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Neck musculoskeletal dysfunction in patients with chronic primary headaches

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Ignacio Elizagaray-García, Celia María de-Toro-Cañizares, Javier Díaz-de-Terán, Alfonso Gil-Martínez & Kerstin Luedtke

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Comparison of the Neck Musculoskeletal Dysfunction Between Patients With Chronic Tension-Type Headache, Chronic Migraine and Chronic Cluster Headache. A cross-sectional study.

AUTHORS AND AFFILIATIONS

Ignacio Elizagaray-García PhD[1,2], Celia María-de-Toro MSc[1,3], Javier Díaz-de-Terán PhD[4,5], Alfonso Gil-Martínez PhD [1,2,5,6], Kerstin Luedtke PhD[7].

1. CranioSPain Research Group. Centro Superior de Estudios Universitarios La Salle. 28023 Madrid (Spain).
2. Clínica Universitaria. Centro Superior Estudios Universitarios La Salle. Madrid. 28023 Madrid (Spain).
3. Fisioterapia 180 Grados. 28100 Madrid (Spain).
4. Departamento de Neurología, Hospital Universitario La Paz, 28029 Madrid, Spain
5. Instituto de investigación biosanitaria del Hospital Universitario La Paz, IdiPAZ, 28029 Madrid. Spain.
6. Unidad de fisioterapia, Hospital Universitario La Paz, 28029 Madrid, Spain
7. Institute of Health Sciences, Department of Physiotherapy, Pain and Exercise Research Luebeck (P.E.R.L.), University of Luebeck, Luebeck, Germany.

Corresponding author

(Primary corresponding author) Alfonso Gil-Martínez (PhD) (Primary)

Email: fongilmar@gmail.com

Affiliations:

- CranioSPain Research Group. Centro Superior de Estudios Universitarios La Salle. 28023 Madrid (Spain).
- Clínica Universitaria. Centro Superior Estudios Universitarios La Salle. Madrid. 28023 Madrid (Spain).
- Instituto de investigación biosanitaria del Hospital Universitario La Paz, IdiPAZ, Madrid. Spain.
- Unidad de fisioterapia, Hospital Universitario La Paz, Madrid, Spain

(Other corresponding author) Ignacio Elizagaray-García

Email: n.elizagaray@gmail.com

- CranioSPain Research Group. Centro Superior de Estudios Universitarios La Salle. 28023 Madrid (Spain).
- Clínica Universitaria. Centro Superior Estudios Universitarios La Salle. Madrid. 28023 Madrid (Spain).

ABSTRACT

Objective: To compare cervical musculoskeletal findings in chronic forms of migraine, tension-type headache, cluster headache, and healthy controls and identify which variables were most strongly associated with headache frequency, neck disability and impact in each headache group.

Methods: Single-blinded cross-sectional study with a non-probabilistic sample. A blinded physiotherapist assessed 129 participants: chronic migraine (n=35), chronic tension-type headache (n=30), chronic cluster headache (n=34) and headache-free controls (n=30). Psychosocial and cervical musculoskeletal variables (head posture, total cervical active range of motion, flexion–rotation test, motor control, symptom reproduction and resolution) were compared. Backward linear regression analyses were performed to explore associations between cervical variables and headache frequency. neck disability and headache-related impact.

Results: Compared to controls, chronic cluster headache showed reduced total cervical active range of motion [F(3,128)=8.8; p=0.001, d=0.75], retraction [F(3,128)=4.66; p=0.007, d=0.70], protraction [F(3,128)=7.77; p=0.017, d=0.73] and flexion–rotation [F(3,128)=3.68; p=0.014, d=0.72]. While sex confounded total active range of motion (p=0.009); neither variable influenced protraction or retraction (all $p \geq 0.26$). Familiar head pain was evoked more in chronic migraine (68.6%) and tension-type headache (72.4%) than controls (23.3%) [$\chi^2(1)=20.85$; p=0.008; $\chi^2(1)=29.99$; p=0.0003].

Erector spinae activity was negatively associated with cluster headache frequency (Adjusted $R^2=0.25$; $\beta=-0.65$; p=0.02), cervical retraction was negatively associated with migraine frequency (Adjusted $R^2=0.11$; $\beta=-1.58$; p=0.03), and no significant associations were found for tension-type headache.

Conclusion: This study provides the first comprehensive assessment of cervical musculoskeletal function in chronic cluster headache and directly compares it with the main chronic primary headaches and free-headache control group. Chronic cluster headache showed reduced cervical range of motion and impaired flexion–rotation versus controls; Although some differences between headache groups were observed, cervical musculoskeletal impairments were broadly present across chronic headache populations, without a clearly distinctive disorder-specific pattern. Neck musculoskeletal findings were not associated with headache frequency or impact.

Key Words. Migraine, Tension type headache, cluster headache, cervical spine, pain, physical examination.

MAIN TEXT

INTRODUCTION

Diagnosis of primary headaches relies on symptom characteristics and associated features such as nausea, phonophobia, and photophobia [1]. Globally, tension-type headache is the most prevalent primary headache disorder (42%), followed by migraine (11%). Although cluster headache has been less extensively studied than migraine and tension-type headache it is associated with substantial disability [2, 3].

Clinical reports from primary care settings, however, state that migraine is frequently misdiagnosed as tension-type headache or even as cervicogenic headache [4]. Differentiating between headache types becomes increasingly challenging in chronic conditions, where symptom overlap and co-occurrences are common [5–7]. Among the various associated features, neck pain is one of the most prevalent, reported by up to 88.4% of patients with tension-type headache and 76.2% of those with migraine [8–10]. In patients with cluster headache, neck pain has also been linked to the onset of attacks [11]. Self-reported neck disability is also common in patients with tension-type headache and migraine but has not been studied in patients with cluster headache [12–14]. Moreover, in chronic tension-type headache (CTTH) and chronic migraine (CM), neck disability was associated with headache frequency in both groups [7].

The mechanisms linking the commonly reported neck pain and neck-related disability to primary headaches remain poorly understood. Although the trigeminocervical convergence has frequently been proposed as a potential explanation [15–17], this mechanism may not fully account for the widespread distribution of neck symptoms since cervical musculoskeletal structures associated with neck pain (e.g., the trapezius or levator scapulae muscles) are only partially innervated by the upper cervical segments proposed to form the trigeminocervical complex [C1–C2/(3)] [18, 19]. A second hypothesis is related to increased central sensitization due to repeated headache experience, as discussed in frequent and chronic migraine [20]. Additional nociception from neck-related structures might serve as a stimulus ("trigger") to this sensitive system and lead to more frequent and/or more severe headaches [21].

Based on these neuroanatomical frameworks, investigating and comparing musculoskeletal findings across primary headaches with different pathophysiologies is warranted. Specifically, due to its central neurovascular and autonomic etiology, Chronic Cluster Headache (CCH) was initially hypothesized to display a functional dissociation from musculoskeletal structures, presenting significantly fewer neck symptoms compared to CM and CTTH**.** Additionally, the inclusion of a healthy, headache-free control group is essential to establish a baseline for normal cervical function, allowing for a precise determination of whether sensorimotor and structural impairments are uniquely associated with the burden of chronic headaches. Therefore, examining these cohorts concurrently may contribute to a better understanding of whether cervical dysfunction unifies chronic headache populations or remains exclusive to specific pathophysiological profiles, while also helping guide future clinical decision-making

Previous studies comparing episodic migraine and tension-type headache have reported differences in cervical musculoskeletal features, particularly active range of motion (AROM) and forward head posture (FHP) [14, 18, 19]. However, to our knowledge, only one study has directly compared musculoskeletal findings between chronic headache types (CM and CTTH), reporting no differences, although the assessment was limited to AROM and FHP [7]. According to international consensus recommendations, a comprehensive evaluation of cervical musculoskeletal dysfunction should include 11 standardized tests [22]. To date, no study has applied this approach in patients with episodic or chronic cluster headache (CCH), nor compared findings across CM, CTTH, and CCH.

Based on previous evidence in CM and CTTH and considering the neurophysiological interaction between trigeminal and upper cervical nociceptive pathways, we hypothesized that patients with the three chronic primary headache disorders would present greater cervical musculoskeletal dysfunction compared with healthy controls. Furthermore, given the distinct clinical characteristics and pathophysiological mechanisms underlying CM, CTTH, and CCH, we also hypothesized that cervical musculoskeletal findings may differ across headache types. Such knowledge may facilitate the development of tailored multimodal treatment strategies within an interprofessional framework

Accordingly, the primary aim of this study was to compare cervical musculoskeletal examination findings, based on expert recommendations, among patients with CM, CTTH and CCH as well as healthy controls. A secondary aim was to determine which cervical variables were most strongly associated with neck disability, headache frequency, and headache-related impact within each headache group.

METHODS

Study design

A single blind, cross-sectional study with a non-probabilistic sample was conducted at [**Information removed for peer review[1]**]. A headache expert neurologist (more than 15 years' experience) recruited patients diagnosed with CM, CTTH or CCH. Headache-free participants were recruited through advertisements and snowball sampling.

The study was carried out from September 2019 to February 2024 at [**Information removed for peer review[2]**]. The protocol was approved by the Ethics Committee of [**Information removed for peer review[3]**] according to ethical standards of the declaration of Helsinki. All participants signed an informed consent document, and all procedures followed the STROBE [23].

Participants

Participants were consecutively recruited during their regular visits to a specialized neurology outpatient clinic as they met the predefined criteria. To prevent self-selection bias based on neck symptoms, patients were enrolled based solely on their headache diagnosis; no advertisement-based or neck-related self-referral recruitment strategies were utilized.

Patients who met the following criteria were included: adults diagnosed with CM, CTTH or CCH by an experienced headache neurologist according to the 3rd edition of the International Classification of Headache Disorders (ICHD-III) [1]. Headache frequency was established based on data extracted from the patients' personal headache diaries, averaged over the previous three months.

Exclusion criteria included the presence of another concomitant headache disorder; a history of trauma or surgery involving the cervical, cranial, or mandibular musculoskeletal regions; medication overuse (analgesics or other drugs); and diagnoses of meningitis, fibromyalgia, or any chronic pain condition other than CM, CTTH, or CCH. Patients were also excluded if they had received physiotherapy treatment within the two weeks prior to assessment, or if they had peripheral neuropathies, rheumatic diseases, or other conditions potentially affecting sensory pathways.

For ethical reasons, participants with CM, CTTH, and CCH were allowed to continue their usual pharmacological treatment.

Control participants were eligible if they reported two or fewer headache episodes in the previous year and did not meet any of the exclusion criteria described above. Healthy controls were also excluded if they presented current spinal pain, a history of medically diagnosed cervical pathology or injury.

Procedures

To ensure examiner blinding, the neurologist recruited eligible patients and forwarded their contact details to a first physiotherapist (CMT), who scheduled the assessments and completed the inclusion procedures.

On the assessment day, participants received verbal and written information about the study procedures. After providing informed consent, they completed sociodemographic and psychosocial questionnaires. The Spanish validated questionnaires of the headache impact test–6 items (HIT-6) [24], quality of life questionnaire Short Form Health Survey (SF-12) [25], neck disability index (NDI) [26] were presented.

A second physiotherapist (IEG), unaware of the diagnosis, performed the neck examination according to international consensus [22]. Headache frequency was established based on data extracted from the patients' personal headache diaries, averaged over the previous three months:

- *Neck active range of motion (AROM):* AROM was quantified using validated inertial sensors (Werium Solutions, Madrid, Spain) [27]. Participants sat while one sensor was placed on the forehead and another on the sternal manubrium. They performed three consecutive repetitions in each direction (flexion, extension, side flexion, rotation), with movements recorded in degrees. Total AROM was calculated by summing the mean values for each direction. (Detailed description in Supplementary Material 1).
- *Flexion Rotation Test (FRT):* To quantify upper cervical spine (C1-C2) rotation, the same inertial sensors were used [27]. The test was carried out according to Hall et al 2008 [28]. The test ended at pain onset or therapist-detected resistance. Means of three left- and right-side

movements were calculated in degrees; as no side differences were found, totals were used for analysis. (Detailed description in Supplementary Material 1).

- *FHP:* the validated cervical inclinometer (CROM) with forward head arm and a vertebral locator (with a bubble leveler) was used (CROM; Cervical Range of Motion Instrument, Performance Attainment Associates, 1988, University of Minnesota) [29]. Data was recorded according to Garret et al (2019) procedure and recorded in centimeters [30]. (Detailed description in Supplementary Material 1).
- *Neck protraction and retraction:* The CROM instrument was also used to measure the active neck protraction and retraction according to the procedure validated by Elizagaray-Garcia et al (2023). Data was recorded in centimeters [31]. (Detailed description in Supplementary Material 1).
- *Motor control* was analyzed using the craniocervical-flexion test (CCFT) according to the procedure described by Falla et al. (2004). A pressure biofeedback unit (Stabilizer, Chattanooga, TN) with five stages (22–30 mmHg) was placed under the cervical spine. The maximum pressure maintained for 10 seconds without compensatory SCM activity was recorded [32, 33] (Detailed description in Supplementary Material 1).

Additionally, surface EMG amplitudes of the SCM and erector spinae muscles (ESM) were analyzed at each test stage. EMGs data were collected with a validated device (mDurance Solutions SL) [34]. Two five-channel sensors were used. After skin preparation, Ag/AgCl electrodes (Grass-Telefactor, Astro-Med, RI, USA) were placed bilaterally on the SCM sternal head and at C2–C3 between SCM and upper trapezius for the ESM [35]. Ground electrodes were placed on the clavicle and C7 spinous process.

Prior to the CCFT, maximal voluntary isometric contractions (MVICs) of the cervical flexor and extensor muscles were performed for EMG normalisation. Participants were positioned in crook-lying position, consistent with the CCFT testing position. For cervical flexion MVIC, manual resistance was applied to the forehead, and participants were instructed to perform maximal isometric flexion effort for 5 seconds, attempting to lift the head towards the chest while the examiner prevented movement. For cervical extension MVIC, participants were instructed to exert maximal isometric effort against the table while the head remained in contact with the support surface.

Following familiarisation trials, a single valid MVIC was recorded for each condition. The central second of each contraction was extracted for analysis, in accordance with established procedures [32]. EMG signals were processed using the same filtering, rectification, and normalisation procedures described for the CCFT analysis.

Signals were amplified (gain=1,000), rectified, and band-pass filtered (Butterworth 20–400 Hz). EMG envelopes were calculated using a fixed (MVIC) or dynamic (CCFT) 500 ms window, and the normalized RMS of the central 5 seconds of each CCFT stage was expressed as a percentage of the corresponding MVIC (%RMS). Additionally, the % RMS symmetry of both pairs of muscles (SCM and ESM left and right side) were analyzed.

- *Neck flexors endurance test:* This test assesses the ability of the deep cervical flexors to sustain a contraction over time. The test is performed with the patient in supine position, lifting the head a few centimeters off the surface while maintaining a chin tuck. The duration for which the patient can hold this position before fatigue or loss of alignment occurs is used to evaluate muscle endurance [36]. Data was recorded in seconds.

- *Reproduction and resolution of symptoms:* Pain recognized as the usual headache (in the patient groups) was recorded through different tests [passive accessory intervertebral movements (PAIVMs), muscle trigger points (MTrP), reproduction and resolution test; AROM and FRT]. 1) For MTrP, four locations in the upper trapezius, four in the SCM and two in the suboccipital muscles were palpated manually with manual pressure held for five seconds [37]. 2) For the PAIVMs assessment, the protocol according to Luedtke K. & May A. (2017) was carried out at nine different locations in the upper cervical spine [38]. 3) For the

Reproduction and Resolution test pain reproduction was recorded at eight different locations of the upper cervical spine [39]. 4) Each movement during the AROM and FRT assessments was evaluated, and participants who experienced their familiar headache at least once were recorded. It was considered positive if the usual headache was evoked at any location after holding the technique for five seconds and disappeared within five seconds after its application. If the headache was not the usual one, pain was only in the neck, or no pain was provoked; the test was considered negative.

Following each provocative manoeuvre, a brief observation period was allowed to ensure that any elicited headache symptoms subsided. If habitual headache symptoms had persisted beyond a reasonable period, the assessment would have been discontinued (this situation did not occur in any participant).

Sample size calculation

The sample size estimation was based on data obtained from an unpublished pilot study conducted by our research group (n=15), performed prior to the main study due to the absence of previous evidence in patients with CCH. The pilot study was used to obtain preliminary estimates of variability and effect size for neck musculoskeletal variables. G*Power 3.1 (University of Düsseldorf, Germany) was used for f-tests (effect size=0.31, power=80%, α<0.05), resulting in a required sample size of 120 participants.

Statistical Analysis

Statistical analyses were conducted using SPSS v24.0 (SPSS Inc., Chicago, IL, USA). Shapiro-Wilk tests (N<50/group) assessed normality. Variables with normal distribution were analyzed parametrically and expressed as mean±SD (quantitative) or N (%) (categorical). sEMG during CCFT and neck flexor endurance showed non-normal distribution; thus, non-parametric analyses were performed and expressed as median (IQR) or N (%).

Comparisons between groups

Quantitative variables with normal distribution were compared using one-way ANOVA with Bonferroni post-hoc, and Kruskal–Wallis with Mann–Whitney post-hoc when they did not follow normal distribution. Effect sizes were calculated as partial eta-squared (η^2: 0.01–0.06 small, 0.06–0.14 medium, >0.14 large). Post-hoc effect sizes were estimated with Cohen's d (0.21–0.50 small, 0.51–0.80 medium, >0.81 large) for parametric analyses and Rosenthal's r for non-parametric analyses (0.10–0.29 small, 0.30–0.49 medium, >0.5 large) [40].

To control for potential confounding factors, age was systematically included as a covariate in the initial ANCOVA models. However, sex was excluded from these multivariate analyses due to a highly skewed distribution across groups that strictly reflects the epidemiological prevalence of these conditions (i.e., the CM and CTTH groups were predominantly female, whereas the CCH group was predominantly male).

Nominal variables were compared using Chi-square (χ^2) tests with Bonferroni-adjusted post-hoc pairwise χ^2 comparisons when the omnibus test was significant. Effect size was calculated using Cramer's V (0.00–0.06 small, 0.06–0.17 medium, 0.18–0.29 large, ≥0.29 very large) [41].

Pairwise post-hoc analyses were only conducted after a statistically significant omnibus test. Bonferroni-adjusted post-hoc comparisons were applied for parametric, non-parametric and categorical between-group analyses.

Multiple backward linear regression

Multiple backward linear regression models examined which neck musculoskeletal variables were associated with headache frequency, neck disability and headache impact. Given non-normality, Spearman's rank correlation (rho) was used (<0.3 weak, 0.3–0.7 moderate, >0.7 strong) [42]. To reduce model overparameterization considering subgroup sample sizes, only a limited number of clinically plausible variables showing at least moderate bivariate associations *(rho at least 0.40)* were considered for exploratory regression analyses.[42], Crucially, these candidate covariates were strictly cross-referenced with clinical and pathophysiological plausibility based on previous literature [18, 19, 43] o ensure a clinically driven refinement. Due to the data-driven nature of this sequential selection process, and the lack of an independent validation dataset, the regression models were considered exploratory and hypothesis-generating rather than confirmatory.

Given group sample sizes, backward elimination ($p<0.10$) was used for regression. Association strength was assessed via (B), R^2, adjusted R^2, and p-values, with standardized β coefficients to allow comparison of the magnitude of associations between variables.

Regression assumptions were verified using the Shapiro-Wilk test for residual normality, Cook's distance for influential outliers ($D>1$), the Durbin-Watson statistic for autocorrelation, and Variance Inflation Factors (VIF) for multicollinearity (cutoff> 10). Statistical significance for all analyses was set at $p<0.05$.

In line with the ANCOVA strategy, all regression models were adjusted for age to evaluate its potential confounding effect independently. Sex was omitted from the regression models to prevent sever near-separation issues across the diagnostic groups and to preserve the statistical power necessary for robust parameter estimation.

RESULTS

Participants and demographic characteristics

A total of 133 participants were recruited; four CCH participants were excluded due to prior greater occipital nerve electrostimulator implantation. The final sample comprised 129 participants (35 CM, 30 CTTH, 34 CCH, 30 controls). Significant group differences were observed for age [F(3,130)=2032.73; $p=0.01$; $\eta^2=0.08$] and gender [$\chi^2(3)=40.91$; $p<0.001$; Cramer's V=0.56] (Table 1).

(Table 1).

Comparisons between groups

Psychosocial outcomes

ANOVA revealed significant group differences in quality of life (SF-12), specifically in the physical health domain [F(3,128)=9.75; $p<0.001$; $\eta^2=0.19$], and in neck disability (NDI) [F(3,128)=23.29; $p<0.001$; $\eta^2=0.36$]. These differences were driven by the comparisons of all headache groups versus the control group as shown in Bonferroni-corrected post-hoc tests. There were no differences between the headache types regarding quality of life, neck disability and headache related disability (HIT-6) (Table 2).

(Table 2).

Head posture and neck movement outcomes

ANOVA analyses for neck posture and movement variables showed significant differences between groups for all measures (FHP, AROM, retraction, protraction, FRT) (Table 3). Bonferroni-corrected pairwise comparisons indicated the CCH group had significantly reduced AROM, retraction, protraction, and FRT versus healthy controls, with large effect sizes (Cohen's $d\geq0.7$) (Table 3).

Controlling for the covariate age, the ANCOVA analysis confirmed significant differences for retraction [F(3)=3.34; p=0.022; $\eta^2p = 0.08$], total AROM [F(3)=8.774; p<0.001] No significant group effect was found for FHP, neck protraction position, or FRT.

For neck retraction, the covariate age (F=1.09, p=0.299) did not show a significant contribution. Post hoc comparisons indicated that participants with CCH presented significantly lower neck retraction values than controls (mean difference=-2.23 cm, Cohen's d = 0.81, pBonf = 0.022). No other pairwise comparisons reached statistical significance.

For the total AROM, the covariate age (F = 36.27, p < 0.001) contributed significantly to the model. Bonferroni-adjusted comparisons showed that controls presented significantly greater total neck AROM than participants with CTTH (mean difference=42.67°, d=0.94, pBonf=0.004) and CCH (mean difference=62.26°, d=1.38, pBonf<0.001). Participants with CM also showed significantly greater AROM than those with CCH (mean difference=46.51°, d=1.03, pBonf=0.005). The remaining comparisons were not statistically significant.

(Table 3).

Reproduction and resolution of symptoms

Chi-square analyses demonstrated significant differences between groups for symptom reproduction during PAIVMs [$\chi^2(3)=22.17$; p<0.001; Cramer's V=0.42] and for headache reproduction and resolution test [$\chi^2(3)=20.62$;

$p<0.001$; Cramer’s V=0.40] (Table 4). Post hoc analyses showed that participants with CM and CTTH reported a significantly higher frequency of familiar head pain in response to PAIVMs ($p<0.05$) and during reproduction and resolution test ($p<0.001$ and $p<0.05$, respectively) compared to healthy controls. No significant differences were observed in the remaining pairwise comparisons, and between-group differences for the presence of MTrPs [$\chi^2(3)=11.32$; $p>0.05$; Cramer’s V=0.30] (Table 4).

(Table 4).

Muscle performance outcomes

Significant between-group differences were observed in the Endurance Flexors Test [$H(3) = 14.43$, $p<0.05$; $\eta^2=0.09$]. Post-hoc pairwise comparisons (Mann–Whitney U test with Bonferroni correction) revealed that endurance time was significantly lower in participants with CM (median=45.88 s; $r=0.19$, $p<0.001$), CTTH (median=53.96 s; $r=0.42$, $p<0.05$), and CCH (median=63.60 s; $r=0.36$, $p<0.05$) compared with controls. Effect sizes ranged from small to moderate. No statistically significant differences were found between the headache groups themselves (all $p>0.05$) (Table 3). For the endurance flexor test, ANCOVA adjusted for age demonstrated that the covariate did not significantly contribute to the model (all $p>0.05$)

Additionally, between-group comparisons of sEMG activity (RMS normalized) during the CCFT revealed no statistically significant differences for the SCM at any CCFT stage (22–30 mmHg) (all Kruskal–Wallis tests, $p>0.05$), with very small effect sizes ($\eta^2 \leq 0.02$) (Table 5). In contrast, significant between-group differences were identified for the ESM at 22 mmHg (H(3)=10.79, $p<0.05$; $\eta^2=0.06$), 24 mmHg (H(3)=10.55, $p<0.05$; $\eta^2=0.06$), 26 mmHg (H(3)=7.04, $p<0.05$; $\eta^2=0.03$), and 28 mmHg (H(3)=7.97, $p<0.05$; $\eta^2=0.04$). At these stages, post-hoc analyses indicated significantly higher ESM sEMG activity in participants with CM compared with controls (small-to-moderate effect sizes, $r \approx 0.31$–0.39). No significant between-group differences were observed at 30 mmHg (H(3)=5.47, $p>0.05$) (Table 5).

No statistically significant differences were observed between-groups regarding the symmetry of neck muscles sEMG activity during the different stages of the CCFT (*Supplementary Material 2*).

(Table 5).

Regression analyses

In the adjusted regression model for age, neck retraction was retained as a variable associated with migraine frequency in the exploratory regression model [F(1,34)=5.39; $p=0.03$; adjusted $R^2=0.11$], with age showing no significant confounding effect ($p=0.87$), while no significant associated variables were found for the CTTH and CCH groups.

In the unadjusted models, AROM was significantly associated with neck disability (NDI) in CM [F(1,34)=5.79; $p=0.03$; adjusted $R^2=0.17$] and CTTH [F(1,29)=5.78; $p=0.02$; adjusted $R^2=0.12$)]. However, after adjusting for age, the overall models were no longer statistically significant, showing non-significant trend in CM [F(2,32)=3.02; p=0.063; adjusted R^2=0.106] and CTTH [F(2,28)=2.67; p=0.088; adjusted R^2=0.107]. In these adjusted models, AROM retained a marginal negative association with NDI (CM: β=-0.073; p=0.053; CTTH: β=-0.061; p=0.065), whereas age was not significantly associated with NDI in either group (CM: p=0.548; CTTH: p=0.962). No significant associated variable was identified for the CCH group.

Finally, after adjusting the regression model for headache impact (HIT-6), the EMG symmetry of the sternocleidomastoid muscle during the fourth stage of the CCFT was a significant associated variable for the CTTH group [F(1,29)=8.75; p=0.009; adjusted R^2=0.30] with age showing no significant confounding effect (p=0.87). While the model for the CCH group showed a non-significant trend after adjusting for age [F(2, 26)=3.19; p=0.063; adjusted R^2=0.166]. In this latter model, sEMG symmetry during the third stage remained a significant independent predictor (p=0.038), whereas age had no significant influence (p=0.690). No significant associated variables were identified for the CM group.

DISCUSSION

This study compared neck musculoskeletal function across CM, CTTH, CCH, and healthy controls. Mobility impairments were evident in CTTH and CCH, with greatest AROM reductions in CTTH. Neck flexor endurance was reduced in all headache groups. sEMG during CCFT showed preserved SCM but altered ESM activity in CM. Regression analyses revealed headache-specific associations between cervical mobility, muscle activity, and clinical outcomes across CM, CTTH, and CCH.

To interpret these findings, we contrasted our initial pathophysiological hypotheses with actual outcomes. As a Trigeminal Autonomic Cephalalgia driven by central nervous system structures, particularly the hypothalamus, which has been associated with the stereotyped nature, circadian pattern and periodicity of attacks [44–46], we hypothesized that CCH would show minimal neck involvement. Surprisingly, CCH patients exhibited significant musculoskeletal impairments (reduced neck AROM and FRT, reduced flexor endurance, high NDI) comparable to CM and CTTH.

This unexpected presentation suggests that despite the distinct neurovascular nature of CCH, chronic and recurrent nociceptive input may also be associated with cervical musculoskeletal alterations. One possible explanation may involve sustained trigeminocervical nociceptive processing and mechanisms related to central sensitization, although the present cross-sectional design does not allow mechanistic or causal inferences. Consequently, shared mechanisms related to chronic nociceptive processing may contribute to overlapping cervical musculoskeletal findings across chronic headache populations. In support of this mechanical interaction through trigeminocervical convergence, preliminary clinical evidence by de-la-Puente-Ranea and Navarro-Fernández et al. (2021) has already suggested that physical therapy targeting the upper cervical spine can successfully decrease headache burden in patients with CCH [47, 48]

The reduced cervical spine mobility observed in this current study should be interpreted in light of the group's significantly older age and higher proportion of male participants compared to the other headache groups and headache-free controls. This concern was confirmed when assessing the influence of age in the ANCOVA which showed that all movement-related tests were significantly influenced by one or both variables, except for neck retraction.

Muscle performance testing also showed a reduced capability of the CCH group to stabilize the cervical spine and maintain craniocervical flexion during the flexor muscle endurance test. This was a finding across all headache groups and significantly more pronounced than in the healthy control group. While this is in line with previous studies on migraine[49] and tension-type headache[50] populations where no mechanistic explanation has been provided, this deficit may be driven by kinesiophobia and avoidance behaviour in a pain-affected region. Neurophysiologically, this performance drop likely reflects an altered motor output stemming from central sensitization and impaired endogenous pain inhibition, where persistent trigeminocervical nociception drives a reflex-mediated, pain-induced inhibition of the deep cervical flexor muscles [51, 52]. A network meta-analysis[53] in patients with whiplash-associated disorders demonstrated that cervical flexor endurance is closely associated with factors such as fear of movement and long-term disability, further supporting this neuromuscular interaction. Additionally, although delayed migraine triggering was not systematically recorded in our study, qualitative clinical observations during testing revealed that numerous participants experienced immediate local neck pain or discomfort during or immediately following the test. This suggests that mechanical loading acutely exacerbates localized nociceptive pathways, which aligns with previous reports of neck endurance tests inducing localized symptoms or migraine-like headaches [54].

Consistent with this, our participants with CCH showed a lower response to headache provocation tests compared with those with CM and CTTH. Reduced cervical mobility may therefore represent a coincidental finding unrelated to an underlying musculoskeletal disorder, or alternatively a secondary consequence of repeated disabling pain leading to increased cervical muscle tension and stiffness [55]. Whether musculoskeletal impairments contribute to disability or influence clinical characteristics of cluster headache remains unclear. Further research is needed to determine whether associations exist between cluster headache frequency, musculoskeletal findings and neck-related disability, as previously reported in migraine populations [7, 56].

More evidence is available to interpret our findings in the CM population. Results partially confirm previous research, especially for head familiar pain provocation tests [7, 57]. While mobility tests in this current sample did not show significant differences compared to the control group, manual palpation (PAIVMs) and the Reproduction and resolution test on upper cervical structures did. Several previous studies reported on an increased sensitivity of patients with migraine, especially, but not only, towards the attack [58–60], caused by reduced endogenous inhibition, which is more pronounced within the reference areas of the trigeminal nerve than in the periphery [61]. Patients with CM no longer have the clear pattern of ictal and interictal phases and hence remain within a state of hypersensitivity. Recent data showed that pain provocation during musculoskeletal testing is not exclusively explained by hypersensitivity [19, 38, 60]. It is currently discussed whether nociceptive signals arising from musculoskeletal structures interacting with the trigeminal nervous system may increase its sensitization. These findings may help contextualize why some patients could potentially benefit from physiotherapy approaches targeting cervical musculoskeletal impairments. However, it is generally accepted that migraine is a central nervous system disease not involving musculoskeletal structures in the neck [62].

The CCTH group mainly showed findings for neck mobility and pain reproduction tests. Increased FHP as found in previous studies [63–65] was not reproduced in this sample. FHP can be measures in a variety of procedures [30, 31, 66–68]. Since we wanted to capture natural head posture, the instruction given to each patient was "*sit in a natural and relaxed and face forward position*" [31, 69] there was no standardization procedure which may have led to different results.

AROM is one of the most important variables in neck function and its reduction is also considered as a diagnostic criterion to determine cervicogenic headache [1, 70]. Although some literature reports that patients with CTTH and CM have a reduced neck AROM compared to asymptomatic controls [14, 19], others did not find movement restrictions in these groups [18]. Our previous study showed that CTTH and CM had comparable reductions in AROM compared to asymptomatic controls [7]. It is well documented in the literature that pain can increase muscle tension, which is a key feature of tension-type headaches and could explain the reduction in movement [55, 71]. Similar to migraine and cluster headache, musculoskeletal restrictions in this primary headache type are a symptom rather than the cause for the pain [72, 73]. Interestingly, patients with CTTH also showed an increased response to pain provocation tests, indicating that CM as well as CTTH share features of hypersensitivity and thereby of other chronic pain diseases [74–77]. Madsen et al. (2018) suggested that muscle hyperalgesia could influence the worsening of cervical function which consequently contributes to the maintenance of headache [55].

Given that numerous studies have reported an alteration in the somatosensory cortex of patients with chronic primary headache and mechanical neck hyperalgesia [7, 78–81], the neural output that neck muscles received may be altered which may worsen muscle performance and/or motor control strategies compared to asymptomatic controls. This may explain why some types of headaches showed some alteration in muscle testing compared to headache-free controls. Although there was no clear pattern common to all, patients with CM showed a feature that has been previously evidenced in the literature [82, 83]. Indeed, Florencio et al. (2015) and Florencio et al. (2016), observed that patients with chronic migraine present a phenomenon of neuromuscular coactivation, i.e. when they perform a maximum isometric contraction movement of cervical flexion, they not only activate the flexor musculature but also the antagonist extensor musculature significantly more than controls. Moreover, we have also observed that this motor control disorder also occurs in submaximal contractions such as the CCFT.

Taken together, these findings support the presence of cervical musculoskeletal alterations across chronic primary headache disorders and may be compatible with differences in underlying nociceptive and sensorimotor processing mechanisms.

Clinical implications

According to our results, neck musculoskeletal findings were observed in some domains, but this was not consistent across all outcomes or groups. Based on the current understanding of the pathophysiology of the three headache types [84–87], these are unlikely to play a causal role for the symptom development but could either be a consequence of repeated headache attacks with associated neck pain and muscle tension or could be independent neck musculoskeletal impairments which are common in the overall population [8, 88, 89]. Overall, some musculoskeletal variables showed statistical associations with headache frequency and related disability in this study and in previous reports. However, several musculoskeletal measures did not differ from those observed in healthy controls, in line with previous findings. This indicates that musculoskeletal alterations are not consistently present across all domains, and the observed associations vary in magnitude. Given that the certainty of the evidence is low to moderate, these results should be interpreted cautiously and within an individualized clinical context [57, 60, 90, 91]. Our results reinforce the need for a structured, standardized, and headache-specific cervical assessment aimed at identifying potentially relevant nociceptive and sensorimotor contributors within the trigeminocervical system. From a clinical perspective, the findings support an individualized decision-making process in which targeted management of neck musculoskeletal dysfunction may be justified in patients with migraine [92], CTTH [93]. Lastly, while the physical therapy management of cervical impairments is well-established for migraine and tension-type headache, preliminary evidence from a case series has also suggested positive clinical outcomes in patients with CCH [47, 48]. Given that our sample explicitly demonstrated significant cervical impairments in the CCH group, future clinical trials are needed to explore whether these cervical musculoskeletal findings may have therapeutic relevance in patients with CCH.

Limitations

Several limitations must be acknowledged. First, as a cross-sectional study, causal inference is not possible; longitudinal studies are needed. Second, although consecutive recruitment minimized neck-related self-selection bias, non-probabilistic sampling limits external validity. Recruiting from specialized tertiary care may overrepresent patients with greater headache severity, frequency, or refractoriness than primary care or the general population. Third, the sample came from a specific geographical area and specialized headache clinic, reducing external validity. Fourth, although the male-to-female ratio (6:3) reflects literature, sex differences may have influenced some variables. Additionally, the marked imbalance in sex distribution across headache groups represents an important limitation. Although this distribution reflects the epidemiology of these disorders, residual confounding related to sex-specific differences in cervical mobility and musculoskeletal function cannot be completely excluded despite the statistical adjustment strategy. Fifth, headache severity on the examination day was not recorded. Sixth, the data-driven variable selection carries risks of overfitting and limited reproducibility. However, regression diagnostics (e.g., VIF and Cook's distance) did not reveal major violations of model assumptions or severe multicollinearity.. Future larger studies should utilize contemporary penalized modelling strategies (e.g., LASSO regression) combined with independent validation cohorts to achieve a more robust variable selection and maximize generalizability. Furthermore, the exploratory regression analyses should be interpreted cautiously due to the relatively small subgroup sample sizes and the potential instability inherent to sequential variable selection procedures. Finally, prior physical therapy for neck pain was not documented, which could have affected patients' neck condition

CONCLUSION

This study provides the first comprehensive assessment of cervical musculoskeletal function in CCH and the first direct comparison across major chronic primary headaches. CCH patients showed reduced cervical AROM and impaired flexion–rotation versus controls, but findings were similar to CM and CTTH, indicating no disorder-specific musculoskeletal profile. Hypersensitivity was the main feature in CM and CTTH. Notably, cervical extensor EMG activity during CCFT was associated with headache frequency in CCH, and retraction movement in CM, suggesting potential exploratory associations with headache frequency.

REFERENCES

1. Olesen J (2018) Headache Classification Committee of the International Headache Society (IHS) The International Classification of Headache Disorders, 3rd edition. Cephalalgia 38:1–211
2. Stovner L, Hagen K, Jensen R, et al (2007) The Global Burden of Headache: A Documentation of Headache Prevalence and Disability Worldwide. Cephalalgia 27:193–210. https://doi.org/10.1111/j.1468-2982.2007.01288.x
3. Olesen J (2018) Headache Classification Committee of the International Headache Society (IHS) The International Classification of Headache Disorders, 3rd edition. Cephalalgia 38:1–211
4. Minen MT, Whetten C, Messier D, et al (2025) Headache diagnosis and treatment: A pilot knowledge and needs assessment among physical therapists. Headache 65:90–100. https://doi.org/10.1111/HEAD.14801

5. Turner DP, Smitherman TA, Black AK, et al (2015) Are migraine and tension-type headache diagnostic types or points on a severity continuum? An exploration of the latent taxometric structure of headache. Pain 156:1200–1207. https://doi.org/10.1097/j.pain.0000000000000157

6. Fernández-de-las-Peñas C, Arendt-Nielsen L, Cuadrado ML, Pareja JA (2009) Generalized mechanical pain sensitivity over nerve tissues in patients with strictly unilateral migraine. Clin J Pain 25:401–6. https://doi.org/10.1097/AJP.0b013e31819655b3

7. Elizagaray-García I, Carvalho GF, Szikszay TM, et al (2022) Psychophysical testing in chronic migraine and chronic tension type headache: An observational study. Cephalalgia 42:618–630. https://doi.org/10.1177/03331024211060315

8. Ashina S, Bendtsen L, Lyngberg AC, et al (2015) Prevalence of neck pain in migraine and tension-type headache: A population study. Cephalalgia 35:211–219. https://doi.org/10.1177/0333102414535110

9. Al-Khazali HM, Younis S, Al-Sayegh Z, et al (2022) Prevalence of neck pain in migraine: A systematic review and meta-analysis. Cephalalgia 42:663–673

10. Ashina S, Bendtsen L, Lyngberg AC, et al (2015) Prevalence of neck pain in migraine and tension-type headache: A population study. Cephalalgia 35:211–219. https://doi.org/10.1177/0333102414535110

11. Schröder P, Gaul C, Drabik A, Molsberger A (2021) Pain localization in cluster headache patients: Onset, peak, and radiation. Acta Neurol Scand 143:441–449. https://doi.org/10.1111/ANE.13396

12. Carvalho GF, Chaves TC, Gonçalves MC, et al (2014) Comparison between neck pain disability and cervical range of motion in patients with episodic and chronic migraine: a cross-sectional study. J Manipulative Physiol Ther 37:641–646. https://doi.org/10.1016/j.jmpt.2014.09.002

13. Houle M, Marchand AA, Descarreaux M (2020) Can Headache Profile Predict Future Disability: A Cohort Study. Clinical Journal of Pain 36:594–600. https://doi.org/10.1097/AJP.0000000000000843

14. Elizagaray-García I, Beltran-Alacreu H, Angulo-Díaz-Parreño S, et al (2020) Chronic Primary Headache Subjects Have Greater Forward Head Posture than Asymptomatic and Episodic Primary Headache Sufferers: Systematic Review and Meta-analysis - PubMed. Pain Med 21:2465–2480

15. Bogduk N (2001) Cervicogenic headache: anatomic basis and pathophysiologic mechanisms. Curr. Pain Headache Rep. 5:382–386

16. Bartsch T (2005) Migraine and the neck: new insights from basic data. Curr Pain Headache Rep 9:191–6. https://doi.org/10.1007/s11916-005-0061-0

17. Bartsch T, Goadsby PJ (2003) The trigeminocervical complex and migraine: current concepts and synthesis. Curr Pain Headache Rep 7:371–6. https://doi.org/10.1007/s11916-003-0036-y

18. Liang Z, Galea O, Thomas L, et al (2019) Cervical musculoskeletal impairments in migraine and tension type headache: A systematic review and meta-analysis. Musculoskelet Sci Pract 42:67–83. https://doi.org/10.1016/j.msksp.2019.04.007

19. Szikszay TM, Hoenick S, von Korn K, et al (2019) Which Examination Tests Detect Differences in Cervical Musculoskeletal Impairments in People With Migraine? A Systematic Review and Meta-Analysis. Phys Ther 99:549–569. https://doi.org/10.1093/ptj/pzz007

20. Cnockaert E, Meeus M, Cagnie B, et al (2026) Human assumed central sensitization in interictal migraine: a systematic review and meta-analysis. Neurol Sci 47:. https://doi.org/10.1007/S10072-026-08825-8

21. Liang Z, Castaldo M (2025) Individualised physiotherapy assessment and management of migraine: the role of cervical sensitisation and musculoskeletal disorder. Musculoskelet Sci Pract 80:. https://doi.org/10.1016/j.msksp.2025.103439

22. Luedtke K, Boissonnault W, Caspersen N, et al (2016) International consensus on the most useful physical examination tests used by physiotherapists for patients with headache: A Delphi study. Man Ther 23:17–24. https://doi.org/10.1016/j.math.2016.02.010

23. von Elm E, Altman DG, Egger M, et al (2014) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for reporting observational studies. Int J Surg 12:1495–9. https://doi.org/10.1016/j.ijsu.2014.07.013

24. Martin M, Blaisdell B, Kwong JW, Bjorner JB (2004) The Short-Form Headache Impact Test (HIT-6) was psychometrically equivalent in nine languages. J Clin Epidemiol 57:1271–1278. https://doi.org/10.1016/j.jclinepi.2004.05.004

25. Vera-Villarroel P, Silva J, Celis-Atenas K, Pavez P (2014) Evaluación del cuestionario SF-12: verificación de la utilidad de la escala salud

mental. Rev Med Chil 142:1275–1283. https://doi.org/10.4067/S0034-98872014001000007

26. Andrade Ortega JA, Delgado Martínez AD, Ruiz RA (2010) Validation of the Spanish Version of the Neck Disability Index. Spine (Phila Pa 1976) 35:E114–E118. https://doi.org/10.1097/BRS.0b013e3181afea5d

27. Elizagaray-García I, Gil-Martínez A, Navarro-Fernández G, et al (2021) Inter, intra-examiner reliability and validity of inertial sensors to measure the active cervical range of motion in patients with primary headache. EXCLI J 20:879–893. https://doi.org/10.17179/excli2021-3799

28. Hall TM, Robinson KW, Fujinawa O, et al (2008) Intertester Reliability and Diagnostic Validity of the Cervical Flexion-Rotation Test. J Manipulative Physiol Ther 31:293–300. https://doi.org/10.1016/j.jmpt.2008.03.012

29. Audette I, Dumas J-P, Côté JN, De Serres SJ (2010) Validity and between-day reliability of the cervical range of motion (CROM) device. J Orthop Sports Phys Ther 40:318–23. https://doi.org/10.2519/jospt.2010.3180

30. Garrett TR, Youdas JW, Madson TJ (1993) Reliability of Measuring Forward Head Posture in a Clinical Setting. Journal of Orthopaedic & Sports Physical Therapy 17:155–160. https://doi.org/10.2519/jospt.1993.17.3.155

31. Elizagaray-García I, Obispo-Villamayor Á, Prats-Martínez C, et al (2024) Measurement proprieties of the CROM instrument for assessing head posture, neck retraction and protraction. Musculoskelet Sci Pract 71:. https://doi.org/10.1016/j.msksp.2024.102950

32. Falla D, Jull G, Hodges P (2004) Patients with neck pain demonstrate reduced electromyographic activity of the deep cervical flexor muscles during performance of the craniocervical flexion test. Spine (Phila Pa 1976) 29:2108–2114. https://doi.org/10.1097/01.brs.0000141170.89317.0e

33. Jull GA, O'Leary SP, Falla DL (2008) Clinical assessment of the deep cervical flexor muscles: the craniocervical flexion test. J Manipulative Physiol Ther 31:525–533. https://doi.org/10.1016/J.JMPT.2008.08.003

34. Molina-Molina A, Ruiz-Malagón EJ, Carrillo-Pérez F, et al (2020) Validation of mDurance, A Wearable Surface Electromyography System for Muscle Activity Assessment. Front Physiol 11:. https://doi.org/10.3389/fphys.2020.606287

35. Falla D, Farina D, Dahl MK, Graven-Nielsen T (2007) Muscle pain induces task-dependent changes in cervical agonist/antagonist activity. J Appl Physiol (1985) 102:601–609. https://doi.org/10.1152/JAPPLPHYSIOL.00602.2006

36. Edmondston S, Björnsdóttir G, Pálsson T, et al (2011) Endurance and fatigue characteristics of the neck flexor and extensor muscles during isometric tests in patients with postural neck pain. Man Ther 16:332–338. https://doi.org/10.1016/J.MATH.2010.12.005

37. Travell JG, Simons DG (1998) Myofascial pain and dysfunction the trigger point manua, 2 nd. Lippincott, Balotimore

38. Luedtke K, May A (2017) Stratifying migraine patients based on dynamic pain provocation over the upper cervical spine. J Headache Pain 18:97. https://doi.org/10.1186/s10194-017-0808-0

39. Watson DH, Drummond PD (2012) Head pain referral during examination of the neck in migraine and tension-type headache. Headache 52:1226–1235. https://doi.org/10.1111/j.1526-4610.2012.02169.x

40. Portney LG, Watkins MP (1993) Foundations of Clinical Research. Applications to Practice, Third. Appleton & Lange, Conneticut

41. Akoglu H (2018) User’s guide to correlation coefficients. Turk J Emerg Med 18:91–93. https://doi.org/10.1016/j.tjem.2018.08.001

42. Sani F, Todman J (2006) Experimental design and statistics for psychology: a first course. Blackwell Publishing Inc., Oxford

43. Luedtke K (2016) International consensus on the most useful physical examination tests used by physiotherapists for patients with headache : .... Man Ther. https://doi.org/10.1016/j.math.2016.02.010

44. May A, Bahra A, Büchel C, et al (1998) Hypothalamic activation in cluster headache attacks. Lancet 352:275–278. https://doi.org/10.1016/S0140-6736(98)02470-2

45. May A, Bahra A, Büchel C, et al (2000) PET and MRA findings in cluster headache and MRA in experimental pain. Neurology 55:1328–1335. https://doi.org/10.1212/WNL.55.9.1328,

46. Wei DY, Goadsby PJ (2021) Cluster headache pathophysiology — insights from current and emerging treatments. Nat Rev Neurol 17:308–324. https://doi.org/10.1038/S41582-021-00477-W,

47. Navarro-Fernández G, de-la-Puente-Ranea L, Gandía-González M, Gil-Martínez A (2019) Endogenous Neurostimulation and Physiotherapy in Cluster Headache: A Clinical Case. Brain Sci 9:60. https://doi.org/10.3390/brainsci9030060

48. de-la-Puente-Ranea L, Gil-Martínez A, Rodríguez-Lopez O, et al (2021) Manual therapy and exercise for patients with cluster headache. EXCLI J 20:948–955. https://doi.org/10.17179/EXCLI2021-3763

49. Pensri C, Liang Z, Treleaven J, et al (2025) Cervical musculoskeletal impairments in migraine and tension-type headache and relationship to pain related factors: An updated systematic review and meta-analysis. Musculoskelet Sci Pract 76:. https://doi.org/10.1016/j.msksp.2024.103251

50. Arslan M, Guruhan S, Celenay ST (2026) Spinal Posture, Mobility, and Muscle Endurance in Women With Tension-Type Headache: A Case-Control Study. Pain Res Manag 2026:5577357. https://doi.org/10.1155/PRM/5577357

51. Latremoliere A, Woolf CJ (2009) Central Sensitization: A Generator of Pain Hypersensitivity by Central Neural Plasticity. Journal of Pain 10:895–926. https://doi.org/10.1016/j.jpain.2009.06.012

52. Baron R, Hans G, Dickenson AH (2013) Peripheral input and its importance for central sensitization. Ann Neurol 74:630–636. https://doi.org/10.1002/ANA.24017

53. Anarte-Lazo E, Liew BXW, Devecchi V, et al (2024) Network analyses reveal the interaction between physical features, fear of movement and neck pain and disability in people with acute and chronic whiplash-associated disorders. Eur J Pain 28:322–334. https://doi.org/10.1002/EJP.2184

54. Carvalho GF, Luedtke K, Szikszay TM, et al (2020) Muscle endurance training of the neck triggers migraine attacks. Cephalalgia 41:383–391. https://doi.org/10.1177/0333102420970184

55. Madsen BK, Søgaard K, Andersen LL, et al (2018) Neck/shoulder function in tension-type headache patients and the effect of strength training. J Pain Res 11:445–454. https://doi.org/10.2147/JPR.S146050

56. Di Antonio S, Castaldo M, Ponzano M, et al (2021) Disability, burden, and symptoms related to sensitization in migraine patients associate with headache frequency. Scand J Pain 21:766–777. https://doi.org/10.1515/sjpain-2021-0050

57. Luedtke K, Starke W, May A (2018) Musculoskeletal dysfunction in migraine patients. Cephalalgia 38:865–875. https://doi.org/10.1177/0333102417716934

58. Di Antonio S, Arendt-Nielsen L, Ponzano M, et al (2023) Trigeminocervical pain sensitivity during the migraine cycle depends on headache frequency. Neurological Sciences 44:4021–4032. https://doi.org/10.1007/S10072-023-06858-X,

59. Schulte LH, Allers A, May A (2018) Visual stimulation leads to activation of the nociceptive trigeminal nucleus in chronic migraine. Neurology 90:e1973–e1978. https://doi.org/10.1212/WNL.0000000000005622,

60. Di Antonio S, Arendt-Nielsen L, Ponzano M, et al (2022) Cervical musculoskeletal impairments in the 4 phases of the migraine cycle in episodic migraine patients. Cephalalgia 42:827–845. https://doi.org/10.1177/03331024221082506,

61. Szikszay TM, Adamczyk WM, Carvalho GF, et al (2020) Offset analgesia : somatotopic endogenous pain modulation in migraine. Pain 161:557–564

62. Luedtke K, Allers A, Schulte LH, May A (2016) Efficacy of interventions used by physiotherapists for patients with headache and migraine - Systematic review and meta-analysis. Cephalalgia 36:474–492. https://doi.org/10.1177/0333102415597889,

63. Fernandez-de-las-Peñas C, Alonso-blanco C, Cuadrado ML, et al (2006) Trigger Points in the Suboccipital Muscles and Forward Head Posture in Tension-Type Headache. Headache 46:454–460. https://doi.org/10.1111/j.1526-4610.2006.00288.x

64. Fernandez-de-las-Peñas C, Cuadrado ML, Pareja JA (2005) Forward head posture and neck mobility in chronic tension-type headache : a blinded, controlled study. Cephalalgia 26:314–319. https://doi.org/10.1111/j.1468-2982.2005.01042.x

65. Fernández-De-Las-Peñas C, Alonso-Blanco C, Cuadrado ML, Pareja JA (2007) Neck mobility and forward head posture are not related to headache parameters in chronic tension-type headache. Cephalalgia 27:158–164. https://doi.org/10.1111/j.1468-2982.2006.01247.x

66. Shaghayegh fard B, Ahmadi A, Maroufi N, Sarrafzadeh J (2016) Evaluation of forward head posture in sitting and standing positions. European Spine Journal 25:3577–3582. https://doi.org/10.1007/s00586-015-4254-x

67. Lee C hyung, Lee S, Shin G (2017) Reliability of forward head posture evaluation while sitting, standing, walking and running. Hum Mov Sci 55:81–86. https://doi.org/10.1016/j.humov.2017.07.008
68. Mylonas K, Tsekoura M, Billis E, et al (2022) Reliability and Validity of Non-radiographic Methods of Forward Head Posture Measurement: A Systematic Review. Cureus 14:. https://doi.org/10.7759/CUREUS.27696
69. Lemeunier N, Jeoun EB, Suri M, et al (2018) Reliability and validity of clinical tests to assess posture, pain location, and cervical spine mobility in adults with neck pain and its associated disorders: Part 4. A systematic review from the cervical assessment and diagnosis research evaluation (CAD. Musculoskelet Sci Pract 38:128–147. https://doi.org/10.1016/J.MSKSP.2018.09.013
70. Murata S, Doi T, Sawa R, et al (2017) Association between joint stiffness and health-related quality of life in community-dwelling older adults. Arch Gerontol Geriatr 73:234–239. https://doi.org/10.1016/j.archger.2017.07.021
71. Hodges PW, Tucker K (2011) Moving differently in pain: a new theory to explain the adaptation to pain. Pain 152:. https://doi.org/10.1016/J.PAIN.2010.10.020
72. Fernández-De-Las-Peñas C, Alonso-Blanco C, Cuadrado ML, Pareja JA (2006) Forward head posture and neck mobility in chronic tension-type headache: A blinded, controlled study. Cephalalgia 26:314–319. https://doi.org/10.1111/J.1468-2982.2005.01042.X,
73. Fernández-de-las-Peñas C, Cook C, Cleland JA, Florencio LL (2023) The cervical spine in tension type headache. Musculoskelet Sci Pract 66:. https://doi.org/10.1016/j.msksp.2023.102780
74. Veves A, Backonja M, Malik RA (2008) Painful diabetic neuropathy: Epidemiology, natural history, early diagnosis, and treatment options. Pain Medicine 9:660–674. https://doi.org/10.1111/J.1526-4637.2007.00347.X,
75. Woolf CJ (2011) Central sensitization: Implications for the diagnosis and treatment of pain. Pain 152:. https://doi.org/10.1016/J.PAIN.2010.09.030,
76. Fingleton C, Smart K, Moloney N, et al (2015) Pain sensitization in people with knee osteoarthritis: A systematic review and meta-analysis. Osteoarthritis Cartilage 23:1043–1056. https://doi.org/10.1016/j.joca.2015.02.163

77. Mohr Drewes A, Pedersen J, Reddy H, et al (2006) Central sensitization in patients with non-cardiac chest pain: A clinical experimental study. Scand J Gastroenterol 41:640–649. https://doi.org/10.1080/00365520500442559,

78. Fernández-de-las-Peñas C, Plaza-Manzano G, Navarro-Santana MJ, et al (2021) Evidence of localized and widespread pressure pain hypersensitivity in patients with tension-type headache: A systematic review and meta-analysis. Cephalalgia 41:256–273

79. Andersen S, Petersen MW, Svendsen AS, Gazerani P (2015) Pressure pain thresholds assessed over temporalis, masseter, and frontalis muscles in healthy individuals, patients with tension-type headache, and those with migraine-a systematic review. Pain 156:1409–1423

80. Chen WT, Hsiao FJ, Ko YC, et al (2018) Comparison of somatosensory cortex excitability between migraine and “strict-criteria” tension-type headache: A magnetoencephalographic study. Pain 159:793–803. https://doi.org/10.1097/j.pain.0000000000001151

81. Gil-Martínez A, Navarro-Fernández G, Mangas-Guijarro MÁ, Díaz-de-Terán J (2019) Hyperalgesia and Central Sensitization Signs in Patients with Cluster Headache: A Cross-Sectional Study. Pain Med 20:2562–2570. https://doi.org/10.1093/pm/pnz070

82. Florencio LL, de Oliveira AS, Carvalho GF, et al (2015) Cervical Muscle Strength and Muscle Coactivation During Isometric Contractions in Patients With Migraine: A Cross-Sectional Study. Headache 5:1312–1322. https://doi.org/10.1111/head.12644

83. Florencio LL, de Oliveira AS, Lemos T, et al (2016) Patients With Chronic, but not Episodic, Migraine Display Altered Activity of Their Neck Extensor Muscles. Journal of Electromyography and Kinesiology 30:66–72. https://doi.org/10.1016/j.jelekin.2016.06.003

84. Ashina S, Mitsikostas DD, Lee MJ, et al (2021) Tension-type headache. Nat Rev Dis Primers 7:1–21. https://doi.org/10.1056/NEJMra1915327

85. Ashina M, Terwindt GM, Al-Karagholi MAM, et al (2021) Migraine: disease characterisation, biomarkers, and precision medicine. The Lancet 397:1496–1504. https://doi.org/10.1016/S0140-6736(20)32162-0

86. May A, Burstein R (2019) Hypothalamic regulation of headache and migraine. Cephalalgia 39:1710–1719. https://doi.org/10.1177/0333102419867280,

87. Arkink EB, Schmitz N, Schoonman GG, et al (2017) The anterior hypothalamus in cluster headache. Cephalalgia 37:1039–1050. https://doi.org/10.1177/0333102416660550,

88. Viana M, Sances G, Terrazzino S, et al (2018) When cervical pain is actually migraine: An observational study in 207 patients. Cephalalgia 38:383–388. https://doi.org/10.1177/0333102416683917

89. Genebra CVDS, Maciel NM, Bento TPF, et al (2017) Prevalence and factors associated with neck pain: a population-based study. Braz J Phys Ther 21:274–280. https://doi.org/10.1016/J.BJPT.2017.05.005,

90. Di Antonio S, Arendt-Nielsen L, Ponzano M, et al (2024) Profiling migraine patients according to clinical and psychophysical characteristics: clinical validity of distinct migraine clusters. Neurological Sciences 45:1185–1200. https://doi.org/10.1007/S10072-023-07118-8,

91. Di Antonio S, Arendt-Nielsen L, Ponzano M, et al (2023) Migraine patients with and without neck pain: Differences in clinical characteristics, sensitization, musculoskeletal impairments, and psychological burden. Musculoskelet Sci Pract 66:. https://doi.org/10.1016/j.msksp.2023.102800

92. Meise R, Carvalho GF, Thiel C, Luedtke K (2023) Additional effects of pain neuroscience education combined with physiotherapy on the headache frequency of adult patients with migraine: A randomized controlled trial. Cephalalgia 43:. https://doi.org/10.1177/03331024221144781,

93. Jung A, Eschke RC, Struss J, et al (2022) Effectiveness of physiotherapy interventions on headache intensity, frequency, duration and quality of life of patients with tension-type headache. A systematic review and network meta-analysis. Cephalalgia 42:944–965. https://doi.org/10.1177/03331024221082073

ple characteristics and comparison between groups.

	Controls (n=30)	**CM (n=35)**	**CTTH (n=30)**	**CCH (n=34)**	**Statistic; η^2 *(effect size)***	**Controls Vs CM**	**Controls Vs CTTH**	**Controls Vs CCH**	**CM Vs CTTH**	**C Vs**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**		**Post-hoc analysis with Bonferroni correct *d (effect size)***				
	47.33 (12.22)	42.8 (13.32)	52.93 (15.79)	51.59 (12.47)	F(3, 128)= 3.18*; (0.08)	0.52	0.69	0.68	0.69*	0

vity	3.95 (3.39)	2.74 (2.41)	4.11 (3.86)	3.5 (3.23)	F(3, 128)= 1.19; (0.02)	0.41	0.04	0.13	0.43
quency	-	29 (8.03)	28 (9.09)	30 (19.52)	F(2, 98)= 0.13; (0.01)	-	-	-	0
set	-	15 (15.08)	9.39 (11.97)	9.65 (7.66)	F(2, 98)= 3.68; (0.07)	-	-	-	0.41
	N (%)	**N (%)**	**N (%)**	**N (%)**	**Statistic; *Cramer´s V* *(effect size)***	**Post-hoc analysis (significant *p-***			
	18 (60%)	32 (94.11%)	24 (80%)	7 (20.58%)	χ^2(3, 128)= 40.91**; (0.56)	*	n.s.	*	n.s.

H) Chronic tension-type headache; (CM) Chronic Migraine; (CCH) Chronic cluster headache; *(F)ANOVA* statis
hi squared; (n.s.) non statistical differences; (*) *p-value*<0.05; (**) *p-value*<0.001

rison between groups of psychosocial variables.

	Controls (n=30)	**CM (n=35)**	**CTTH (n=30)**	**CCH (n=34)**	**Statistic; *η² (effect size)***	**Controls Vs CM**	**Controls Vs CTTH**	**Controls Vs CCH**	**CM Vs CTTH**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**					
ubsc	76.45 (14.61)	48.53 (24.88)	55.52 (16.73)	55.08 (26.4)	F(3, 128)= 9.75**; (0.19)	0.83**	0.83*	0.78*	0.59
bsc	58.89 (23.72)	57.10 (17.75)	52.37 (13.01)	61.97 (18.96)	F(3, 128)= 1.40; (0.03)	0.18	0.34	0.12	0.17
/60)	11.93 (2.88)	28.69 (6.69)	27.37 (7.79)	25.91 (23.08)	F(3, 128)= 23.29**; (0.36)	0.99**	0.97**	0.73**	0.55
	-	65.23 (6.07)	61.97 (8.17)	61.53 (10.04)	F(2, 98)= 2.06; (0.04)	-	-	-	0.46

Chronic tension-type headache; (CM) Chronic Migraine; (CCH) Chronic cluster headache; (HIT-6) Headache in
ex; *(F)ANOVA* statistic; (η^2) Eta square; (*) *p-value*<0.05; (**) *p-value*<0.001

arison between groups of the head posture and neck movement outcomes

	Controls (n=30)	**CM (n=35)**	**CTTH (n=30)**	**CCH (n=34)**		**Post-hoc analysis with Bonferroni corr**			
						Controls Vs CM	**Controls Vs CTTH**	**Controls Vs CCH**	**CM Vs CTTH**
								(effect size)	
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Statistic; *η² (effect size)***	**Post-hoc analysis with Bonferro Cohen´s *d (effect s***			
ure	17.53 (2.54)	17.05 (2.22)	17.5 (3.16)	19.2 (2.99)	F(3, 128)= 4.01*; (0.09)	0.53	0.5	0.61	0.55
²)	354.96 (40.09)	335.13 (45.51)	296.11 (54.33)	305.49 (61.37)	F(3, 128)= 8.8**; (0.17)	0.62	0.81**	0.75*	0.72*
sitior	13.95 (2.99)	14.01 (2.21)	14.67 (2.8)	16.17 (3.02)	F(3, 128)= 4.66*; (0.10)	0.51	0.57	0.7*	0.57
ositic	21.52 (2.76)	20.92 (2.11)	21.14 (3.63)	23.91 (2.89)	F(3, 128)= 7.77**; (0.15)	0.57	0.53	0.73*	0.52
	90.61 (15.97)	79.34 (22.73)	77.35 (16.77)	74.42 (21.84)	F(3, 128)= 3.68*; (0.09)	0.66	0.71	0.72*	0.53
Endurance flexors test & Craniocervical Flexion Test (CCFT)									
	Median (Range)	**Median (Range)**	**Median (Range)**	**Median (Range)**	**Statistic; *η² (effect size)***	**Post-hoc Mann-Whitney Test w correction – *r (effect***			
test	96.03 (445.00 – 91.17)	45.88 (180.00 – 37.88)	53.96 (190.00 – 45.10)	63.60 (165 – 37.13)	H(3, 128)= 14.43*; (0.09)	0.19**	0.42*	0.36*	0.28*
ed	30 (27-30)	28 (26-30)	30 (24-30)	30 (24-30)	H(3, 128)= 2.60; (0.003)	0.40	0.48	0.20	0.13

Chronic tension-type headache; (CM) Chronic Migraine; (CCH) Chronic cluster headache; (AROM) Neck activ
lexion-rotation test; (CCFT) craniocervical flexion test; (mmHg) millimetre of mercury for the stage of the
square; ***(X^2)*** Chi squared; (n.s.) non statistical differences; (*) p-value<0.05; (**) p-value<0.001

Table 4. Comparison between groups of the reproduction and resolution of headache symptoms.

REPRODUCTION OF HEADACHE	Controls (n=30)	CM (n=35)	CTTH (n=30)	CCH (n=34)	Statistic; Cramer´s V (effect size)
	Nº (%)	Nº (%)	Nº (%)	Nº (%)	
Neck AROM (headache)	0 (0)	4 (11.4)	3 (12.9)	3 (8.8)	χ^2(3, 128)=3.97; (0.18)
Neck FRT (headache)	0 (0)	5 (14.3)	1 (3.3)	3 (8.8)	χ^2(3, 128)=5.92; (0.21)
Neck MTrP (headache)	5 (16.7)	15 (42.9)	13 (41.9)	5 (14.7)	χ^2(3, 128)=11.32; (0.30)
PAIVMs (headache)	0 (0)	14 (40)	14 (48.3)	6 (18.2)	χ^2(3, 128)=22.17**; (0.42)
Reproduction Resolution Test – (headache)	7 (23.3)	24 (68.6)	21 (72.4)	13 (39.4)	χ^2(3, 128)=20.62**; (0.40)

Legend: (CTTH) Chronic tension-type headache; (CM) Chronic Migraine; (CCH) Chronic cluster headache¸ Active range of motion; (FRT) Flexion-rotation test;(PAIVMs) Passive accessory intervertebral movements; (MTrPs) Myofascial Trigger Points; (χ^2) Chi squared; (*) p-value<0.05; (**) p-value<0.001

rison between groups of CCFT (sEMG muscle activity).

Controls (n=30)	CM (n=35)	CTTH (n=30)	CCH (n=34)	Statistic; η^2 (effect size)	Post-hoc Dunn´s Test with Bonferro			
					Controls Vs CTTH	Controls Vs CM	Controls Vs CCH	CM Vs CTTH
Median (Range)	Median (Range)	Median (Range)	Median (Range)					
CCFT (Sternocleidomastoid muscles)								
7.94 (3.15 – 12.50)	9.56 (6.11 – 17.13)	12.41 (5.95 – 19.40)	11.44 (4.22 – 19.59)	H(3, 128)= 2.91 η^2= 0.01	0.24	0.21	0.15	0.06
8.78 (4.16 – 19.13)	11.43 (7.99 – 16.40)	12.29 (5.32 – 26.93)	8.26 (4.81 – 18.09)	H(3, 128)= 1.66 η^2= 0.01	0.10	0.14	0.01	0.04
17.46 (8.94 – 38.22)	15.40 (10.68 – 30.36)	18.31 (8.35 – 43.66)	21.17 (9.85 – 27.54)	H(3, 128)= 0.09 η^2= 0.02	0.01	0.01	0.01	0.02
10.17 (6.66 – 23.03)	13.83 (10.39 – 20.82)	13.83 (4.42 – 25.78)	7.81 (5.24 – 36.22)	H(3, 128)= 2.88 η^2= 0.01	0.07	0.17	0.02	0.08
15.25 (6.67 – 22.70)	12.99 (9.12 – 20.33)	11.54 (4.48 – 17.84)	7.25 (4.88 – 15.95)	H(3, 128)= 5.2 η^2= 0.02	0.14	0.04	0.21	0.17
CCFT (Erectors Spinae muscles)								
8.3 (5.56 – 12.36)	15.03 (8.06 – 30.31)	11.45 (6.30 – 18.38)	12.05 (8.18 – 27.54)	H(3, 128)= 10.79* η^2= 0.06	0.1819	0.39*	0.31	0.18
10.73 (8.11 – 17.33)	19.52 (13.05 – 30.56)	17.25 (10.95 – 30.71)	15.61 (7.93 – 32.06)	H(3, 128)= 10.55 * η^2= 0.06	0.27	0.39*	0.17	0.11
8.29 (6.95 – 18.35)	17.77 (9.59 – 24.66)	14.98 (9.14 – 24.75)	12.31 (8.15 – 24.07)	H(3, 128)= 7.04 * η^2= 0.03	0.26	0.31*	0.26	0.04
13.55 (9.54 – 27.17)	29.35 (13.63 – 44.98)	17.22 (9.90 – 27.61)	13.95 (6.02 – 37.13)	H(3, 128)= 7.97* η^2= 0.04	0.07	0.32	0.03	0.21
16.35 (10.28 – 23.10)	22.66 (12.69 – 43.94)	14.90 (8.09 – 22.87)	13.42 (7.92 – 21.34)	H(3, 128)= 5.47 η^2= 0.02	0.02	0.23	0.04	0.18

TTH) Chronic tension-type headache; (CM) Chronic Migraine; (CCH) Chronic cluster headache; (CCFT) cran
metre of mercury for the stage of the CCFT; (RMS%) Root mean square normalized; (η^2) eta squared; (*) p-v

LIST OF ABBREVIATIONS

(CTTH) Chronic tension type headache

(CM) Chronic migraine

(CCH) Chronic cluster headache

(AROM) Active range of motion

(FHP) Forward head posture

(PAIVMs) Passive accessories intervertebral movements

(MTrP) Myofascial trigger point

(ICHD-III) International classification headache disorders (3rd edition)

(HIT-6) Headache impact test – 6 items

(SF-12) Short Form Health Survey

(NDI) Neck disability index

(BDI) Beck depression inventory

(CROM) cervical inclinometer

(CCFT) Craniocervical flexion test

(SCM) Sternocleidomastoid muscle

(ESM) Erectors Spinae muscles

(EMGs) Surface electromyography

(MVIC) maximal voluntary isometric contractions

(RMS) Root mean square

(Ag/AgCl) silver/silver chloride.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study protocol received ethical approval from the La Paz University Hospital Ethics Committee, Madrid (Approval No. Pi-3442)

CONSENT FOR PUBLICATION

Not applicable

AVAILABILITY OF DATA AND MATERIALS

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

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- Ignacio Elizagaray-García: Conceptualization, Methodology, investigation, Formal analysis, writing original draft, writing–review & editing
- Celia María-de-Toro: Investigation
- Javier Díaz-de-Terán: investigation, resources
- Alfonso Gil-Martínez: Conceptualization, Methodology, writing–review & editing
- Kerstin Luedtke: Methodology, writing–review & editing

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1. Hospital Universitario La Paz in Madrid (Department of Neurology, Headaches Unit).

2. Hospital Universitario La Paz (Madrid, Spain)

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