

The intra-rater reliability of measured thoracic spine mobility in chronic rotator cuff pathology

V.B. Anderson

Centre for Health Exercise and Sports Medicine, The University of Melbourne, Australia

Abstract

Objectives: The relationship between thoracic spine dysfunction and painful shoulder pathologies is poorly understood. This study sought to determine the intra-rater reliability of a protocol aimed at assessing the active mobility of the thoracic spine in individuals with chronic rotator cuff pathology. **Methods:** Ten individuals (6 men and 4 women) with chronic rotator cuff pathology were recruited and screened according to strict criteria. Voluntary active thoracic spine motion was recorded in two planes using a multidimensional motion analysis system. Each assessment was undertaken on two occasions, two days apart. **Results:** The dominant upper-limb was affected in the majority of cases. There were no statistically significant differences between sessions during measurement of thoracic extension ($p=0.93$), lateral flexion towards the affected side ($p=0.09$), and lateral flexion away from the affected side ($p=0.38$). Intraclass correlation coefficients for each of the thoracic spine movements ranged from 0.968 to 0.995. No significant difference was observed between thoracic lateral flexion between sides. **Conclusions:** Excellent intra-rater reliability of the test protocol was observed among individuals with chronic rotator cuff pathology. Future studies assessing impairment among these disorders should interpret results in light of these reliability measurements.

Keywords: Rotator Cuff, Reliability, Spine

Introduction

Painful shoulder disorders are a frequent cause of morbidity and reduced function^{1,2}. Although precise diagnostic boundaries and classifications are unclear, chronic rotator cuff pathology (CRCP) is thought to be the most common painful shoulder disorder³. It encompasses a range of related conditions associated with impingement, glenohumeral instability, and musculotendinous damage within the rotator cuff. Many clinicians who treat CRCP observe a kyphotic posture, with a corresponding reduction in the mobility of the thoracic spine, particularly during extension movements^{4,5}. Such (mal)adaptations of the cervical and thoracic spines are thought to be as-

sociated with dysfunctional movement patterns⁶⁻⁹, though there is considerable confusion regarding which causes which, and the relationships between these scapulothoracic changes have not been adequately investigated in individuals with shoulder disorders.

In an asymptomatic population, the biomechanical effects of reducing mobility in the thoracic spine revealed a strong relationship between range of arm elevation and range of thoracic extension among subjects¹⁰. Yet despite this association, there are surprisingly few investigations that have assessed thoracic spine mobility in shoulder disorders¹¹. The study of Meurer and colleagues utilised inclinometry to assess thoracic mobility in the sagittal and coronal planes in individuals with shoulder impingement. However, that study was limited in so far as reliability was not reported, the applied tools for measurement are adversely affected by body contour, and have been demonstrated to be relatively inaccurate¹².

Reliability concerns the extent to which a measurement is consistent and free from error, relative to the true component of the measurement^{13,14}. Adequate intra-rater reliability ensures that an instrument and/or individual is capable of measuring a variable with consistency¹⁵. However, experimental muscle pain has been demonstrated to reduce consistency of muscular performance^{16,17} and the concept of population-specific reli-

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Corresponding author: Dr Vincent B. Anderson, Centre for Health Exercise and Sports Medicine, The University of Melbourne, Parkville VIC 3010, Australia

E-mail: v.anderson2@pgrad.unimelb.edu.au

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bility means that greater variability may exist in individuals with painful disorders such as CRCP. It is therefore important to establish reliability figures as a precursor to the valid assessment of mobility in these individuals.

Aside from radiographic methods, many non-invasive techniques have been used to assess the static posture of the thoracic spine, including sagittal inclinometers^{18,19}, DeBrunner's kyphometer²⁰, a flexicurve ruler^{20,21}, and photogrammetry. In a laboratory setting, the extension of the application of these superficial techniques to record the dynamic spine may be a useful means of mobility assessment. A three-dimensional motion analysis system manufactured by Vicon Peak (Oxford, United Kingdom), uses infrared cameras to record the position and movements of superficial skin markers within a data capture area. It has been extensively utilised for the kinematic assessment of limb motion during human gait, and its' adequate reliability in this field has recently been demonstrated²². However, its reliability for the technique of assessing spinal mobility has not yet been established.

The aim of this study was to investigate the intra-rater reliability of thoracic spine range of movement in individuals with CRCP using a multidimensional motion analysis system. Using pre-established guidelines for statistical interpretation of reliability, it was hypothesised that these investigations would be sufficiently reliable in both the sagittal and coronal planes.

Materials and Methods

Participants

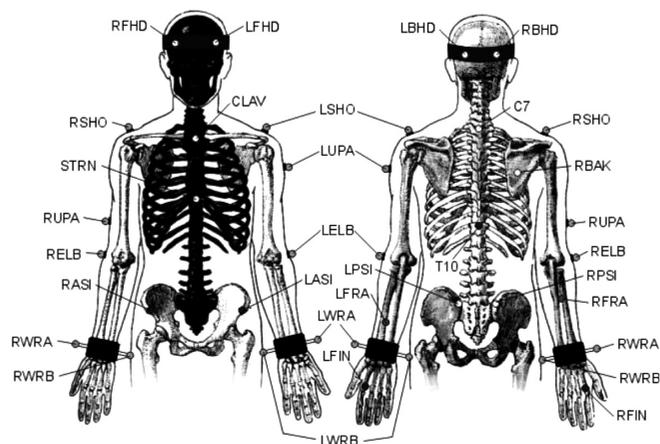
Individuals with CRCP were recruited from metropolitan orthopaedic and rheumatology clinics at selected hospital in Melbourne, Australia. All potential participants were screened by an experienced musculoskeletal clinician at the Centre for Health Exercise and Sports Medicine, The University of Melbourne, Australia. To meet criteria for inclusion, participants were required to have greater than 3 months of shoulder pain associated with active abduction or external rotation, of intensity greater than 3/10 on a visual analogue scale, and a positive Neer impingement test. All criteria were required to be met for inclusion. Exclusion criteria included shoulder pain intensity greater than 7/10, or any radiological or clinical evidence of a complete rotator cuff tear. Participants were also required to be free of history that included systemic inflammatory arthropathies, prior fracture, surgery, or active interventions (such as physiotherapy or corticosteroid injections) affecting the shoulder or thoracic spine in the preceding 3 months. The minimum sample size for repeated measures analyses was based on the work of Donner and Eliasziw²³. By applying an expected minimum reliability of 0.80, alpha of 0.05, and the number of measures equal to two (test and retest), this value was determined to be 9.2. In accordance with the Declaration of the World Medical Association, institutional ethics approval was gained prior to commencement of this study and all participants provided written informed consent.

Procedure

To determine intra-rater reliability for the measures of thoracic extension and lateral flexion, assessment measures were repeated on two occasions. On the first assessment, additional demographic data (age, height and weight) was also collected. The interval between assessments was two days, to minimise deleterious effects associated with the first assessment, yet sufficiently short to ensure no actual change in acuity occurred. The examiner who applied the markers, the test methodology and all equipment remained identical between assessments.

Twenty-seven reflective markers of 10 mm diameter were affixed to skin, and their movements and position relative to a local coordinate area captured by six infra-red cameras (Vicon Systems *m-series* camera and 20 mm lens). The anatomical positions of these markers were according to the Vicon plug-in-gait (upper-body) model (Figure 1). Axial markers were placed on the left front head (label LFHD), located over the left temporalis; right front head (RFHD), located over the right temporalis; left back head (LBHD), placed on the back of the head in the sagittal plane of LFHD; right back head (RBHD), placed on the back of the head in the sagittal plane of RFHD; over the spinous process of the seventh cervical vertebrae (C7SP); over the spinous process of the tenth thoracic vertebra (T10P); overlying the jugular notch of the sternoclavicular joint (CLAV) and overlying the xiphoid process of the sternum (STRN). Bilateral makers were placed overlying the superior aspect of the acromioclavicular joint (LSHO, RSHO); on the lateral epicondyle of the left and right humerii (LELB, RELB); on the dorsum of the head of the second metacarpal (LFIN, RFIN); on the anterior superior iliac spine of the pelvis (LASI, RASI), and on the posterior superior iliac spine of the pelvis (LPSI, RPSI). Participants also wore wrist cuffs bilaterally, each with a radial (LWRA, RWRA) and ulnar (LWRB, RWRB) marker attached via a 14 cm-long wand, positioned at the level of the dorsal wrist crease.

Figure 1. Positions of the 27 reflective makers according to the Vicon plug-in-gait (upper body) model (from Vicon Peak, Oxford, United Kingdom).



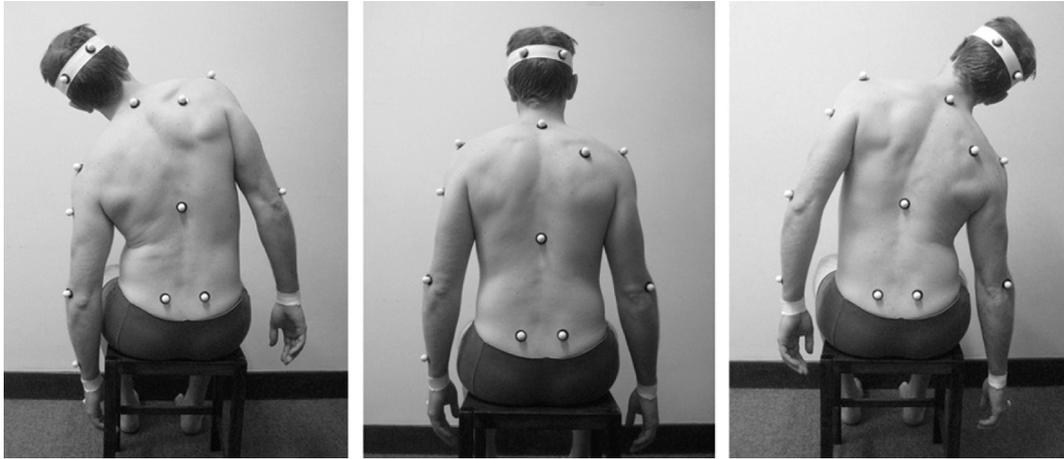


Figure 2. Experimental procedure demonstrating the midline position and placement of markers within the data capture area.

Prior to measurement, the sequence of the movements performed (extension and lateral flexion), and within that specification, the direction of the movement (lateral flexion towards/away from the affected side) was determined randomly by tossing a coin. Participants were seated on a stool 0.50 m high within the motion capture area of the Vicon cameras (Figure 2). Where required, an adjustable step was placed under the feet of participants to ensure that the hip and knee joints were flexed to 90° whilst in the sitting posture. Following a demonstration by the examiner, participants were instructed to move ‘as far as possible’ in the desired direction at a speed which they considered most comfortable. To ensure each movement was being performed correctly, two warm-up trials were permitted prior to measurement, and deviation from the desired plane of movement were corrected with feedback and further demonstration, where necessary. During the assessment of lateral flexion, participants were required to maintain the correct plane of movement by sliding the hand ipsilateral to the direction of movement along a vertical ruler. Participants received verbal feedback following each trial. The examiner also received real time feedback about the position and extent of thoracic and pelvic movement. Three maximal repetitions of each movement were captured in a continuous trial, with a minimum of 5 seconds rest enforced between repetitions.

Data Analysis

Following a static recording of the participant in the midline position (Figure 2), each point was labelled, and the relevant body segments were reconstructed. The vertices of each segment were defined by the relative positions of the reflective markers. At the thorax, the thoracic segment was defined by a polygon with vertices centred on CLAV, STRN, T10P and C7SP. Markers placed on LASI, RASI, LPSI and RPSI defined the vertices of the pelvic segment. Using Cartesian coordinates (X/Y/Z axes), the locations and orientations of both segments were recorded with Vicon Workstation software (Version 5.1, Vicon Peak, Oxford, United Kingdom).

During assessment of thoracic lateral flexion, the dynamic position of the thoracic segment relative to pelvic motion was recorded. The angular displacement of the thoracic segment from the midline position was measured, and the peak value obtained in the coronal plane was used for analysis. During assessment of peak extension, an equivalent measurement was undertaken in the sagittal plane. All participants performed three sequential trials of each motion, and the peak value from each trial was recorded. These three values were then averaged and used for analysis. This calculation was undertaken separately for extension, lateral flexion to the affected side, and lateral flexion to the unaffected side.

Statistical Analysis

All data were analysed to establish normality, and the coefficient of variation (CV) calculated as a normalised measure to assess the dispersion of values for each variable. A two-tailed, paired t-test was implemented to determine whether there were any significant differences between the test means for each session, and the intraclass correlation coefficient (ICC) used to assess between-session agreement. ICC (model 3,3) was considered the most suitable model as it uses a repeated measures analysis of variance, and is appropriate for testing intrarater reliability where the investigator is a fixed effect²⁴. The following guidelines for the clinical interpretation of reliability coefficients were used, based on the recommendations of other authors: ICC<0.50= poor, 0.50<0.75= moderate, 0.75<0.90= good, >0.90= excellent^{25,26}. While arbitrary in their divisions, the classification of ICC’s with these definitions provide a standardised baseline for discussion and interpretation. The standard error of measurement (SEM) was also calculated to quantify systematic error in the original units of measurement (degrees). This was calculated using $SEM = \sqrt{\text{root mean square}}$. The SEM represents the change required to show a significant difference, taking into account the amount of error associated with the measurement procedure^{14,27,28}.

Gender	Age (years)	Height (m)	Mass (kg)	Symptom duration (mo)	Upper-limb dominance	Affected side
Male	72.9	1.78	85.0	48	Left	Left
Male	55.5	1.75	72.0	18	Left	Right
Male	62.7	1.75	76.0	8	Right	Right
Female	84.3	1.60	67.0	24	Right	Right
Male	58.7	1.80	69.5	6	Left	Left
Male	56.6	1.83	75.0	18	Right	Right
Male	52.6	1.77	98.0	36	Right	Left
Female	57.3	1.54	57.0	7	Right	Right
Female	60.9	1.68	96.0	5	Right	Left
Female	62.8	1.63	67.0	18	Right	Right
Mean (SD)	62.4 (9.5)	1.71 (0.10)	76.3 (13.1)	18.8 (14.1)		

Table 1. Demographic statistics of the participants.

	mean (SD)	range of values	CV	t(p)	ICC _{3,3} (95% CI)	SEM (SD)
Extension 1 (°)	25.9 (9.9)	8.1-39.4	0.38	-0.09 (0.93)	0.995 (0.982-0.999)	0.9 (1.8)
Extension 2 (°)	25.9 (9.7)	7.5-39.7	0.37			
LF affected 1 (°)	34.4 (5.5)	27.2-42.3	0.16	-1.88 (0.09)	0.968 (0.872-0.992)	1.5 (2.9)
LF affected 2 (°)	35.7 (6.6)	28.6-46.5	0.18			
LF non-aff 1 (°)	34.5 (7.7)	23.1-46.8	0.22	-0.92 (0.38)	0.984 (0.934-0.996)	1.4 (2.8)
LF non-aff 2 (°)	35.1 (7.9)	22.4-50.4	0.23			

LF= lateral flexion, CV= coefficient of variability, CI= confidence interval

Table 2. Reliability of range of movement measurements for extension, lateral flexion to the affected side, and lateral flexion to the non-affected side between session 1 and 2.

Comparison between the range of thoracic lateral flexion towards and away from the affected side was made with a two-tailed, paired t-test. The alpha level for all comparisons was set at $p < 0.05$. All statistical analyses were undertaken using Statistical Package for Social Sciences software (SPSS, Version 15.0).

Results

Assessment of a consecutive sample of 10 adults with CRCP was conducted. The affected shoulder was ipsilateral to the dominant upper-limb in 70% of cases. Demographic results are displayed in Table 1. Of the movements assessed, the range of thoracic extension was the most variable measurement, with a spread of over 30° observed between subjects. Large between-subject variability was supported by the CV, where the magnitude during extension exceeded 35% (Table 2). No systematic bias was observed between sessions and the difference in mean scores was not statistically significant for any of the range of movement tests. ICC's ranged from 0.968 to 0.995 (excellent) for the three movements. Based on the SEM, 95% confidence intervals ranged from $\pm 1.8^\circ$ for extension to $\pm 2.9^\circ$ for lateral flexion. The magnitude of the mobility of the tho-

racic extension was found to be most reliable, with the mean range equal to 25.9° on both sessions, and an ICC of 0.995. There were no significant differences observed between the range of thoracic lateral flexion between sides during session one ($t=0.06$, $p=0.96$) or session two ($t=0.43$, $p=0.68$).

Discussion

This study is the first to investigate the intra-rater reliability of thoracic spine movements in individuals with CRCP. Using the interpretation guidelines developed by Spitzer and colleagues, the results of this study indicate excellent intra-rater reliability for measures of thoracic spine mobility using the Vicon system. Strictly defined criteria were used to select participants with CRCP, however the author acknowledges the heterogeneity of shoulder disorders and the limited size of the sample somewhat restrict the generalisability of the results. In addition, the magnitude of the CV for each movement highlighted a large between-subject variability; though this variability was seen for both assessment sessions.

The reliability of the current motion analysis system has not previously been evaluated in this region of the body, though it has been utilised to assess the kinematics of gait in a patho-

logical group²². McDermott and colleagues recently demonstrated ICC's ranging from moderate to excellent during the assessment of knee and hip joint angles. SEM's in that study equated to less than 4°. The size and demographics of the sample were similar to the present study, though the slight reduction in consistency may reflect an increase in time between assessments. At the thoracic spine, a similar study investigated the intra-rater reliability of inclinometry to assess the active range of motion for flexion, extension and lateral flexion in participants without thoracic pathology²⁹. Intra-rater reliability coefficients ranged from 0.79-0.86 for rater one and 0.48-0.88 for rater two. These authors concluded that inclinometry lacks the sensitivity to objectively monitor changes in thoracic range of movement. The improved magnitude of the reliability coefficients observed within the current study (ICC's ranged from 0.968 to 0.995) are at the expense of clinical convenience, as the application of the protocol is time consuming and such equipment is not routinely available in a standard clinical setting. However in a clinical context, the calculation of the SEM for the movements assessed in the present study means that one can be 95% certain that any measurement obtained is within 1.5° of the true measurement.

In comparison to the cervical and lumbar spines, the thoracic spine contributes less to total spinal movement in the coronal plane^{10,29,30}. This is due primarily to the position of the ribs and the orientation of the thoracic articular facets, though the impact of shoulder pathology on this balance remains largely unknown. In individuals with shoulder impingement, Meurer and colleagues demonstrated significantly reduced thoracic spine range of motion in both the sagittal and coronal planes¹¹. However in that study, no assessment of reliability was undertaken and the definition of shoulder impingement was imprecisely described. This makes it difficult to accurately interpret their findings, or make comparison to other samples of individuals. The current results suggest that the measures for lateral flexion were extremely consistent, both between sessions and between sides, with values ranging from 34.4° to 35.7°. A similar inclinometric study demonstrated a total range of motion in the coronal plane ranging from 41 to 48 degrees in individuals with low back pain¹⁸. However it is problematic to make direct comparison with this result due to differences in methodology - fundamentally a large variation exists in the bony landmarks utilised for measurement. The kinematic model utilised in the present study is somewhat limited in that the thoracic spine is defined as one segment. While a single segment was sufficient for characterising the intra-rater reliability of movement, future studies addressing sub-segmental mobility may provide further information and more precisely characterise the intricate nature of thoracic spine motion. There is a need to determine this in both primary upper-limb and thoracic spine pathologies.

Another limitation of the current kinematic model is the confounding effect of baseline thoracic posture. Individuals that exhibit an increase in the extent of the thoracic kyphosis may have impaired mobility (in particular during extension), though it was not possible to determine this using the defined

setup. The proposed variability in the resting posture and the heterogeneity of the spines assessed in CRCP may be associated with the large CV's observed.

Factors contributing to reliability

Importantly, the Vicon motion analysis system was re-calibrated at the commencement of each day of testing to ensure that any movement of the camera equipment between test sessions did not alter the accuracy of the obtained data. Range of movement testing is likely to improve following initial trials as a result of lengthening of the soft tissue, thus improving mobility^{30,31}. In order to minimise performance variability, participants were given standardised practice trials to become accustomed to the procedure. The mean of three trials was used for analysis of consistency, as it was thought this would be most representative of the individuals' actual performance, and has been used by other authors³². Guided by a standardised protocol, a sole investigator applied all the markers, performed all the measurements, and ensured that the same measuring equipment was used on both test occasions. All of these factors may have been beneficial in minimising the degree of systematic bias between sessions. No major trend towards increased or decreased mobility was seen on the second session, suggesting that neither a learning effect nor a fatigue effect impaired the assessment.

Conclusions

Using individuals with chronic rotator cuff pathology, the present study has demonstrated a satisfactory protocol for reliable measurement of thoracic spine extension and lateral flexion, though there was great variability observed between participants. This study serves as an initial step into better understanding the association between mobility of the thoracic spine and painful shoulder disorders. Future studies investigating thoracic spine mobility between individuals with CRCP compared to asymptomatic controls would be useful in highlighting whether the observed measures are representative of impairments. In doing so, rehabilitation targeted at improving mobility could be better justified and implemented.

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