Comparison of range of motion during the cervical flexion rotation versus the side-bending rotation test in individuals with and without hyperlaxity

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ABSTRACT

Objective: The flexion rotation test (FRT) is used to determine C1-2 involvement in individuals with neck pain and headaches. Some individuals present with generalized joint hyperlaxity (GJH) which could influence the results of this test, which relies on a soft tissue locking mechanism. The purpose of this study was to examine the side-bend rotation test (SBRT), which utilizes osseous locking, compared to the FRT.

Methods: Thirty-eight healthy individuals (25 female, 26.03 years) were assessed for GJH via the Beighton Hypermobility Index (BHI). A blinded examiner performed the FRT and SBRT bilaterally, measuring ROM using a digital goniometer device.

Results: Statistically significant differences in ROM were present for the FRT based on negative (0–3) and positive (4–9) BHI score: (Right 46.4 ± 3.6 , 49.6 ± 4.8 , $p = .031$), (Left 45.5 ± 3.5 , 49.0 ± 5.2 , $p = .023$); no differences were observed for the SBRT (Right 37.6 ± 4.3 , 38.9 ± 3.4), (Left 37.7 ± 4.2 , 37.6 ± 3.4). When further stratifying the groups, a one-way ANOVA and post-hoc testing revealed significant differences of FRT range of motion between the BHI 7–9 group (52.4 ± 4.4 – 53.9 ± 3.4) compared to BHI 0–3 (45.4 ± 3.6 – 46.2 ± 3.5) and 4–6 groups (46.0 ± 3.7 – 46.4 ± 2.2), $p < .001$; there were no significant differences between the 0–3 and 4–6 groups. There were no between group differences for the SBRT, BHI 0–3 (37.5 ± 4.4 – 37.7 ± 4.3), BHI 7–9 (39.9 ± 3.7 – 39.2 ± 3.5).

Discussion: Individuals with GJH demonstrated significant differences in ROM for the FRT, but not the SBRT. The SBRT may be a useful alternative to the FRT for individuals with hyperlaxity. However, further research needs to be conducted to assess the diagnostic ability of this test in individuals with cervical pathology.

KEYWORDS

Cervicogenic headache; flexion-rotation test; generalized joint hyperlaxity; biomechanics; upper cervical; range of motion

Introduction

The flexion rotation test is commonly used in the examination of patients suspected of having cervicogenic headache (CGH). Approximately 20% of all chronic headaches are considered to be cervicogenic in origin [1,2]. CGH has been observed more frequently in women than men in approximately a 3:1 [3] to 4:1 ratio [2,4], with mean age of onset 29 ± 13 years [3], and a mean age of 42.9 years, with the majority of patients experiencing symptoms for a mean of 6.8 years [4]. Previous research has suggested that C1-C2 joint restriction may be involved in the majority of CGH cases [5]. Current literature provides evidence of the clinical utility of the flexion rotation test (FRT), which is reported to isolate motion to the C1-C2 segments [5–8], in the CGH population [5–7]. Hall and Robinson [6] examined the FRT and determined that the test is valid for the detection of C1-C2 joint restriction while Oginc et al. [7] found the cervical FRT to be extremely reliable with high sensitivity and specificity for determining C1-C2 joint restrictions.

The performance of the FRT involves placing the lower cervical spine in a position of maximal flexion; flexing the cervical joints pretensions the posterior

cervical articular joint capsules and other soft tissues, which reportedly stabilizes the segments distal to C1-C2 [8,9]. The head is then rotated over the stabilized lower cervical spine, which isolates motion primarily to the C1-C2 segment [5–8]. The C1-C2 spinal segments are reported to be responsible for approximately 90° of total rotation, 45° in each direction, with the remaining rotational range of motion (ROM) accounted for in the lower cervical spine [5,6]; *in vivo* CT studies have demonstrated movement of approximately 43° to each side in healthy individuals [10]. However, cadaveric studies following a transection at C3 and the occiput have reported that the mean rotation at C1-C2 was 31.4–38.9°, with C0-C1 responsible for an additional 1.7–5.9° of upper cervical rotational motion [11–14]. In an effort to understand these discrepancies, previous research has shown that rotational ROM differences could be predicted by variables including age, gender, and cervical ROM available in other planes [15]. Panjabi established in a cadaver model that 75% of the motion of a C1-C2 segment takes place in the neutral zone, while the remaining 25% occurs following stretch into the elastic zone of the

motion segment [12]. Takasaki et al [9] have reported on the stabilizing effect of the flexed, compared to the neutral, neck posture. They reported significant reductions in ROM in the flexed position except for the upper cervical segments, reporting a 16.3% reduction in rotation range at C1-C2, 68.1% at C2-C3, 61.4% at C3-C4, and 76.9% at segments below C4 [9]. Their results indicated that the C1-C2 segment provided 73.5% of the total rotation in the flexed position, with the remainder occurring at other levels of the spine [9]. From these data, it appears likely that a significant portion of the ROM observed during the FRT may occur at levels other than C1-C2 and may also be influenced by individual differences in the onset of ligamentous tension.

While the FRT is a reliable test [6], it is possible that it is less effective in populations with greater overall mobility. In the investigators' clinical experience, it is not uncommon for individuals with generalized joint hyperlaxity (GJH) to reach a position of full cervical flexion (chin to chest) while demonstrating very little locking of the lower cervical spine and apparent rotation well beyond 45° to each side during FRT performance. Since the FRT utilizes ligamentous and soft tissue tension to stabilize the lower cervical spine, patient populations with joint hyperlaxity may not achieve the lower cervical ligamentous tension required for adequate stabilization, allowing excessive lower cervical motion, possibly leading to a false negative result. The prevalence of GJH is reported to be up to 35% for males and up to 57% for females [16], and generally diminishes with age. The Beighton Hypermobility Index (BHI) is a clinical measure used to assess GJH [17,18]. The BHI is scored 0–9, with scores of 4/9 or greater indicating generalized joint hyperlaxity [17–19], with scores of $\geq 7/9$ [19–21] suggested to indicate clinical hyperlaxity.

Based on clinical experience and the proposed incidence of hyperlaxity, we propose that rather than using full cervical flexion to stabilize the lower cervical spine to isolate motion at the C1-C2 level, a cervical side-bend combined with contralateral rotation can be used to generate mechanical stabilization of the lower cervical spine. In a systematic review by Cook et al, 100% of the biomechanical papers reviewed were in agreement that lower cervical spine motion is coupled in ipsilateral side bending and rotation [22]. Many authors have reported the use of noncoupled motions (contralateral side bending and rotation in the lower cervical spine) to create mechanical stability and isolate movement to a desired level in the spine via joint apposition and ligamentous tension [22–26], as ipsilateral lateral flexion and rotation have been described as 'inexorably linked' [23]. Rotation of the upper cervical spine is reported to be coupled in a combined contralateral side bend-rotation motion; this positioning may then allow assessment of available

rotation of the upper cervical (C0-C1-C2) segments [13,25,27,28] while mechanically locking segments caudal to C2.

We hypothesize that widespread joint hyperlaxity may influence the results of the FRT. Based on this hypothesis, this study sought to determine if there were differences in upper cervical ROM when comparing the Cervical Side Bend Rotation Test (SBRT) to the FRT based on generalized joint hypermobility as indicated by BHI score.

Methods

Study design

This study, approved by the University of New England Institutional Review Board, was a single arm observational study comparing the SBRT to the FRT in healthy volunteers without neck pain.

Participants

Participants were recruited from a sample of convenience at the University of New England medical sciences graduate campus in Portland, ME, USA. Healthy participants were recruited through word-of-mouth and via e-mail. All volunteers completed a screening form to determine their eligibility based on the inclusion and exclusion criteria and completed a written informed consent process.

Inclusion

To be included in the study, individuals needed to be between the ages of 18 to 60, have the ability to read and understand English, self-report being in current good health, and have no current neck pain.

Exclusion

Exclusion criteria were developed with consideration of the IHS criteria for cervicogenic headache [29] and cervical pathology to avoid the recruitment of individuals with upper cervical pathology. Participants were excluded if they presented with any of the following criteria: current neck pain; whiplash injury within six weeks, history of fractures to spine, osteoporosis, infections within the spine, current treatment of cancer, conditions associated with potential upper cervical instability (e.g. Rheumatoid Arthritis, Down syndrome), currently pregnant, epidural steroid injection into the neck within four weeks, consumption of oral steroids within six months, current headaches, current neck pain or stiffness, current dizziness or visual disturbances, known congenital conditions of cervical spine (e.g. congenital fusion), known contraindications to full

neck flexion (e.g. stenosis, osteophytes, dural tension), and any known latex allergy.

Sample size

Power calculations were performed to determine the sample size required for the study using the MDC and SD for cervical ROM measures of Krauss et al [30], Hoving et al [31], as well as guidelines proposed by Sim and Lewis [32]. The study was designed with the α value set to .05 (type I error) and the β set at 0.2 (type 2 error). The effect size was calculated utilizing the minimum detectable change of 7.09–13.9°, and the standard deviation of 5.83–13.4°. In an effort to adequately power the study, the most conservative ROM estimate was used, assuming a .05/95% confidence interval and using the formula $n = (16\sigma^2/\Delta^2) + 1$ resulted in an estimate of 16 participants per group based on BHI (0–3, 4–9) status [33].

However, to allow for subgroup analysis, recruitment continued until there were a minimum of 10 participants per BHI group (0–3, 4–6, 7–9), with a resulting total sample of 38 individuals.

Measurement

Goniometry has been demonstrated to have moderate to good reliability in the measurement of cervical rotation (ICC .78-.90) [34], and is the most commonly used clinical method [35]. To reduce error, a head

mounting apparatus was constructed for consistent placement of the goniometer axis of rotation across all trials, increasing reliability of ROM measurement. Previous research using a fixation apparatus to assess cervical ROM measurements demonstrated improved levels of reliability [36,37]. The use of a digital goniometer device minimized possible error associated with reading a universal goniometer [38,39]. Since cervical ROM was measured in multiple planes of motion, a bubble level was affixed to the end of the moving arm of the goniometer to aid in vertical alignment during the SBRT (Figure 1). Midline markers at the anterior and posterior aspects of the headband were provided to allow for accurate and repeatable placement of the apparatus on the participant's head. All participants donned a latex swim cap to create a consistent surface that would minimize aberrant motion of the measurement apparatus during testing. Alignment of the measurement apparatus was achieved using bony landmarks: the external occipital protuberance and bridge of the nose were used to determine sagittal alignment and the external auditory canals were used to determine coronal alignment; the position of the goniometer axis thereby approximated the position of the atlanto-axial axis of rotation [40].

The apparatus was validated prior to data collection via 3D motion analysis in the University of New England motion analysis lab. Twelve total trials (three trials each of the SBRT and FRT to each side) were

Figure 1. Measurement of the Flexion Rotation Test (FRT) and Side Bend Rotation Test (SBRT).

A Start position of the SBRT

B Start position of the FRT

C End position of the FRT, with visualization of the measurement device

Figure 2. Validation of rotational ROM assessment.

Rendering of motion capture for the Flexion Rotation Test and Side Bend Rotation Test

collected and analyzed using Visual3D Software (C-Motion, Germantown, MD) as a gold standard reference (Figure 2). Across all trials, the goniometer device measurements were $\pm 1.42^\circ$ compared to motion capture (0.4–3.3 degrees, $r = .934-.989$). As this error was well within the accepted standard error for goniometry [35] the device was deemed reliable and utilized for the remainder of the study.

Procedure

Prior to testing, all participants were assessed for systemic hyperlaxity via the BHI by a blinded examiner [18,19]. Complete descriptions of the BHI test performance and interpretation have been previously published [18,19,41]. Following assessment for hyperlaxity, the participant was fitted with the measurement apparatus as previously described.

The FRT was performed as described by Hall et al. [5,6]. The participant was placed supine on a treatment table; the examiner passively flexed the participant's cervical spine to the limit of the available range

and subsequently rotated their head to one side until firm resistance was encountered. A measurement was taken using the digital goniometer, with one arm aligned with the subject's umbilicus, and the other fixed to the measurement apparatus in line with the midline of the participant's nose. The participant was returned to the resting position and the test was then repeated to the opposite side.

For the SBRT portion of the test, the participant was placed supine on a treatment table. The examiner passively side bent the participant's lower cervical spine to the limit of its range of motion to one side; force was initiated at C2 and focused caudally while maintaining the participant's head position such that the goniometer remained pointed vertically. Care was taken to avoid flexing the cervical spine. From this starting position, the examiner subsequently rotated the participant's head in the direction opposite the side bend until firm resistance was encountered (Figure 3). A measurement was then taken with the digital goniometer. During measurement, the mobile arm was placed vertically (assessed with a bubble

Figure 3. Clinical performance of SBRT.

A: Start position in maximal side bending

B: End position, side bend maintained with contralateral upper cervical rotation

SBRT = Side Bend Rotation Test

level fixed to the distal end of the goniometer arm) while the fixed arm rotated with the participant's head. The participant was returned to the resting position, and the test was then repeated to the opposite side. A third examiner recorded all measurement data, blinded to the BHI score.

Data analysis

Statistical analysis was performed using statistical software SPSS (version 21, IBM, Chicago, IL). All data was analyzed quantitatively in aggregate form; the level of significance was established a priori $p = .05$. All data were analyzed for extreme outliers using SPSS, as well as for normality using the Shapiro-Wilk test, visual inspection of the Q-Q plot and the Levene statistic for homogeneity of variance. Descriptive statistics (means, standard deviations, frequency counts) were carried out using Excel Version 2010 (Microsoft Corporation) for the participants' characteristics including height, weight, age, and gender. To assess between group differences for ROM based on the Beighton 0–3 and 4–9 groups, independent samples t -tests were utilized. To determine the source of any differences, groups were stratified based on BHI score with 0–3 indicating a negative result, 4–6 possible hyperlaxity, and 7–9 clinical

hyperlaxity [17,19–21,41]. A one-way ANOVA was utilized to assess for between group differences, with post-hoc testing to determine the source of the differences.

Results

Among the 39 individuals interested in participating in our study, 38 qualified for inclusion in this study, consisting of 25 females and 14 males. Mean age of participants was 26.03 years, mean height was 67.57 in (1.72 m), and mean weight was 160.03 lbs. (72.59 kg) (Table 1).

Independent samples t -tests revealed significant between-group differences for ROM during the FRT based on a positive ($\geq 4/9$) BHI score compared to those with a negative ($\leq 3/9$) BHI score, FRT Right $t = -2.243$, $p = .031$, FRT Left $t = -2.372$, $p = .023$. There were no statistically significant differences in SBRT scores (Table 2). Upon comparing the FRT and the SBRT ROM values, greater ROM was noted with the FRT versus the SBRT in both the negative and positive BHI group. A one-way ANOVA demonstrated significant between-group differences for ROM within the FRT based on BHI score, FRT Right $F = 20.451$, $p < .0001$, FRT Left $F = 11.488$, $p = .0001$. *Post hoc* tests revealed significant differences for both FRT conditions for the group scoring 7–9 on the BHI

Table 1. Subject demographics.

BHI Score	Age (yrs.)	Gender	Height (in)	Weight (lbs.)
Negative (0–3) $n = 16$	$26.94 \pm .181$	9 male, 7 female	68.12 ± 3.72	163.12 ± 44.96
Positive (4–9) $n = 22$	25.29 ± 1.43	5 male, 17 female	67.57 ± 3.58	160.01 ± 38.80

Table 2. Between group differences, Beighton score by test.

	Negative Beighton ($\leq 3/9$) $n = 16$	Positive Beighton ($\geq 4/9$) $n = 22$
FRT Right*	46.4 $\pm$ 3.6	49.6 $\pm$ 4.8
FRT Left*	45.5 $\pm$ 3.5	49.0 $\pm$ 5.2
SBRT Right	37.6 $\pm$ 4.3	38.9 $\pm$ 3.4
SBRT Left	37.7 $\pm$ 4.2	37.6 $\pm$ 3.4

* = significant at the $p = .05$ level

Independent samples t -tests revealed that there were significant between group differences for ROM during the Flexion Rotation Test (FRT) based on a positive ($\geq 4/9$) Beighton score compared to those with a negative test ($\leq 3/9$), FRT Right $t = -2.243$, $p = .031$, FRT Left $t = -2.372$, $p = .023$. SBRT = Side Bend Rotation Test

with all differences $p < .001$; there were no significant differences between the groups scoring 0–3 and 4–6 (Table 3). When comparing the SBRT ROM data based on BHI scores, there were no statistically significant differences between the groups.

Discussion

While extensive research has been conducted on the reliability and validity of the FRT [5–7], to our knowledge research has not been performed comparing the FRT to the SBRT. In the current study, the FRT demonstrated overall ROM of $47.86^\circ \pm 3.07$, which is similar to the $44\text{--}50^\circ$ previously described [5,42]. It is possible that the FRT results were on the higher end of the reported normal range due to the high prevalence of hyperlaxity in our sample, as well as the younger, predominantly female sample. Age and gender have been previously associated with greater cervical ROM [15,42]. The SBRT demonstrated a smaller total ROM of $37.95^\circ \pm 3.66$. However, unlike the FRT, there were no significant between group differences based on BHI score for any of the SBRT groups. The overall ROM observed during the SBRT across all participants appears quite similar to the current estimates of upper cervical rotation demonstrated in cadaver and recent MRI studies, which reported upper cervical (Occiput-C1-C2) ROM of $35.35\text{--}38.9^\circ$ [11,12], and *in vivo* studies demonstrating axial rotation of Occiput-C1 and C1-C2 as $1.7\text{--}2.5^\circ$ and $36.2\text{--}36.7^\circ$ respectively

[13,14]. We believe these findings support the hypothesis that the stabilization of the lower cervical spine via mechanical locking effectively isolates the upper cervical spine.

These findings should not be interpreted as stating that the upper cervical spine ROM is not influenced by laxity, as both tests demonstrated increased overall ROM as the BHI score increased. The FRT demonstrated increases of $6.7\text{--}7.0^\circ$ while the SBRT demonstrated a $1.4\text{--}2.4^\circ$ increase between the BHI 0–3 and 7–9 levels. As the FRT has been shown to allow approximately 23% of the rotational motion of the lower cervical spine to contribute to the overall ROM in the FRT position [9]; the soft tissue locking of the FRT in individuals with hyperlaxity may not allow for adequate isolation to assess C1-C2 motion in the GJH population, making it difficult to detect C1-C2 joint restriction. The difference in ROM between the two tests is likely of clinical significance. Smith et al [15] suggested that an 8° loss of ROM may be meaningful for detection of C1-C2 joint restrictions in the CGH population with the FRT. The 7° difference in FRT ROM between individuals with the lowest and highest BHI scores may serve to mask the true differences in upper cervical ROM and the presence of true C1-C2 joint dysfunction in the GJH population. While the SBRT demonstrated progressive increases in ROM based on BHI score, the overall differences observed did not reach statistical significance; therefore, we propose that the osseous locking mechanism appears relatively unaffected by GJH.

Table 3. Between group differences by stratified Beighton score and test.

	Beighton 0–3 $n = 16$	Beighton 4–6 $n = 12$	Beighton 7–9 $n = 10$
FRT Right*	46.2 $\pm$ 3.5	46.4 $\pm$ 2.2	52.9 $\pm$ 3.4
$p < .0001$	vs BHI 4–6: $p = .981$ vs BHI 7–9: $p = .0001$	vs BHI 0–3: $p = .981$ vs BHI 7–9: $p = .0005$	vs BHI 0–3: $p = .0001$ vs BHI 4–6: $p = .0005$
FRT Left*	45.4 $\pm$ 3.6	46.0 $\pm$ 3.7	52.4 $\pm$ 4.4
$p = .0001$	vs BHI 4–6: $p = .905$ vs BHI 7–9: $p = .0002$	vs BHI 0–3: $p = .905$ vs BHI 7–9: $p = .001$	vs BHI 0–3: $p = .0002$ vs BHI 4–6: $p = .001$
SBRT Right	37.5 $\pm$ 4.4	38.1 $\pm$ 2.9	39.9 $\pm$ 3.7
$p = .282$	vs BHI 4–6: $p = .893$ vs BHI 7–9: $p = .257$	vs BHI 0–3: $p = .893$ vs BHI 7–9: $p = .516$	vs BHI 0–3: $p = .257$ vs BHI 4–6: $p = .516$
SBRT Left	37.7 $\pm$ 4.3	36.2 $\pm$ 2.7	39.2 $\pm$ 3.5
$p = .174$	vs BHI 4–6: $p = .517$ vs BHI 7–9: $p = .592$	vs BHI 0–3: $p = .517$ vs BHI 7–9: $p = .150$	vs BHI 0–3: $p = .592$ vs BHI 4–6: $p = .150$
Gender	9 male, 7 female	5 male, 7 female	0 male, 10 female
Age (yrs.)	26.9	25.7	25.1
Height (in)	68.2	68.1	67.6
Weight (lbs.)	164.6	157.8	160.0

* = significant at the $p = .05$ level SBRT = Side Bend Rotation Test FRT = flexion-rotation test

One-way ANOVA demonstrated significant between-group differences for ROM on the FRT based on BHI score, FRT Right $F = 20.451$, $p < .0001$, FRT Left $F = 11.488$, $p = .0001$. *Post hoc* tests revealed significant differences for the FRT Right and Left for the group scoring 7–9 on the BHI, $p < .001$, while there were no significant differences between the groups scoring 0–3 and 4–6.

Other factors related to starting position, besides locking mechanics, may have played a role in the overall differences in ROM observed between the two tests during this study. Dvorak [10] reported that the initial starting position of flexion resulted in the greatest limitation of cervical rotation, while Walmsley [42] reported that flexion and extension were both limiting factors and variable by age. Both the SBRT and FRT attempt to assess C1-C2 rotation in isolation, without allowing for normal three-dimensional coupling mechanics to occur. Normal C1-C2 rotation is accompanied by 14° of extension [23], and concurrent contralateral lateral flexion, observed to be Occiput–C1 of 4.1° and C1-C2 of 3.8° [13]. Differences in coupled motion may have occurred during the two tests which may explain some of the differences in the observed ROM. Cattrysse et al. examined upper cervical ROM using a three-dimensional locking position as would be used in manipulation (flexion, rotation, contralateral side bend) compared to manual fixation of C2 [43]. Interestingly, they observed increased freedom of rotation at C1-2 ($55.1^\circ \pm 9.2$) in the 3-D locking position with limited C0-C1 motion and very little coupled motion occurring [43]. The difference in application between localized 3-D locking in flexion and global locking via maximal side-bend in slight extension may account for the observed differences. Despite the differences observed with mechanical locking, Cattrysse et al. [43] also observed upper cervical rotation with manual fixation of C2 ($35.7 \pm 11.9^\circ$) that was very similar to the ROM observed during the SBRT (37.5–39.9°) in the current study.

It is important to note that while upper cervical contralateral coupling appears to be well agreed upon when rotation is the first movement, not all studies have demonstrated agreement of the upper cervical coupling pattern when motion is initiated via side bending [12,13,22,44,45]. It is unclear if the SBRT as performed, initiating a maximal side bend via contact at C2 and progressing caudally prior to adding rotation to the upper cervical spine, was influenced by the potentially variable upper cervical mechanics that have been described when side bending is initiated cranially. It is possible that some individuals may have experienced noncoupled motions during the SBRT, which could potentially limit the available ROM.

While efforts were made during the SBRT to initiate lower cervical lateral flexion at C2 and progress caudally, it is possible that the pre-positioning of the lower cervical spine influenced the upper cervical rotation. Side bending and ipsilateral rotation are obligated to occur during lower cervical rotation. It is possible that, for example, right lower cervical side bending caused a concurrent right rotation; to maintain the head in a neutral rotation, some degree of relative left upper cervical rotation may have occurred. This may have influenced the overall result as the starting position

may not have been a true zero degrees of rotation at C1-C2.

The prevalence of GJH in this sample of young, healthy individuals without neck pain is important to consider. At first glance, the proportion of participants with GJH may appear high. The prevalence of BHI scores of ≥ 4 was 57.8%, which is in line with the upper bounds of prevalence in the literature [16]. The group with the greatest overall ROM was the 7–9 BHI group, representing 26.3% (10/38) of participants, which is also in line with published reports [20,21]; notably all individuals in this group were female. Given the fact that GJH is far more prevalent in a young, primarily female population – which is also the predominant CGH population – the need to assess for hyperlaxity may be an important clinical consideration during assessment. In this population, we suggest that the SBRT may be a useful tool to measure upper cervical ROM, as the SBRT was a consistent measure of ROM regardless of BHI score.

Limitations

This study compared the ROM of the SBRT and FRT relative to scores of GJH in a young healthy population. Most participants were graduate health sciences students. It is not known if these results would be different in individuals from other demographic groups or in individuals with cervical pathology. This study represents a single session of testing with a small sample. Future research should seek to address these limitations.

Conclusion

The SBRT appears to have construct validity as a method to assess upper cervical mobility in individuals with and without systemic hyperlaxity, as overall ROM scores were consistent with published biomechanical data. As a result, future studies comparing the SBRT and FRT in individuals with CHG should be considered to determine if the test has diagnostic validity as well. While future studies are required to confirm this hypothesis, we suggest that if GJH is present, the SBRT may be a useful test for upper cervical mobility, as the FRT may overestimate ROM in this population. Further research should also be conducted to explore its application, reliability, validity, and associated outcomes in patients of various ages and cervical pathology, particularly the CGH population.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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