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Original article

Reliability and diagnostic accuracy of cervicothoracic differentiation testing and regional unloading for identifying improvement after thoracic manipulation in individuals with neck pain

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ABSTRACT

Background & purpose: The cervicothoracic differentiation test (CTDT), cervical and thoracic unloading are used clinically to guide treatment. This study sought to determine the reliability and diagnostic accuracy of these tests.

Methods: A prospective diagnostic accuracy study was performed at two outpatient clinics and one university research center. A convenience sample of 48 individuals with neck pain was recruited. Cervical and thoracic unloading tests and CTDT were performed with symptom relief considered a positive test. Pain was assessed using a visual analog pain scale (VAS) at rest and during provocative movements. The reference standard was pain relief following thoracic manipulation. Change in pain was used to identify improvement at the MCID (15 mm) and 50% improvement thresholds.

Results: All three tests demonstrated high levels of inter-rater reliability, K = 0.90[0.77–1.00]. Of 48 individuals who completed the study, 39 (81.3%) were improved ≥ MCID; compared to 34 (70.8%) at the 50% threshold. As a single test, the CTDT yielded the strongest diagnostic utility (at MCID threshold) based on ROC curve: AUC 0.791 s.e. 0.078; with high specificity (0.89[51.75–99.72]); LR+ 6.23 [0.97–40]; LR- 0.35 [0.20–0.58]; and PPV 96.43. Unloading tests demonstrated high sensitivity, but poor specificity and likelihood ratios. Composite tests improved specificity, but with lower accuracy and minimal changes in ROC area compared to the CTDT in isolation.

Conclusions: The CTDT is a specific test with significant diagnostic utility to identify individuals who will experience immediate pain relief following thoracic manipulation. The CTDT should be considered during the clinical decision making process when treating individuals with neck pain.

1. Introduction

Neck pain is a common diagnosis, with approximately 34–43% of the population reporting neck pain at some time during the past year, and up to 70% during their lifetime (Blanpied et al., 2017; Carroll et al., 2009). Manual therapy has been shown to be more effective in treating neck pain than treatment by a general practitioner (Hoving et al., 2006), and thoracic manipulation in particular has been shown to decrease pain and improve function (Cleland et al., 2007a; Furlan et al., 2012). Systematic reviews have concluded that thoracic spine thrust manipulations result in a positive effect immediately following treatment (Cross et al., 2011; Gross et al., 2015). As a result, thoracic manipulation has been recommended as a primary manual therapy intervention for the treatment of neck pain by clinical practice guidelines (Blanpied et al., 2017).

Thoracic manipulation is considered to be safer and have fewer side-effects than cervical manipulation (Cagnie et al., 2004; Hurwitz et al., 2004), while resulting in similar neurophysiological effects such as muscle inhibition and hypoalgesia (Pickar, 2002; Vicenzino et al., 1998). While serious adverse events following thoracic spine manipulation are extremely rare, the risk of adverse effects does exist with the use of thrust manipulation and may be underreported (Puentedura and

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O'Grady, 2015). A previous trial of thoracic manipulation reported transient side effects in 17/60 subjects (Cleland et al., 2007a), while others have reported occurrence rates of side effects as high as 60.9% (Cagnie et al., 2004). While the occurrence of adverse effects is likely decreased by performing a thorough examination and using sound clinical judgement (Puentedura and O'Grady, 2015), this risk may be further reduced by the use of clinical diagnostic tests which help identify individuals likely to improve following thoracic manipulation, allowing for more discriminate application of thrust techniques.

There is limited evidence to assist our clinical decision-making process to determine which individuals with neck pain will benefit from thoracic manipulation. The probability of success, based upon individuals reporting at least moderate improvement on a global rating of change following one to two sessions of thoracic manipulation for neck pain, has been reported to be approximately 54% (Cleland et al., 2007b). In an attempt to identify a subgroup of patients with neck pain who would respond favorably to thoracic manipulation, a clinical prediction rule (CPR) was developed (Cleland et al., 2007b), but this CPR was not shown to be valid (Cleland et al., 2010). There is, however, evidence to support the role of applied biomechanics in determining thoracic involvement in neck pain. Tsang et al. (2013) examined the normal kinematics of the neck and concluded that there is a considerable contribution from the upper thoracic spine to total motion during cervical range of motion. Willems et al. (1996) performed an in vivo study of the primary and coupled rotations of the thoracic spine, reporting that cervical positioning and cervicothoracic soft tissues influenced upper thoracic movement patterns. Norlander and colleagues concluded that limitations in thoracic spine mobility can lead to neck and shoulder pain (Norlander et al., 1997; Norlander and Nordgren, 1998). It is therefore possible that applied biomechanical maneuvers may help to identify the involvement of the thoracic spine.

Cervical-Thoracic differentiation testing (CTDT) is a biomechanical maneuver described by Evjenth and Gloeck that is proposed to differentiate neck pain originating from the cervical and thoracic regions of the spine (Evjenth and Gloeck, 2002). To our knowledge, CTDT has not been tested for reliability, validity, or diagnostic accuracy at this time. The test may be performed as part of a standard cervical active range of motion exam when patients have pain during active cervical movements. To perform the test, the thoracic spine is positioned opposite the provocative direction of cervical movement; this counter-positioning is maintained and then the provocative cervical motion is then retested. It has also been speculated that specific unloading tests, where an examiner selectively unloads a portion of the weight of the cervical and/or thoracic spine through manual distraction, may help determine the involved region. Conceptually, unloading procedures take the weight bearing stress off a sensitive segment. Cervical unloading is routinely performed as part of a clinical examination as a symptom alleviation procedure; thoracic unloading techniques are similarly applied with the intention of determining load sensitivity of the thoracic spine (Kaltenborn, 2012). While primarily proposed as an indication to perform traction techniques, these techniques have also been proposed as localization procedures (Kaltenborn, 2012).

The authors hypothesize that individuals with neck pain who have positive differentiation tests indicating thoracic spine involvement will have greater improvements in pain following a thoracic manipulation than those who have negative test results for thoracic spine involvement. The purpose of the study is to evaluate the reliability and diagnostic accuracy of the CTDT, cervical unloading test, and thoracic unloading test, and to determine if the results of these tests serve as prognostic factors for improvement following thoracic manipulation in a sample of individuals with neck pain.

2. Methods

A prospective single arm diagnostic accuracy study was performed between September 1, 2016 and June 1, 2017 at two outpatient physical therapy clinics and one university research center. The protocol was reviewed and approved by the Institutional Review Board before the initiation of the study. This study was prospectively registered at ClinicalTrials.gov. NCT number: NCT02882061.

2.1. Participants

Sample size estimations were performed a-priori. The initial sample was planned to be 50 participants, distributed into two groups determined by results of the cervicothoracic differentiation tests, based upon the minimal sample size requirements for diagnostic accuracy studies as reported by Bujang and Adnan (2016). A prevalence estimate of 60% of individuals demonstrating improvement following manipulation was utilized, with the intent to have 80% power ($p < .05$) to be able to detect sensitivity and specificity values of 80% that were significantly different than sensitivity and specificity values of 50%. This resulted in a required sample of between 33 and 50 individuals. While we planned to recruit and enroll a total of 50 participants; due to a change in the availability of key study staff, recruitment was closed after 48 participants had completed the study.

A sample of convenience was recruited via flyer, email, and word of mouth. All interested individuals were screened for eligibility via questionnaire. Inclusion criteria required participants to be between the ages of 18 and 60 years, and to have a primary complaint of neck pain reported to be > 3/10 while performing provocative cervical movements to limit any potential floor effects (Gatchel, 2001). Exclusion criteria included: identification of any medical signs suggestive of a non-musculoskeletal etiology, arm pain or radicular symptoms below the shoulder, a history of a whiplash injury within the prior 6 weeks, any medical red flags (e.g., tumor, fracture, metabolic diseases, rheumatoid arthritis, severe osteoporosis, history of prolonged corticosteroid use), bilateral upper extremity symptoms, diagnosis of cervical spinal stenosis, evidence of any central nervous system involvement, signs consistent with nerve root compression (at least 2 of the following had to be diminished for nerve root involvement to be considered: myotomal strength, sensation, or reflexes), previous cervicothoracic surgery, unwilling to consent to grade V thoracic spine thrust manipulation, or pending legal action.

All participants reviewed and signed a consent form approved by the Institutional Review Board of the University of New England before participation. Following consent, all participants underwent a physical exam, and were asked to provide information regarding demographics, symptom location, and symptom duration.

2.2. Outcome measures

2.2.1. VAS

Visual analog scale (VAS) scores were assessed in both the resting and pain provoking positions. The VAS consists of a 100-mm line, with one end marked no pain, and the other end marked as the worst pain imaginable. The VAS has been shown to be valid and reliable, and has been used in similar research involving thoracic manipulation (González-Iglesias et al., 2009; Cleland et al., 2005) with an estimated MCID of 9–14.4mm. (Bird and Dickson, 2001; Gallagher et al., 2001; MacDowall et al., 2018). All VAS scores were measured by a blinded examiner.

2.2.2. NDI

To ensure that baseline levels of self-reported disability were similar in both groups, all participants completed the Neck Disability Index (NDI). The NDI is a valid and reliable self-report measure used to determine perceived disability (Vernon and Mior, 1991; Ackelman and Lindgren, 2002). Each question is rated zero to five and the score is expressed as a percentage, with higher scores equaling greater disability.

2.2.3. Clinical index tests

2.2.3.1. Cervico-thoracic differentiation test (CTDT). Participants were seated and pre-positioned in an erect posture to minimize any postural influences on the cervical ROM (Dunleavy and Goldberg, 2013). All participants were cued to the Frankfurt-horizontal position, defined as the position where a line passing through the inferior margin of the left orbit and the upper margin of each external auditory meatus is most nearly parallel to the floor (Lundstrom et al., 1995). This posture was selected for its high levels of reliability and reproducibility between examiners (Lundstrom et al., 1995), while not significantly altering the mechanical axis of the spine relative to the self-balanced posture (Armijo-Olivo et al., 2006).

Participants were assessed using the CTDT as described by Evjenth & Gloeck (Evjenth and Gloeck, 2002). Participants were asked to move through full cervical ROM in each direction (flexion, extension, right rotation, left rotation) to identify their most painful movement (comparable sign). The investigator noted the most painful motion and asked the participant to record their pain on the VAS (Cook et al., 2015). If rotation was the painful movement, after bringing their head back to midline, the participant was asked to turn their body so that their chest was facing the opposite direction of cervical rotation (counter rotation of thoracic spine)(Appendix 1). The examiner maintained this body position by stabilizing the participants' trunk as the participant again turned their neck into the provocative direction until the limit of their ROM was reached or pain was felt. This position of cervical rotation was again noted by the investigator. The participant was then asked: "Are your symptoms 'better', 'worse', or 'the same'"? A positive test was indicated by a response of 'better', as well as 'the same' if significant improvement in cervical rotation was obtained. A negative test was indicated by a response of 'worse', as well as 'the same' when significant improvement in cervical rotation was not obtained. Significant improvement in cervical motion was operationally defined as 10°, as this surpasses the MDC_{95} for cervical rotation of 5.79–6.82° as described by Krauss et al. in their study of individuals with neck pain (Krauss et al., 2008). If the most painful direction was flexion, the participant was asked to "arch" backwards into extension of the thoracic spine. This position was maintained by the investigator, and the participant then repeated the cervical flexion. If the most painful direction was extension, the participant was asked to "slump" forward into flexion of the thoracic spine. This position was maintained by the investigator, and the participant then repeated the cervical extension. The same follow up question of "better, worse, or the same" was asked, and the results were recorded (Appendix 1).

2.2.3.2. Cervical unloading. The cervical unloading test was performed as described by Kaltenborn (2012). To perform this test, participants were seated in erect posture as previously described with an investigator standing behind them; a longitudinal distraction maneuver was then applied to the cervical and upper thoracic vertebrae along the axis of the neck. If the participant was experiencing pain in the resting, neutral cervical position, cervical unloading was performed in this position. If the participant was not experiencing pain in the resting position, the cervical spine was positioned in the previously identified provocative position at a point coinciding with the onset of their pain, and cervical unloading was then performed. The participant was then asked to report if their pain was 'better', 'worse', or 'the same'. A positive test was recorded if the participant reported 'better', while a negative test was recorded if the participant reported 'worse' or 'the same' (Appendix 1).

2.2.3.3. Thoracic unloading. The thoracic unloading test was performed as described by Kaltenborn (2012). To perform this test, participants were seated in erect posture with an examiner standing behind them. The participants were asked to cross their arms by placing their hands on their opposite shoulders/upper arms. Thoracic unloading consisted of a longitudinal distraction maneuver applied upward along the axis of the spine by applying force through the participants' elbows. If the participant experienced pain in the neutral cervical position, then thoracic unloading was performed in this position. If the participant was not experiencing pain in the resting position, thoracic unloading was performed with the cervical spine positioned in the previously identified provocative position at a point coinciding with the onset of their pain. The participant was then asked to report if their pain was 'better', 'worse', or 'the same'. A positive test was recorded if the participant reported 'better', while a negative test was recorded if the participant reported 'worse' or 'the same' (Appendix 1).

2.2.4. Reference standard

2.2.4.1. Supine thoracic thrust manipulation. All participants received thoracic grade V thrust manipulation to the thoracic spine as described by Cleland et al. (2007a,b) and Karas and Olson Hunt (2014), as supine manipulations have been demonstrated to elicit greater pain relief compared to seated techniques (Karas and Olson Hunt, 2014). All manipulations were performed by fellowship trained manual therapists with a minimum of 10 years of experience. The manipulation was targeted to the upper thoracic spine at a level pragmatically determined by the examiner. The most hypomobile and/or painful (tender to examiner's palpation) segment between T1-T4 was determined at the examiner's discretion, and the thrust was applied to this segment. If a cavitation was not heard or felt by either the participant or examiner, a second thrust was performed. A maximum of 2 attempts were permitted, and all interventions involved only a single segment. After completion of the manipulation, the participant returned to an erect seated position, the provocative motion was repeated, and a second set of VAS were completed, both at rest and for the provocative motion. Pain levels as reported on the VAS pre-post manipulation were then used to identify individuals as improved/not improved at both the MCID (15 mm) and 50% thresholds.

2.3. Reliability

To assess inter-rater reliability of the CTDT, cervical, and thoracic unloading tests, a subgroup of 20 participants were tested by pairs of experienced, blinded examiners, who were paired based upon location. The same testing protocol was used for all participants regardless of recruitment source. For each pair of examiners, the first examiner performed all the clinical examination measures on each participant; the second examiner, blinded to the previous results, then performed the same testing procedures. Whenever possible, the raters alternated the role of first and second tester to minimize any possible order effect.

2.4. Data analysis

Statistical analysis was performed using statistical software: SPSS (version 21, IBM, Chicago, IL) and MedCalc for Windows, version 18.2.1 (MedCalc Software, Ostend, Belgium). All data were analyzed quantitatively in aggregate form; the level of significance was established a priori with the α value set to 0.05 (type I error) and the β set at 0.2 (type 2 error). All data were assessed 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.

Reliability coefficients with 95% confidence intervals (CIs) and percentage agreement were calculated for the entire sample for the CTDT, cervical unloading, and thoracic unloading tests. Inter-rater reliability was based upon the dichotomous scoring of "positive" or "negative" for each test, and calculated based on the pooled data from all assessment pairs utilizing the Kappa statistic.

As we were assessing a test proposed to indicate a clinical test-treatment response, results were dichotomized into groups based upon improvement relative to the established benchmarks. Participants were identified as improved/not improved determined by change in VAS score for their

provocative motion, pre-post manipulation, with improved defined as exceeding the 15 mm MCID on the 100 mm VAS. The MCID of 14.4 mm (rounded to 15 mm for measurement purposes) was selected as the most appropriate metric based upon a recent validation of the VAS in spine research (MacDowall et al., 2018), although levels as low as 9–11 mm (Bird and Dickson, 2001; Gallagher et al., 2001) have been reported in the literature. A secondary, exploratory, analysis was conducted utilizing a cut-off score of greater than 50% relief as suggested in the IMMPACT recommendations (Dworkin et al., 2008). These groups (improved/not improved) were analyzed for baseline differences for age, gender, NDI score, direction of comparable sign, and chronicity using simple t-tests for continuous variables, the Mann-Whitney *U* test for ordinal data, and Fisher's exact test for dichotomous nominal data.

Two by two contingency tables were constructed and utilized to calculate sensitivity, specificity, positive and negative predictive values, and likelihood ratios with 95% confidence intervals independently for each index test, as well as for combinations of tests. When a zero cell value was encountered, 0.5 was added to all cell values in the table to allow for the calculation of likelihood ratios and their corresponding 95% confidence intervals (Wainner et al., 2003). To further establish the diagnostic accuracy of the index tests, receiver operator characteristic (ROC) curves were calculated, as ROC curves combine sensitivity and specificity, with the area under the curve (AUC) serving as a summary measure of discrimination achieved by a test.

2.5. Results

A total of 71 volunteers were screened for participation (Figs. 1–3), and a total of 48 individuals (30.78 yrs, 29 female, 19 male) participated in this trial (Table 1). There were no reports of any adverse events during or following this study. There were no significant differences at baseline between groups for age, gender, NDI score, direction of motion reproducing the comparable sign, or chronicity (Table 2). There was one extreme outlier for change in VAS in the CTDT positive group. Data were assessed including and excluding the outlier value; there were no significant changes to the results and therefore the value was included to improve generalizability of the results.

2.5.1. Reliability

The cervicothoracic differentiation test, cervical unloading, and thoracic unloading demonstrated high levels of inter-rater reliability, with 95% raw agreement for each test (K = 0.90, CI_{95} 0.77–1.00).

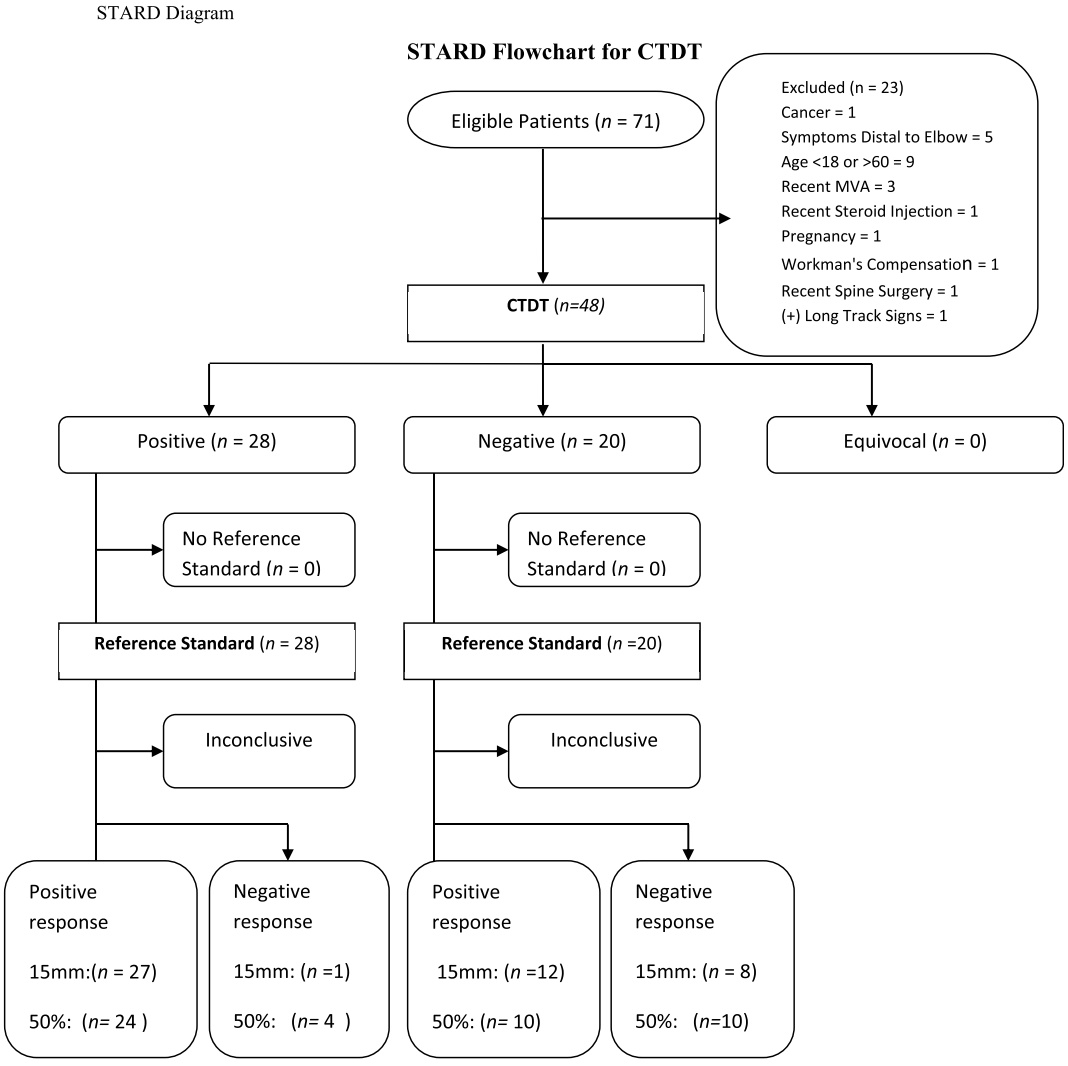


Fig. 1. STARD diagram.

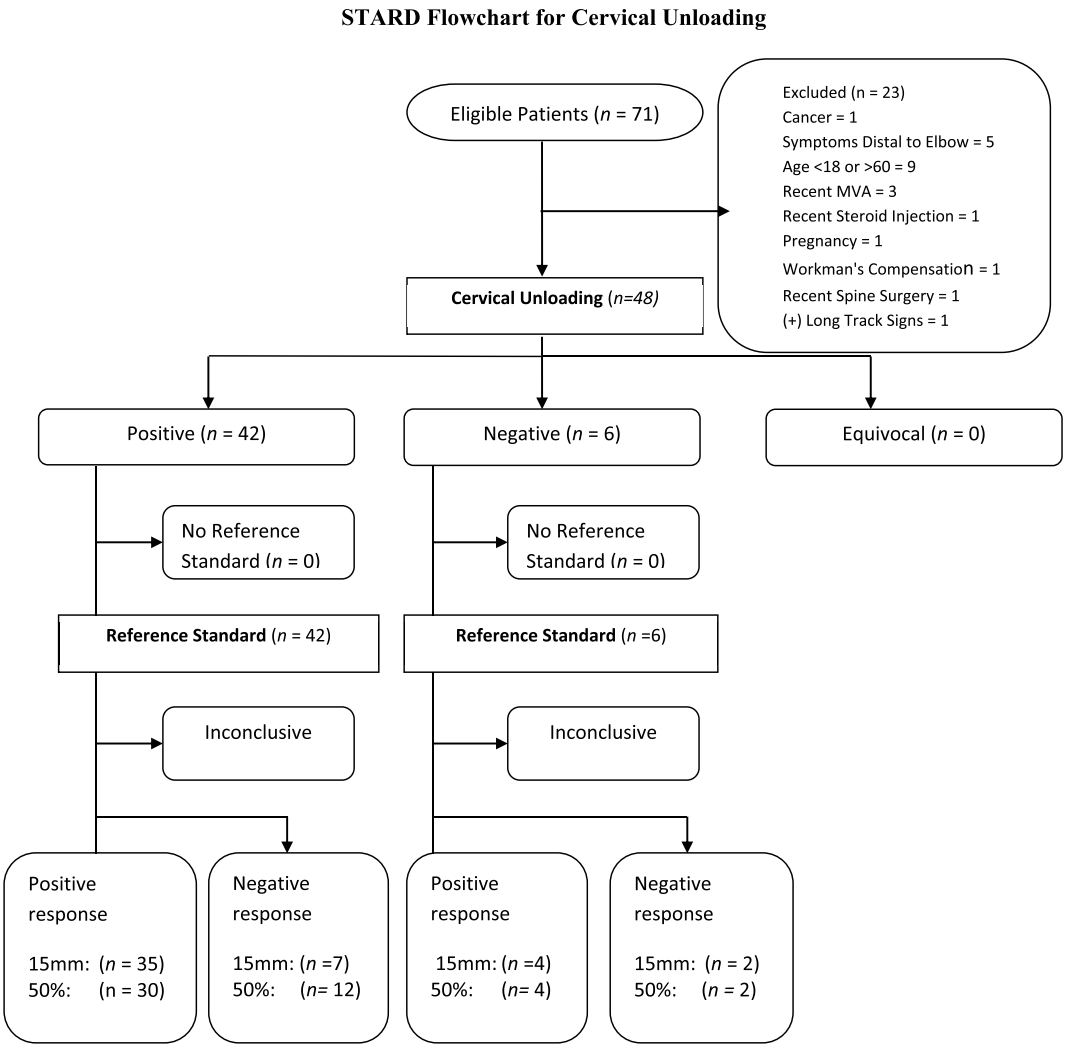


Fig. 2. STARD flowchart cervical unloading.

2.5.2. Diagnostic accuracy

Of the 48 individuals who completed the study, 39 (81.3%) were considered "improved" at the 15 mm MCID threshold. When considered at the 50% improvement threshold, 34 (70.8%) were "improved". Two by two contingency tables were constructed for improvement status by index test (Table 3). Sensitivity, specificity, positive and negative predictive values and likelihood ratios with 95% confidence intervals are presented in Table 4.

Based on the initial calculations, the CTDT (15 mm MCID) demonstrated the highest positive predictive value, specificity, and clinically useful positive and negative likelihood ratios. However, both the cervical and thoracic unloading tests demonstrated superior levels of sensitivity. Therefore, specific combinations of tests were analyzed. The addition of either the cervical or thoracic unloading test to the CTDT, as well as all three tests in combination, improved the positive predictive value from 96.43% to 100%, as well as increasing the specificity of the test from 0.89 to 1.00. When analyzed using the ROC curve, the CTDT alone presents with AUC of 0.791, s.e. 0.078. The addition of either thoracic unloading (AUC 0.731, s.e.0.075) or all three tests in combination (AUC 0.705, s.e.079) resulted in a decreased area under the curve. The addition of cervical unloading to the CTDT resulted in an AUC of 0.808, s.e. 0.079, however this minimal improvement in AUC was accompanied by a decrease in the sensitivity of the test compared to the CTDT alone (Fig. 4).

3. Discussion

The CTDT is a highly specific test, which appears to accurately identify individuals likely to experience immediate, clinically meaningful, changes in pain following cervical manipulation at both the MCID and 50% thresholds of improvement. For individuals with a positive CTDT the resulting positive predictive value was 96.4%, while a negative test result decreased the likelihood of improvement to 60%. When considered at the more rigorous 50% relief threshold, the positive predictive value remains strong at 89%, with a corresponding 50% negative predictive value. While promising, these values need to be interpreted with caution. Positive predictive values are known to increase in the presence of high levels of prevalence (Portney and Watkins, 2009). The overall sample in the current study had a very high prevalence (81.3%) of improvement following manipulation, which was significantly higher than the previously reported prevalence of 54% (Cleland et al., 2007b), perhaps due to differences in sampling methodology, outcome measures, or application of thoracic intervention.

Due to the relationship between prevalence in a sample and predictive values, consideration of likelihood ratios may be more clinically meaningful. Likelihood ratios (LR) are summary measures of diagnostic test performance, used to indicate how much a given diagnostic test will raise or lower the post-test probability, and are independent of prevalence. A positive LR (LR+) $\geq$2.0 or the negative LR (LR-) $\leq$ 0.50

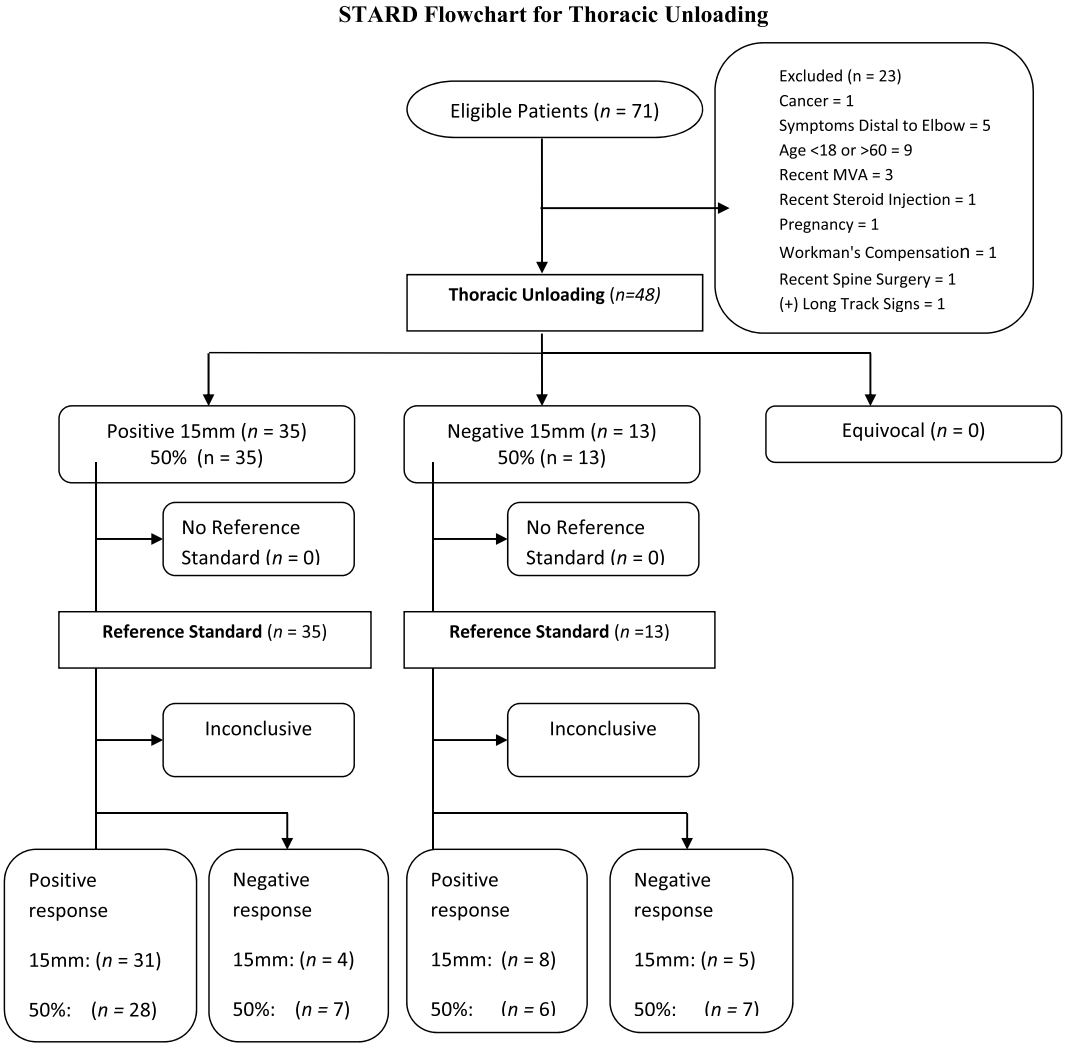


Fig. 3. STARD flowchart thoracic unloading.

Table 1
Participant demographics.

Age (yrs.)	30.79 ± 10.28 (range 18–59)
Gender	Female 30 (62.5%)
	Male 18 (37.5%)
NDI score	19.33 ± 9.78 (range 6–50)
Duration of symptoms	
Acute (< 6 weeks)	13 (27.1%)
Sub-acute (6–12 weeks)	6 (12.5%)
Chronic (> 12 weeks)	29 (60.4%)
Distribution of symptoms	
Neck only	31 (64.6%)
To scapula	16 (33.3%)
Above elbow	1 (2.1%)
Pain at rest	75%, mean 13.49 mm
	Range: 0–59 mm
Comparable sign	
Flexion	15
Extension	7
Right rotation	14
Left rotation	12

Table 2
Participant demographics by CTDT response.

	CTDT Positive (n = 28)	CTDT negative (n = 20)	P value
Age	31.41 ± 10.39	29.95 ± 10.34	.636
Gender	Female 17	Female 13	.769
	Male 11	Male 7	
NDI score	21.50 ± 10.63	16.30 ± 7.69	.069
Duration of symptoms			
Acute	6	7	
Sub-acute	3	3	.228
Chronic	.19	10	
Distribution of symptoms			
Neck only	18	13	
To scapula	9	7	.786
Above elbow	.1	0	
Comparable sign			
Flexion	10	5	
Extension	3	4	
Right rotation	6	6	.890
Left rotation	.9	5	
Cervical unloading response	Positive = 24	Positive = 18	
	Negative = 4	Negative = 2	.667
Thoracic unloading response	Positive = 20	Positive = 15	
	Negative = 8	Negative = 5	.789

may be meaningful, while LR + values ≥ 5 and LR-values ≤ 0.2 are considered to represent important effects (Portney and Watkins, 2009). As a stand-alone test, the CTDT was the only individual test to yield a

Table 3
2 x 2 Contingency Tables: MCID Improvement Threshold, 50% Improvement Threshold.

Test	Positive (improvement greater than MCID)	Negative (Improvement less than MCID)	Totals
CTDT positive	27	1	28
CTDT negative	12	8	20
totals	39	9	48
Cervical unload positive	35	7	42
Cervical unload negative	4	2	6
totals	39	9	48
Thoracic unload positive	31	4	35
Thoracic unload negative	8	5	13
totals	39	9	48
CTDT + cervical unload positive	24	0	24
CTDT + cervical unload negative	15	9	24
totals	39	9	48
CTDT + Thoracic unload positive	18	0	18
CTDT + Thoracic unload negative	21	9	30
totals	39	9	48
All three tests positive	16	0	16
Less than 3 tests positive	23	9	32
totals	39	9	48

Test	Positive (Improvement greater than 50%)	Negative (Improvement less than 50%)	Totals
CTDT positive	24	4	28
CTDT negative	10	10	20
totals	34	14	48
Cervical unload positive	30	12	42
Cervical unload negative	4	2	6
totals	34	14	48
Thoracic unload positive	28	7	35
Thoracic unload negative	6	7	13
totals	34	14	48
CTDT + cervical unload positive	21	3	24
CTDT + cervical unload negative	13	11	24
totals	34	14	48
CTDT + Thoracic unload positive	16	2	18
CTDT + Thoracic unload negative	18	12	30
totals	34	14	48
All three tests positive	14	2	16
Less than 3 tests positive	20	12	32
totals	34	14	48

LR + greater than 2.0 (LR+ 6.23). The addition of cervical unloading to the CTDT did result in a significantly higher value (LR+ 12.25), but the addition of this extra test into a battery resulted in lower sensitivity, while not substantially changing the area under the ROC curve or the diagnostic accuracy. As with all diagnostic tests, with a shift to a higher criterion value, there is improved specificity and fewer false positives, at the expense of lower sensitivity and smaller true positive fraction (Portney and Watkins, 2009). When considering the use of thoracic thrust manipulation, the addition of additional tests to the CTDT did not shift the probability of success to a meaningful extent. This suggests that the CTDT can be considered as a single test as part of the clinical decision-making process for the treatment of individuals with neck pain.

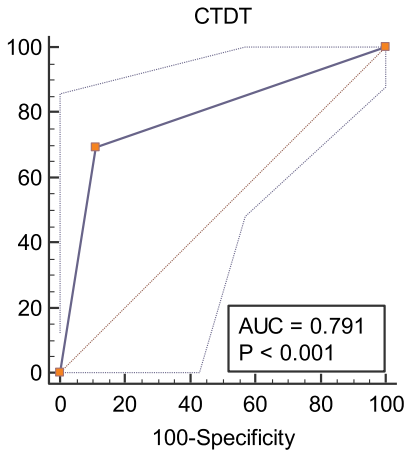
The use of thoracic manipulation in lieu of cervical manipulation has been suggested as a means to mitigate the risk associated with cervical manipulative techniques (Cleland et al., 2005; Erhard RE Piva, 2000), and may result in equivalent effects (Martínez-Segura et al., 2012). Despite the relative safety of thoracic manipulation, rare but serious complications have been reported (Puentedura and O'Grady, 2015). The clinical use of diagnostic tests such as the CTDT, which indicate an improved probability of success following a thoracic manipulation intervention, should be considered as a means to further mitigate undue risk. Based on the established metrics of the CTDT at the MCID threshold, it appears that this test may allow the clinician to better assess the possible risk-benefit ratio in the use of

Table 4
Diagnostic accuracy.

TEST	Sensitivity	Specificity	LR +	LR-	Prevalence	PPV	NPV	Accuracy
CTDT 15 mm	69.23 [57.43–82.98]	88.89 [51.75–99.72]	6.23 [0.97–40.01]	0.35 [0.20–0.58]	81.25 [67.37–91.05]	96.43 [80.79–99.43]	40.00 [28.30–52.97]	72.92 [58.15–84.72]
CTDT 50%	70.59 [52.52–84.90]	71.43 [41.90–91.61]	2.47 [1.05–5.82]	0.41 [0.22–0.76]	70.83 [55.94–83.05]	85.71 [71.82–93.39]	50.00 [35.04–64.96]	70.83 [55.94–83.05]
Cervical Unloading 15 mm	89.74 [75.78–97.13]	22.22 [2.81–60.01]	1.15 [0.80–1.66]	0.46 [0.10–2.14]	81.25 [67.37–91.05]	83.33 [77.13–87.81]	33.33 [9.73–69.88]	77.08 [62.69–87.97]
Cervical Unloading 50%	88.14 [72.55–96.70]	14.29 [1.78–42.81]	1.03 [0.80–1.32]	0.82 [0.17–3.99]	70.83 [55.94–83.05]	71.43 [66.14–76.19]	33.33 [9.34–70.81]	66.67 [51.59–79.60]
Thoracic Unloading 15 mm	79.49 [63.54–90.70]	55.56 [21.20–86.30]	1.79 [0.85–3.78]	0.37 [0.16–0.86]	81.25 [67.37–91.05]	88.57 [78.58–94.24]	38.46 [21.08–59.40]	75.00 [60.40–86.36]
Thoracic Unloading 50%	82.35 [65.47–93.42]	50.00 [23.04–76.96]	1.65 [0.95–2.84]	0.35 [0.14–0.86]	70.83 [55.94–83.05]	80.00 [69.84–87.36]	53.85 [32.27–74.07]	72.92 [58.15–84.72]
CTDT + Cervical Unloading 15 mm	61.54 [44.62–76.64]	100 [66.37–100]	12.25[a] [0.81–184.63]	0.38 [0.26–0.57]	81.25 [67.37–91.05]	100	37.5 [28.74–47.16]	68.75 [53.75–81.34]
CTDT + Cervical Unloading 50%	61.76 [43.56–77.83]	78.57 [49.20–95.34]	2.88 [1.02–8.13]	0.49 [0.29–0.81]	70.83 [55.94–83.05]	87.50 [71.27–95.18]	45.83 [33.75–58.43]	66.67 [51.59–79.60]
CTDT + Thoracic Unloading 15 mm	46.15 [30.09–62.82]	100 [66.37–100]	9.25[a] [0.61–140.72]	0.54 [0.40–0.72]	81.25 [67.37–91.05]	100	30.00 [24.27–36.43]	56.25 [41.18–70.52]
CTDT + Thoracic Unloading 50%	82.35 [65.47–93.24]	50.00 [23.04–76.96]	1.65 [0.95–2.84]	0.35 [0.14–0.86]	70.83 [55.94–83.05]	80.00 [69.84–87.36]	53.85 [32.27–74.07]	72.92 [58.15–84.72]
All 3 tests positive 15 mm	41.03 [25.57–57.90]	100 [66.37–100]	8.25[a] [0.54–126.10]	0.59 [0.45–0.77]	81.25 [67.37–91.05]	100	28.12 [23.15–33.70]	52.08 [37.19–66.71]
All 3 tests positive 50%	41.18 [24.65–59.30]	85.71 [57.19–98.22]	2.88 [0.75–11.05]	0.69 [0.48–0.98]	70.83 [55.94–83.05]	87.50 [64.60–96.41]	37.50 [29.65–46.07]	54.17 [39.17–68.63]

[a] Calculated based on 0.5 added to all cells.

ROC Curve, Cervicothoracic Differentiation Test, 15mm MCID



ROC Curve, Cervicothoracic Differentiation Test + Cervical Unloading, 15mm MCID

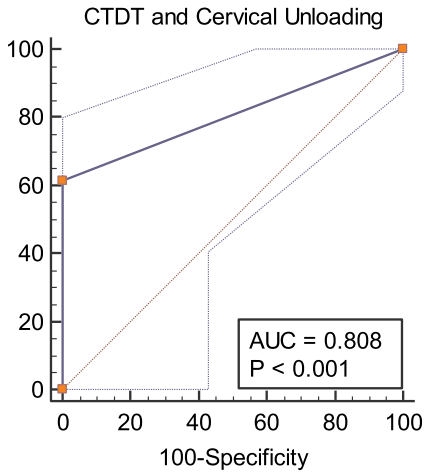


Fig. 4. ROC curves.

manipulation. In the current study, there was only one individual (1/28) who presented with a positive CTDT but did not improve following manipulation (7 mm increase in pain post intervention). In most cases, the CTDT in isolation provides good utility to assist in the prognostic decision-making process. Use of this test may serve to mitigate any undue risk for the patient, particularly those less likely to benefit from manipulative therapy.

Multiple studies have assessed pain as a measure of the efficacy of thoracic manipulation, however the pain has generally been measured at rest (Cleland et al., 2005; Karas and Olson Hunt, 2014). We opted to base our outcome on change in pain in the most provocative position, or what Maitland would call the “asterisk” or “comparable sign” (Maitland, 1986), for several reasons. In our clinical experience it is not uncommon for patients to report a transient increase in soreness at rest following thoracic manipulation, which is in line with published reports (Puentedura and O'Grady, 2015). Overall levels of resting pain were, on average, quite low (mean 13.49 mm) and the levels of pain relief experienced at rest were similar to previous studies (Cleland et al., 2005). This low resting pain level may have resulted in a floor effect, where more significant change could not be measured, and may partially account for the greater changes in pain observed during motion than at rest. Asking participants to assess change in pain with movement may also allow for a more clear differentiation of change following intervention (Cook et al., 2015; Maitland, 1991; Tuttle, 2005), and the reassessment of the concordant motion is consistent with clinical practice (Maitland, 1986).

The current results demonstrated a meaningful difference between individuals based upon CTDT results. The significant differences between the two groups observed following alterations of movement patterns and loading support the hypothesis that a biomechanical dysfunction, such as a movement restriction, is at least partially contributory to the patient's experience of pain. This is in contrast to previous research which has demonstrated that interventions directed at clinician identified impaired segments in the cervical spine were no more beneficial that treatments directed at random segments (Haas et al., 2003), and it has been suggested that specificity may not be important in the application of manipulation (de Oliveira et al., 2013; Vicenzino et al., 1996). This non-specific effect has been partially explained by the neurophysiologic mechanisms known to result from manipulative therapy (Coronado et al., 2012; Bialosky et al., 2009). While we are unable to conclude that identification of a specific level of dysfunction is required, identification of the mechanically sensitive region resulted in clinically meaningful shifts in the probability of success, and appears to offer a prognostic indicator for the immediate effects of manipulative treatment beyond the previously identified global effects.

There were several notable limitations to this study. Outcome measures only included the use of immediate term measurements of a single factor (pain), and there were no additional measurements or follow-up testing performed. Since longer-term effects of treatment were not evaluated, it is not possible to say whether improvements in the immediate-term resulted in any significant carry-over or functional improvements. All participants in this study underwent a minimum of three diagnostic tests as part of the data collection process. The effects of repeated testing may confound the interpretation of single test results, therefore progressive changes in pain response to multiple tests cannot be ruled out. A different study design would be required to eliminate this confounder, but such a design would not allow for the comparison of response to different tests in a single participant, and would be less like the actual clinical application of these tests. The participants enrolled into this study were not consecutive, but rather a sample of convenience and the possibility of a selection bias cannot be eliminated. Estimates of prevalence presented in this report should therefore be interpreted cautiously; the calculations of predictive values in a sample selected based on the presence of neck pain may not be generalizable to other patient populations. The observed prevalence of 81.3% is much higher than previous reports of improvement following thoracic manipulation, and therefore higher than the 60% estimate utilized to establish sample size. While this was unforeseeable, based on the observed prevalence a sample size of approximately 100 participants would have been required to achieve 80% power. The point estimates of the sensitivity, specificity, and likelihood ratios for most test items were associated with wide 95% CIs, and these estimates should also be interpreted with caution. While these early results are certainly promising, further research is required to refine the point estimates for this test.

4. Conclusions

The CTDT is an easy to apply mechanical test which assists with the identification of patients with neck pain who may experience immediate pain relief beyond MCID following thoracic manipulation. Based on the meaningful positive likelihood ratios, strong positive predictive values, and high specificity at the 15 mm improvement threshold, the CTDT should be considered as part of the clinical decision-making process when thoracic manipulation is considered during the treatment of individuals with neck pain, however further research is required to confirm these findings.

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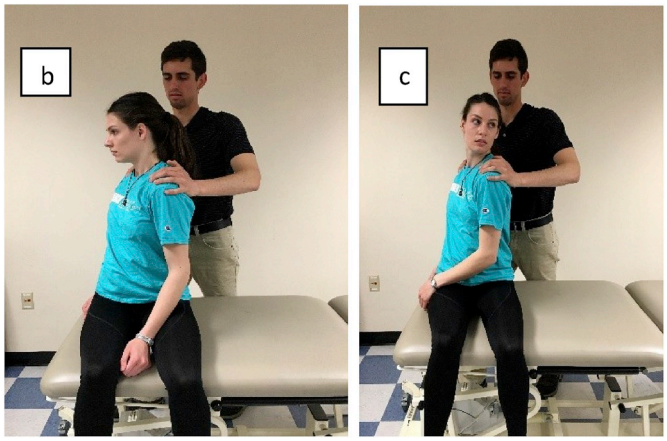
Appendix 1

Cervico-thoracic differentiation test

The participant was seated, with the therapist standing behind the participant.

(a) The participant was asked to turn their head in the painful direction until their pain came on.
The investigator then measured the rotational ROM with a standard goniometer to provide a reference point in the event that pain is unchanged in the presence of improved ROM.
The participant then returned to the neutral midline posture.
(b) The participant was then asked to turn their body (thoracic spine) in opposite direction. The therapist helped to maintain this body position.
(c) The participant was then asked to turn their head in the painful direction again until their pain came on.

The participant was asked to report their pain as “better”, “worse”, or “the same”.
In the event that the participant reported “the same”, a repeat measure of ROM was taken.



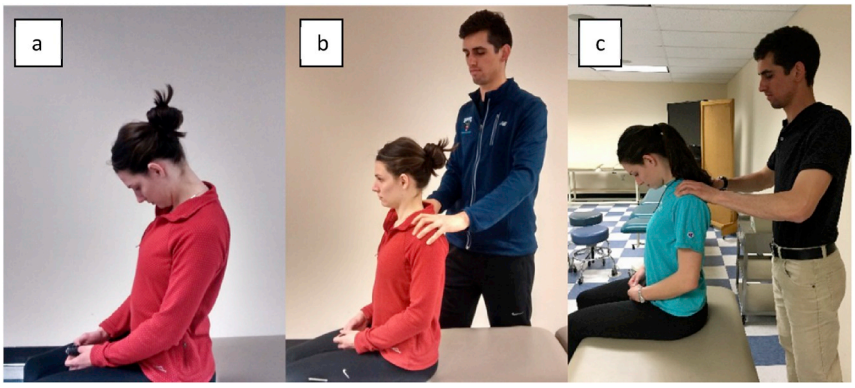
Results were determined as positive if the participant rated their pain as “better” or “the same” but demonstrated substantially more range of motion before onset of pain. The operational definition for this study was a 10° increase in ROM.

Results were determined to be negative if the participant reported “worse”, or “the same” with no improvement of ROM.

Variation 2

Most painful cervical flexion

a) The participant flexed to the point of pain
b) The participant extended their thoracic spine, with this position maintained by the investigator
c) While in this position, the participant again flexed their neck

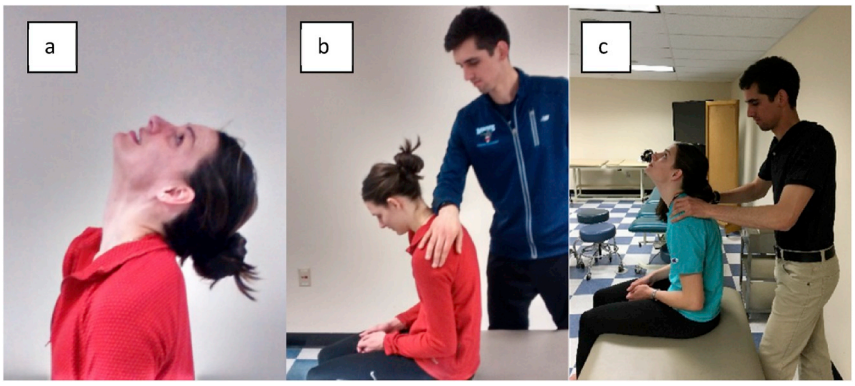


Variation 3

Most painful cervical extension

a) The participant extended their neck to the point of pain
b) The participant flexed their thoracic spine, with this position maintained by the investigator

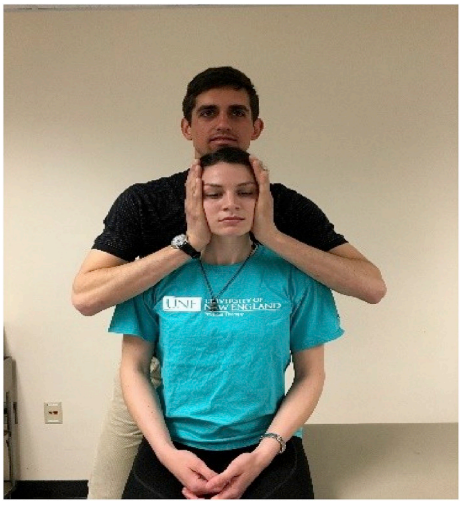
c) While in this position, the participant again extended their neck



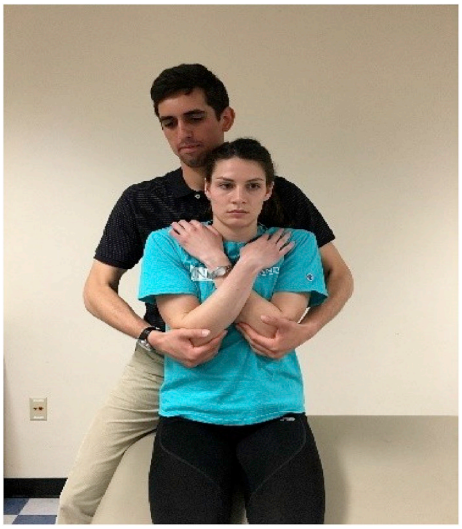
Unloading tests

The participant was seated, with the investigator standing behind the participant. If the participant experienced pain at rest, the unloading tests were performed in neutral. If the participant experienced pain only with movement, then the participant was asked to move their head in the direction of their pain until their pain JUST BEGAN. The investigator then performed two tests in this position.

Cervical Unloading: The investigator gently lifted upward on the participants head to unload the spine. The participant was asked to report their pain as “better”, “worse”, or “the same”.



Thoracic Unloading: The investigator lifted upward via the participant's elbows with the arms crossed across the chest. The participant was again asked to report their pain as “better”, “worse”, or “the same”.



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