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Original Research

# Diagnostic accuracy of the flexion-rotation test and cut-off value in acute whiplash-associated disorders: A secondary analysis of a cross-sectional study

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ABSTRACT

*Background:* Headache is common in people with whiplash-associated disorders (WAD). Upper-cervical structures may be involved in the presence of headache, and the flexion-rotation test (FRT) has been widely studied to assess cervicogenic headaches.
*Objectives:* To evaluate the diagnostic accuracy of the FRT for the presence of headache in people with WAD, and its cut-off value.
*Methods:* In this secondary analysis from a previously published study 47 people with WAD were consecutively recruited, 28 with and 19 without headache. FRT was assessed by a single blinded evaluator, with production of headache during the test as the reference standard. Sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios were assessed through cross-tabulation. The cut-off value was calculated based on the Youden's Index. The positivity of the test was defined based on: a) range of motion (ROM) <32°; and ROM <32° combined with headache provocation.
*Results:* Differences between groups were significant for both most and least restricted sides of FRT in terms of ROM ($p < 0.001$). For the most restricted side, moderate sensitivity and specificity was found (82.1% [95%CI = 68.4%, 95.8%] and 63.2% [95%CI = 40.8%, 85.6%], respectively) when only ROM was considered. When headache provocation was included, sensitivity and specificity were 78.6% (95%CI = 63.1%, 93.7%) and 68.4% (95%CI = 47.5%, 88.5%), respectively. A cut-off value of 31.5° was found.
*Conclusion:* Moderate diagnostic accuracy through both ways of assessing the FRT was found for this test to detect the presence of whiplash-associated headache from upper cervical origin. The FRT may be considered positive if ROM is less than 31.5°.

## Introduction

Whiplash-associated disorders (WAD) are defined as the group of signs and symptoms associated to an acceleration-deceleration mechanism of energy transfer to the neck,[1] affecting up to 83% of individuals injured in traffic collisions,[2] with an estimated incidence of 600 per 100 000 people.[3,4] One of the most common symptoms of WAD is headache, with a prevalence between 46% to 73% in the short term, which can significantly impact the quality of life and functional capacity of affected individuals.[5]

According to the International Headache Society, whiplash-associated headache (WAH) is considered when it appears within seven days after the whiplash injury.[6] Although it is considered a secondary headache and, therefore, due to the trauma or injury to the neck, the underlying pathophysiological mechanisms of headache in WAD remain unclear, making its management challenging.[7] These mechanisms are thought to be multifactorial, with associations between physical and psychological factors and the presence of headache already demonstrated,[8-10] involving both peripheral and central processes.[11] Therefore, the assessment of headache in people with WAD requires a comprehensive evaluation including both subjective and objective measures.

Ethics Committee: The study was approved by the ethics committee from University Rey Juan Carlos, Madrid, Spain (Ref: 1,003,202,108,121).

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The assessment of upper cervical dysfunction is considered essential in the management of people with headache due to the convergence of neurons in the trigemino-cervical nucleus,[12-14] and it has been suggested that there is an association between the provocation of headache during manual testing and the presence of headache in people soon after a whiplash injury.[15] The flexion-rotation test (FRT) is an easily applied method of physical examination that has been developed to assess rotation at the C1-C2 level,[16] which accounts for 50% of the rotation in the cervical spine.[17,18] According to Ogince et al. ,[19] this test is considered positive when the amount of motion is $<32^{\circ}$, which is suggestive of cervicogenic headache.[19] It has also been suggested that the mechanical provocation of headache during the FRT may suggest the presence of cervicogenic headache.[20]

Various studies have assessed its diagnostic accuracy in people with cervicogenic headache.[19,21] However, the diagnostic accuracy to identify the presence of headache from upper cervical origin in people with whiplash-associated headache has not been investigated. Assessing sensitivity, specificity, positive and negative predictive values, and likelihood ratios is crucial to determine the clinical utility of the FRT in people with headache after a whiplash injury.

Therefore, this study aims: a) to evaluate the diagnostic accuracy of the FRT in detecting headache from upper cervical origin in people with acute WAD; b) assess the performance of the test in those with and without WAH.

## Methods

### *Study design*

This is a secondary analysis of a previously published cross-sectional study. Data collection was planned before the index test and reference standard were assessed. The study was performed in a Traumatology Clinic in Spain between September 2020 to February 2021. This study had approval by the Ethics Committee from University Rey Juan Carlos, Madrid, Spain (Ref: 1,003,202,108,121). The study was conducted according to the Declaration of Helsinki and is reported in accordance with STARD Guidelines.[22] All participants agreed to participate in the research and provided written informed consent prior to their participation in this study.

### *Participants*

People with a diagnosis of WAD attributed to a motor vehicle crash in the last 30 days were consecutively recruited. To have a more homogenous group and considering that Grade II represents the majority of people with WAD,[23] we only included those with WAD grade II according to the Quebec Task Force,[24] who are defined as those with neck complaints and musculoskeletal sign(s), including decreased range of motion and point tenderness. Inclusion and exclusion criteria consisted of: Grade II WAD, as defined by The Quebec Task Force on Whiplash-Associated Disorders between 7 and 30 days after the accident and aged between 18 and 65 years old. Individuals were excluded if they experienced previous headache that did not increase after the accident (as considered by the International Headache Society), were diagnosed with fibromyalgia or had a history of generalized pain, had experienced a previous whiplash injury, had a diagnosed temporomandibular joint disorder (TMD), had been diagnosed with osteoporosis, cervical myelopathy, vertebral fractures and/or inflammatory or rheumatic diseases, had a known psychological disorder or congenital disturbances, had undergone previous surgery in the cervical region, had received physical therapy treatment after the accident before participation in the study, or were not able to complete patient-reported outcome measures. In addition, with the aim of excluding individuals who sustained a concussion, we followed the criteria of the International Headache Society,[6] and we excluded those who had experienced one or more of 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.

### *Test methods*

Participants were asked not to disclose their headache status to the evaluator. A physician recorded the presence or absence of headache and then the participants were referred to the Physical Therapy department. All measurements were collected in a single session conducted at a research center by the same rater, who was a physical therapist with four years of experience dealing with people with neck pain, and specifically one year dealing with people with WAD.

In this study, the reference standard was the presence or absence of headache and the evaluator was blinded to the patient's group membership.

The index test for this study was the FRT, and it was evaluated twice for each side, considering most and least restricted sides. For the range of motion, the mean of both assessments was calculated. For the assessment of headache provocation, a positive/negative answer (presence/absence) was recorded. We considered that the provocation of headache was present if it was produced in both assessments. The visual analogue scale (VAS) was evaluated to determine the level of association with the FRT.

*Visual Analogue Scale (VAS)*. Neck pain intensity during the last 7 days was assessed through the VAS, with a score varying from 0 to 100 (0 = no pain; 100 = worst pain imaginable),[25] which has demonstrated good reliability.[26]

*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, the number of degrees rotation were recorded by the evaluator with the Smartphone Compass Application, as done previously,[27] and the subject was asked to report the presence or absence of headache. The test was performed bilaterally.[19] The most restricted side was determined based on the results of the range of motion (ROM) assessment. The presence of headache was recorded if symptoms were referred to the head, irrespective of the familiarity of headache.[28] Quantitative assessment of ROM and headache reproduction have demonstrated good reliability.[21,29]

Two different ways were used to consider the positivity of the Index Test: a) the test was positive if the ROM was less or equal to $32^{\circ}$ (Index Test 1)[18]; b) the test was positive if the ROM was less or equal to $32^{\circ}$ and headache was produced or increased (Index Test 2).

Age, sex, height, and weight were recorded for all participants. Immediately after the performance of the FRT, the participants were asked about the presence of any adverse events.

### *Statistical analysis*

The sample size estimation was performed using the Granmo calculator v.7.12. Because this is a secondary analysis of another publication,[21] the study was performed based on the sample size for the previous study. Nonetheless, considering an alpha risk of 0.05, power of 80%, an estimated prevalence of 50%, and an expected sensitivity and specificity of 0.80, the sample size required was 40 participants.[30]

Statistical analyses were performed using the IBM-SPSS Statistics 24 software. In all cases alpha level was set at 0.05. The Shapiro wilk's test was used to assess the normality of the sample. Differences in sociodemographic features were assessed through the student-T test. For the assessment of diagnostic accuracy, sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios were calculated.[31] For these values, data were cross tabulated according to the positivity of the test and the presence of headache. In addition, a

receiver operator characteristic (ROC) curve was developed with quantitative data coming from the ROM assessment from all the sample.[32] The cut-off score which provides the highest sensitivity and the lowest specificity was calculated according to the Youden's Index.[33]

To determine the relationship between neck pain intensity and ROM during the FRT, a Pearson's correlation analysis was used.

## Results

Forty-nine participants were assessed and after the exclusion of two with a history of neck surgery, 47 participants remained in the study. Among them, 28 participants (59.6%; 16 women) presented with headache. Nineteen (40.2%; 5 women) were considered as controls due to the absence of headache. No significant differences between groups were found for age, sex, height, weight, or days from the accident to the assessment. Significant differences were found for neck pain intensity between groups ($p = 0.001$) and FRT ($p < 0.001$) for most and least restricted sides (Table 1). No adverse events were observed. A flow diagram can be found on Supplementary Material 1 and 2.

The frequency of positive tests used to calculate diagnostic accuracy can be found in Table 2. For the FRT only based on ROM, 82% of participants with headache had a positive test for the most restricted side and 36% to the least restricted side, while in participants without headache frequencies were 37% and 11%, respectively. For the FRT based on ROM + headache provocation, 79% of participants with headache had a positive test for the most restricted side and 32% to the least restricted side, while in participants without headache, percentages were 32% for the most restricted side and 0% for the least restricted side.

The diagnostic accuracy values for each assessment are outlined on Table 3. The highest sensitivity (0.82) was found for the FRT to the most restricted side when positivity was considered with ROM < 32°, while the highest specificity was found for the FRT to the least restricted side when positivity was considered with the ROM < 32° and the provocation of headache (that is, no participant without headache demonstrated a positive test).

The ROC curve (Fig. 1) shows the relationship between sensitivity and specificity. The value 0.841 (95%CI = 0.723, 0.959) means that presented with a randomly chosen pair of participants, the physical therapist can make a correct diagnosis in 84% of cases ($p < 0.001$) when the FRT is used. Furthermore, applying the Youden`s Test, the cut-off value was 31.5°. That is, if the FRT value is less or equal to 31.5°, the test is considered positive.

**Table 1**
Sociodemographic features, neck pain intensity, and flexion-rotation test differences between participants with and without headache ($n = 47$).

| Variables | Group | | Z |
|---|---|---|---|
| | Headache ($n = 28$) | No Headache ($n = 19$) | P |
| Age (years)[a] | 37.6 (11.1) | 40.9 (10.9) | 0.319 |
| Sex [b](male/female) | 12/16 | 14/5 | 0.064 |
| Height (cm) [a] | 174.5 (8.8) | 177.1 (9.9) | 0.370 |
| Weight (kg) [a] | 70.7 (10.1) | 76.6 (10.4) | 0.064 |
| Days [a] | 13.4 (4.3) | 11.7 (3.7) | 0.152 |
| Neck pain intensity (VAS) (mm) [a] | 61.2 (14.5) | 35.5 (14.4) | 0.001* |
| Most restricted FRT (°) [a] | 26.6 (6.3) | 34.0 (4.3) | <0.001* |
| Least restricted FRT (°) [c] | 32.5 (6.9) | 38.2 (3.8) | <0.001* |

VAS: Visual Analogue Scale. Data are means (standard deviations), except for sex where number of participants is used.
[a] T-Student.
[b] Chi-Square.
[c] U-Mann Whitney.
* statistical significance ($p < 0.05$).

**Table 2**
Frequencies used to calculate the diagnostic accuracy.

| | | | Reference standard | | |
|---|---|---|---|---|---|
| | | | Headache ($n = 28$) | Non-Headache ($n = 19$) | Total ($n = 47$) |
| FRT (ROM < 32°) | Most restricted side | Negative | FN: 5 | TN: 12 | 17 |
| | | Positive | TP: 23 | FP: 7 | 30 |
| | Least restricted side | Negative | FN: 18 | TN: 17 | 35 |
| | | Positive | TP: 10 | FP: 2 | 12 |
| FRT (ROM < 32° + HP) | Most restricted side | Negative | FN: 6 | TN: 13 | 19 |
| | | Positive | TP: 22 | FP: 6 | 28 |
| | Least restricted side | Negative | FN: 19 | TN: 19 | 38 |
| | | Positive | TP: 9 | FP: 0 | 9 |

FN, False Negative; FP, False Positive; FRT, Flexion-Rotation Test; HP, Headache Production; ROM, Range of Motion; TN, True Negative; TP, True Positive; FP.

Additionally, significant moderate correlations were found between neck pain intensity and the ROM during the FRT for the most ($r = -0.552$) and least (rho = −0.556) restricted sides (Supplementary online material 3).

## Discussion

Our study aimed to assess the diagnostic accuracy of the FRT in diagnosing the presence of a headache of upper cervical origin in participants with acute WAD, based on two different ways of defining positivity. We found that the highest sensitivity (0.82) was found when considering the FRT to the most restricted side as positive if ROM was less than or equal to 32°. The highest specificity was found when the FRT was considered positive when headache provocation was added to the assessment of the ROM. Additionally, based on a ROC curve, we evaluated the cut-off of this test to diagnose the presence of a headache. According to our findings, if the test is less than or equal to 31.5°, it should be considered positive. To the best of our knowledge, this is the first study aimed at evaluating this test in this population.

This study found that the range of cervical rotation was reduced for both the most and least restricted sides in those participants with acute WAD who presented with a headache compared to those who did not ($p < 0.001$). These results concur with previous studies comparing cervicogenic headache not only with healthy controls,[34] but also with people with migraine.[18] Nonetheless, neck pain intensity was also significantly higher in the group with a headache. Thus, together with the inversely significant correlation between the ROM during the FRT and the intensity of neck pain, it may imply that the results may not be a consequence of an impairment of the upper cervical structures, but rather a consequence of increased neck pain. In that sense, it has been stated that performing the FRT during an episode of increased pain might alter the movement response, limiting the range of cervical rotation.[35] Indeed, the average ROM in the non-headache group was 35°, while in asymptomatic controls, it has been reported to be up to 42°.[36] Therefore, this fact should be considered.

Despite this, our results indicate that the FRT has moderate diagnostic accuracy in diagnosing the presence of a headache of upper cervical origin in people with acute WAD. The test is more sensitive to the most restricted side, but its specificity is lower, indicating a higher risk of false positives. Furthermore, the reliability assessment demonstrated high reliability for this test.[21,29] Additionally, this study established a range of 31.5° as the cut-off value at which the FRT is deemed positive. This is in line with previous studies assessing the cut-off value of this test, with values between 30° and 32° in people with cervicogenic headache.[18,20] This enables the clinician to consider this test with confidence in clinical practice, assisting the physical examination of people

**Table 3**
Diagnostic accuracy of the FRT.

| | | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | LR+ | LR- |
|---|---|---|---|---|---|---|---|
| FRT (ROM < 32°) | Most restricted side | 82.1 | 63.2 | 76.7 | 70.5 | 2.23 | 0.49 |
| | Least restricted side | 35.7 | 89.5 | 83.3 | 48.6 | 3.40 | 0.72 |
| FRT (ROM < 32° + HP) | Most restricted side | 78.6 | 68.4 | 78.6 | 68.4 | 3.16 | 0.31 |
| | Least restricted side | 32.1 | 100 | 100 | 50.0 | – | 0.68 |

FRT, Flexion-Rotation Test; HP, Headache Production; LR+, Positive Likelihood Ratio; LR-, Negative Likelihood Ratio; NPV, Negative Predictive Value; PPV, Positive Predictive Value; ROM, Range Of Motion.

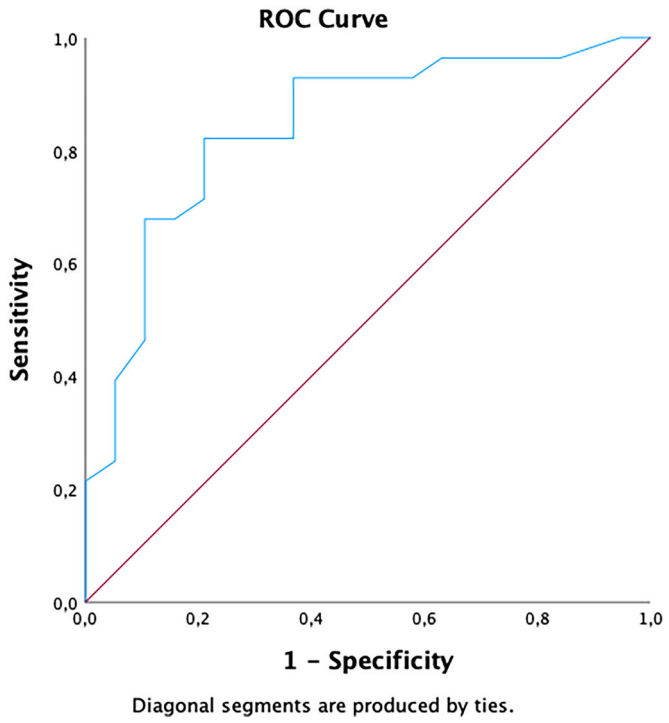


**Fig. 1.** The ROC curve of the flexion-rotation-test. The area under the curve is 0.841 ($p < 0.001$; 95%CI = 0.723, 0.959).

with acute whiplash-associated headaches.

In that sense, it has been stated that considering the provocation of a headache as a criterion to establish that the test is positive may increase the accuracy of the FRT, as it may be a sign of increased tension over the upper cervical structures theoretically affected.[37] However, only one study evaluating the accuracy of the FRT on people with cervicogenic headache considered this criterion.[20] In our study, results did not differ significantly because including headache provocation only resulted in one less participant with a positive test.

Previous studies have identified that ROM is related to the presence of a headache in people with WAD.[38] However, this is the first study to assess the FRT in this population. Although other factors and/or structures may be influencing whiplash-associated headaches, the findings from this study could be a first step to improve the assessment of upper cervical structures, which may be involved in the presence of a headache, as previously suggested.[22]

Methodological considerations: A few limitations must be stated. Firstly, the use of a single assessor to perform the FRT using manual diagnosis may raise concerns about extrapolating the results; future studies should involve more clinicians. Nonetheless, the previously demonstrated intra-rater reliability[21,29] provides considerable confidence in our findings. Secondly, the absence of a gold standard to compare the results of the FRT, despite the headache diagnosis, should be considered. This is important because a headache after a whiplash injury may be a consequence of other structures or processes, and the FRT is a relatively isolated test of movement impairment of the C1-C2 motion segment.[39] However, the absence of a clinically possible gold standard did not allow us to consider diagnostic accuracy evaluation, as the best available gold standard may be a zygapophyseal joint nerve block, which is quite invasive, rarely available, and carries inherent risks.[40] Additionally, the evaluation of the ROC curve demonstrated that the clinician was able to perform a correct diagnosis 84% of the time. Therefore, these results demonstrate that clinicians may be moderately confident in considering the FRT in the physical assessment of people with acute whiplash-associated headaches.

## Conclusion

The FRT demonstrated moderate diagnostic accuracy, considering the positivity of the FRT both through the ROM and ROM combined with headache provocation, to detect the presence of a headache. A cut-off of 31.5° may be considered as a positive FRT in people with acute WAD.

## Conflicts of interest

The authors declares no conflicts of interest.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjpt.2024.101134.

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