Reliability of a seated three-dimensional passive intervertebral motion test for mobility, end-feel, and pain provocation in patients with cervicalgia

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Objectives: Neck pain can be evaluated with passive intervertebral motion (PIVM). No study has evaluated the reliability of three-dimensional (3D) segmental PIVM testing of the cervical spine in symptomatic subjects in a functional, seated position. The purpose of this study was to evaluate inter-rater reliability of such 3D PIVM technique for pain provocation, hypomobility, and end-feel detection.

Methods: Subjects ($n=63$), age 44 ± 15.6 years, neck pain 3.4 ± 1.6 cm with visual analog scale, were evaluated by two of three raters with varied manual therapy education and experience. To perform the test, the rater passively invoked side-bending motion at each cervical joint from C2–C3 to C6–C7, allowing segmental synkinetic rotation and extension to occur. Each joint was assessed for hypomobility, hard end-feel, and pain provocation. Kappa statistics were used to determine the inter-rater reliability for each variable for joints C2–C3 through C6–C7 for both the most painful and least painful sides.

Results: Percent agreements for pain provocation, hypomobility, and end-feel ranged 65–83%, 62–84%, and 68–87%, respectively. Kappa values for pain provocation, hypomobility, and end-feel on the most painful side were fair to moderate (0.29–0.53, 0.21–0.48, and 0.25–0.50, respectively), and on the least painful side were fair to substantial (0.43–0.65, 0.33–0.58, and 0.28–0.60, respectively).

Discussion: This is the first investigation to assess reliability of 3D cervical segmental testing in sitting and to assess reliability of end-feel. The seated 3D PIVM test has sufficient clinical reliability for use in patients with cervicalgia for the assessment of hypomobility, end-feel, and pain provocation.

Keywords: Reliability, Cervicalgia, Manual therapy, Passive motion

Background

Neck pain is a common condition affecting 30–50% of adults for at least 1 day per year. It accounts for 20% of all healthcare visits to a primary care facility for musculoskeletal pain.^{1–4} Yearly, 11–14% of the working population reports limitations in their functional abilities as a direct result of neck pain, with 5–8.5% of workers missing at least one workday per year due to neck pain.⁵

Orthopedic manual therapy (OMT), including joint and soft tissue mobilizations and manipulations, has emerged as a promising treatment for neck pain.⁶ When compared to a self-stretching group, patients who received OMT had significantly lower levels of pain.⁷ Improved range of motion, decreased neck

disability, fewer missed days of work and decreased healthcare costs have been reported in patients treated with OMT as compared to those treated with traditional physical therapy or general practitioner care.^{8,9}

Clinicians determine OMT treatment based on clinical assessment. This may include passive intervertebral motion (PIVM) to determine the pain generating segment(s), as well as quality and quantity of joint mobility.¹⁰ Abbott *et al.*¹¹ surveyed therapists of New Zealand and the United States to determine beliefs on the validity of PIVM for assessment of low back pain. They found that 98% of those surveyed used the results of PIVM assessment to determine treatment plan.¹² In a 2008 survey of Dutch manual therapists, van Trijffel investigated how therapists used findings of segmental PIVM in their clinical decision-making.¹⁰ The authors found that 23% of therapists relied primarily on pain

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provocation in decision-making. Moreover, 80% of therapists chose three-dimensional (3D) coupled motions to assess segmental PIVM, while only 6% use 1D movements.¹⁰

Coupling is a process in which movement along one axis of motion produces translation along the other axes. Winkelstein *et al.*¹² found that coupled movements provided the greatest stress, due to motion occurring in three planes, to the joint capsules of the cervical disc segments (e.g. C2–C3 to C6–C7). Coupled motions take up the slack of the joint capsule more so than movements in one or two planes of motion. This allows the joint to be taken more closely to its end range of motion.

The literature does not support dependable lumbar and thoracic spine coupling patterns, but there is strong evidence to support the presence of consistent cervical spine coupling patterns.^{13–15} This suggests that in most people, cervical spine movement in one plane consistently produces the same synkinetic, or involuntary, movements in the other planes of motion.

Goel *et al.*¹⁶ suggested that cervical spine loading that occurs in an upright posture, in conjunction with 3D coupled motion, further increases the stress to the joint capsule. As a result, gross and segmental movements differ in a loaded versus unloaded spine.¹⁶ In a loaded spine, the joint capsule will be more wound up, allowing a more complete assessment of the full excursion of the joint.¹⁶ Testing in an unloaded position could limit joint assessment at the end range of motion, and could subsequently alter the treatment approach, if hypomobilities are not detected. The movement toward functional outcome based treatment dictates that the most functional positioning be sought in patient evaluation and treatment. The seated position is more functional for those experiencing symptoms in a loaded position than the supine testing position. Nonetheless, no study has evaluated the reliability of seated, 3D PIVM of the cervical spine in symptomatic subjects.

While most manual physical therapists consider joint-specific test findings to be important in establishing a functional diagnosis and treatment plan, there is limited research as to the validity of these clinical tests.¹⁰ Few studies have investigated validity, as there is no true gold standard for comparison. Jull *et al.*¹⁷ reported 100% sensitivity and specificity of segmental testing as compared to cervical zygapophyseal joint block to detect the involved level. King *et al.*¹⁸ found lower sensitivity and specificity of 88 and 39%, respectively, for determining the correct zygapophyseal joint. In both of these studies, subjects were assessed in prone using central and unilateral postero-anterior glides.^{17,18} Fernandez-de-las-Penas *et al.*¹⁹ reported therapists' findings of segmental

hypomobility with passive lateral flexion in supine to be as good as radiologic findings. Humphreys *et al.*²⁰ found moderate to substantial agreement for detecting the level of congenitally-blocked vertebrae using both rotation and lateral flexion assessment of seated subjects. These studies support the validity of OMT techniques for assessing segmental hypomobility in cervical disc segments.

When compared to peer-reviewed studies reporting validity, there have been a greater number of reliability studies of PIVM in the cervical spine. However, the inter-rater reliability of cervical PIVM for joint hypomobility testing is poor to moderate and for pain provocation is poor to substantial. In these studies, most reliability scores did not reach clinically acceptable levels.^{21,22} According to Haneline *et al.*,²³ kappa value of 0.4, or fair reliability, is the minimum for clinically acceptable reliability. A summary of findings of studies assessing reliability is provided in Table 1.^{24–29}

In a review of 37 previous studies of quantitative (excursion) and qualitative (end-feel) spinal motion palpation, Haneline *et al.*²³ concluded that end-feel testing had similar reliability in the lumbar, thoracic and upper cervical spine. However, there has been no evaluation of end-feel assessment in the cervical disc segments.

As previously noted, many manual therapists base their clinical decision-making of manual treatments on PIVM outcomes. Currently, there are no tests of cervical PIVM that have been shown to be reliable for assessment of pain provocation, joint hypomobility and end-feel assessment. Manual therapists are in need of a reliable tool to evaluate and guide treatment planning.

Therefore, the purpose of this study was to evaluate the inter-rater reliability of the cervical segmental sidebending test (CSSBT) in the cervical disc segments of symptomatic subjects, using a seated, 3D technique, to assess joint hypomobility, end-feel, and pain provocation.

Methods

This study was approved by Tennessee State University and Texas Tech University Health Sciences Center Institutional Review Boards. All subjects provided informed consent before participating in the study.

Power analysis

A priori power analysis with $\alpha=0.05$ estimated that 61 subjects were necessary to achieve clinically significant levels of reliability for the cervical segmental side-bending test.³⁰

Subjects

A convenience sample of 64 symptomatic subjects participated in this study. Participants were recruited from two outpatient physical therapy clinics. The

following inclusion criteria were considered: (1) age 18 years or older; (2) able to speak English; (3) presence of neck pain within 1 week of testing; and (4) minimum to moderate disability levels as indicated by a score of $\leq 60\%$ on the Neck Disability Index (NDI).^{29,31} Subjects were excluded if they had a history of previous surgery to the cervical spine within the last 6 months, a history of a systemic inflammatory condition, were unable to sit for a minimum of 5 consecutive minutes, had symptoms of vertebrobasilar insufficiency, or if they were pregnant.

Raters

The original study methodology utilized two raters for subject testing. However, a change in clinical staffing required that a total of three raters be used for testing in this study. All raters were licensed physical therapists. Rater A and Rater B1 were certified orthopedic manual physical therapists (Cyriax-based and Australian-based, respectively) with a mean of 6 years of clinical experience. Rater B2 had 1 year of clinical experience using OMT in an outpatient setting. As a result of the change in clinical staffing, testing of the first 26 subjects was completed by Raters A and B1, while testing of the remaining 38 subjects was completed by Raters A and B2. This explains the small inequality in the number of subjects tested by Raters B1 and B2.

Raters B1 and B2 were unfamiliar with the technique used for this study. Both were trained using a video demonstration of the technique followed by a 30-minute hands-on tutorial conducted by Rater A.³²

Description of a seated, 3D test of PIVM

The 3D CSSBT was first described by Jirout,³³ and is based on the coupling principle that cervical side-bending produces synkinetic ipsilateral rotation. For this test, the subject was seated on a treatment plinth with the posterior aspect of the head in close vertical alignment with the most posterior aspect of thoracic kyphosis. The rater's fingers were positioned on the articular pillar of the inferior vertebra of the joint tested. The rater passively invoked a side-bending motion at each cervical joint, allowing segmental synkinetic rotation and extension to occur (Fig. 1). The rater compared the mobility and end-feel of each joint to that of the joint above it, starting at C2–C3 and ending at C6–C7. Each rater used standardized surface anatomy to determine each cervical segmental level.³⁴ As testing moved from the upper to the lower cervical disc segments, side-bending motion above the tested joint increased as a result of the cumulative movement occurring in cervical joints proximal to the tested joint. A test was considered hypomobile when a segment displayed less PIVM than the segment above it, as noted by visual comparison of available movement. A test was considered to have a hard end-feel if a firm, abrupt end of motion was reached when passively moving the joint to its end range. C2–C3 segmental mobility was determined as compared to the segment below. Reproduction of the subject's pain at a segment was considered a positive test for pain provocation.

Testing sequence

Subjects completed a demographic questionnaire with information concerning medical history, pain

Table 1 Summary of studies evaluating the reliability of PIVM of the cervical disc segments

Author	Subjects used	Joints tested, position and dimensions	Mobility testing level and reliability	Pain testing level and reliability	Qualifications of testers
DeBoer <i>et al.</i> ²⁴	40 asymptomatic	C3–T1 Sitting 1D motion	C3–C6 $\kappa=0.01$ –0.05 C6–T1 $\kappa=0.4$ –0.45	None	3 chiropractors 5–14 years experience
Strender <i>et al.</i> ²⁵	50 asymptomatic	C2–C3 Supine 1D motion	C2–C3 $\kappa=0.057$	C2–C3 $\kappa=0.37$	2 physiotherapists 21 and 23 years experience
Fjellner <i>et al.</i> ²⁶	48 asymptomatic	C2–T5 Sitting 3D motion	C2–T1 R rotation $\kappa=0.04$ –0.16 L rotation $\kappa=0.06$ –0.16	None	2 physiotherapists 6 and 12 years experience
Smedmark <i>et al.</i> ²⁷	61 symptomatic	C2–C3, C7–T1 Supine 1D motion	C2–C3 $\kappa=0.43$ C7–T1 $\kappa=0.36$	None	2 physical therapists >25 years experience
Pool <i>et al.</i> ²⁸	32 symptomatic	C2–T2 Supine 1D motion	Joint R/L κ value C2–C3 0.34/0.63 C3–C4 0.20/0.26 C4–C5 0.16/–0.09 C5–C6 0.17/0.09 C6–C7 0.34/0.03	C2–C6 ICC=0.5–0.78 C6–C7 ICC=0.22–0.59	2 physiotherapists Experience not specified
Piva <i>et al.</i> ²⁹	30 symptomatic	C2–C6 Supine 1D motion	C2–C3 $\kappa=0.46$ C3–C4 $\kappa=0.25$ C4–C5 $\kappa=0.27$ C5–C6 $\kappa=0.18$ C6–C7 $\kappa=-0.07$	C2 $\kappa=0.42$ C3 $\kappa=0.29$ C4 $\kappa=0.65$ C5 $\kappa=0.55$ C6 $\kappa=0.76$	2 physical therapists 2 and 10 years experience

Note: κ , kappa; ICC, intraclass correlation coefficient.

Figure 1 (A) starting position for the seated cervical side-bending test and (B) ending position for the seated cervical side-bending test at C2–C3 segment.

level, pain location, and NDI. Subjects were assigned to be assessed first by either Rater A or Rater B. Each rater performed the CSSBT bilaterally in joints C2–C7, beginning with passive movement toward the non-painful side. In cases of equal pain, both raters began with passive movement toward the left side. Both raters used the same order, as determined by the first rater assessing the subject. Each rater performed no greater than two repetitions at each level on each side. Testing by the second rater occurred within 5 minutes of testing by the first rater. Raters were blinded to each other's findings. A dichotomous scale was used for each variable with: (1) mobility scored as 'hypomobile' or 'not hypomobile', where hypomobility was described as less passive movement available at a joint as compared to the joint above it; (2) end-feel scored as 'hard' or 'not hard,' where a hard end-feel was described as increased firmness at the end of available range of motion at a joint; and (3) pain provocation scored as 'pain provoked' or 'no pain provoked.'

Statistical analysis

Descriptive statistics including mean, range, and standard deviation were calculated for age, sex, symptom duration, pain level, and NDI scores. Percent agreement was determined for each joint on the most and least painful sides for all variables.

Pairwise kappa statistics were used to determine the inter-rater reliability of assessing joint hypomobility, end-feel, and pain provocation for joints C2–C3 through C6–C7 for both the most painful and least painful side. The findings of Raters B1 and B2 were pooled for comparison to Rater A's findings. Kappa values were not calculated individually for

raters B1 and B2 as each rater did not evaluate a large enough number of subjects to achieve sufficient power. As described by Koch and Landis, values less than 0.2 indicated poor reliability, 0.2–0.39 fair reliability, 0.4–0.59 moderate reliability, 0.6–0.79 substantial reliability, and greater than 0.8 indicated excellent reliability.³⁵ Kappa values of 0.4 or greater were considered clinically acceptable.²³

Results

Sixty-four subjects, including 49 women and 15 men, age 44 ± 16 years were recruited for the study. One male subject was excluded due to absence of pain at the time of testing, resulting in a total of 63 subjects. Demographic findings are presented in Table 2.

Percent agreements for pain provocation, joint hypomobility, and end-feel when testing the most painful side ranged 65–76%, 62–75%, and 68–78%, respectively. Percent agreements for pain provocation, joint hypomobility, and end-feel when testing the least painful side ranged 75–83%, 75–84%, and 75–87%, respectively. These values are presented in Table 3.

Kappa values for pain provocation, joint hypomobility, and end-feel on the most painful side ranged 0.29–0.53, 0.21–0.48, and 0.25–0.50, respectively. Kappa values ranged 0.43–0.65, 0.33–0.58, and 0.28–0.60, respectively, on the least painful side. These values are presented in Table 3.

Discussion

This is the first study to determine the reliability of a seated, 3D test of cervical PIVM for pain provocation, joint hypomobility, and end-feel assessment, in subjects with cervicalgia. Additionally, it is the first study to use raters of various OMT backgrounds and

Table 2 Descriptive statistics

Variables	Mean (SD)	Range
Age (years)	44 (15.6)	19–83
Symptom duration (months)	13 (30.5)	0.25–180
Report of least pain (cm)	2.36 (1.84)	0–7
Report of average pain (cm)	3.44 (1.61)	0.5–7.25
Report of most pain (cm)	4.69 (1.83)	0.5–8.0
Report of current pain (cm)	2.45 (1.77)	0–6.75
Neck disability index	27.6 (12.9)	2–54

to assess the reliability of a test of PIVM for the most and least painful sides, as opposed to the right and left sides. The designs of previous investigations presented three limitations, which were all taken into account in this study: (1) they tested asymptomatic subjects, which limited the external validity of their findings to an asymptomatic population; (2) they tested subjects in the supine posture, which lacked functionality; and (3) they tested 1D motions, which did not take into account the intrinsic coupling pattern of the cervical spine that allows greatest capsular stretch.¹² These short-comings highlight the need for further study of PIVM.

The results of this study indicate that the reliability of cervical 3D PIVM testing for pain provocation was fair to moderate on the most painful side, and moderate to substantial on the least painful side. The reliability of joint hypomobility assessment was fair to moderate on the most painful side. It was fair in the upper cervical disc segments (C2–C4) on the least painful side and moderate in the lower cervical disc segments (C4–C7). The reliability of end-feel detection was fair to moderate on the most painful side. The reliability in the upper cervical disc segments

(C2–C4) of the least painful side was fair, while it was moderate in the lower cervical disc segments (C4–C7) of the same side.

When compared to the results of previous investigations (Table 1), the reliability of seated, 3D PIVM for pain provocation (Table 3) was better than that found by Streder *et al.*,²⁵ and comparable to that of Piva *et al.*,²⁹ who used 1D testing in a supine position. Pool *et al.*²⁸ reported good reliability of pain provocation at only one cervical level, as calculated with intraclass correlation coefficient. Findings of joint hypomobility assessment in this study displayed higher levels of reliability than all other studies, with the exception of Pool *et al.* and Piva *et al.*^{24–29} Both of these studies reported higher levels of reliability at C2–C3.^{28,29} Fjellner *et al.*²⁶ had the most similar study design to this investigation in terms of subject position and dimensions of testing. The results of this study exceeded those of Fjellner *et al.*²⁶ at all levels for joint hypomobility assessment. No comparison is feasible with previous studies in regard to end-feel assessment as this is the first investigation to assess the reliability of this variable for cervical PIVM.

The results of this study suggest a trend toward greater reliability on the least painful side of the cervical spine for pain provocation, joint hypomobility, and end-feel detection. Two levels on the most painful side (C2–C3 and C4–C5) displayed lower levels of reliability for pain provocation. This is consistent with the findings of Piva *et al.*²⁹ who reported lower reliability values at C2–C3 and C3–C4 segments as compared to the more distal joints. Our data further showed that the second rater was more

Table 3 Percent agreement, prevalence of positive findings, and kappa (95% confidence interval) for pain provocation, joint hypomobility, and end-feel assessment on the most and least painful side (n=63)

Joint	Values	Pain provocation		Hypomobility		End-feel	
		Most	Least	Most	Least	Most	Least
C2–C3	PA	65%	78%	67%	75%	70%	75%
	PPF	47%	27%	44%	25%	39%	22%
	κ	0.29	0.44	0.32	0.33	0.37	0.28
	95% CI	0.05 : 0.53	0.20 : 0.68	0.08 : 0.57	0.08 : 0.58	0.13 : 0.61	0.05 : 0.51
C3–C4	PA	76%	75%	67%	76%	78%	75%
	PPF	53%	33%	42%	28%	33%	24%
	κ	0.53	0.43	0.33	0.41	0.50	0.32
	95% CI	0.29 : 0.77	0.18 : 0.68	0.09 : 0.57	0.16 : 0.65	0.26 : 0.75	0.10 : 0.55
C4–C5	PA	65%	81%	75%	76%	71%	81%
	PPF	57%	40%	43%	28%	33%	22%
	κ	0.29	0.60	0.48	0.41	0.39	0.47
	95% CI	0.05 : 0.54	0.36 : 0.85	0.23 : 0.73	0.16 : 0.65	0.17 : 0.61	0.25 : 0.69
C5–C6	PA	73%	83%	62%	83%	68%	86%
	PPF	53%	47%	40%	28%	30%	23%
	κ	0.46	0.65	0.21	0.57	0.25	0.60
	95% CI	0.21 : 0.71	0.41 : 0.90	−0.04 : 0.45	0.33 : 0.81	0.01 : 0.50	0.35 : 0.84
C6–C7	PA	76%	75%	62%	84%	70%	87%
	PPF	55%	43%	41%	25%	29%	19%
	κ	0.52	0.48	0.22	0.58	0.28	0.59
	95% CI	0.28 : 0.77	0.24 : 0.73	−0.02 : 0.46	0.34 : 0.83	0.04 : 0.52	0.34 : 0.84

Note: PA, percent agreement; PPF, prevalence of positive findings; κ , kappa; CI, confidence interval; Most, most painful side of the neck; Least, least painful side of the neck.

likely to report the presence of pain in instances of disagreement, especially on the most painful side. This suggests that repeated cervical segmental testing required for the testing methodology could have created a change in the subject's pain, with greater likelihood of pain provocation when the second tester evaluated the subject. It is also possible that each rater's prior knowledge of subjects' most painful side could create bias in their assessment, producing disagreement between raters. Interestingly, in our raw data, we typically did not find the pain generating segments and the hypomobile segments to be located at the same cervical segmental level.

With the exception of C2–C3, reliability values of joint hypomobility assessment surpassed the reliability reported in all other studies on both the most and least painful sides. In instances of disagreement, it is possible that repeated testing provoked increased pain and guarding to passive movement, causing the second rater to report hypomobility at a joint. As proposed by Piva *et al.*,²⁹ it is also likely that repeated testing caused a change in joint mobility. This is consistent with intrinsic variability of the subjects' segmental motion rather than variability resulting from tester error.

The test demonstrated good external validity, as it was evaluated in a patient population attending an outpatient clinic for cervical conditions. Validity is further supported since testing was performed by one rater familiar with the technique, while the other was unfamiliar with testing in a seated position. Additionally, the raters used in this study had varied OMT educational backgrounds (Australian- and Cyriax-based). Our findings support the use of this technique across OMT backgrounds, for consistent assessment of pain provocation, joint hypomobility, and end-feel in the cervical spine.

This test provides a means to assess patients in a functional posture. This allows the clinician an improved consistency in evaluating joint hypomobility and pain generators in the patient's typical position for performance of activities of daily living. Other cervical segmental tests reported in the literature require the subjects to be positioned supine to assess for pain provocation and joint hypomobility. Furthermore, in supine the absence of loading limits the stress that can be applied to the joint capsules, thereby limiting a thorough functional assessment for joint hypomobility.

Additionally, this test employs 3D coupling assessment. Coupling takes up a majority of the slack in the capsule; more so than one- or two-dimensional motion alone.¹² Therefore, use of coupled motion for assessment, in conjunction with spinal loading, increases the examiner's capability to reach full joint excursion to better determine if hypomobilities

exist.¹⁶ This improves the evaluator's ability to appropriately detect joints that require mobilization to improve mobility.

The primary limitation of this study was the unforeseen change in clinical staffing that necessitated adding Rater B2. All measures were taken to ensure this rater was trained similarly to Rater B1. Another limitation was the intrasubject variability in segmental mobility and pain provocation. This is a result of repeated testing by two raters. Despite methodology to allow for the least testing per subject, it was difficult to control variability in symptomatic subjects. The final limitation of this study is that raters were aware of each subject's most versus least painful side. This could have created some bias in testing outcomes.

Future studies of the 3D CSSBT test could investigate the internal validity of seated testing. Studies of reliability of novice versus expert raters using this test as well as the inter-rater reliability of raters educated on the technique using video or internet imaging technology would be beneficial.

Conclusion

The CSSBT displayed clinically acceptable levels of reliability for pain provocation on both the most and least painful sides. Clinically acceptable reliability was found for assessment of joint hypomobility and end-feel in the lower cervical disc segments of the least painful side. Clinically, this test can reliably assist the clinician in locating hypomobile and painful segments. This information can guide the clinician in determining which joints could be mobilized to improve joint hypomobility or treated with pain-relieving techniques.

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