3. Results

3.1. Study selection

Forty-eight studies were included in this review (Fig. 1). The search of five databases produced 11,897 citations excluding duplicates. Titles were screened and relevant abstracts were perused to exclude 11,710 studies. Full texts of 186 studies were examined, yielding 43 eligible studies. Authors of five potentially relevant conference abstracts were contacted. Three responded, and consequently one (de Oliveira et al., 2017) was included using additional data provided by the authors (Florencio et al., et al.). An additional four unpublished studies from three theses were identified for inclusion, bringing the total number of studies to 48. Two (Aguila et al., 2017; Florencio et al., 2017a) theses' authors were contacted to confirm studies were not published, the third could not be contacted (Attia, 2002).

3.2. Study characteristics

Of the 48 studies included, 20 were migraine, 18 TTH, and 10 had both migraine and TTH participants. All studies used healthy controls as a comparator group except for one which used subjects with CEH for comparisons (Hall et al., 2010). Four studies involved both CEH and healthy controls. Study characteristics are presented in Table 1.

3.3. Participants

The studies involved a total of 2209 participants with TTH or migraine. Few specified if their participants had episodic or chronic headache (Table 1). Almost all (93%) defined their populations using International Classification of Headache Disorders criteria. Diagnoses were sometimes made by neurologists. Participant recruitment was mainly from neurology or headache clinics. Study sample size ranged from nine to 372 headache participants. Mean age ranged between 20 and 55 years. The majority were female.

Participants' headache features were reported to varying extents. Sixteen studies did not state the years with headache (Sohn et al., 2010; Attia, 2002; Horwitz and Stewart, 2015; Ogince et al., 2007; Tali et al., 2014; Dugailly et al., 2017; Formisano et al., 1988; Kidd and Nelson, 1993; Sandrini et al., 1994; Watson and Drummond, 2012; Madsen et al., 2016, 2018; Marchand et al., 2014; Rosenhall et al., 1996; Stroppa-Marques et al., 2017; Sturgis et al., 1984), while 11 did not state headache frequency (Attia, 2002; Horwitz and Stewart, 2015; Ogince et al., 2007; Dugailly et al., 2017; Kidd and Nelson, 1993; Watson and Drummond, 2012; Rosenhall et al., 1996; Sturgis et al., 1984; Nagasawa et al., 1993; Zito et al., 2006; Zwart, 1997). Headache descriptions were mostly limited to bilateral or side of pain. Few studies provided information on associated symptoms. Despite neck pain being presumably present in all studies except one (Ogince et al., 2007), only eight study cohorts provided information on neck pain prevalence, disability, years with neck pain, neck pain intensity or frequency (Table 2). Aside from studies performing manual examination of the cervical spine, only three (Fernández-de-las-Peñas et al., 2007a; Florencio et al., 2015; Sohn et al., 2013) specified whether neck pain was present or reproduced during testing. No study described behaviour of neck pain and its temporal relationship with headache.

3.4. Outcomes

Fourteen different measures of cervical musculoskeletal impairment and three measures of sensorimotor impairment (cervical proprioception measured as joint position error, cervical proprioceptive influences on oculomotor impairment and standing balance) were found (Table 1). Although similar outcomes were assessed across studies, validity of measurements varied.

3.5. Risk of bias

Authors of 32 of the 48 studies were contacted to clarify selection criteria, results and/or blinding. Of these, 19 replied and risk of bias improved for two studies (Dugailly et al., 2017; Jull et al., 2007). The authors of seven studies could not be contacted (Attia, 2002; Formisano et al., 1988; Rosenhall et al., 1996; Sturgis et al., 1984; Nagasawa et al., 1993; Marcus et al., 1999; Rossi et al., 2005). There was excellent agreement between reviewers for risk of bias rating ($\kappa = 0.86$, $p < 0.0001$). Eight studies were rated to have low risk of bias. The majority ($n = 26$) were rated as moderate risk of bias. High risk of bias was found in 14 studies (Table 3). The ratings are specific to our research question, especially with regard to potential confounders of cervical impairments. For studies assessing other outcomes, our rating decisions were based on descriptions and reporting of outcome(s) included in this review. Earlier studies, while complying with reporting expectations at the time of publication, were scored on current guidelines and thus tended to have greater risk of bias scores.

Many studies failed to adequately control for confounding factors. Comorbid musculoskeletal cervical disorders will exert confounding influences on measures of cervical impairments. Several studies ($n = 16$) did not exclude nor identify coexisting musculoskeletal cervical disorders in migraine or TTH participants. In those that did ($n = 23$), only readily identifiable cervical musculoskeletal disorders (e.g. cervical trauma and radiological abnormalities), were excluded. Any presence of idiopathic neck pain and CEH was mostly unaccounted for. Only five studies attempted to exclude coexisting idiopathic musculoskeletal cervical disorders in headache subjects by recruiting migraine participants without neck pain (Ogince et al., 2007), excluding migraine participants with interictal neck pain (Hall et al., 2010), physically examining the neck during recruitment of TTH participants to exclude CEH (Madsen et al., 2016, 2018), or excluding headache patients with moderate neck disability (i.e. > 28% on the Neck Disability Index) (Wanderley et al., 2015). Another three studies (Zito et al., 2006; Jull et al., 2007; Dumas et al., 2001) included CEH as a study group, and excluded CEH or other idiopathic musculoskeletal cervical disorders from the other groups through the selection process.

Migraine prodromes are also potential confounders. Neck pain is a common premonitory symptom in migraine (Lampl et al., 2015) so

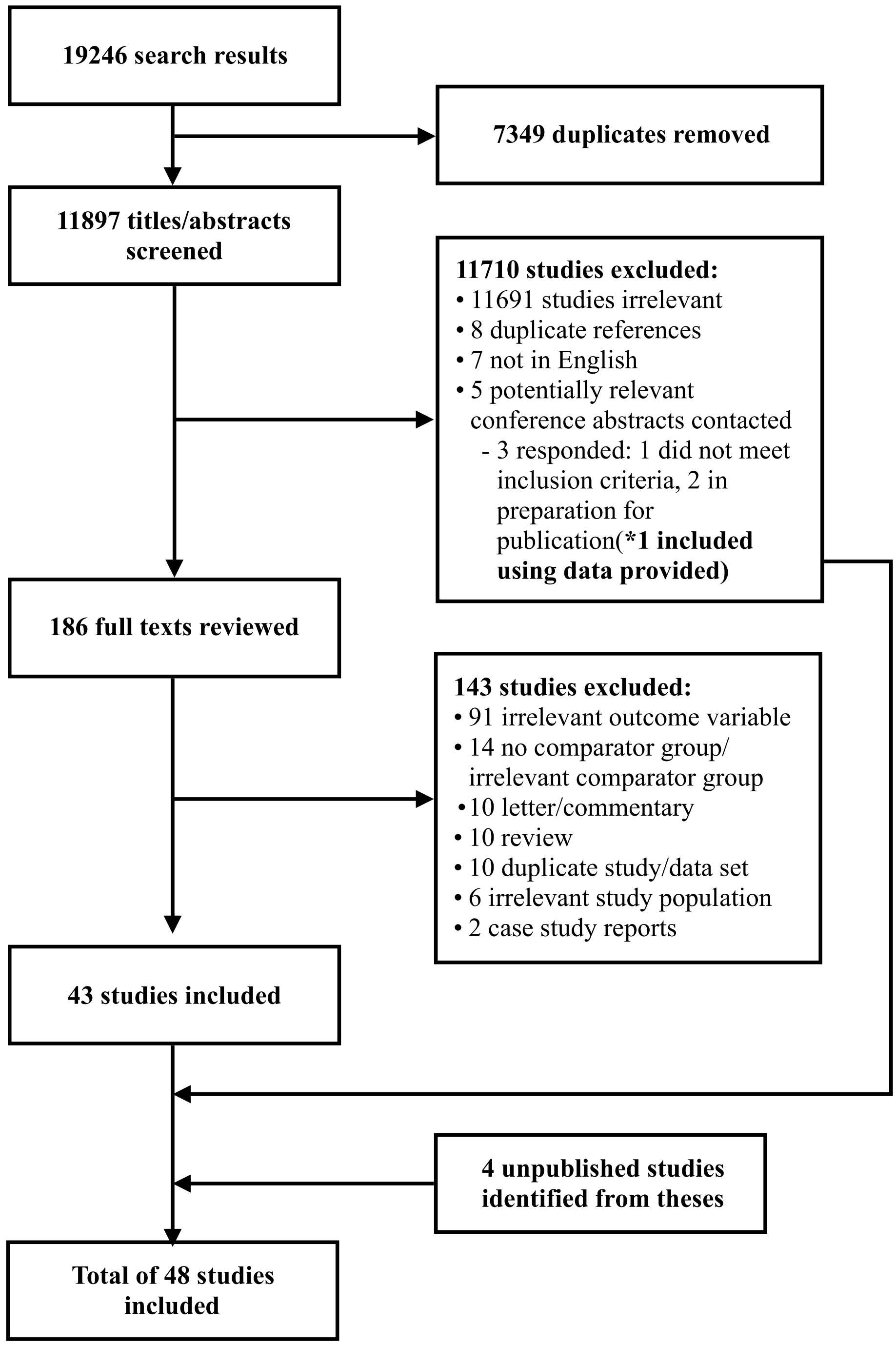

Fig. 1. Study selection.

cervical function during this period may be influenced by pain mechanisms related to migraine. Only one study explicitly screened for premonitory neck pain (Luedtke et al., 2018). Similarly, the presence of headache during assessment may be associated with sensitisation mechanisms that could affect cervical function. Although most studies (n = 35) noted the headache status of participants at time of testing and limited headache to low intensities, only four studies (Luedtke et al., 2018; Hall et al., 2010; Fernández-de-las-Peñas et al., 2006a; Luedtke and May 2017) ensured interictal status by testing at least 48 h after headache. Two studies repeated assessments at ictal and interictal time points (Zwart, 1997; Jensen, 1996).

3.6. Synthesis of results

Most common measures were cervical posture (n = 19), range of motion (ROM) (n = 16), manual examination of cervical segments (n = 11), and muscle activity during isometric contractions or movements (n = 11). Meta-analyses were not performed on most measures due to limited data and/or heterogeneity of assessment and scoring methods. In particular, manual examination and muscle activity were measured using various procedures, preventing meta-analyses. Results from meta-analyses are described below. Subgroup and sensitivity analyses are presented in Appendices C and D.

Nineteen studies measured various angles of cervical posture in migraine. The craniocervical angle, as a measure of forward head posture (FHP), was assessed in 11 studies, three (Luedtke et al., 2018;

Table 1
Characteristics of studies included in the review. All measures relevant to this review are listed but only significant findings are described in full.

Study ID	Study Population n = ( )	Outcomes[a]	Summary of Findings	Comments
Studies with Low Risk of Bias				
Dumas et al. (2001)	M (16) CEH (44) Controls (17)	Posture ROM Manual examination Strength, endurance (flex, ext) Proprioception	M vs Controls: No differences in any measure	–
Hall et al. (2010)	M (20) MixH (n 20) CEH (20)	FRT	M within normative range: 41.8 [5.1] CEH reduced ROM 25.2 [11.1] "Neck movement or positions provoke headache" most significant predictor of FRT range (41% of variance)	Excluded M subjects with interictal neck pain "neck movement or positions provoke headache": M 15%; CEH 100%; MixH 40%
Jull et al. (2007)	M (22) TTH (33) CEH (18) Controls (57)	ROM Manual examination Strength (flex, ext) CCFT Extensor CSA Proprioception	M vs TTH vs controls: No differences in any measure	–
Madsen et al. (2016)	ETTH (25) CTTH (35) Controls (30)	Strength (flex, ext, shoulder abd)	ETTH vs CTTH: No differences TTH + M vs TTH: No differences TTH < controls Extensors: 17.1[9.2] vs 21.5[10.3] Extensor-flexor ratio: 1:1.5 vs 1:1.7 Shoulder abduction 38.7[15.9] vs 44.3[19.3]	Excluded participants with coexisting CEH (physical examination) 12 TTH participants had coexisting migraine
Madsen et al. (2018)	Same cohort as (Madsen et al., 2016).	Muscle performance (flex, ext, shoulder abd)	TTH < Controls Rate of force development shoulder abd MVC: 157[94] vs 210[166] Force steadiness sustained cervical extension: 0.024[0.011] vs 0.020[0.008]	
Ogince et al. (2007)	M (12) CEH (23) Controls (23)	FRT	M vs Controls: No differences	Excluded subjects with neck pain in M and control groups Headache Severity Index score not correlated to FRT results Headache intensity during testing no effect on outcomes
Wanderley et al. (2015)	EM (21) ETTH (16) Controls (11)	Longus colli CSA Muscle activity (iso-metric contraction)	CSA: no differences between EM, ETTH, controls ETTH < controls SCM activity, start of isometric contraction: (R): 0.4[0.3–0.5] vs 0.6[0.4–0.8]; (L): 0.4[0.3–0.5] vs 0.6 [0.4–0.8]	Included subjects with mild neck disability only (< 28% on Neck Disability Index) Excluded chronic neck pain
Zito et al. (2006)	M (25) CEH (27) Controls (25)	Posture ROM Manual examination CCFT Muscle extensibility Proprioception Nerve extensibility	M vs Controls: No differences in any measure	–
Studies with Moderate Risk of Bias				
Aguila et al. (2017)	M (40) Non-M (45) Controls (40)	ROM; FRT Manual examination Strength, endurance (flex, ext) CCFT Extensor test Extensor CSA	M vs Non-M: No differences M < Controls Ext-Flex strength ratio: 1.5 [1.2–1.9] vs 2.2 [1.7–2.6] Ext ROM: 70 [60–70] vs 75 [62.5–80.0]	Non-M included CEH, TTH ROM in all directions combined into one score, only extension ROM presented in results. Muscle strength and endurance presented as F:E ratio only
Bevilaqua Grossi et al. (2009)	EM (15) CM (15) Controls (15)	ROM	CM < controls: ROM: Ext: 59.3 [10.8] vs 68.1[11.3], (L) lat flex: 44.5[8.0] vs 49.1[6.3], (R) rot: 62.3[10.4] vs 68.6[8.5] CM < EM: Ext: 59.3[10.8] vs 68.5[10.3] EM < controls: Rot: 60.8[6.7] vs 68.6[8.5]	Intensity and prevalence of pain during testing assessed but not specified to be head or neck pain Results not influenced by pain or headache ROM not reduced on symptomatic side

(continued on next page)

Table 1 (*continued*)

Study ID	Study Population n = ( )	Outcomes[a]	Summary of Findings	Comments
Fernández-de-las-Peñas et al. (2006a)	M (20) Controls (20)	Posture ROM	M < controls ROM: Ext: 60.6[9.6] vs 68.9[12.7] Flex + Ext: 117.5[14.8] vs 129.8[14.8] M > controls FHP: Sitting: 42.2[6.4] vs 52.6[7.2] Standing: 44.7[9.6] vs 53.7[7.2] Smaller CV angle (greater FHP) associated with lesser neck mobility in all directions except (R) lat flex: r = 0.4 to 0.6	
Fernández-de-las-Peñas et al. (2006c)	CTTH (20) Controls (20)	Posture	CTTH > controls FHP: Sitting: 44.9[7.5] vs 51.9[5.7] Standing: 47.9[7.9] vs 54.3[6.5] CTTH: Smaller CV angle (greater FHP) associated with higher headache frequency (r = −0.6) and longer headache duration (r = −0.5)	Overlapping datasets with (Fernández-de-las-Peñas et al., 2006b)
Fernández-de-las-Peñas et al. (2006b)	CTTH (25) Controls (25)	Posture ROM	CTTH > controls FHP: 45.3[7.6] vs 54.1[6.3] CTTH < controls ROM: Flex: 49.1[10.3] vs 59.9[7.8]; Ext: 54.9[20.1] vs 68.3[17.2]); (L) lat flex: 34.6[8.3] vs 41.4[6.1]; (R) rot: 57.6[10.1] vs 73.6[7.9]; (L) rot: 58.3[8.4] vs 72.2[5.7] Smaller CV angle (greater FHP) associated with less mobility (r = 0.4 to 0.5) CTTH: Smaller CV angle associated with greater headache frequency (r = −0.5), (R) rot ROM associated with headache duration (r = −0.5) and frequency (r = −0.4)	Headache features assessed but not fully presented in results. Overlapping datasets with (Fernández-de-las-Peñas et al., 2006c)
Fernández-de-las-Peñas et al. (2007a)	CTTH (10) Controls (10)	CCFT Posture	CTTH < controls CCFT: Activation pressure score: 6.6[2.3] vs 12.6[4.3]; Performance index: 32.4[15.8] vs 66.8[23.5] CTTH > controls FHP standing: 42.0[6.6] vs 48.8[2.5] No associations between FHP and CCFT. Headache duration associated with highest activation/pressure score (r = 0.7)	Positive association between headache duration and CCFT scores implies better CCFT performance in participants with longer duration of headache. This suggests a lack of CCFT impairment in CTTH.
Fernández-de-las-Peñas et al. (2007c)	CTTH (15) Controls (15)	Extensor CSA	CTTH < controls CSA: Rectus capitis posterior minor: 78.1[22.6] vs 122.3[35.1]; Rectus capitis posterior major: 102.1[18.4] vs 126.9[30.8] Muscle size negatively correlated with headache features (intensity, duration, frequency): r = −72 to −0.44	–
Fernández-de-las-Peñas et al. (2007b)	ETTH (15) Controls (15)	Posture ROM	ETTH < controls ROM: Flex: 47.2[11.4] vs 66.8[9.7]; flex + ext: 96.4[18.7] vs 115.2[28.7]; (L) lat flex: 34.8[7.7] vs 43.4[5.6]; (R) rot: 58.2[9.7] vs 72.5[5.5] ETTH > controls FHP: Sitting: 48.8[7] vs 53.8[4]; Standing: 50[7] vs 55.9[5.5]	No correlations between neck mobility or FHP and headache parameters
Fernández-de-las-Peñas et al. (2008)	CTTH (9) Controls (10)	Strength (flex, ext) Muscle activity (MVC, isometric contractions)	CTTH < controls Max strength: Flex: 32[10]% < controls, ext: 24[15]% < controls (mean values not presented) CTTH > controls Co-activation of antagonist muscles during submaximal contractions: flex: left splenius capitis; ext: SCM	–
Ferracini et al. (2016)	M (33) Controls (33)	Posture	M vs Controls: No differences. Smaller high cervical angle (greater head extension on neck) associated with higher migraine frequency: r = −0.42, R^2 = 10%.	–

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Table 1 (*continued*)

Study ID	Study Population n = ( )	Outcomes[a]	Summary of Findings	Comments
Ferracini et al. (2017a)	EM (55) CM (16) Controls (22)	ROM; FRT Posture Manual examination Proprioception	EM, CM < controls ROM Rot: (graphed only, (R): p = 0.005; (L): p = 0.012). EM, CM > controls Positive FRT (< 32°): 85.5% EM, 100% CM, 4.5% controls. EM: Greater cervical lordosis associated with lesser cervical rot (r = 0.4), smaller values on FRT associated with greater JPE from ext: (R) r = −0.3; (L) r = −0.4 CM: FHP associated with JPE in rot (r = 0.5) No differences posture or proprioception between groups	Manual examination not performed on controls, hence results not included in this review.
Ferracini et al. (2017b)	M (50) Controls (50)	Posture	M < controls Cervical lordosis: smaller anterior translation distance: 4.9[1.8–8.8]; hyoid triangle: 3.0[1.0–5.0]	Results not influenced by neck pain.
Ferreira et al. (2014)	M (22) M + TMD (22) Controls (22)	Posture	M > controls Cervical lordosis (smaller lordosis angle): 15.0[15.4–14.6] vs 16.4[17–15.7]	Only results of M without TMD included for this review.
Florencio et al. (2015)	EM (31) CM (21) Controls (31)	Strength (flex, ext, lat flex) Muscle activity (MVC)	CM < controls Extension strength: 12.7[10.9–14.8] vs 17.1[15.8–18.4] CM > controls Time to peak force: flex 2.4[2.1–2.8] vs 1.9[1.6–2.2]; (L) lat flex: 2.8[2.7–2.9] vs 2.4[2.1–2.6] EM, CM > controls Antagonist activity during flex: Splenius capitis mean difference: CM = 21.4[11.6–31.2]%, EM = 18.9[9.5–38.3]% Extension force associated with migraine frequency (r = −0.30[-0.53 to-0.02], neck pain frequency (r = −0.26[-0.45 to −0.04]), and neck pain intensity (r = −0.27[-0.46 to −0.06])	Same cohort as (Florencio et al., 2016). Some of CM reported headache (33%–57%) and neck pain (48%–57%) during max contractions, but neck pain did not influence results.
Florencio et al. (2016)	EM (31) CM (21) Controls (31)	CCFT	CM > controls Ext activity during CCFT; splenius capitis, upper trapezius EM vs CM vs controls: no differences in flex activity during CCFT	Increased extensor muscle activity during CCFT not reported in neck disorders. Neck pain/disability did not influence results.
Florencio et al. (2017a)	EM (31) CM (21) Controls (31)	Muscle activity (MVC)	CM > controls SCM amplitude during ext MVC: 0.84[0.05] vs 0.80[0.06]	Same cohort as (Florencio et al., 2016). Duplicate data on muscle strength reported in (Florencio et al., 2015) not included here. Results amended by authors via correspondence.
Florencio et al. (2017b)	EM (52) CM (16) Controls (23)	Posture CCFT	EM, CM > controls Cervical extensor activity at 30 mmHg CCFT CM: Greater FHP associated with greater UT activity during 4 stages of CCFT (r = −0.50 to −0.65)	Increased extensor muscle (UT) activity during CCFT not reported in neck disorders.
Florencio et al. in preparation	M (26) Controls (26)	Endurance (flex, ext)	M < controls: Flex: 41 [28] vs 71 [45]; Ext: 207 [163] vs 309 [140]	Conference abstract. Further data provided by authors.
Luedtke and May (2017)	M (179) Controls (73)	Manual examination	M > controls Proportion with local pain: 89% vs 49% Proportion with referred pain: 46% vs 15% Local pain provocation: high sensitivity (0.9) low specificity (0.5) Pain referral to head during sustained pressure: low sensitivity (0.5) high specificity (0.8) Headache frequency correlated with pain provocation (p = 0.03) and referred pain (p = 0.02) (r values not presented).	Joint motion not taken into account during manual examination.
Marchand et al. (2014)	TTH (16) Controls (17)	ROM Proprioception	TTH < controls ROM: flex + ext: 125.7[16.1] vs 140.8[20.2] TTH > controls JPE: Constant error: p = 0.05, Absolute error: p = 0.03 Constant error correlated with headache frequency and disability (frequency: r = 0.4; NDI: r = 0.4; HIT-6: r = 0.3 Absolute error correlated with headache frequency and disability (frequency: r = 0.4; NDI: r = 0.5; HIT-6 scores: r = 0.4)	Pain VAS assessed in all participants after testing but unclear if this referred to neck pain or headache: TTH 5.4[1.3]; controls 3.6[2.2]

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Table 1 (*continued*)

Study ID	Study Population n = ( )	Outcomes[a]	Summary of Findings	Comments
Rosenhall et al. (1996)	TTH (22) Controls (24)	Cervical oculomotor function	TTH < controls Gain values for all test conditions: differences in gain 0.07 to 0.23	Pilot study- smooth pursuit neck torsion test. A difference in gain between neck torsion and neck neutral conditions is positive for cervical oculomotor dysfunction. No difference demonstrated.
Rossi et al. (2005)	M (35) ETTH (10) CTTH (10) M + ETTH (12) Controls (20)	Standing balance with altered cervical proprioception	Proportion with postural instability due to cervical proprioceptive alteration: CTTH = 37.5%, M + ETTH = 62.5%, M = 0%, ETTH = 0%	–
Sohn et al. (2010)	ETTH (36) CTTH (23) Controls (42)	Posture ROM	ETTH vs controls: No differences detected CTTH > controls FHP: 137.7[7.7] vs. 133.3[5.6] CTTH < controls Rot ROM: (R) 56.8[11.8] vs 68.6[9.8]; (L) 60.8[13.2 vs 72.3[9.8]	No correlations between headache features and FHP or ROM.
Sohn et al. (2013)	ETTH (14) CTTH (14) Controls (13)	Muscle activity (MVC, isometric contractions)	CTTH < controls Muscle activity during MVC: SCM; UT Muscle activity during sustained contractions: SCM, UT CTTH, ETTH > controls SCM fatigability. Muscle activity of SCM and UT during MVC and sustained contractions correlated to headache frequency and duration (r = −0.3 to −0.5)	Headache or neck-shoulder pain intensity during testing was assessed but location of pain not described in results: ETTH = 1.8, CTTH = 1.9 (out of 10)
Tali et al. (2014)	EM (20) Controls (20)	Posture ROM Manual examination	EM > controls Prevalence of upper cervical joint stiffness: Occiput-C1: 20% vs 0%; C1-2: 50% vs 5%	No difference in ROM does not reflect the prevalence of joint stiffness
Zwart (1997)	M (28) TTH (34) CEH (28) Controls (51)	ROM	M vs TTH vs controls: No differences in any measure	Headache at time of testing did not affect outcome.
Studies with High Risk of Bias				
Attia (2002)	TTH (20) Controls (20)	Muscle activity (head positions)	TTH > controls UT activity in head retraction position: 62.1[27.3] vs 43.2[13.6]	Although reported as significant, results table shows no significant difference for protraction
Dugailly et al. (2017)	M (30) TTH (18) Controls (80)	FRT (range, torque, stiffness)	M, TTH < controls Passive range (R): M 47.9[41.6–54.2]; TTH: 46.1[34.6–52.3]; controls: 54.1[49.9–61.9] Elastic zone range (R): M 19.5[16.6–26.9]; TTH 21.7[12.0–23.6]; controls 26.5[21.7–31.4]	Passive range: controls outside normative values for FRT, M and TTH within normative range.
Formisano et al. (1988)	M, TTH, MixH (31) Controls (5)	Muscle activity (MVC)	M vs controls: No differences detected TTH > controls Increase in neck paraspinals activity between baseline and MVC: 2860.7[2388.2] vs 1236.7[796.0]	Number of subjects in each headache group not stated.
Horwitz and Stewart (2015)	PerimenstrualM (40) Controls (46)	Posture ROM Manual examination Muscle strength Muscle extensibility Nerve extensibility	M < controls Rot ROM: (R) 82.9[12.6] vs 88[9.7]; (L) 87.5[11.3] vs 93.5[10.5] Muscle extensibility: less in trapezius, SCM, occipitals Proportion achieved “full neural tension position”: (R) 13% vs 33%; (L) 2% vs 18% M > controls Pain on muscle stretch: levator scapulae, trapezius, SCM, sub-occipital muscles Manual examination: Pain C4-C6; stiffness C5 and C7	Rot ROM for controls beyond normative range (left rot > 90°). Only values for rotation presented. Values for muscle strength not presented.
Jensen (1996)	ETTH (9) CTTH (19) Controls (30)	Muscle activity (MVC)	TTH vs controls: No differences in muscle activity during MVC trapezius	No differences during or outside headache episode.
Jensen et al. (1998)	ETTH (28) CTTH (28) Controls (30)	Muscle activity (MVC)	TTH vs controls: No differences in muscle activity during MVC trapezius	–
Kidd and Nelson (1993)	M, TTH (37) Controls (37)	ROM	M and/or TTH > controls Prevalence of 2 or more ROM “abnormalities”	No objective measures of ROM. Number of subjects in each headache group not stated.

(*continued on next page*)

Table 1 (*continued*)

Study ID	Study Population n = ( )	Outcomes[a]	Summary of Findings	Comments
Luedtke et al. (2018)	EM (88) CM (50) Controls (73)	Posture ROM FRT Upper cervical quadrant Manual examination (3 different measures) CCFT "Upper trapezius"	EM, CM < controls Scores on CCFT: EM, CM 26[22–28] vs controls 28[22–28] EM < controls FRT bilateral range: 89[13.9] vs 98[17.1] EM, CM > controls Positive findings on PAIVM (hypomobility and/or pain response): EM 6[0–12]; CM 6[2–11]; controls 2[0–10] Stepwise logistic regression identified 5 tests that best fit the model for M: PAIVMs, CCFT, FRT, symptom reproduction and resolution test, myofascial trigger points. Further regression modelling: greater number of positive findings on manual joint testing associated with lower headache frequency r = −0.26 to −0.42	Median scores for CCFT for EM and CM appear within normative values. ROM for all directions summed into 1 score. FRT scores are in normal range for all groups This result is inconsistent with the hypothesis that cervical joint dysfunction has a major role in M.
Marcus et al. (1999)	M (24) TTH (24) M + TTH (24) Controls (24)	Posture Manual examination	M, TTH, M + TTH > controls Proportion with postural abnormalities: M 66.7%; TTH 66.7%; M + TTH 66.7%; controls 45.8%, Chi (Plesh et al., 2012) = 26.0	–
Nagasawa et al. (1993)	TTH (372) Controls (225)	Posture	TTH < controls Prevalence of "cervical spine instability": 20.4% vs 30.7% Cervical lordosis: 14.6[11.9]% vs 19.4[11.1]% TTH > controls Prevalence of "low-set shoulders": mild: 48.4% vs 38.2%; severe: 9.1% vs 3.6%	Clinical relevance of "low-set shoulder" and "cervical spine instability" measures uncertain.
Sandrini et al. (1994)	M (21) ETTH (15) CTTH (29) Controls (37)	Muscle activity (MVC)	No differences amongst groups in muscle activity during MVC trapezius	–
Stroppa-Marques et al. (2017)	ETTH (30) Controls (30)	Posture	TTH > controls FHP: 51.9[5.5] vs 53.81[4.6] Cervical lordosis: 51.4[8.3] vs 59.9[4.9]	Difference in FHP between TTH and controls (2°) unlikely to be clinically relevant.
Sturgis et al. (1984)	TTH (12) Controls (12)	Muscle activity (neck movements)	TTH vs controls: No differences in SCM or trapezius activity during neck movements	–
Watson and Drummond (2012)	M (20) TTH (14) Controls (14)	Manual examination	M, TTH > controls Proportion head pain reproduced: M 95%; TTH 100%; controls 57%	Joint mobility assessed but not presented in results.

abd = abduction; CCFT = craniocervical flexion test; CEH = Cervicogenic headache; CM = chronic migraine, CSA cross sectional area; CTTH = chronic TTH; EM = episodic migraine; ETTH = episodic TTH; FHP = forward head posture; FRT = flexion rotation test; MID = minimal important difference; M = migraine; MixH = mixed headaches; MVC = maximal voluntary contraction; ROM = range of motion; SCM = sternocleidomastoid; TMD = temporomandibular disorders; TTH = tension type headacheUT = upper trapezius; VAS = visual analogue scale.

[a] Only measures included in this review are shown.

Table 2
Characteristics of neck pain associated with headache.

Study ID	Prevalence (%)	Neck Disability Index Scores (%)	History (years since onset)	Frequency (days/month)	Intensity (0–10)
Ferracini et al. (2017a)	EM: 80 CM: 93 Controls: 23	–	EM: 10[12.3] CM: 13.9[15.8] Controls: 5[4.6]	–	EM: 5.2[2.9] CM: 6.6[2.7] Controls: 3.8[1.4]
Ferracini et al. (2017b)	M: 78 Controls: 18	M: 23.6[2] Controls: 9[2.8]	M: 6.9[1.2] Controls: 4.8[1.4]	–	M: 4.9[0.5] Controls: 1.4[0.4]
Florencio et al. (2015) Florencio et al. (2016) Florencio et al. (2017a)	M: 77 CM: 90 Controls: 19	EM: 18.4[11.7] (26% none, 48% mild, 26% moderate) CM: 26.2[12.7] (14% none, 43% mild, 43% moderate) Controls: 4[5.4] (81% none, 19% mild)	EM: 7.6[6.3] CM: 5.4[5.9] Controls: 5.4[6.9]	EM: 10.7[10] CM: 18.5[11.3] Controls: 5.2[5.7]	EM: 6.6[2.2] CM: 6.3[1.8] Controls: 3.8[1.5]
Florencio et al. (2017b)	EM: 98 CM: 89	–	EM:10.3[6.8–13.8] CM:13.9[5.5–22.3]	–	EM:5.3[4.5–6.1] CM: 6.6[5.1–8]
Florencio et al.	M: 69 Controls: 12	–	M: 4[3.7] Controls: 1.6[0.6]	M: 11[6.3] Controls: 10[4.4]	M: 5[1.6] Controls: 6[2]
Luedtke et al. (2018)	–	EM: 22[12.1] CM: 32[12] Controls: 6 [6.4]	–	–	–
Marchand et al. (2014)	–	TTH: 23.2[17.8] Controls: 3.8[8.2]	–	–	–
Wanderley et al. (2015)	–	M: 17.7 CI[12.1–20.5] TTH: 12.8 CI[9.7–18.5] Controls: 6.4 CI[3.4–9.8]	–	–	–

CM = chronic migraine; EM = episodic migraine; M = migraine; TTH = tension-type headache.

Horwitz and Stewart, 2015; Marcus et al., 1999) with high risk of bias. Pooled analysis (eight studies, 350 participants) demonstrated no significant difference in FHP between participants with migraine and healthy controls ($p = 0.11$). Exploratory meta-analyses of FHP when measured either in sitting or standing did not change findings. Level of evidence assigned was moderate, down-rated for substantial heterogeneity (I (Plesh et al., 2012) = 87%, large variation in point estimates across studies). Subgroup analyses showed greater FHP (MD = −3.4°[-4.1, −2.6]) in episodic migraine (three studies, 156 participants, $p < 0.001$, $I^2 = 0\%$).

Seven studies measured FHP in TTH. Two studies had overlapping datasets (Fernández-de-las-Peñas et al., 2006b; Fernández-de-las-Peñas et al., 2006c) so results from the larger study (Fernández-de-las-Peñas et al., 2006b) only were included in analysis. After excluding two studies due to reporting and methodological problems (Stroppa-Marques et al., 2017; Marcus et al., 1999), pooled analysis of the remaining four studies (165 participants) showed greater FHP in TTH participants than controls ($p < 0.001$, MD = −6.2°[−8.2°, −4.2°], $I^2 = 3\%$). Subgroup analysis of chronic TTH in three studies (135 participants) produced similar findings. Level of evidence for FHP was low, down-rated for the presence of substantial bias and limited number of studies and participants. Results of FHP are presented in Fig. 2.

Cervical ROM was assessed in 12 migraine studies, three had high risk of bias (Luedtke et al., 2018; Horwitz and Stewart, 2015; Kidd and Nelson, 1993). One study reported movement in all planes as a total value, and could not be included in meta-analyses (Aguila et al., 2017). We analysed results in planes of movement to optimize the number of studies with data whilst maintaining clinical relevance of the findings. Pooled data showed a significant reduction in range for participants with migraine compared to controls (Sagittal plane: eight studies, 389 participants, $p = 0.02$, MD = −5.4°[-9.9°, −0.9°]; Frontal plane: seven studies, 349 participants, $p = 0.04$, MD = −3.2°[-6.2°, −0.2°]). There was considerable heterogeneity ($I^2 = 56\%$, large variations in point estimates) and the MD of 5° in total flexion and extension ROM is unlikely to be clinically relevant. Sensitivity analyses of three studies (162 participants) with low risk of bias found no differences in ROM between participants with migraine and controls (Sagittal plane: $p = 0.09$, $I^2 = 0\%$; Frontal plane: $p = 0.87$, $I^2 = 27\%$). Subgroup analysis of ROM in episodic migraine did not differ greatly from the original pooled analysis (three studies, 162 subjects, Sagittal plane: $p = 0.02$, MD = −3.93°[-8.50°, −0.64°]). Overall, the level of evidence for impaired cervical ROM in migraine was very low due to significant heterogeneity, small effect size and substantial bias as supported by sensitivity analyses.

Results from six TTH studies (353 participants) were pooled after one was excluded due to high risk of bias and lack of objective measures (Kidd and Nelson, 1993). ROM was significantly reduced in all planes of movement (Sagittal plane: $p = 0.001$, $I^2 = 57\%$, MD = −9.9° [-15.9°, −3.8°]; Transverse plane: $p = 0.02$, $I^2 = 95\%$, MD = −15.0°[-27.7°, −2.3°]; Frontal plane: $p = 0.003$, $I^2 = 53\%$, MD = −5.4°[-9.0°, −1.8°]) but there was significant heterogeneity (I^2 = 53%–95%, large variations in point estimates) and all but one study (Jull et al., 2007) had moderate risk of bias. Consequently, level of evidence regarding cervical ROM in TTH was deemed low. ROM results are presented in Fig. 3.

Cervical muscle strength was measured in six studies but sufficient data was only available for flexion and extension strength in five studies. Meta-analyses revealed no significant differences in flexion and extension strength between controls and migraine participants (three studies, $n = 164$, flexion: $p = 0.28$, $I^2 = 0\%$; extension: $p = 0.14$, $I^2 = 69\%$) or TTH (three studies, $n = 199$, flexion: $p = 0.15$, $I^2 = 84\%$; extension: $p = 0.11$, $I^2 = 71\%$) (Fig. 4). Levels of evidence were low for strength changes in both headache types.

The craniocervical flexion test (CCFT) assesses the activation of the deep cervical flexors and measures any inappropriate activation of the superficial neck flexors (sternocleidomastoid). Seven studies examined the CCFT, two were in TTH, one of which had methodological concerns (Fernández-de-las-Peñas et al., 2007a). The study with low risk of bias detected no impaired CCFT performance in participants with TTH (Jull et al., 2007). For migraine, pooled results from four studies (220 participants) for sternocleidomastoid activity during the final stage of CCFT showed no significant differences between participants with migraine and controls ($p = 0.71$, $I^2 = 96\%$) (Fig. 5). Two studies found higher cervical extensor activity during CCFT in migraine participants (Florencio et al., 2016, 2017b). It is difficult to interpret the relevance of this finding. Impaired cervical flexor activity during CCFT is the primary measure of the test (Jull and Falla, 2016), but this was not demonstrated in these studies. Therefore, we regard the body of evidence as indicating CCFT performance in migraine and TTH was no different to controls.

Joint position error (JPE) was assessed in five studies with only two (Marchand et al., 2014; Jull et al., 2007) involving participants with

Table 3
Risk of bias.

Study ID	Selection	Measurement	Reporting	Confounding		Blinding	Overall Risk
				Cervical Disorders	Headache status at testing		
Aguila et al. (2017)	+	Physical examination of controls by novice, headache subjects by experienced physiotherapists	+	Partial exclusions	Not stated	+	Moderate
Attia (2002)	+	+	Inconsistent, unclear reporting	Partial exclusions	Not stated	+	High
Bevilaqua Grossi et al. (2009)	+	+	+	No exclusions	53–67% with headache, no influence on results	+	Moderate
Dugailly et al. (2017)	+	FRT range of controls outside normative values (Hall and Robinson, 2004; Dvorak et al., 1992)	No characterisation of headache	Partial exclusions	Not stated	+[a]	High
Dumas et al. (2001)	+	+	+	+	Not stated	+	Low
Fernández-de-las-Peñas et al. (2006a)	+	+	+	No exclusions	No headache, ≥1 week after migraine episode	+	Moderate
Fernández-de-las-Peñas et al. (2006c)	+	+	+	No exclusions	Headache < 4/10	+	Moderate
Fernández-de-las-Peñas et al. (2006b)	+	+	Headache features assessed but not fully presented in results.	No exclusions	Headache < 4/10	+	Moderate
Fernández-de-las-Peñas et al. (2007c)	+	+	+	Partial exclusions	Headache < 3/10	+	Moderate
Fernández-de-las-Peñas et al. (2007b)	+	+	+	No exclusions	No headache	+	Moderate
Fernández-de-las-Peñas et al. (2007a)	Small sample size	Validity of CCFT: Activation score for controls outside testing range.	+	No exclusions	Headache < 4/10	+	Moderate
Fernández-de-las-Peñas et al. (2008)	Small sample size	+	+	Partial exclusions	Headache < 4/10	Not stated	Moderate
Ferracini et al. (2016)	+	+	+	Partial exclusions	58% with headache	+	Moderate
Ferracini et al. (2017a)	+	+	+	Partial exclusions	Not stated	+	Moderate
Ferracini et al. (2017b)	+	+	+	Partial exclusions	54% with headache	+	Moderate
Ferreira et al. (2014)	+	+	+	Partial exclusions	No acute pain	+	Moderate
Florencio et al. (2015)	+	+	+	Partial exclusions	No headache	+	Moderate
Florencio et al. (2016)	+	+	+	Partial exclusions	No headache	+	Moderate
Florencio et al. (2017a)	+	+	+	Partial exclusions	No headache	+	Moderate
Florencio et al. (2017b)	+	+	+	Partial exclusions	No headache	+	Moderate
Florencio et al.	+	+	+	Partial exclusions	No headache	+	Moderate
Formisano et al. (1988)	+	No description of MVC procedure.	Limited characterisation of headache	No exclusions	No headache ≥2 days prior testing	Not stated	High
Hall et al. (2010)	+	+	+	+	No headache ≥2 days prior testing	+	Low
Horwitz and Stewart (2015)	+	Rot ROM exceeds normative range in controls	Citation errors, partial reporting of results	Partial exclusions	Between 2 days before and 3 days after predicted date of menstruation	+	High
Jensen (1996)	+	Trapezius MVC procedure not described or referenced	+	No exclusions	Tested twice, with and without headache	+	High
Jensen et al. (1998)	+	As above	+	No exclusions	No headache	+	High
Jull et al. (2007)	+	+	Non-significant results for JPE not presented	+[a]	33% with headache	+	Low

(continued on next page)

Table 3 (*continued*)

Study ID	Selection	Measurement	Reporting	Confounding		Blinding	Overall Risk
				Cervical Disorders	Headache status at testing		
Kidd and Nelson (1993)	+	No objective measures of ROM.	M and TTH grouped together. Impaired ROM directions not reported	No exclusions	35% with headache	+	High
Luedtke et al. (2018)	+	FRT outside normative range for controls (Hall and Robinson, 2004; Dvorak et al., 1992) Limited test range (20–28 mmHg) for CCFT. "Upper trapezius test" refers to lower trapezius.	Results of reproduction and resolution test reported in error as significant.[a]	Partial exclusions	CM: no headache, EM: no headache ≥2 days prior testing. Not during prodromal phase	+	High
Luedtke and May (2017)	+	+	+	Partial exclusions	CM: no headache, EM: no headache ≥2 days prior testing	+	Moderate
Madsen et al. (2016)	+	+	+	+	63% with headache	+	Low
Madsen et al. (2018)	+	+	+	+	63% with headache	+	Low
	+	+	+	Partial exclusions	No headache	Not stated	Moderate
Marcus et al. (1999)	+	No objective measures of FHP or spinal curvature.	No details of postural abnormalities in results.	No exclusions	Not stated	No blinding	High
Nagasawa et al. (1993)	+	+	+	No exclusions	Not stated	Not stated	High
Ogince et al. (2007)	+	+	+	+	No influence on results	+	Low
Rosenhall et al. (1996)	+	+	+	Partial exclusions	Not stated	Not stated	Moderate
Rossi et al. (2005)	+	+	+	Partial exclusions	Not stated	Not stated	Moderate
Sandrini et al. (1994)	+	Limited description of MVC procedure.	Limited characterisation of headache in participants	No exclusions	30–59% with headache	+	High
Sohn et al. (2010)	+	+	+	Partial exclusions	Headache < 3/10	+	Moderate
Sohn et al. (2013)	+	MVC performed without resistance.	+	Partial exclusions	No headache	+	Moderate
Stroppa-Marques et al. (2017)	+	+	+	No exclusions	Not stated	No blinding[a]	High
Sturgis et al. (1984)	+	+	No characterisation of headache	No exclusions	Not stated	Not stated	High
Tali et al. (2014)	+	Posture assessment differs from cited reference. Possible assessor bias: consensual evaluation process of manual examination	+	Partial exclusions	No headache	+	Moderate
Wanderley et al. (2015)	+	+	+	+	Not stated	+	Low
Watson and Drummond (2012)	+	+	Limited characterisation of headache	No exclusions	No headache	No blinding	High
Zito et al. (2006)	+	+	+	+	No headache	+	Low
Zwart (1997)	+	+	+	No exclusions	Repeated tests, no difference with and without headache	+	Moderate

"+" = low risk of bias, EM = episodic migraine, CM = chronic migraine, CCFT = craniocervical flexion test; FHP = forward head posture; FRT = flexion rotation test; JPE = joint position error; M = migraine; MVC = maximal voluntary contraction; ROM = range of motion; TTH = tension type headache.

[a] Clarified by authors via correspondence.

Study or Subgroup	Migraine or TTH Mean [Degrees]	Migraine or TTH SD [Degrees]	Total	Healthy Controls Mean [Degrees]	Healthy Controls SD [Degrees]	Total	Weight	Mean Difference IV, Random, 95% CI [Degrees]
1.8.1 Migraine FHP								
Dumas 2001	49	8.3	16	47.4	6.3	17	9.3%	1.60 [−3.45, 6.65]
Fernández-De-Las-Peñas 2006a	42.2	6.4	20	52.6	7.2	20	10.6%	−10.40 [−14.62, −6.18]
Ferracini 2016	46.1	5.3	33	44.5	5.1	33	13.6%	1.60 [−0.91, 4.11]
Ferracini 2017	34.5	6.6	16	37.9	5.3	22	11.2%	−3.40 [−7.32, 0.52]
Ferreira 2014	69.88	2.95	22	73.03	3.72	22	14.4%	−3.15 [−5.13, −1.17]
Florencio 2017b	34.5	1.5	16	38	1	23	15.6%	−3.50 [−4.34, −2.66]
Tali 2014	50.99	7.29	20	53.21	4.37	20	11.5%	−2.22 [−5.94, 1.50]
Zito 2006	53.3	3.9	25	50.3	4.6	25	13.8%	3.00 [0.64, 5.36]
Subtotal (95% CI)			**168**			**182**	**100.0%**	**−1.96 [−4.35, 0.43]**
Heterogeneity: $Tau^2 = 9.32$; $Chi^2 = 52.98$, df = 7 (P < 0.00001); $I^2 = 87\%$								
Test for overall effect: Z = 1.61 (P = 0.11)								
1.8.3 TTH FHP								
Fernández-De-Las-Peñas 2006	45.3	7.6	25	54.1	6.3	25	25.9%	−8.80 [−12.67, −4.93]
Fernández-de-Las-Peñas 2007	48.8	7	15	53.8	4	15	23.4%	−5.00 [−9.08, −0.92]
Fernández-de-las-Peñas 2007	42	6.6	10	48.8	2.5	10	20.4%	−6.80 [−11.17, −2.43]
Sohn 2010	133.31	5.6	42	137.74	7.68	23	30.3%	−4.43 [−8.00, −0.86]
Subtotal (95% CI)			**92**			**73**	**100.0%**	**−6.18 [−8.18, −4.18]**
Heterogeneity: $Tau^2 = 0.11$; $Chi^2 = 3.08$, df = 3 (P = 0.38); $I^2 = 3\%$								
Test for overall effect: Z = 6.06 (P < 0.00001)								

Test for subgroup differences: $Chi^2 = 7.04$, df = 1 (P = 0.008), $I^2 = 85.8\%$

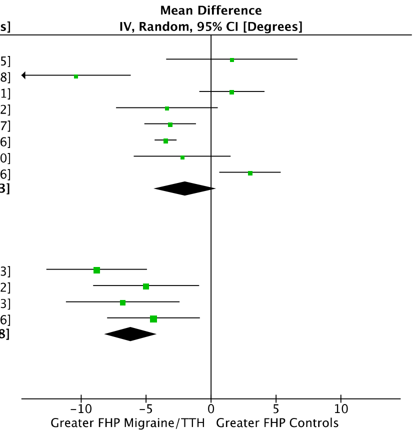

Fig. 2. Meta-analyses of forward head posture between migraine or tension-type headache and controls Legend: FHP = forward head posture, TTH = tension type headache.

TTH. One had moderate risk of bias (Marchand et al., 2014), and the other found no differences between participants with TTH and controls (Jull et al., 2007). Pooled results from three migraine studies, 160 participants, found no significant differences between migraineurs and controls in JPE (Left rotation: p = 0.36, $I^2 = 60\%$; Right rotation: p = 0.70, $I^2 = 49\%$) (Fig. 5).

The results for the remaining measures could not be pooled for analyses. A narrative synthesis of these findings is presented in Appendix E. Six studies reported the flexion rotation test (FRT) in migraine but meta-analysis was not possible. Two studies provided a cumulative left, right score (Aguila et al., 2017; Luedtke et al., 2018), a third study used an atypical version of the test (Dugailly et al. (2017)), and the fourth study compared migraine and CEH without healthy controls (Hall et al., 2010). Of note, manual segmental examination was assessed and scored diversely across 11 studies. Joints were considered symptomatic or awarded positive test scores based on perceived joint mobility and/or pain provoked during assessment. Since pain response during manual examination may reflect the degree of pain hypersensitivity in patients, confounding bias was highly plausible when abnormal joint mobility was not required for a positive test. This was the case for four studies (Luedtke et al., 2018; Aguila et al., 2017; Watson and Drummond, 2012; Luedtke and May 2017) three of which reported significant findings. In the remaining seven studies, one did not employ controls (Ferracini et al., 2017a) and one was likely influenced by assessor bias due to a consensual evaluation process (Tali et al., 2014). The other six studies did not detect any differences in upper cervical manual examination findings between participants with migraine and controls. One migraine study detected significantly greater pain and stiffness in lower cervical segments (Horwitz and Stewart, 2015) which more likely reflected a coexisting neck disorder (Dewitte et al., 2014) as there is no neuroanatomical basis for this region to refer pain into the head (Bogduk, 2014).

A summary of all findings and the level of evidence associated with each finding is provided in Table 4.

4. Discussion

This review included 48 studies investigating cervical musculoskeletal or sensorimotor impairments in migraine and TTH. A total of 17 measures were examined and meta-analyses performed on five of these measures. Pooled data showed that participants with TTH had greater FHP and reduced ROM compared to headache-free controls, albeit with low levels of evidence. A greater number of studies and participants were available for meta-analyses in migraine. ROM was reduced but by less than six degrees in the plane most restricted. The level of confidence in this finding was further lowered due to unexplained heterogeneity across studies and because sensitivity analyses showed no differences between groups in studies rated low risk of bias. Other pooled analyses found no differences between migraineurs and controls for FHP, cervical strength, CCFT performance and joint position error. Subgroup analyses showed increased FHP and reduced ROM in episodic migraine, but the number of studies and participants were limited and differences were minor. For measures outside meta-analyses, there was some evidence of altered superficial muscle activity during isometric contractions for migraine and TTH. Other outcomes had very low levels of evidence due to limited data. This review also set out to evaluate neck pain features alongside cervical impairments but limited data prevented this evaluation.

We implemented a rigorous process of risk of bias assessment. Several key issues diminished our confidence in the findings. Foremost, many studies did not adequately control for confounding bias. Musculoskeletal cervical disorders are highly prevalent (GBD, 2015, 2015) and may coexist with primary headache and this could be reflected in headache participants reporting high frequencies of neck pain (Florencio et al., 2015, 2016) and moderate levels of neck disability (Luedtke et al., 2018; Florencio et al., 2016). One study which screened for CEH found that 82% of the 325 headache subjects interviewed reported overlapping symptoms of CEH and migraine and could not be included in their study (Ogince et al., 2007). Previous studies have found CEH to coexist with migraine or TTH (Pfaffenrath and Kaube, 1990; Antonaci et al., 2001; Amiri et al., 2007; Sjaastad and Bakketeig, 2008), prevalence ranging from 7% (Pfaffenrath and Kaube, 1990) to 40% (Ogince et al., 2007; Antonaci et al., 2001). Co-existing CEH might be a particular issue in chronic migraine, in which, by definition, only 8 of the 15 or more headache days per month need to exhibit features of migraine (Headache Classification Committee, 2018). This operational definition reflects the variability of symptoms in chronic migraine, but opens up the possibility of undiagnosed coexisting headaches whose symptoms overlap with migraine, resulting in a migraine-like headache. Although secondary headaches are not counted in the definition of chronic migraine, it may be possible for patients to mistake CEH for a milder version of their migraine since they share common features such as unilaterality of headache and neck pain (Blumenfeld and Siavoshi, 2018). Furthermore, a lack of association between headache features and FHP (Sohn et al., 2010; Fernández-de-las-Peñas et al., 2007b) or ROM (Sohn et al., 2010; Fernández-de-las-Peñas et al., 2007b) in TTH, and FRT (Ogince et al., 2007) in migraine, support the possibility that cervical impairments can sometimes be unrelated to headache and, in some participants, be incidental features or co-existing cervical disorders. Failure to exclude idiopathic cervical disorders including CEH

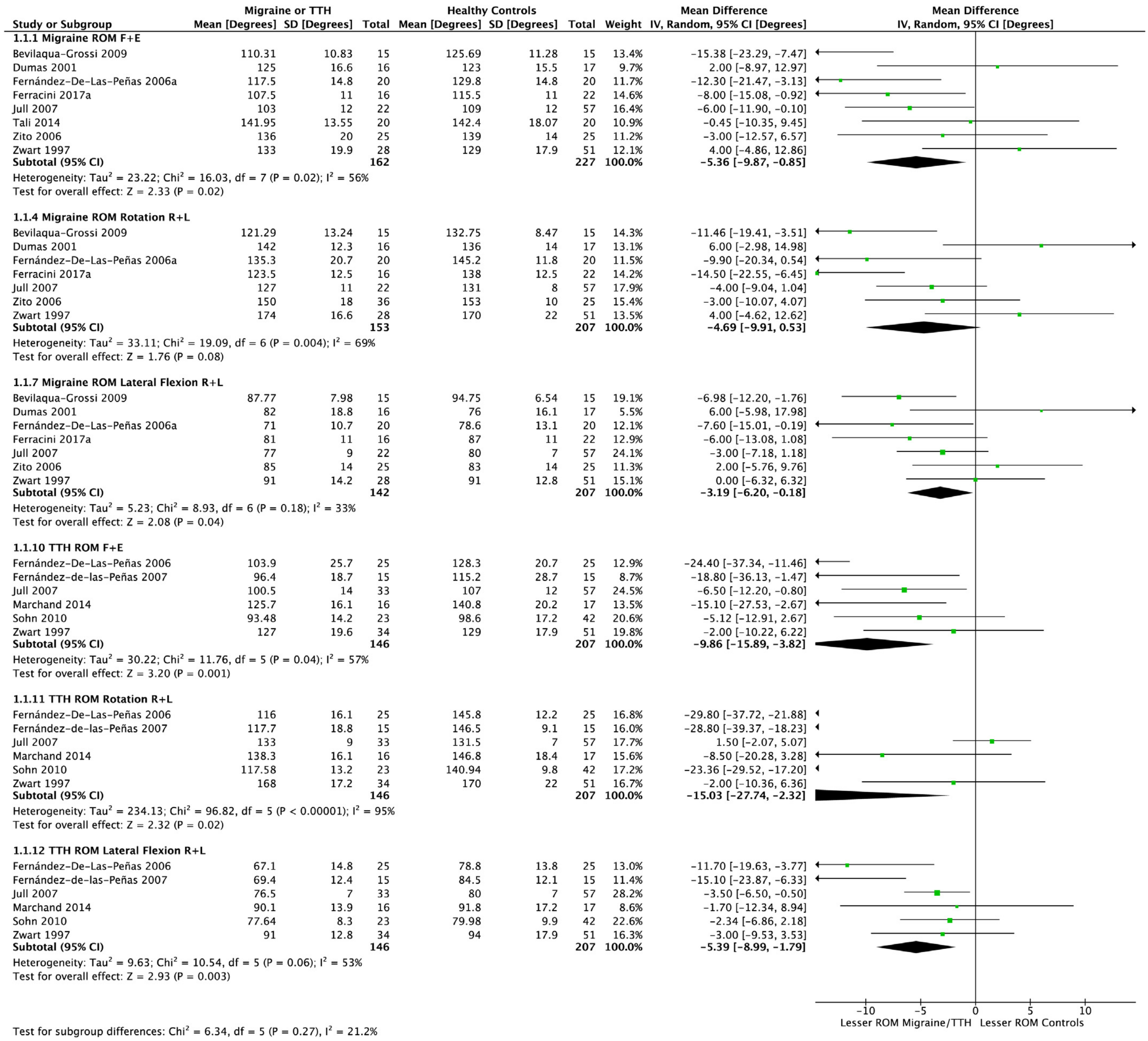

Fig. 3. Meta-analyses of range of motion between migraine or tension-type headache and controls. Legend: E = Extension, F = Flexion, R = right, L = left, ROM = range of motion, TTH = tension type headache.

could reflect the methodological difficulties of identifying such disorders in migraine and TTH on a symptomatic basis.

Sensitisation mechanisms during and around the time of headache may also confound results. Only one study (Luedtke et al., 2018) explicitly avoided testing during migraine prodromes. Although many studies avoided testing when headache was present, this was not always possible in chronic headache. A few studies showed that the presence of headache did not influence muscle activity (Jensen, 1996), ROM (Zwart, 1997; Bevilaqua Grossi et al., 2009), or FRT (Ogince et al., 2007) results. However, headache may exert differential effects on individual cervical measures.

In neck conditions such as idiopathic neck pain and whiplash associated disorders, musculoskeletal dysfunction is characterized by a collection of cervical impairments spanning the domains of cervical motion, neuromuscular performance, articular function and proprioception (Jull et al., 2018). Whilst there was evidence of three impairments in TTH, this was not so for migraine. Minor or isolated findings may be manifestations of central mechanisms within the trigeminocervical nucleus (Bartsch, 2005), especially where pain was the limiting factor. This may be the same reason why, contrary to expectations, CCFT performance was not associated with neck-related disability in migraine (Florencio et al., 2016).

Finally, our meta-analyses combined data from multiple studies to provide more precise evaluations of differences between migraine or TTH and healthy controls, however the patient populations and measurement methods differed across studies. Attempts to perform subgroup analyses of chronic and episodic headache versus controls were limited by the few studies with defined headache subgroups. It is possible that pooled results from more studies in episodic and chronic migraine or TTH may produce different results. Although funnel plots of measures with eight or more studies were performed, these were inconclusive therefore we are unable to exclude publication bias from our results.

In conclusion, this review found more cervical musculoskeletal impairments in TTH than in migraine, but levels of confidence in all the findings were low. Future studies investigating cervical musculoskeletal

Study or Subgroup	Headache (M or TTH) Mean	SD	Total	Controls Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
5.1.1 Migraine Flexion MVC								
Dumas 2001	76.54	51.2	16	97.32	40.1	17	22.0%	−0.44 [−1.13, 0.25]
Florencio 2015	40.1	14.9387	21	41.5	15.8123	31	34.4%	−0.09 [−0.64, 0.47]
Jull 2007	80	35	22	85	45	57	43.6%	−0.12 [−0.61, 0.38]
Subtotal (95% CI)			**59**			**105**	**100.0%**	**−0.18 [−0.50, 0.15]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.72$, df = 2 (P = 0.70); $I^2 = 0\%$								
Test for overall effect: Z = 1.08 (P = 0.28)								
5.1.2 Migraine Extension MVC								
Dumas 2001	150.6	58.9	16	170.8	67.9	17	29.9%	−0.31 [−1.00, 0.38]
Florencio 2015	83.9	25.7033	21	113.1	29.171	31	33.3%	−1.03 [−1.62, −0.44]
Jull 2007	170	50	22	173	70	57	36.8%	−0.05 [−0.54, 0.45]
Subtotal (95% CI)			**59**			**105**	**100.0%**	**−0.45 [−1.06, 0.16]**
Heterogeneity: $Tau^2 = 0.20$; $Chi^2 = 6.46$, df = 2 (P = 0.04); $I^2 = 69\%$								
Test for overall effect: Z = 1.46 (P = 0.14)								
5.1.3 TTH Flexion MVC								
Fernández–De–Las–Peñas 2008	68	10	9	100	15	10	22.7%	−2.37 [−3.61, −1.14]
Jull 2007	87.5	50.5	33	87	50	57	38.7%	0.01 [−0.42, 0.44]
Madsen 2016	11.4	5.66	60	12.79	5.83	30	38.5%	−0.24 [−0.68, 0.20]
Subtotal (95% CI)			**102**			**97**	**100.0%**	**−0.63 [−1.49, 0.23]**
Heterogeneity: $Tau^2 = 0.45$; $Chi^2 = 12.72$, df = 2 (P = 0.002); $I^2 = 84\%$								
Test for overall effect: Z = 1.43 (P = 0.15)								
5.1.4 TTH Extension MVC								
Fernández–De–Las–Peñas 2008	76	15	9	100	15	10	20.4%	−1.53 [−2.58, −0.48]
Jull 2007	170	70	33	173	70	57	40.1%	−0.04 [−0.47, 0.39]
Madsen 2016	17.07	9.16	60	21.49	10.31	30	39.5%	−0.46 [−0.90, −0.02]
Subtotal (95% CI)			**102**			**97**	**100.0%**	**−0.51 [−1.13, 0.11]**
Heterogeneity: $Tau^2 = 0.20$; $Chi^2 = 7.02$, df = 2 (P = 0.03); $I^2 = 71\%$								
Test for overall effect: Z = 1.61 (P = 0.11)								

Test for subgroup differences: $Chi^2 = 1.76$, df = 3 (P = 0.62), $I^2 = 0\%$

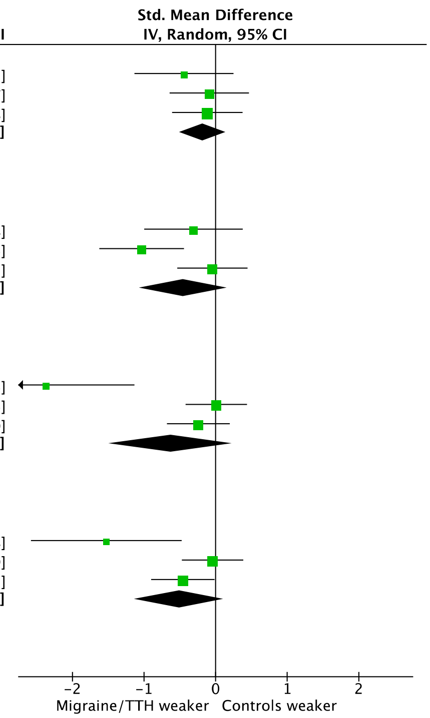

Fig. 4. Meta-analyses of flexion and extension strength between migraine or tension-type headache and controls. Legend: MVC = maximal voluntary contraction, TTH = tension type headache.

impairments in migraine or TTH should differentiate episodic from chronic headache, identify coexisting idiopathic neck pain disorders and characterise neck pain behaviour A more comprehensive and accurate clinical picture will be achieved by assessing a collection of measures, considering the phase of headache during assessment, and interpreting findings alongside neck pain and headache features. Overall more research is required to gain a better understanding of the nature of neck pain in migraine and TTH so that ultimately individual patients can receive the most suitable management.

Conflicts of interest

Nil.

Ethics approval

NA.

Study or Subgroup	Migraine Mean	SD	Total	Controls Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
7.1.1 Migraine SCM activity during final stage of CCFT								
Florencio 2016	11.4	1	21	8	1	31	24.4%	3.35 [2.48, 4.22]
Florencio 2017b	12.5	2.5	16	21	5	23	24.7%	−2.00 [−2.79, −1.21]
Jull 2007	0.59	0.1	22	0.59	0.1	57	25.5%	0.00 [−0.49, 0.49]
Zito 2006	220	115.37	25	220	180.1	25	25.4%	0.00 [−0.55, 0.55]
Subtotal (95% CI)			**84**			**136**	**100.0%**	**0.32 [−1.36, 2.00]**
Heterogeneity: $Tau^2 = 2.82$; $Chi^2 = 80.96$, df = 3 (P < 0.00001); $I^2 = 96\%$								
Test for overall effect: Z = 0.38 (P = 0.71)								
7.1.2 Migraine Joint Positioning Error Left Rotation								
Dumas 2001	6.1	4.4	16	4.6	2.9	17	28.6%	0.40 [−0.29, 1.09]
Ferracini 2017a	6.5	2.1	55	5.3	1.7	22	37.0%	0.60 [0.09, 1.10]
Zito 2006	5.5	2.7	25	6.1	2.1	25	34.4%	−0.24 [−0.80, 0.31]
Subtotal (95% CI)			**96**			**64**	**100.0%**	**0.25 [−0.28, 0.78]**
Heterogeneity: $Tau^2 = 0.13$; $Chi^2 = 5.00$, df = 2 (P = 0.08); $I^2 = 60\%$								
Test for overall effect: Z = 0.92 (P = 0.36)								
7.1.3 Migraine Joint Positioning Error Right Rotation								
Dumas 2001	5.8	3.5	16	4.8	3.4	17	27.5%	0.28 [−0.40, 0.97]
Ferracini 2017a	5.7	2.2	55	5.6	2	22	38.5%	0.05 [−0.45, 0.54]
Zito 2006	4.7	2.6	25	6.2	2.8	25	34.0%	−0.55 [−1.11, 0.02]
Subtotal (95% CI)			**96**			**64**	**100.0%**	**−0.09 [−0.56, 0.38]**
Heterogeneity: $Tau^2 = 0.08$; $Chi^2 = 3.92$, df = 2 (P = 0.14); $I^2 = 49\%$								
Test for overall effect: Z = 0.38 (P = 0.70)								

Test for subgroup differences: $Chi^2 = 0.98$, df = 2 (P = 0.61), $I^2 = 0\%$

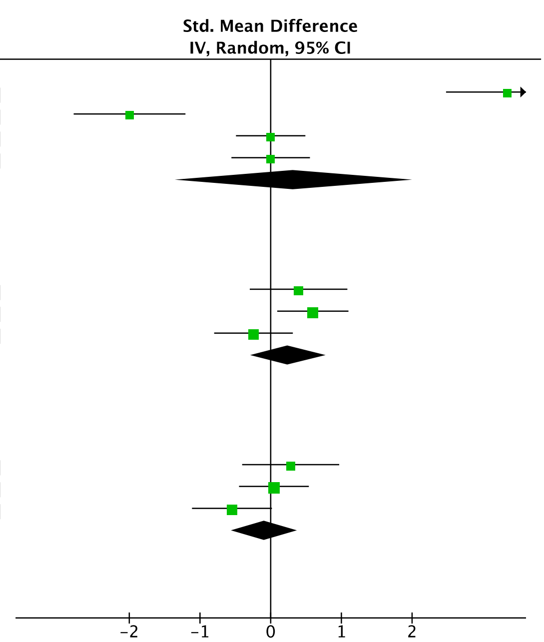

Fig. 5. Meta-analyses of CCFT and joint positioning error between migraine and controls. Legend: CCFT = craniocervical flexion test, SCM = sternocleidomastoid.

Table 4
Summary of findings.

Level of Evidence	Migraine	Tension Type Headache
Moderate	• Normal cervical posture • Normal performance of CCFT • Normal joint mobility during manual examination • Normal upper cervical mobility (FRT) • Normal cervical proprioception	–
Low	• Normal muscle dimensions. • Normal muscle endurance. • Normal muscle strength	• Increased FHP • Reduced cervical range of motion • Altered superficial muscle activity during isometric contractions • Normal cervical strength
Very Low	• Reduced cervical ROM • Altered superficial muscle activity during isometric contractions • Normal nerve extensibility • Normal muscle extensibility	• Normal cervical proprioception • Normal cervical muscle dimensions. • Normal joint mobility during manual examination • Normal CCFT performance

CCFT = craniocervical flexion test; FHP = forward head posture; FRT = flexion rotation test; ROM = range of motion.

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PROSPERO registration

CRD42018083683.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2019.04.007.

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