A normative study of cervical range of motion measures including the flexion–rotation test in asymptomatic children: side-to-side variability and pain provocation

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Objectives: Cervical movement impairment has been identified as a core component of cervicogenic headache evaluation. However, normal range of motion values in children has been investigated rarely and no study has reported such values for the flexion–rotation test (FRT). The purpose of this study was to identify normal values and side-to-side variation for cervical spine range of motion (ROM) and the FRT, in asymptomatic children aged 6–12 years. Another important purpose was to identify the presence of pain during the FRT.

Methods: Thirty-four asymptomatic children without history of neck pain or headache (26 females and 8 males, mean age 125.38 months [SD 13.14]) were evaluated. Cervical spine cardinal plane ROM and the FRT were evaluated by a single examiner using a cervical ROM device.

Results: Values for cardinal plane ROM measures are presented. No significant gender difference was found for any ROM measure. Mean difference in ROM for rotation, side flexion, and the FRT were less than one degree. However, intra-individual variation was greater, with lower bound scores of 9.32° for rotation, 5.30° for side flexion, and 10.89° for the FRT. Multiple linear regression analysis indicates that movement in the cardinal planes only explains 19% of the variance in the FRT. Pain scores reported following the FRT were less than 2/10.

Discussion: Children have consistently greater cervical spine ROM than adults. In children, side-to-side variation in rotation and side flexion ROM and range recorded during the FRT indicates that the clinician should be cautious when using range in one direction to determine impairment in another. Range recorded during the FRT is independent of cardinal movement variables, which further adds to the importance of the FRT, as a test that mainly evaluates range of movement of the upper cervical spine.

Keywords: Range of movement, Flexion–rotation test, Cervical spine

Introduction

Cervicogenic headache predominantly arises from articular dysfunction of the cervical spine, which can be expressed as a reduction of overall and segmental cervical spine mobility.[1] Limitation of cervical range of motion (ROM), in conjunction with other physical examination criteria, has been shown to be one of defining features of cervicogenic headache in adults.[2,3] In contrast to other neck pain disorders, assessment of cervical ROM is a crucial element when evaluating a patient with headache.

The cervical spine of children differs to that of adults in many ways,[4] which is reflected by larger ROM values in children.[5,6] However, these studies did not report intra-individual variation in side-to-side cervical spine mobility. This is an important question when determining the presence of unidirectional movement impairment.

In addition to active cervical mobility measured in the cardinal planes, it is possible to measure ROM of the upper cervical spine using the flexion–rotation test (FRT).[7] The FRT is described as a reliable, non-invasive method of cervical manual examination,[8] which is useful in differential diagnosis of cervicogenic headache.[2] In this test, the cervical spine and upper thoracic spine are placed in end-range flexion so that movement occurs predominantly at the C1/2 vertebral segment.[7] The head and neck are rotated to the left and right, with the end-point of either the patient's report of pain or firm resistance.[9] ROM in adults is influenced by the presence of sub-clinical

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neck pain, cervicogenic headache and, to some degree, by ROM in the cardinal plane, but not by other lifestyle factors such as side dominant lifestyle, prone head turned sleeping position and hours spent sitting daily.[10] The relationship between these factors is not known in children.

Normal values for ROM during the FRT in asymptomatic adults are reported as 38° (Ref. 8) and 45° (Ref. 9) to each side, while range less than 32° is the positive cut-off value.[11] Previous reports indicate high levels of intra-rater reliability for ROM measured by trained and inexperienced examiners using the FRT.[12,13] Furthermore, ROM recorded during the test and examiner interpretation of the test has been shown to be consistent over time with a minimal detectable change of at most seven degrees.[12] Despite this evidence, no studies have reported normal values or side-to-side variation in asymptomatic children. In addition, there are no reports regarding the presence or severity of pain provocation during the FRT in asymptomatic children or adults. Pain during testing is an important consideration when evaluating children, and pain-free tests are preferred.

The primary purpose of this study was to determine normal values and side-to-side variation of cervical spine cardinal plane ROM measures, as well as the FRT in asymptomatic children. The secondary purposes were to determine the degree of pain provocation during the FRT and whether ROM recorded during the FRT was dependent on ROM measures in the cardinal planes.

Methods

A normative value study was designed to assess cervical spine ROM and range of rotation in maximum flexion, as well as pain responses, during the FRT, in order to identify normal values in asymptomatic children.

Subjects

Due to difficulties in obtaining a random sample of children, the subjects in this study were a sample of convenience recruited from a high school and a handball club in Bremen/Germany. The parents and children were informed of the study and provided written informed consent. All subjects had been informed of their right to refuse to participate or to withdraw consent to participate at any time without reprisal. In addition, the rights of the children were protected at all times. Thus the protocol for this study followed the ethical principles of the Declaration of Helsinki of the World Medical Association.

The sample consisted of 34 children (26 females; mean age 125.38 months [SD 13.14]), who were part of a larger study investigating headache in children. Subjects were included if they were asymptomatic and aged between 6 and 12 years. Subjects were excluded if they had headache more than once per month, any history of cervical spine surgery, a diagnosis of Down's syndrome or Rheumatoid arthritis, or inability to tolerate the FRT.

A physiotherapist with 3 years postgraduate experience undertook all testing procedures in a quiet, private room in the high school or handball club.

Instrumentation

The Keno®-cervical measurement instrument (Kuntoväline Oy & David Fitness & Medical Ltd, Helsinki, Finland) (Fig. 1) was used to measure the range of active cervical ROM during flexion, extension, side flexion and rotation using separate inclinometers. Each inclinometer is attached to a frame: one in the sagittal plane for flexion–extension, one in the frontal plane for side flexion and a third one is attached in the horizontal plane for rotation. The inclinometer in the horizontal plane has a magnetic (compass-like) needle and the other two in the sagittal and frontal plane, have a gravity-dependent needle. In previous studies, the Keno®-instrument demonstrated correlation for intraobserver reliability from 0.62 to 0.91 and for interobserver reliability from 0.80 to 0.87.[14,15] These findings correlate with another study, in which intraclass correlation coefficients varied from 0.73 to 0.95, and inter-rater reliability varied from 0.73 to 0.92 for all six cervical movements assessed in 20 patients with orthopaedic disorders.[16] These and other studies indicate that the cervical ROM measuring device offers good reliability and validity.[17,18]

A compass goniometer fixed to the subject's head with elasticated Velcro straps (Fig. 2) was used to measure ROM during the FRT (Plastimo Airguide Inc. (Compasses), Buffalo Groove, IL, USA) according to previously reported method.[9,12] This measurement method has been shown to be reliable, even when used by inexperienced examiners.[13]

Subjective pain responses arising during the FRT were assessed with a coloured visual analogue scale (CAS). This scale provides vivid gradations in colour, area, and length, so that the children can see concretely how different scale positions would reflect different values of pain intensity.[19] The reverse side has numerical ratings to enable quick determination of the child's pain score from 0 to 10. The CAS has found to be an accurate and valid measuring instrument for measuring pain in children 5 years and older.[19]

Procedures

All measurements were assessed in a standardized manner to ensure reproducibility. Cervical spine cardinal plane ROM was determined first. Each child was given a practical demonstration of the assessment

Figure 1 Keno®-cervical measurement instrument.

procedure for all six standard movements. They were also given a trial practice run to ensure familiarity with the testing protocol. Each child was instructed to sit in an erect posture on a plinth, with the thighs fully supported and the arms relaxed at the sides. Subjects were asked to keep the trunk stationary. If necessary the movement was corrected by the examiner to ensure movement of the head in only one plane. The examiner manually and verbally cued the subject's head movements so that, to the best visual estimate of the tester, the subject's chin, nose and eyes moved evenly in one place. The child was asked to move his/her head as far as they could comfortably go. After each movement, the subject was asked to return to the starting position. Each movement was performed once.

Following this, the FRT was performed in supine (Fig. 2). The testing procedure was based on previous investigations.[9,12] The child lay on a physiotherapy treatment couch with his/her hands relaxing on the abdomen. Both legs were positioned in parallel and not crossed. The head and neck was then moved into end-range flexion. In this position the head and neck was passively rotated to the left and then the right as far as possible within comfortable limits. The examiner stopped the movement as soon as she noticed a firm resistance, or the child requested the movement to be stopped due to pain. In all cases, resistance rather than pain limited the movement. Immediately following the FRT each child was requested to rate the discomfort felt during the FRT on the CAS.

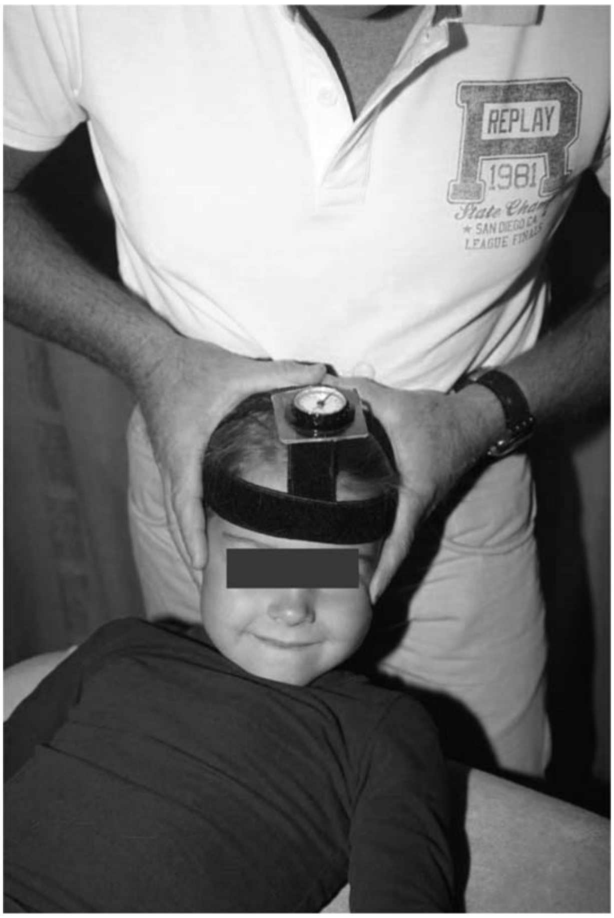

Figure 2 Flexion–rotation test (FRT).

Data analysis

All data were analysed using Statistical Package for Social Sciences version IBM SPSS Statistics 19. In all cases, the level of statistical significance was set at the 0.05 level. A 1-sample Kolmogorov-Smirnov test revealed normal distribution of all variables. Descriptive statistics including means, standard deviations, ranges and standard error of means (SEM) for all cervical ROM measures were calculated for the whole sample, as well as separately for girls and boys. Differences in mean cervical spine ROM between girls and boys were calculated using an independent samples t-test. A multiple linear regression was used to determine whether ROM recorded during the FRT is predicted by range recorded in the three cardinal planes (combined rotation to the left and right, combined side flexion, and combined flexion and extension). Prior to analysis, all assumptions for the use of multiple linear regression were met. A lower bound score was calculated to determine the cut-off point at which the degree of difference between the ROM to each side could be considered greater than that accounted for by measurement error and variability.[20] The lower bound score was calculated by multiplying the standard deviation of the mean absolute value (MAV) by the t-score (1.69) of a one-tailed t-test (alpha= 0.05) with 33 degrees of freedom and adding the MAV {lower bound score= (SD) (1.69) + MAV} between sides.[20]

Results

All data were normally distributed. Table 1 represents the means, standard deviations, ranges and SEMs for

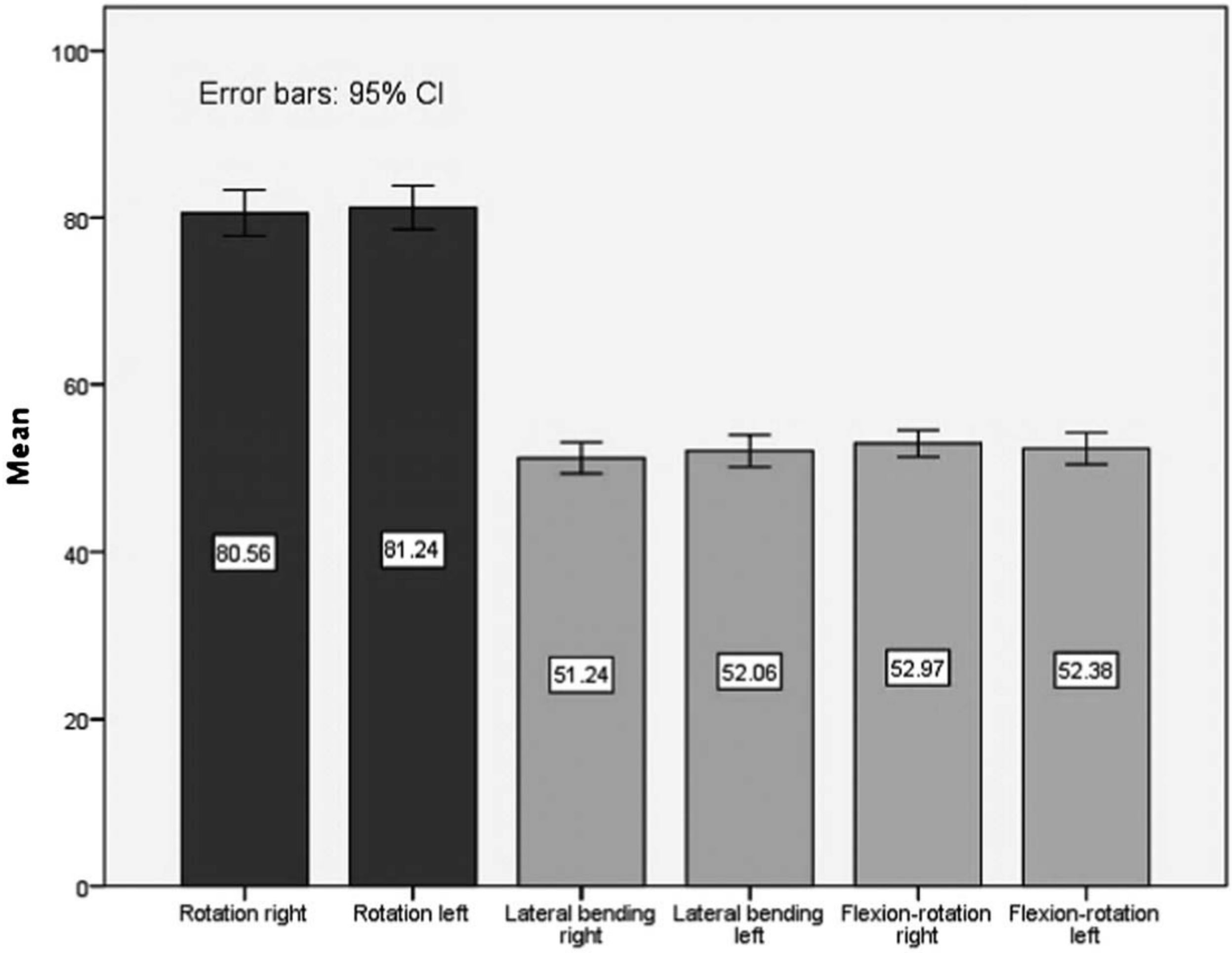

Figure 3 Mean ranges of motion and 95% confidence intervals for rotation, side flexion and range recorded during the flexion–rotation test.

Table 1 Means, ranges, standard deviations (SD), standard error of mean (SEM) and range in degrees for cervical range of motion measures (n=34)

Movement	Mean	SD	Range	SEM
Flexion	**72.96**	**13.10**	**48–100**	**2.25**
Female	73.19	13.94	48–100	2.73
Male	71.00	11.02	52–82	4.16
Extension	**87.97**	**9.87**	**71–110**	**1.69**
Female	89.54	10.31	72–110	2.02
Male	82.57	6.82	71–92	2.58
Rotation right	**80.56**	**7.87**	**61–98**	**1.35**
Female	80.50	8.03	61–98	1.57
Male	80.14	8.28	71–92	3.13
Rotation left	**81.24**	**7.55**	**70–99**	**1.29**
Female	80.96	8.07	70–99	1.58
Male	81.57	6.16	81–90	2.33
Side flexion right	**51.24**	**5.42**	**41–62**	**0.93**
Female	50.46	5.37	41–62	1.05
Male	53.57	5.47	45–59	2.07
Side flexion left	**52.06**	**5.52**	**41–65**	**0.95**
Female	51.35	5.68	41–65	1.11
Male	54.29	4.89	49–60	1.85
Flexion–rotation right	**52.97**	**4.65**	**45–63**	**0.80**
Female	52.54	4.00	45–60	0.78
Male	53.57	6.52	45–63	2.46
Flexion–rotation left	**52.38**	**5.47**	**40–63**	**0.94**
Female	52.50	5.90	40–63	1.16
Male	51.57	4.16	46–59	1.57

all ROM measures and also provides data regarding ROM for males and females. Figure 3 shows the mean ranges of motion and 95% confidence intervals (CI) for rotation, side flexion and range recorded during the flexion–rotation test. Differences between genders in terms of ROM, as well as CI, are summarized in Table 2. An independent samples t-test revealed no significant difference for any ROM measure between girls and boys ($P>0.14$).

Table 3 provides mean difference scores between left and right sides with standard deviations for rotation, side flexion and the FRT. The lower bound scores indicate that children need at least a ROM difference between sides of 9.32° for rotation, 5.30° for side flexion, and 10.89° for the FRT (Table 3) to be certain that the difference is more than measurement error and variability.

Multiple linear regression analysis, with combined left and right rotation during the FRT as the dependent variable, was not significant (Table 4). Furthermore, the independent variables of ROM in the three cardinal planes (rotation, side flexion, and flexion/extension) explained only 19% of the variance (R^2) in range recorded during the FRT.

Table 2 Comparison of range of motion (ROM) across gender with 95% confidence intervals (CI), statistical significance, and standard error of measurement (SEM)

Movement	Mean difference scores (95% CI)	*P* value	SEM
Flexion	1.07 (−9.88–12.02)	0.84	5.38
Extension	6.66 (−1.23–14.56)	0.95	3.88
Rotation right	−0.25 (−6.83–6.33)	0.94	3.23
Rotation left	−1.16 (−7.46–5.14)	0.71	3.09
Side flexion right	−3.29 (−7.66–1.08)	0.14	2.15
Side flexion left	−3.03 (−7.52–1.46)	0.80	2.20
Flexion–rotation right	−1.84 (−5.67–1.99)	0.34	1.88
Flexion–rotation left	0.50 (−4.07–5.07)	0.82	2.24

Pain was an uncommon accompaniment to the FRT, with only 14 out of 34 children reporting pain during the test. Generally pain levels were very low with a maximum of 2/10, and with a mean of 0.42 (SD 0.64) and 0.45 (SD 0.65) when testing the FRT to the right and left, respectively.

Discussion

The primary purpose of this study was to determine normal values and side-to-side variation of cervical spine cardinal plane active ROM measures and the FRT in asymptomatic children. The results for cardinal plane ROM data found in this study are comparable to previous reports by Lynch-Caris *et al.*[6] who measured ROM in children of a similar age. In contrast, ROM data were quite different to that published by Arbogast *et al.*[5] who observed consistently less ROM across all measures, with up to 12° less flexion/extension, 8° less rotation, and 5° less side flexion. One explanation for these differences in ROM may arise from different measurement methods.[7] For example, Arbogast *et al.*[5] utilized external fixation devices to stabilise the subjects' trunk while measuring cervical ROM. The children in the present study sat unsupported without a backrest and without other fixation, which may have allowed a more natural pattern of movement, enabling a greater ROM. In our study and consistent with previous studies, we found no significant difference between females and males for any ROM measure.[5,6]

Cervical ROM in children appears to be consistently greater in range for all cardinal planes when compared to previous reports for adults.[9,21] For example, rotation to the right in adults is reported as 64.9° (Ref. 9) or 73.2°,[21] whereas in our study rotation was 80.6°. Knowledge that children have consistently greater ROM than adults is important to enable clinicians to identify movement impairment when examining children with conditions such as cervicogenic headache or neck pain.

Mean ranges for rotation to the right and left recorded during the FRT were 52.97 (SD 4.65) and 52.38 (SD 5.47), respectively. To our knowledge this is the first study to report ROM values for the FRT in children. Again, comparisons of ROM data with published reports for adults demonstrate consistently higher values in children,[8–10] with between 8–14° more rotation during the FRT. Previously, it has been suggested that immature cervical spines are much more mobile due to laxity of ligaments and capsules, shallow and angled facet joints and incompletely formed uncinate processes.[22]

Children frequently suffer from headache[23] and the FRT has been shown to be a useful means to identify impairment of the upper cervical spine and aid in the diagnosis of cervicogenic headache,[2,7,11] and as a potential treatment outcome.[24] Hence, the FRT may be a useful test in children. However previous investigations in adults indicate a positive cut-off value of 32 or 33°.[8,11] As children have greater ROM than adults, these cut-off scores should not be applied to children. Based on the lower bound scores for the FRT, side-to-side variation needs to be greater than 11° to establish potential impairment as opposed to measurement error. Further studies need to investigate this in symptomatic populations.

Table 4 *T*, *P*, R^2 and *F* values for multiple linear regression analysis

Dependent variable	Independent variable	*T*	*P*	R^2	*F*
Total FRT	Total rotation	1.49	0.14	0.19	2.30
	Total side flexion	0.76	0.44		
	Total flexion–extension	0.75	0.46		

Table 3 Comparisons of range to the left and right for rotation, side flexion, and the flexion–rotation test (FRT): Mean difference scores and 95% confidence intervals (CI), mean absolute values (MAV) with standard deviations (SD), and lower bound scores

Movement	Mean difference score (95% CI)	MAV (SD)	Lower bound score
Rotation	0.68 (2.49, −1.06)	3.74 (3.28)	9.32
Side flexion	0.82 (1.77, −0.13)	2.12 (1.87)	5.30
FRT	0.59 (1.49, −2.67)	4.64 (3.70)	10.89

To our knowledge this is the first study to report side-to-side variation in active ROM measures and the FRT in children. The mean difference scores for rotation, side flexion and the FRT were relatively small, being 0.68, 0.82, and 0.59, respectively. Previous reports of cardinal plane ROM have also demonstrated very small mean differences (2° side flexion, 0.1° for rotation) between sides.[5] Despite the small mean difference, we found larger variation among individuals with the lower bound scores revealing a difference between sides of up to 11° for the FRT, 9° for the rotation, and 5° for side flexion. These data indicate that clinicians should be careful when interpreting ROM findings in symptomatic children, as small differences between sides may be normal, and may also be due to measurement errors.[20]

A secondary purpose of our study was to determine whether ROM recorded during the FRT was dependent on ROM measured in the cardinal planes. Interestingly we found that movement of the neck in the cardinal planes explained only 19% of the variance (R^2=0.19) in range recorded during the FRT, which was not significant (P>0.14). This finding is not consistent with the findings of Smith *et al.*[10] who found that, in adults, the total range of lateral bending and the presence of sub-clinical neck pain explains 59% of the variance (R^2=0.58) in the range recorded during the FRT. One explanation for the difference may be the presence of pain in the regression analysis performed by Smith *et al.*[10], which was not included in our calculation. Despite this, the results from the present study indicate that range recorded during the FRT is relatively independent of other movement variables. This would appear to build on the evidence that the FRT tests mainly the upper cervical spine ROM.[7,11] While in contrast, cardinal plane ROM tests include movement of the upper and lower cervical spine.

Pain provocation during the FRT was not a common feature in asymptomatic children. Only 14 of 34 children experienced low pain levels during the FRT with a maximum of 2/10 on the CAS. The low levels of pain provocation indicate that the FRT is a comfortable test for, at least, asymptomatic children. Future studies should investigate whether pain levels during the FRT differ between symptomatic and asymptomatic children.

Conclusion

Normal values for cervical spine ROM measures and the FRT, in asymptomatic children aged between 6 and 12 years, have been presented. Ranges are consistent among males and females but consistently greater in children compared with previous reports for adults. In children, side-to-side variation in rotation and lateral bending ROM and range recorded during the FRT indicates that the clinician should be cautious when using range in one direction to determine impairment in another. The FRT appears to be a movement largely independent of cardinal plane ROM measures. Finally, pain during the FRT is a minimal feature in asymptomatic children.

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