The flexion–rotation test performed actively and passively: a comparison of range of motion in patients with cervicogenic headache

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Limitation in cervical spine range of motion (ROM) is one criterion for diagnosis of cervicogenic headaches (CHs). The flexion–rotation test, when performed passively (FRT-P), has been shown to be a useful test in diagnosis of CH. Few investigations have examined the flexion–rotation test when performed actively (FRT-A) by the individual, and no studies have examined the FRT-A in a symptomatic population. The purpose of this study was to compare ROM during the FRT-A and FRT-P in patients with CH and asymptomatic individuals and to compare ROM between sides for these two versions of the test. Twelve patients with CH and 10 asymptomatic participants were included in the study. An eight-camera Motion Analysis system was used to measure head motion relative to the trunk during the FRT-P and the FRT-A. Cervical rotation ROM was measured in a position of full cervical flexion for both tests. No significant difference was observed between right and left sides for cervical rotation ROM during the FRT-P nor the FRT-A when performed by asymptomatic participants. In patients with CH, a significant difference was observed between sides for the FRT-P ($P=0.014$); however, the FRT-A failed to reveal bilateral discrepancy in rotation ROM.

Keywords: Flexion rotation test, Headache diagnosis, Range of motion, Upper cervical

Introduction

Differential diagnosis of cervicogenic headaches (CHs) from other headache types is an essential factor in guiding clinicians to the development of appropriate intervention plans. The diagnostic criteria for CH, as established by the International Headache Society (IHS), facilitates this process.^{1,2} Facet joints at Occiput/C1, C1/C2, and C2/C3 have been found to refer localized symptoms to the occipital and suboccipital region, which can be associated with CH pain.^{3–5} Headache type is often misdiagnosed⁶ and this is complicated by the fact that many subjective features of headaches are common among differing headache types.^{2,7} The IHS criteria for diagnosis of CH contain factors related to limitations in cervical range of motion (ROM), making the examination of the cervical spine an important component of differential diagnosis.^{1,8} These ROM criteria include evidence of limited global active cervical ROM, passive intervertebral joint play,^{9–11} and passive ROM specifically at the C1/C2 spinal segment in patients with CH.^{12,13} Although global limitations in active ROM and passive limitations in intervertebral motion have been found in this population, active

ROM limitations specific to the upper cervical spine have not been investigated in patients with CH.

The flexion–rotation test has been described as a method to differentiate rotational motions taking place at the upper versus lower cervical spine.^{14–16} The test is commonly performed passively. The passive flexion–rotation test (FRT-P) is performed with the patient supine. An examiner passively positions the patient's neck into full flexion to pre-tension the structures of the middle and lower cervical spine, then the patient's head is passively rotated each direction while the flexed position is maintained.¹⁵ Since the C1/C2 motion segment accounts for 40–60% of the total cervical ROM, this test is intended to isolate motion at that segment.^{17,18} Criteria for a positive test consists of ROM restriction with firm resistance, a 10-degree difference in motion between painful and non-painful sides, and pain provocation.^{12,19}

The FRT-P has been found to have a high degree of sensitivity (90–91%) and specificity (88–90%) when used to examine patients with CH.^{12,20} Hall and Robinson¹⁹ found the FRT-P to be positive in patients with CH originating from C1/C2. Significant differences have been shown in FRT-P results when comparing unilateral rotation ROM in patients with CH to those with migraine headaches and multiple headache forms.²⁰

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Although the FRT was originally designed to assess C1/C2 rotation ROM passively, an active version of the test (FRT-A) has been evaluated for its reliability in healthy individuals. It was found highly reliable in regards to ROM measurement.¹⁵ Despite the reliability of the FRT-A, this test has not been compared to the FRT-P in patients with CH.

Performance of the FRT-A has been previously described in a healthy population. Participants were seated in a chair and actively bent their neck downward to introduce cervical flexion. While maintaining this position, they rotated their head as far as possible in each direction.¹⁵

The FRT-P has been shown to be a valid test to diagnose CH;¹² however, there may be a benefit to performing the FRT actively. The FRT-A is performed with the patient in a seated position which incorporates functional weight-bearing, as opposed to the FRT-P, which is performed with the patient in a supine position.¹⁵ The weight-bearing position is advocated in some approaches to segment-specific examination and intervention of the cervical spine.^{21,25} This position also affords an alternative for patients who are unable to lie supine comfortably. In patients with considerable pain, the active neck movement may be preferable, since they can control the motion compared to a passive movement performed by the clinician. In this case, there is potential for muscle guarding to occur against passive testing. An additional potential advantage for the FRT-A is that it is not dependent upon the clinician's manual skill to determine the end-feel.

Despite the high reliability of the FRT-A measurements,¹⁵ its ability to detect bilateral rotation ROM differences has not been investigated. Additionally, FRT-A measurements have not been compared to the FRT-P in patients with CH. Thus, the diagnostic value and the clinical utility of the FRT-A is unknown. Therefore, the aim of this study was to compare ROM during the FRT-A and FRT-P in patients with CH and asymptomatic participants and to determine if the FRT-A can be used to identify side-to-side differences in ROM in patients with CH.

Methods

Participants

This study was registered at Clinicaltrials.gov (NCT 02070172). Participants were recruited through ads posted on the institutional website. The sample size

estimates for FRT-P measurements were derived a priori using a statistical power and alpha level set at 0.95 and 0.05, respectively. The mean and standard deviation data for the between groups comparisons were taken from Hall and Robinson,¹⁹ Ogince *et al.*,¹² and Hall *et al.*¹³ The maximum required total sample size was 16 participants (eight in each group), based on a calculated effect size range 2.10–3.06 and a standard deviation range 5.8–11. For the within-group (between sides) differences, a maximum sample size of six participants was required based on data available from Hall and Robinson¹⁹ for a calculated effect size range 1.78–3.57. A total of 24 male and female participants between the ages of 22 and 50 years were recruited to participate in the study (50% more than required according to sample size estimation). Data were analyzed on only 22 of the 24 participants due to limitations related to marker visibility.

Demographic data including symptom duration are shown in Table 1. Symptom duration in the CH group ranged from 6 to 156 months (mean $\pm$ SD = 96.17 $\pm$ 91.34 months). Participants in the asymptomatic group were excluded from the study if they reported a history of headaches or neck pain. Patients in the CH group were subjectively screened initially through an interview before being invited for an objective screening. Patients were allowed to continue any current headache medications during their participation in the study. Patients with CH were required to meet the following inclusion criteria, which fulfills five of seven criteria for diagnosis of CH.^{1,20,26} These five criteria have been used previously in a study of the FRT-P.^{12,20}

- unilateral headaches that do not shift sides;
- precipitation of headaches from neck movement or sustained head positioning;
- ipsilateral neck, shoulder, or arm pain;
- intermittent headaches of varying duration and pain level at the rate of one headache per week for greater than 2 months;
- headaches of moderate intensity.

Participants in both the CH and asymptomatic groups were excluded from the study if they met any of the following exclusion criteria:

- a diagnosis of rheumatoid arthritis;
- current pregnancy;
- IHS criteria for other headache forms, such as tension type or migraine;^{1,2,19,22}
- cervical radiculopathy;
- treatment for headaches by a physical therapist, chiropractor, massage therapist, or osteopath in the past month;

Table 1 Demographics and functional ability

Group	Male	Female	Age (years)	Duration (months)	NPQ
Asymptomatic (<i>n</i> =10)	5	5	29.08 $\pm$ 8.25	N/A	N/A
CH (<i>n</i> =12)	5	7	29.41 $\pm$ 9.76	96.17 $\pm$ 91.34	18.05 $\pm$ 7.38

Note: Demographics and functional ability score expressed as percent disability according to the Northwick Park Neck Pain Questionnaire (mean $\pm$ SD) for subjects in the asymptomatic group and cervicogenic headache (CH) group.

Figure 1 (A) The Active Flexion-Rotation Test (FRT-A); (B) The Passive Flexion-Rotation Test (FRT-P)

- positive test for vertebral artery insufficiency or cranio-vertebral ligament instability.

The objective screen was performed by a physical therapist who was blind to the results of the FRT-P and FRT-A. This examiner also performed passive segmental mobility testing.¹² In addition to meeting the subjective criteria above, symptomatic C1/C2 dysfunction was an inclusion requirement for those in the CH group; this method has previously been used by Ogince *et al.*¹² as a reference standard to diagnose CH. Each participant completed a Northwick Park Neck Questionnaire (NPQ). This questionnaire was developed based on the Oswestry Disability Index and has been used in previous studies to examine disability in patients with CH.^{22–24}

Each participant was informed of the purpose and procedures involved with the study and signed a written informed consent to participate. This study received approval by the Institutional Review Board.

Measurements

Data were collected in the Des Moines University Motion Analysis Laboratory. Kinematic data were collected to measure upper cervical ROM during the FRT-P and FRT-A using a 3D eight-camera Motion Analysis system (Motion Analysis Corporation, Santa Rosa, CA, USA).²⁷ A 3D laboratory coordinate system was used with the positive *z*-axis in the vertical direction pointing up. The laboratory reference frame was established by using a horizontally leveled L-frame with four markers at known locations with respect to each other. A 500 mm long three-marker wand was moved throughout the measurement volume to calibrate the system and scale the individual camera views. The linear/angular measurement accuracy of the motion capture system is calibration based. The precision in measurement is smaller than 1 mm over a known length of 500 mm, which is equivalent to an angular precision measurement of better than 0.2% (corresponding to 0.12 of a degree). These angular

precision values highlight potential measurement errors of <0.5 of a degree when computing flexion-rotation angles in the upper cervical region. This provides confidence that the 3D motion analysis methodology enables detection of small effect sizes of around 1°.

The degree of upper cervical rotation ROM in the position of maximum cervical flexion was measured using relative segmental motion of the head with respect to the upper thorax. A total of 10 reflective markers were securely affixed using double sided adhesive tape (five on each participant's head and five on the upper thorax). A tight fitting swimming cap was used to secure the head markers. Specifically, one marker was placed on the center of the forehead, one on each parietal bone, and one on each temporal bone. The five markers on the upper trunk were placed on the sternum, one on each acromion process, and one on the mid-shaft of each clavicle (Fig. 1).

Two 3D local reference frames were created — one for the head and one for the trunk, from the respective markers. The position orientation of each local reference frame was evaluated with respect to the lab reference system (global frame). Flexion and rotation were assessed as the relative motion between the two local reference frames (head and trunk) using in-house written code in MATLAB. The flexion angle and the rotation ROM (right and left) were assessed as the average flexion maintained during the rotation interval to the left and right and the peak rotation to the left and right, respectively (Fig. 2).

Procedure

Cervical rotation ROM was measured from a position of end-range cervical flexion during the FRT-P and FRT-A. This procedure was done for participants in both the CH group and the asymptomatic group. The FRT-P was performed by a fellowship trained manual physical therapist of the American Academy of Orthopedic Manual Physical Therapists; this examiner also provided instruction to

Figure 2 Typical single trial data recorded during the FRT. Top flexion angle, bottom rotation angle versus time. Illustration of the flexion angle calculation: average flexion maintained during the rotation interval to the left and right. Measurement of peak rotation to the left and right is also shown.

participants on performance of the FRT-A. This examiner was blind to the participants' group allocation. The two tests were performed in a random order.

For the FRT-P, participants laid supine on a plinth. The examiner cradled the occiput between the ear eminences with thumbs over the temporal bones and passively flexed the cervical spine fully (Fig. 1A). While maintaining this flexed position, the examiner passively rotated the individual's head in each direction to the end of the available range.¹⁵ The examiner determined the end of range through a firm end feel as previously described.¹² The individual's cervical spine was brought back to neutral and the head was returned to the support of the plinth between trials.

The FRT-A was performed in a seated position, as has been previously reported.¹⁵ Participants were seated in a straight-back chair with their feet flat on the floor and with their hands in their lap. Instructions were given to each individual on performance of the FRT-A. Beginning in an upright position, participants were asked to focus on a fixed point on the wall in front of them. They were instructed to first move into full cervical flexion and were provided the following instruction: 'Bend your neck downward, as if to bring your chin toward your chest as far as you can'. Each person determined his/her own endpoint in the FRT-A

for both rotations. Flexion was maintained throughout a full cycle of the movements (Fig. 1B). Participants were given the following instruction: 'While keeping your neck bent downward, turn your head as far as you can to the left'. Once the participant reached that point, which they determined was as far as they could go, the instruction was repeated for rotation to the right; the flexed position was maintained throughout a full cycle of combined flexion with rotation each direction. Three practice trials were done prior to recording three trials; the average was used for analysis.

Statistical analysis

Trial-to-trial reliability analysis was done using average intra-class correlations on the three trials within each test condition. Paired *t*-tests were done to determine ROM differences between the left and right sides in the asymptomatic group and between the asymptomatic and symptomatic sides in the CH group. This was done for both the FRT-P and the FRT-A. Independent *t*-tests were done to determine if differences exist in ROM between the asymptomatic group and CH group for both the FRT-P and FRT-A. The data analyses were done using SPSS version 17.0 (SPSS Inc, Chicago, IL, USA). The criterion for significance was set at an alpha level ≤ 0.05 .

Table 2 Range of motion for the active flexion rotation test (FRT-A)

Group	Side: left/asymptomatic	Side: right/symptomatic	Paired <i>t</i> -test (between sides)
Asymptomatic (<i>n</i> =10)	29.5 (8.5)	27.4 (6.9)	<i>P</i> =0.305
CH (<i>n</i> =12)	29.2 (9.2)	26.6 (9.3)	<i>P</i> =0.188
Independent <i>t</i> -test (between groups)	<i>P</i> =0.931	<i>P</i> =0.809	

Note: Means $\pm$ standard deviations of ROM in degrees during the FRT-A for both groups. Left/right sides for the asymptomatic group and asymptomatic/symptomatic sides for the cervicogenic headache (CH) group.

Results

Twenty-two individuals were included in the analysis, 12 CH and 10 asymptomatic participants (Table 1). Following data collection, two individuals from the asymptomatic group were dropped from the study because their markers were not visible, and therefore, their data could not be analyzed. Age and gender characteristics were similar for the two groups (CH and asymptomatic). Patients in the headache group had a mean NPQ score of 18.2% disability.

Intraclass correlation coefficients (ICCs) for trial-to-trial reliability of the FRT-A were 0.90–0.95 for the asymptomatic group and 0.97–0.98 for the CH group. ICCs for trial-to-trial reliability of the FRT-P were 0.93–0.95 for the asymptomatic group and 0.91–0.96 for the CH group. All ICC measures were higher than 0.81, which according to Landis and Koch,²⁸ can be classified as ‘almost perfect’ (ICC: 0.81–1.00). The average standard errors of measurement values for the asymptomatic group were 2.08° and 2.07° for the FRT-A and FRT-P, respectively, with the corresponding values for the CH group 1.46° and 3.91°, respectively. Interestingly, the CH group showed the highest reliability values when performing the FRT-A test and the least reliable values during the FRT-P test. Group mean and standard deviation for rotation ROM in each direction achieved during the tests can be found for FRT-A in Table 2 and for FRT-P in Table 3.

The ROM values were significantly greater for the FRT-P for all participants, as reflected by the group values in Tables 2 and 3. For the FRT-A, there were no significant differences found between left and right sides for the asymptomatic group (*P*=0.305), nor between the asymptomatic and symptomatic sides for the CH group (*P*=0.188), (Table 2). Additionally, there were no significant differences found in FRT-A ROM between the asymptomatic group and the CH group, regardless of the side (*P*=0.931 and *P*=0.809 for the asymptomatic and the symptomatic sides, respectively). For the FRT-P (Table 3), there were no side-to-side

differences found in the asymptomatic group ROM: 43.2 $\pm$ 8.0° for the left versus 43.8 $\pm$ 9.0° for the right side (*P*=0.738); however, significant (*P*=0.014) limitations towards the symptomatic side were found for the CH group (ROM: 47.1 $\pm$ 15.4° for the asymptomatic side versus 37.9 $\pm$ 15.9° for the symptomatic side).

Discussion

The aim of this study was to examine upper cervical rotation ROM in individuals with CH compared to asymptomatic participants using the cervical FRT-P and FRT-A. ROM findings were different between the FRT-P and the FRT-A. A side-to-side rotation difference was found in the CH group for the FRT-P, but not for the FRT-A.

Intra-rater reliability for the FRT-P has been reported as excellent (ICC=0.93) when performed by experienced examiners, which is consistent with our results, and has slightly lower reliability when performed by inexperienced examiners (ICC=0.76–0.84).^{12,13} We found intra-rater reliability of the FRT-P to be excellent for patients with CH (ICC=0.91–0.96) and for the asymptomatic participants (ICC=0.93–0.95). ICC values for the FRT-A ranged from 0.97–0.98 in the CH group and from 0.90–0.95 in the asymptomatic group. This is consistent with the findings of Amiri *et al.*¹⁵ who reported ICCs ranging from 0.85 to 0.95 for the FRT-A in healthy individuals.

The validity of the FRT-P has been previously reported in differential diagnosis of patients with CH, demonstrating high levels of sensitivity and specificity.^{12,13} These studies, however, performed only the FRT-P and their results cannot be applied to the FRT-A. Although the current study found both the FRT-P and FRT-A to be reliable in patients with CH, caution should be used with interpretation of the test results clinically, since use of the FRT-A to assist in diagnosis of CH is unknown.

The degree of ROM present with the cervical FRT-A was different than the FRT-P in both the asymptomatic

Table 3 Range of motion for the passive flexion rotation test (FRT-P)

Group	Side: left/asymptomatic	Side: right/symptomatic	Paired <i>t</i> -test (between sides)
Asymptomatic (<i>n</i> =10)	43.2 (8.0)	43.8 (9.0)	<i>P</i> =0.738
CH (<i>n</i> =12)	47.1 (15.4)	37.0 (15.9)	* <i>P</i> =0.014
Independent <i>t</i> -test (between groups)	<i>P</i> =0.451	<i>P</i> =0.290	

Note: Means $\pm$ standard deviations of ROM in degrees during the FRT-P for both groups. Left/right sides for the asymptomatic group and asymptomatic/symptomatic sides for the cervicogenic headache (CH) group.

and CH groups. This study found a greater degree of motion available with the FRT-P compared to the FRT-A in all cases. Dvorak *et al.*²⁹ compared the results of the FRT performed actively and passively in asymptomatic individuals and found 10.2° more motion for the FRT-A compared to the FRT-P. The explanation given was that, under the FRT-A, participants did not maintain the cervical spine flexed as consistently, therefore, the lower cervical segments were utilized resulting in a greater degree of motion.²⁹

The greater amounts of ROM produced during the FRT-P, as opposed to the FRT-A, may also be accounted for by the principles related to the neutral and elastic zones of motion, as described by Panjabi *et al.*¹⁷ These authors defined the neutral zone as displacement from the neutral point to the beginning of elastic deformation. The elastic zone is defined as the displacement due to the application of a load beyond the neutral zone, and the ROM is the sum of the two. Panjabi *et al.*¹⁷ found axial rotation ROM at C1/C2 in fresh cadaveric spines to be 9.3° greater each direction when measuring the entire ROM compared to that motion occurring in the neutral zone alone. It is possible that, in the current study, participants were maintaining their active ROM within the neutral zone and the FRT-P carried the spine into the elastic zone completing the entire ROM. Additionally, it is possible that the degree of ROM during the FRT-A stressed contractile tissue, but did not attain the range required to provoke the joint involved. Since the joint is thought to be a pain source in CH,³⁻⁵ perhaps the degree of motion required to reproduce the headache is only attainable through the FRT-P. Although the FRT-A may be more functional, it may not stress the underlying tissue associated with this pathology. Another point to consider is the possibility that FRT-A was self-limited in the sense that patients with CH may avoid their true end-ranges of motion in an effort to avoid pain. A future study may consider using different cues to the patient during the FRT-A, such as motivation or encouragement to attain their full range.

Results of this study indicate that there is no significant difference in ROM between sides for the asymptomatic group during the FRT-P and the FRT-A. These findings are consistent with those of Hall and Robinson¹⁹ for the FRT-P on healthy individuals. However, our findings during the FRT-A are in contrast to those of Amiri *et al.* They explain the difference that they observed by the fact that participants did not fully maintain the flexed position of the cervical spine, thus allowing a greater contribution of motion from the lower cervical segments. However, it is unclear how the degree of flexion may impact right-to-left differences. It is possible that, if the individual's neck flexion was greater during rotation to one side

compared to the other, that asymmetry may result. Panjabi *et al.*'s¹⁷ study utilizing cadaveric spines found a 3° difference in right rotation compared to left at C1/C2. A possible explanation offered is that asymmetry in normal individuals may reflect an anatomical variations since this asymmetry was seen in both within and between day trials.¹⁴ A study comparing FRT-P in patients with CH during episodes of pain compared to pain-free interludes may provide information to help clarify this issue. This may help to differentiate whether ROM changes occur when symptoms resolve or whether the impairment is consistent and potentially related to anatomical variation or other factors.

The current study found no difference between groups for the FRT-A, but did find differences for the FRT-P. This finding is unique to this study as previous investigations of the FRT-A have been done only on healthy individuals. A limitation of this study is the small sample size. Although a power analysis was done, and we included more individuals than required, it is possible that the differences between tests observed in this study may not be reflected in a larger population of symptomatic individuals. Our study population included relatively young individuals and slightly more males than the typical CH population. Future studies should consider examination of the validity of the FRT-A for use in diagnosis of patients with CH.

Conclusion

Although the FRT-P can reveal limitations in ROM toward the side of symptoms in individuals with CH, the FRT-A failed to reveal such ROM discrepancies. Clinicians should use the FRT-P in examination of patients with CH, but should use caution with interpretation of the FRT-A. This study did not examine the ability of the FRT-A to detect the presence of CH. Future investigations should examine the sensitivity and specificity of the FRT-A. Additional studies are needed to determine the clinical usefulness of the FRT-A to assist in diagnosis of patients with CH.

Disclaimer Statements

Contributors Petersen: inception of study idea, study design, data collection, manuscript writing. Vardaxis: study design, data collection and analysis, interpretation of data, manuscript writing.

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Conflicts of interest There is no conflict of interest associated with this study.

Ethics approval This study received approval by the Des Moines University Institutional Review Board.

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