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# Headache production during physical examination in patients with and without headache atributted to a whiplash injury: A case-control study

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ABSTRACT

*Background:* Provocation of headache on physical examination of the neck may reflect a role of cervical structures in the presence of acute whiplash-associated headache (WAH).
*Objective:* To determine differences in headache provocation during physical tests in people with and without WAH after a whiplash injury.
*Design:* Case-control study.
*Methods:* Forty-seven people with acute whiplash-associated disorders participated, 28 with WAH. Passive accessory intervertebral movement over the tubercle of C1, the spinous processes of C2-C3 and facet joints of C0-C4, the flexion-rotation test (FRT), manual palpation of cranio-cervical muscles and the upper limb neurodynamic test + cranio-cervical flexion were assessed bilaterally twice by a blinded examiner; headache provocation was determined. Cohen's kappa and Chi-squared were determined to evaluate the intra-rater reliability of test results and differences between groups, respectively. A logistic regression model was also performed.
*Results:* Intra-rater reliability of headache provocation was good or excellent for most tests. Significant differences between groups were found with higher positive tests in WAH for the assessment of C2 (68%), the most painful side of C0-C1 (57%), C1-C2 (75%) and C2-C3 (53%), most (79%) and least (25%) restricted sides of the FRT, and manual palpation of the most painful side for the trapezius (53%), masseter (50%) and temporalis (46%) muscles. Provocation of headache during the assessment of C2 and C1-C2 on the most painful side demonstrated the highest association with WAH.
*Conclusion:* Mechanical provocation of headache is more frequent in people with WAH than in those without headache soon after a whiplash injury.

## 1. Introduction

Whiplash associated-disorders (WAD) are defined as the group of signs and symptoms caused by an acceleration-deceleration mechanism of energy transfer to the neck resulting from a rear-end or side impact (Yadla, Ratliff, Harrop, 2008). Among the symptoms experienced by people with WAD, headache is common (GBD 2016 Disease and Injury Incidence and Prevalence Collaborators, 2017), with a prevalence of 60% shortly after the accident (Anarte-Lazo et al., 2022). According to the International Headache Society, acute headache is considered to be caused by a whiplash injury if it appears less than 7 days after the accident, or if a pre-existing headache is made worse in close temporal relation to the whiplash injury, and is known as whiplash-associated headache (WAH) (Headache Classification Committee of the, 2018).

Following a whiplash injury, different structures such discs, joints or muscles, have been identified as possible sources of nociception (Chen et al., 2009; Siegmund et al., 2009). The neurophysiological interactions within the trigemino-cervical complex have been suggested as a possible explanation for the referral of pain to the head region when nociception is experienced from cervical structures, mainly from the upper cervical region (Castien and De Hertogh, 2019; Bogduk, 2001). Indeed, both basic and clinical studies have elicited headache as referred pain via stimulation of cervical nociceptors from the upper cervical segments (Castien and De Hertogh, 2019; Schmidt-Hansen et al., 2006; Bogduk and Govind, 2009). If there is a causal relationship between cervical structures and headache in people with whiplash, identifiable cervical

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neuromusculoskeletal dysfunction may be more common in those with headache than in those without.

Physical testing through manual pressure over articular and myofascial structures has been recognized as a way of provoking/reproducing headache in different headache populations, such as cervicogenic headache or tension-type headache (Watson and Drummond, 2012; Hall et al., 2010a; Luedtke et al., 2018). In addition, the flexion-rotation test (FRT) has been widely accepted as a valid test to assess dysfunction of the upper cervical structures (Ogince et al., 2007; Hall et al., 2010b). Moreover, it was reported that 7.4% of people with cervicogenic headache reported provocation of their headache when the Upper Limb Neurodynamic Test + Cranio-Cervical Flexion (CCF) were performed (Zito et al., 2006).

Reproduction of headache upon physical examination of the neck has been considered as an indicator of local cervical dysfunction and/or increased sensitisation of these structures in headache patients (Castien and De Hertogh, 2019; Watson and Drummond, 2012). In people with headache, despite some controversy, the reproduction of headache on physical testing has been suggested to increase the accuracy of clinical tests, such as the FRT (Paquin et al., 2022), therefore helping healthcare professionals make informed treatment decisions i.e., targeting the cervical spine if physical examination confirms a likely cervical source of headache. However, no studies have assessed headache provocation on physical examination in people with WAD and WAH. Thus, the purposes of this study were to 1) examine the intra-rater test-retest reliability and agreement between repeated test results of headache provocation on different physical tests in people with acute WAD, 2) evaluate differences in headache provocation during physical tests between patients after a whiplash injury who have WAH versus those who do not, and 3) to assess the strength of the association of a set of headache provocation tests with the presence of WAH. We hypothesised that in people with WAH, the prevalence of headache provocation on physical examination of the neck will be higher. We also hypothesised that the tests would be reliable in people with acute WAD. Additionally, we expected to find that some of the assessments performed in the upper cervical region are strongly associated with the presence of headache, suggesting a potential role of nociception and/or hypersensitivity over cervical structures contributing to their headache.

## 2. Material and methods

### 2.1. Participants

A case-control study was performed with consecutive patients with a diagnosis of acute WAD, who were recruited from a private clinic in Madrid, Spain, from September 2020 to February 2021. We only included patients with Grade II WAD, as defined by The Quebec Task Force on Whiplash-Associated Disorders (Headache Classification Committee of the, 2018), due to the potential challenges of conducting some of the physical tests in people with higher WAD Grades. Further inclusion criteria were recruitment between 7 and 30 days after the whiplash injury and aged between 18 and 65 years. Exclusion criteria were: fibromyalgia diagnosis or history of generalized pain, previous whiplash injury, diagnosis of osteoporosis, cervical myelopathy, temporomandibular disorders, vertebral fractures and/or inflammatory or rheumatic diseases. People were also excluded if they had undergone surgery in the cervical region, had a known psychological disorder or congenital disturbances, or were not able to complete patient-reported outcome measures. Patients above 65 years old were excluded to avoid the inclusion of older people who may have declined physical function of their neck. In addition, with the aim of excluding people suffering from concussion, we followed the criteria of the International Headache Society (Headache Classification Committee of the, 2018) and excluded people with a possible concussion, according to the following signs and/or symptoms: confusion, disorientation or impaired consciousness; loss of memory for events immediately before or after the accident; and one or more of the following: nausea, vomiting, visual disturbances, dizziness and/or vertigo, gait and/or postural imbalance, and impaired memory and/or concentration.

Participants with a previous headache condition were included if the headache intensity increased within 7 days after the accident, according to criteria established by ICHD-III (Headache Classification Committee of the, 2018).

The study was approved by the ethics committee from University Rey Juan Carlos, Madrid, Spain (Ref: 1003202108121) and was conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent prior to the commencement of the study. This study is reported in accordance with STROBE Guidelines (von Elm et al., 2014; Vandenbroucke et al., 2007).

The sample size estimation was performed using the website Epitools (https://epitools.ausvet.com.au/casecontrolss). Since no previous publication in the area of headache reproduction in people with WAD had been performed, and with the aim of calculating a sample size for the current study, we followed the Odds Ratio observed in a study performed in people with cervicogenic headache (Cummins et al., 2022). Therefore, estimating an alpha risk of 5% (0.05), a beta risk of 20% (0.20), a unilateral contrast, a minimum Odds Ratio to detect of 36.0 and assuming no dropouts due to the design of the study, at least 28 participants were required, 14 per group.

### 2.2. Procedures

Participants were diagnosed by a physician and those who agreed to participate in the study provided written informed consent. People with a previous headache condition which increased after the accident were asked to state their previous headache diagnosis when available. For those who presented headache previously and didn't know if the condition was episodic or chronic, they were asked about the frequency of their headache. If the headache was present on 15 days or more per month, it was classified as chronic (Headache Classification Committee of the, 2018). Then, they were referred to the Physiotherapy Department for the assessment and were asked not to reveal the presence/absence of headache to the evaluator. Thus, the examiner was blinded. All measurements were collected in a single session. The examiner was a physiotherapist with four years of clinical experience and with a Master's Degree in Orthopaedic Manual Therapy.

All tests were evaluated twice, in two sets. Reliability was calculated based on the results of both repetitions for each test. Ten minutes of rest was provided between repeated testing for the assessment of each set. During this time, participants sat on a chair resting. The order of testing was comparable between sets. When tests were performed bilaterally then the outcomes were considered separately according to the more painful/restricted side. Since headache provocation was defined as positive/negative, we considered the test as positive if both repetitions of the same test were positive. A test was considered positive when symptoms were referred to the head, irrespective of the familiarity of headache (Luedtke and May 2017).

### 2.3. Outcome measures

#### 2.3.1. Age, sex, height, and weight were recorded for all participants

*Passive Accessory Intervertebral Movements (PAIVMs).* Central and bilateral posterior-anterior intervertebral movements were applied over C1-C3 (central, tubercle of C1 and the spinous processes of C2 and C3) and C0-C1/C3-C4 (bilateral, facet joints). The participant was asked to state if he/she felt headache with the pressure (Hall et al., 2010a). The most painful side was evaluated by asking the patient to report their local pain intensity during the assessment.

*Flexion-Rotation Test (FRT).* The participant lay in supine on the plinth. They were asked to relax while their neck was moved to end range cervical flexion by the examiner. In this flexed position, the head and neck were passively rotated as far as possible within comfortable limits, and the subject was asked to report the presence or absence of headache. The test was performed bilaterally (Hall et al., 2010b). The most restricted side was determined based on the results of a range of motion assessment, as previously done (Satpute et al., 2019).

*Muscle palpation.* Palpation was performed at predetermined points over different muscles. A single location in the middle of muscle belly was palpated and the participants were asked to rate their pain intensity upon palpation over the upper trapezius, suboccipitalis, masseter, temporalis and sternocleidomastoid bilaterally. Pincer palpation was performed for upper trapezius and sternocleidomastoid whereas pressure palpation was performed for the remaining muscles. Participants were asked to stay if they experienced headache during the application of the pressure. All points were assessed with the subject lying supine with the neck in a neutral position. The most painful side was evaluated by asking the patient to report their local pain intensity during the assessment.

*Mechanosensitivity during Upper Limb Neurodynamic Testing (ULNT) combined with Cranio-Cervical Flexion (CCF).* The participant was asked to perform active CCF and then the ULNT1 was performed as described previously, while the CCF position was sustained (Zito et al., 2006). The elbow was the last joint moved until the point where the patient reported discomfort, and then the positions were relaxed. The participant was asked to report the presence or absence of headache during the test.

The order of testing was chosen to minimise change in the patients position and adhered to the following sequence: PAIVMs, FRT, muscle palpation, and ULNT+CCF.

### 2.4. Statistical analysis

Statistical analyses were carried out using the IBM-SPSS Statistics 24 software. First, the intra-rater test-retest reliability and agreement were calculated for headache provocation for the different tests for all participants.

#### 2.4.1. Relative intra-rater test-retest reliability

The kappa value was calculated via Cohen's kappa (k) coefficient. K-values were categorized as low (≤0,40), moderate (0,41-0,60), good (0,61-0,80); and excellent reliability (0,81-1,00) (Lexell and Downham, 2005).

#### 2.4.2. Agreement

The percent of agreement between repeated test results was calculated according to the following formula: A/Nx100, where A reflects the number of tests where agreement was found, and N is sample size (Brennan and Silman, 1992).

Secondly, $Chi^2$ was used for the between-group analysis, comparing people with WAD with and without WAH. The alpha level accepted for significance of the results was $p < 0.05$. The outcomes were entered in a backward regression analysis with the presence of headache as the dependent variable. The regression analysis was conducted in two stages. In the first stage, each independent variable was entered in a univariate logistic regression analysis. For the second stage, due to our sample size, we reduced the number of variables to five. Therefore, only the five variables with highest influence in the model measured through $R^2$ were included in our model.

## 3. Results

Forty-nine participants were recruited. Two were then excluded because they had undergone cervical surgery. Thus, 47 subjects remained and were assessed and included in data analysis. Twenty-eight participants (16 female) presented with WAH. Five of them suffered from previous headaches which had increased after the whiplash injury: two were diagnosed with migraine (one episodic and one chronic), and three with tension-type headache (one episodic and two chronic). The control group (WAD with no headache) was composed of 19 people (5 female), none with previous headache. No significant differences between groups were found for age, weight, height, or days from the accident to the assessment (Table 1).

Table 2 presents the data for reliability and agreement regarding provocation of headache during the physical examination. Excellent reliability was found when the following measurements were assessed: C3 (k = 0.850), most painful side of C0-C1 (k = 0.869), least painful side of C1-C2 (k = 0.810), most painful side of C2-C3 (k = 0.869), most (k = 0.910) and least (k = 0.810) restricted sides of FRT, most painful side for the sternocleidomastoid (k = 0.821), trapezius (0.826), masseter (0.823) and temporalis (k = 0.821) muscles. Reliability was moderate for the least painful side for the trapezius (k = 0.555) and temporalis (k = 0.468) muscles. The remaining tests presented good reliability. Agreement ranged from 78.7% for the least painful side for the masseter muscle to 95.8 for the most restricted side of the FRT.

For differences between-groups (Table 3), we found significant differences for the assessment of C2 ($p < 0.001$), most painful side of C0-C1 ($p = 0.001$), most painful side of C1-C2 ($p < 0.001$), most painful side of C2-C3 ($p = 0.009$), most ($p = 0.001$) and least ($p = 0.002$) restricted sides of FRT, and most painful side for the trapezius ($p = 0.009$), masseter ($p = 0.017$) and temporalis ($p = 0.010$) muscles.

The univariate regression analysis (Table 4) showed a significant increased likelihood of producing headache in people with WAH during the assessment of C2 ($p < 0.001$, $R^2 = 0.403$), most painful side of C0-C1 ($p = 0.004$, $R^2 = 0.294$) and C1-C2 ($p < 0.001$, $R^2 = 0.411$), most ($p = 0.002$; $R^2 = 0.273$) and least ($p = 0.018$; $R^2 = 0.244$) restricted sides of the FRT, and most painful side for the trapezius ($p = 0.013$, $R^2 = 0.194$).

Finally, after performing the backward regression analysis applied for the five variables with the highest $R^2$ (C2, most painful side of C0-C1 and C1-C2, most and least restricted sides of FRT and most painful side for the trapezius muscle), two variables demonstrated statistical significance (C2: $p = 0.005$; most painful side of C1-C2, $p = 0.003$; Table 5). The regression analysis explained 59.7% (Table 6; $R^2$ of Nagelkerke) of the variation in the presence/absence of headache in patients with acute WAD.

## 4. Discussion

This study evaluated differences in the provocation of headache on physical examination of different cervical structures between patients with and without WAH. As hypothesised, headache provocation on manual testing was more common in people who reported WAH, including manual assessment of the spinous process of C2, most painful sides of C0-C3, both sides of the FRT and palpation of trapezius, masseter and temporalis muscles. Furthermore, headache provocation when a posterior-anterior intervertebral movement of the spinous process of C2 and the facet joint of C1-C2 on the most painful side were performed were the assessments with the highest association with the presence of headache. These findings may suggest that an increased sensitisation of these structures is commonly associated with the presence of headache

**Table 1**
Sociodemographic features of the participants with and without headache.

| Variables | Group | | Z |
|---|---|---|---|
| | Headache (n = 28) | No Headache (n = 19) | P value* |
| Age (years) (i) | 37.6 (11.1) | 40.9 (10.9) | 0.319 |
| Sex (Male/Female) (ii) | 12/16 | 14/5 | – |
| Height (cm) (i) | 174.5 (8.8) | 177.1 (9.9) | 0.370 |
| Weight (kg) (i) | 70.7 (10.1) | 76.6 (10.4) | 0.064 |
| Days from the accident (i) | 13.4 (4.3) | 11.7 (3.7) | 0.152 |
| Headache (VAS) (i) | 47.4 (14.2) | – | – |

Z: Shapiro-Wilk Normality Test; P: Statistical Significance; *: T Student; (i) Data expressed as means ± standard deviation; (ii) Data expressed as percent (partial/total). †Indicate statistically significant differences between groups ($P < 0.05$). VAS: Visual Analogue Scale.

**Table 2**
Reliability and agreement of categorical data.

| Test | Positive rate | Cohen's kappa (95% CI) | Agreement |
|---|---|---|---|
| C1 | 18/47 | 0.742 (0.550, 0.934) | 87.2% |
| C2 | 21/47 | 0.702 (0.502, 0.902) | 85.1% |
| C3 | 14/47 | 0.850 (0.707, 0.993) | 93.6% |
| Most painful C0-C1 | 18/47 | 0.869 (0.702, 0.980) | 93.6% |
| Least painful C0-C1 | 11/47 | 0.740 (0.526, 0.954) | 89.4% |
| Most painful C1-C2 | 24/47 | 0.785 (0.608, 0.961) | 89.4% |
| Least painful C1-C2 | 14/47 | 0,810 (0.633, 0.986) | 91.5% |
| Most painful C2-C3 | 18/47 | 0.869 (0.745, 0.992) | 93.6% |
| Least painful C2-C3 | 8/47 | 0.746 (0.511, 0.981) | 91.5% |
| Most painful C3-C4 | 13/47 | 0.673 (0.451, 0.894) | 85.1% |
| Most painful C3-C4 | 6/47 | 0.648 (0.376, 0.920) | 89.4% |
| Most restricted FRT | 28/47 | 0.910 (0.802, 0.998) | 95.8% |
| Least restricted FRT | 14/47 | 0.810 (0.634, 0.986) | 91.5% |
| Most painful SCM | 16/47 | 0.821 (0.656, 0.985) | 87.4% |
| Least painful SCM | 7/47 | 0.619 (0.342, 0.895) | 87.4% |
| Most painful TRAP | 18/47 | 0.826 (0.663, 0.988) | 91.4% |
| Least painful TRAP | 4/47 | 0.555 (0.171, 0.939) | 91.4% |
| Most painful SO | 21/47 | 0.703 (0.501, 0.905) | 85.1% |
| Least painful SO | 11/47 | 0.695 (0.469, 0.920) | 87.1% |
| Most painful MAS | 17/47 | 0.823 (0.658, 0.987) | 91.4% |
| Least painful MAS | 11/47 | 0.695 (0.469, 0.920) | 87.1% |
| Most painful TEMP | 15/47 | 0.821 (0.670, 0.972) | 93.6% |
| Least painful TEMP | 8/47 | 0.468 (0.186, 0.750) | 78.7% |
| Most restricted ULNT+FCC | 7/47 | 0.670 (0.403, 0.937) | 89.4% |
| Least restricted ULNT+FCC | 5/47 | 0.665 (0.363, 0.967) | 91.4% |

FRT (Flexion-Rotation Test)), ULNT (Upper Limb Neural Test), CCF (Cranio-Cervical Flexion), SCM (Sternocleidomastoid), TRAP (Trapezius), SO (Suboccipitalis), MAS (Masseter) TEMP (Temporalis).

in these patients.

WAH is still a controversial diagnosis, and clinical characteristics of WAH overlap with other headache conditions, such as migraine or tension-type headache (Drottning-Ronne, 2008; Schrader et al., 2006; Obermann et al., 2010). The pathophysiology of whiplash-associated headache appears to be related to the interaction of cervical and trigeminal afferents in the trigemino-cervical complex and ongoing peripheral nociception from cervical structures (Woolf and Salter, 2000; Quinn et al., 2010), as in cervicogenic headache.

Although headache reproduction has been previously studied in different headache conditions (Watson and Drummond, 2012; Cummins et al., 2022; Luedtke and May 2017), to the best of our knowledge, only one study (Hall et al., 2010a) assessed the reliability of the symptomatic headache response in people with cervicogenic headache and found a reliability higher than 0.70. Nonetheless, it was done together with the consideration of hypomobility (Hall et al., 2010a). Previous studies have considered that manual palpation is valid and reliable in the diagnosis of cervical facet joint pain (Schneider et al., 2013, 2014). In line with these results, we found good or excellent reliability for all of the headache provocation tests except for the least painful side for the trapezius and temporalis muscles. Nonetheless, the current study only evaluated intra-rater test-retest reliability. Further studies should assess inter-rater reliability of headache provocation.

According to previous studies, the FRT is one of the most useful tests to identify upper-cervical dysfunction that could be involved in the presence of headache (Ogince et al., 2007; Anarte-Lazo et al., 2021). In the current study, we found that it was the only test which was significantly different for both the most and least restricted sides between people with and without WAH, supporting the importance of this test in the assessment of people with headache (Demont et al., 2022; Hall and Robinson, 2004). Considering that the FRT is a test of C1-2 movement impairment, we believe that these findings support the idea that C1-C2 is the most affected in those presenting with WAH. Nonetheless, future studies may consider assessing if headache provocation is related to a positive FRT in terms of range of motion, which has been established at $< 32^{\circ}$ (Ogince et al., 2007). Moreover, we also found differences between groups upon physical examination of the cervical spine, namely posterior-anterior intervertebral movement of the spinous process of C2 and C0-C3 facet joints on the most painful side, which supports the association between sensitisation of upper cervical structures and the presence of headache (Watson and Drummond, 2012; Bartsch and Goadsby, 2003).

Muscle trigger points have been described in people with acute WAD (Fernández-Pérez et al., 2012) and some studies have described referred pain to the craniofacial region upon manual palpation of trigger points, including those within the sternocleidomastoid and upper trapezius (Simons et al., 1999). However, we did not evaluate the presence of trigger points, but rather the provocation of headache via manual pressure over specific cranio-cervical muscles. Nonetheless, according to the results of the current study, the only muscles which showed differences between groups in eliciting headache were the masseter, temporalis and trapezius, but not the sternocleidomastoid or suboccipitalis. Although previous studies have demonstrated similar findings for trapezius, temporalis and masseter in other health conditions (Do et al., 2018; Fernández-de-Las-Peñas et al., 2007a), previous studies have also found referred pain to the craniofacial region for the suboccipital and sternocleidomastoid muscles (Fernández-de-Las-Peñas et al., 2007; Fernández-de-Las-Peñas et al., 2006). It could be hypothesised that the findings from the current study, mainly for masseter and temporalis, are related to the common association between whiplash injuries and temporomandibular disorders (Freund and Schwartz, 2002; Friedman and Weisberg, 2000). Nonetheless, future studies should assess if this hypothesis is sustained.

Nociceptive sources which lead to headache may be attributed to peripheral sensitisation of cervical nerves (Schneider et al., 2014) in addition to cervical muscles and joints. In the current study, we did not find significant differences between those with and without headache when the ULNT was performed together with CCF (Zito et al., 2006). It could be argued that this test is not sensitive enough to detect dysfunction or a sensitisation of upper cervical structures that could be involved in the headache condition. Indeed, only five out of 47 participants reported provocation of headache when tested on the most restricted side. Future studies should assess if other neural tests, such as the occipitalis long sitting-slump test (Szikszay et al., 2018), evoke

**Table 3**
Prevalence and differences in headache provocation between groups for each test.

| Test | Headache (n = 28) | No Headache (n = 19) | $\chi^2$ | P value |
|---|---|---|---|---|
| C1 | 13 (46.43%) | 5 (26.32%) | 1.938 | 0.164 |
| C2 | 19 (67.86%) | 2 (10.53%) | 15.052 | <0.001* |
| C3 | 10 (35.71%) | 4 (21.05%) | 1.163 | 0.281 |
| Most painful C0-C1 | 16 (57.14%) | 2 (10.53%) | 10.409 | 0.001* |
| Least painful C0-C1 | 8 (28.57%) | 3 (15.79%) | 1.032 | 0.310 |
| Most painful C1-C2 | 21 (75%) | 3 (15.79%) | 15.881 | <0.001* |
| Least painful C1-C2 | 11 (39.28%) | 3 (15.79%) | 2.988 | 0.084 |
| Most painful C2-C3 | 15 (53.57%) | 3 (15.79%) | 6.838 | 0.009* |
| Least painful C2-C3 | 7 (25%) | 1 (5.26%) | 3.122 | 0.077 |
| Most painful C3-C4 | 10 (35.71%) | 3 (15.79%) | 2.246 | 0.134 |
| Least painful C3-C4 | 4 (14.28%) | 2 (10.53%) | 0.144 | 0.705 |
| Most restricted FRT | 22 (78.57%) | 6 (31.57%) | 10.379 | 0.001* |
| Least restricted FRT | 13 (50%) | 1 (5.26%) | 9.171 | 0.002* |
| Most painful SCM | 12 (42.86%) | 4 (21.05%) | 2.397 | 0.122 |
| Least painful SCM | 5 (17.86%) | 2 (10.53%) | 0.480 | 0.488 |
| Most painful TRAP | 15 (53.57%) | 3 (15.79%) | 6.838 | 0.009* |
| Least painful TRAP | 3 (10.71%) | 1 (5.26%) | 0.432 | 0.511 |
| Most painful SO | 15 (53.57%) | 6 (31.57%) | 2.215 | 0.137 |
| Least painful SO | 9 (32.14%) | 2 (10.53%) | 2.950 | 0.086 |
| Most painful MAS | 14 (50%) | 3 (15.79%) | 5.738 | 0.017* |
| Least painful MAS | 5 (26.32%) | 1 (5.26%) | 1.612 | 0.204 |
| Most painful TEMP | 13 (46.42%) | 2 (10.53%) | 6.714 | 0.010* |
| Least painful TEMP | 7 (25%) | 1 (5.26%) | 3.122 | 0.077 |
| Most restricted ULNT+CCF | 5 (17.86%) | 2 (10.53%) | 0.480 | 0.488 |
| Least restricted ULNT+CCF | 3 (10.71%) | 2 (10.53%) | 0.000 | 0.984 |

FRT (Flexion-Rotation Test)), ULNT+CCF (Upper Limb Neural Test), CCF (Cranio-Cervical Flexion), SCM (Sternocleidomastoid), TRAP (Trapezius), SO (Suboccipitalis), MAS (Masseter) TEMP (Temporalis). *$p < 0.05$.

headache in this population.

Of all the tests that were conducted, only physical examination of the C2 spinous process and C1-C2 facet joint on the most painful side were found to partially predict the presence of headache in patients with acute WAD. We were surprised that the FRT did not demonstrate greater importance in our regression model. However, we observed that it was the test with highest prevalence (31.57%) of headache provocation in those without headache, therefore reducing its importance in the regression model to predict the presence of headache.

### 4.1. Clinical considerations

To the best of our knowledge, this is the first study to assess headache provocation on physical examination of the cervical region between those who present with headache soon after a whiplash injury and those who do not. Therefore, the current study provides an initial step to confirm the relevance of cervical sensitivity as a contributor to headache in people with acute WAD.

We demonstrated that headache provocation on physical examination is good to excellent in terms of intra-rater test-retest reliability for almost all the tests performed in this study, with the therapist blinded to the headache status. Moreover, we demonstrated that mechanical provocation of headache through the assessment of the C2 spinous process and C1-C2 facet joint on the most painful side could partially predict the presence of headache. Thus, we provide some evidence that

**Table 5**
Final results for the backward logistic regression analysis model for prediction of the presence of headache based on headache provocation findings.

| Test | B | S.E. | Exp(B) | 95%CI Lower Limit | 95%CI Upper Limit | P value |
|---|---|---|---|---|---|---|
| C2 | 2.715 | 0.960 | 15.111 | 2.302 | 99.194 | 0.005* |
| Most painful side C1-C2 | 2.606 | 0.878 | 13.551 | 2.423 | 75.804 | 0.003* |

*$p < 0.05$; C2: spinous process of C2; C1.C2: Facet joint of C1-C2.

**Table 6**
Summary statistics of the final model.

| Hosmer & Lemeshow's Test | Summary of the model | |
|---|---|---|
| Significance | $R^2$: Cox & Snell | $R^2$: Nagelkerke |
| 0.708 | 0.442 | 0.597 |

**Table 4**
Results of the univariate logistic regression analyses with the presence of headache as the dependent variable.

| Test | $R^2$ | B | S.E. | [Exp(B)] | 95%CI LL | 95%CI UL | P value |
|---|---|---|---|---|---|---|---|
| C1 | 0.056 | 0.887 | 0.644 | 2.427 | 0.687 | 8.578 | 0.169 |
| C2 | 0.403 | 2.887 | 0.850 | 17.944 | 3.391 | 94.948 | <0.001* |
| C3 | 0.034 | 0.734 | 0.687 | 2.083 | 0.542 | 8.011 | 0.285 |
| Most painful C0-C1 | 0.294 | 2.428 | 0.839 | 11.333 | 2.187 | 58.734 | 0.004* |
| Least painful C0-C1 | 0.030 | 0.758 | 0.756 | 2.133 | 0.485 | 9.379 | 0.316 |
| Most painful C1-C2 | 0.411 | 2.773 | 0.766 | 16.000 | 3.567 | 71.762 | <0.001* |
| Least painful C1-C2 | 0.088 | 1.239 | 0.739 | 3.451 | 0.811 | 14.678 | 0.094 |
| Most painful C2-C3 | 0.194 | 1.817 | 0.734 | 6.154 | 1.459 | 25.961 | 0.013 |
| Least painful C2-C3 | 0.098 | 1.792 | 1.116 | 6.000 | 0.673 | 53.495 | 0.108 |
| Most painful C3-C4 | 0.066 | 1.086 | 0.743 | 2.963 | 0.691 | 12.700 | 0.144 |
| Least painful C3-C4 | 0.004 | 0.348 | 0.922 | 1.417 | 0.232 | 8.635 | 0.706 |
| Most restricted FRT | 0.273 | 2.072 | 0.675 | 7.944 | 2.116 | 29.832 | 0.002* |
| Least restricted FRT | 0.244 | 2.603 | 1.096 | 13.500 | 1.575 | 115.696 | 0.018* |
| Most painful SCM | 0.070 | 1.034 | 0.680 | 2.812 | 0.742 | 10.665 | 0.128 |
| Least painful SCM | 0.014 | 0.614 | 0.896 | 1.848 | 0.319 | 10.693 | 0.493 |
| Most painful TRAP | 0.194 | 1.817 | 0.734 | 6.154 | 1.459 | 25.961 | 0.013* |
| Least painful TRAP | 0.013 | 0.770 | 1.195 | 2.160 | 0.207 | 22.488 | 0.519 |
| Most painful SO | 0.063 | 0.916 | 0.622 | 2.500 | 0.738 | 8.464 | 0.141 |
| Least painful SO | 0.089 | 1.393 | 0.850 | 4.026 | 0.761 | 21.304 | 0.101 |
| Most painful MAS | 0.165 | 1.674 | 0.734 | 5.333 | 1.265 | 22.477 | 0.023 |
| Least painful MAS | 0.050 | 1.364 | 1.140 | 3.913 | 0.419 | 36.532 | 0.231 |
| Most painful TEMP | 0.197 | 1.997 | 0.838 | 7.367 | 1.425 | 38.077 | 0.017 |
| Least painful TEMP | 0.098 | 1.792 | 1.116 | 6.000 | 0.673 | 53.495 | 0.108 |
| Most restricted ULNT+CCF | 0.050 | 1.364 | 1.140 | 3.913 | 0.419 | 36.532 | 0.231 |
| Least restricted ULNT+CCF | 0.000 | 0.020 | 0.965 | 1.020 | 0.154 | 6,767 | 0.984 |

LL: Lower Limit; UL: Upper Limit; FRT (Flexion-Rotation Test)), ULNT+CCF (Upper Limb Neural Test), CCF (Cranio-Cervical Flexion), SCM (Sternocleidomastoid), TRAP (Trapezius), SO (Suboccipitalis), MAS (Masseter) TEMP (Temporalis). *$p < 0.05$.

could be used by clinicians to interpret upper cervical hypersensitivity in people with acute WAD to ascertain whether there is a cervical source to their headache.

Nevertheless, there has been some criticism of using mechanical provocation of headache with manual pressure over the upper cervical area in order to determine whether the headache originates from cervical structures (Jaeger, 1989; Meloche et al., 1993; Watson and Drummond, 2014). Hypersensitivity has been described to occur soon after a whiplash injury (Sterling et al., 2003; Kasch et al., 2022). Thus, mechanical provocation of headache on palpation of upper cervical structures may be due to sensitisation mechanisms within the trigeminocervical nucleus, rather than an indicator of absolute signs of cervical musculoskeletal dysfunction (Jull and Hall, 2018). Indeed, headache provocation was also observed in some people with an acute whiplash injury without headache, and the presence of hypersensitivity may be the reason for this. Furthermore, singular positive test findings do not reflect the typical presentation of musculoskeletal disorders and may be secondary to sensitisation (Liang et al., 2021). Thus, examination findings must be considered in the context of other factors and clinical reasoning to guide interpretation of clinical findings. In addition, other clinical tests assessing headache provocation, such as cervical retraction, could be included in future studies to ensure an even more comprehensive clinical assessment (Cummins et al., 2022). Since we wanted to avoid potential aggravation of symptoms by sustaining manual pressure, and due to the amount of tests included in our study, we did not evaluate headache resolution, which may also be of interest to integrate into the physical assessment in future studies. Finally, other tests which have been assessed in earlier studies may be considered in future research, for example, the straight leg raise test in people with CGH (Zito et al., 2006).

## 5. Conclusion

Provocation of headache on physical examination of the spinous process of C2, the most painful facet joints of C0-C3, the FRT and palpation of the most painful sides of temporalis, masseter and trapezius muscles was more common in people with an acute whiplash injury and WAH compared to those who did not develop headache. The provocation of headache on physical examination of the spinous process of C2 and the facet joint of C1-C2 on the most painful side were the two assessments demonstrating the highest association with the presence of headache.

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## Author’s contributions

EAL performed the data acquisition and data management. CBU and CRB were involved in methodological design and statistical analysis. DF, CRB and EAL contributed to the development of the manuscript. CBU and DF contributed to supervision and conceptualization. All authors have read and agreed the final version of the manuscript.

## Declaration of competing interest

Authors declare no conflict of interest.

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