Land, Helen, Gordon, Susan, and Watt, Kerrianne (2017) *Clinical assessment of subacromial shoulder impingement – which factors differ from the asymptomatic population?* Musculoskeletal Science and Practice, 27. pp. 49-56.

http://dx.doi.org/10.1016/j.msksp.2016.12.003

**Background:** To date, the significance of factors purported to be associated with subacromial shoulder impingement (SSI) and what differences, if any, are present in those with SSI compared to a matched asymptomatic population has not been identified. Gaining information about differences between people with SSI and asymptomatic people may direct clinicians towards treatments that impact upon these differences.

**Objective:** Compare the assessment findings of factors suggested to be associated with SSI; passive posterior shoulder range, passive internal rotation range, resting cervical and thoracic postures, active thoracic range in standing and scapula positioning between cases experiencing SSI and a matched asymptomatic group (controls).

**Study Design:** Case Control Study.

**Method:** Fifty one SSI cases and 51 asymptomatic controls were matched for age, gender, hand dominance and physical activity level. The suggested associated factors were measured bilaterally. Independent t-tests were used to compare each of these measurements between the groups. Any variables for which a significant difference was identified, were then included in a conditional logistic regression analysis to identify independent predictors of SSI.

**Results:** The SSI group had significantly increased resting thoracic flexion and forward head posture, as well as significantly reduced upper thoracic active motion, passive internal rotation range and posterior shoulder range than the matched asymptomatic group. No independent predictors of SSI were identified in conditional logistic regression analysis

**Conclusion**: Thoracic posture, passive internal rotation range and posterior shoulder range were significantly different between cases experiencing SSI and a matched asymptomatic group.

**Level of Evidence:** Level 3a

***Key Words:*** *Subacromial, Impingement*, *Posterior Shoulder, Posture, Scapula*

**INTRODUCTION**

Multiple types of subacromial shoulder impingement (SSI), (intrinsic, extrinsic and internal), each with different underlying pathomechanical causes, have been proposed (Braman, Zhao, Lawrence, Harrison, & Ludewig, 2013; Jeremy. S Lewis, Green, & Dekel, 2001; Michener, McClure, & Karduna, 2003). Anterolateral catching or aching shoulder pain, without a history of trauma, emanating from the rotator cuff tendons, subacromial bursa, biceps tendon and shoulder capsule or a combination of these structures is characteristic of SSI (Jeremy. S Lewis et al., 2001; Michener et al., 2003). Forty to 60 years of age is reported as the peak age for SSI (Ostor, Richards, Prevost, Speed, & Hazleman, 2005; van der Windt, Koes, de Jong, & Bouter, 1995) with an increased prevalence of these symptoms reported in occupations and athletes who perform frequent overhead activities (P.M. Ludewig & Cook, 2000).

Extrinsic SSI is where “inflammation and degeneration of the tendon occur as a result of mechanical compression by some structure external to the tendon” (Michener et al., 2003). The mechanical factors external to the tendon which may potentially lead to SSI include restriction of the capsule and soft tissues of the posterior shoulder (N. Hanchard, Cummins, & Jeffries, 2004; Michener et al., 2003), altered cervical and/or thoracic posture (N. Hanchard et al., 2004; Jeremy. S Lewis et al., 2001; Michener et al., 2003), altered scapula movement (J.D. Borstad & Ludewig, 2002; P.M. Ludewig & Cook, 2000; Timmons et al., 2012) and dysfunction or weakness of the rotator cuff musculature (Brox et al., 1999; N. Hanchard et al., 2004; Leroux et al., 1994; Michener et al., 2003; Reddy, Mohr, Pink, & Jobe, 2000;

Sorohan & Mc Creesh, 2009; Warner, Micheli, Arslanian, Kennedy, & Kennedy, 1990).

Glenohumeral instability has been suggested as a contributing mechanism to SSI due to excessive humeral head translation with arm movement resulting in irritation of the same structures within the subacromial space (Jeremy. S Lewis et al., 2001; Paula.M. Ludewig & Cook, 2002; Warner et al., 1990). However, clinical presentation and conservative and operative treatments differ for SSI with related instability and SSI without instability,(Braman et al., 2013) therefore studies investigating SSI should not group those found to have signs of shoulder instability with those who don't.

In the clinical setting, physiotherapists use past clinical experience, history taking and examination to diagnose SSI. Factors affecting the width of the subacromial space are included in the examination to assist in the diagnosis of SSI and guide the therapist to provide the most appropriate advice and treatment (Sorohan & Mc Creesh, 2009). Orthopaedic special tests currently used to reproduce subacromial pain have either high specificity or high sensitivity, but not both, meaning that no one test can be accurate in diagnosing SSI (Calis et al., 2000; Cleland, 2007; Hegedus, 2012; Sorohan & Mc Creesh, 2009). Hence a minimum of three positive orthopaedic special tests (Michener, Walsworth, Doukas, & Murphy, 2009; Park, Yokota, Gill, Rassi, & McFarland, 2005) and an appropriate history are proposed for diagnosis of SSI.

Evidence based guidelines for the clinical examination of SSI recommend including measurement of shoulder range of motion, cervical and thoracic posture and dynamic scapula motion in addition to orthopaedic special tests (N. Hanchard et al., 2004). Few studies have described and compared these physical attributes in an asymptomatic group and a SSI group, with most comparative studies examining a single physical factor in isolation. Reduced posterior scapula tilt in the sagittal plane and an elevated position of the scapula in maximum arm elevation was identified, using a 3D electromechanical digitiser, in those with SSI compared to an asymptomatic group (Lukisewicz, McClure, Michener, Pratt, & Sennett, 1999). Reducing thoracic spine kyphosis has been shown to increase the range of shoulder flexion and scapular plane abduction in those with SSI and those without (Jeremy. S. Lewis, Wright, & Green, 2005) and posterior shoulder restriction has been quantified in those with SSI compared to an asymptomatic group using a side lying clinically valid measurement technique (Tyler , Nicholas, Roy, & Gleim, 2000). However, examination of only one factor between these groups does not consider the dynamic relationship between biomechanical and anatomical factors of the shoulder girdle (Jeremy. S Lewis et al., 2001). Comparison between published studies is difficult with significant variation in participant demographics and diagnostic criteria used to identify SSI.

To date, the significance of factors purported to be associated with SSI and what differences, if any, are present in those with SSI compared to a matched asymptomatic population has not been identified. Gaining information about differences between people with SSI and asymptomatic people may direct clinicians towards treatments that impact upon these differences.

This study describes and compares the assessment findings of passive internal rotation shoulder range, posterior shoulder range, passive cervical and thoracic postures, active thoracic range in standing and scapula positioning between those diagnosed with SSI and an asymptomatic group. Participants were matched for age, gender, hand dominance and physical activity level. The hypothesis was that there would be a difference in these physical assessment findings between the groups.

## METHODS

### Participant Information and Consent

Ethical approval for this study was granted by the James Cook University (JCU) Human Ethics Committee (approval: H3945). Written informed consent was obtained from each of the participants.

Participants were recruited from the Townsville community and clients presenting to the JCU Physiotherapy Clinic between June 2011 and July 2013. Recruitment for both groups was via emails and word of mouth to University staff, students and their extended networks. In addition, case recruitment used an advertisement in the local Townsville press and in the waiting area of the clinic. Cases identified with the advertisement ‘Do you feel a sharp catch in your shoulder when raising your arm which eases when you lower your arm down? Is this making it difficult for you to wash your hair or reach up into an overhead cupboard or get your shirt on easily? Is it becoming painful to lie directly onto that shoulder at night?’ They then contacted the investigator who arranged an assessment to determine eligibility. Controls were asked to be between 40 and 60 years of age with no history of shoulder, neck or upper back injuries and no reports of painful symptoms in any of these areas in the previous twelve months. Both groups were required to meet the inclusion criteria.

### Power Analysis

A pre-study sample size calculation was performed based on shoulder passive internal rotation range in those with SSI and those without (mean difference $9^0$, (Tyler  et al., 2000) standard deviation $12^0$ (John.D. Borstad et al., 2007) ) with alpha = 0.05 and power 0.8.(Altman, 1991) A minimum of 45 cases and 45 controls was calculated to be needed. However, values for the postural and scapula measurements were not available from the literature. Ethical approval was obtained to recruit up to 100 participants in each group, if available, to ensure the results were robust.

**Inclusion and Exclusion Criteria**

Forty to 60 year old participants were recruited for this study to reflect the reported peak age for SSI (Ostor et al., 2005; van der Windt et al., 1995). Symptom free volunteers as well as people with unilateral shoulder pain completed a screening questionnaire to determine their eligibility for this study. The questionnaire was used to exclude participants, in both the case and control groups, who had:

- Been participating in intense shoulder strength training during the 6 months prior to entering the study. This was defined as high load upper body weight training two or more times per week.
- Recent (within previous two years) or current pregnancy. This exclusion was necessary due to the effect of ligamentous laxity and postural changes associated with pregnancy.
- Previously undergone shoulder surgery or suffered a fracture of the shoulder girdle
- Glenohumeral instability identified by a grade 2 or 3 anterior, posterior or inferior load and shift test (assessed objectively) or a history of shoulder dislocation

- Scoliosis (also observed visually)
- Been experiencing cervical or thoracic pain currently or had in the previous six months
- Diagnosed systemic or neurological disease (Type 2 diabetes was not screened for)
- Shoulder corticosteroid injection at any time in the past

If the questionnaire indicated they were eligible, a physical assessment was conducted on both the case and control volunteers.

In order to rule out other shoulder diagnoses and focus only on SSI, case group participants had:

- a minimum of three positive orthopaedic special tests, (Michener et al., 2009; Park et al., 2005). Hawkins-Kennedy (Hawkins & Kennedy, 1980) and/or Neer (Neer, 1983) must be positive along with two of the following: external rotation resistance test (Michener et al., 2009), tendon palpation (N. Hanchard et al., 2004), horizontal (cross-body) adduction (Park et al., 2005), painful arc (Kessel & Watson, 1977), drop arm test (Park et al., 2005), Yergason test (Dalton, 1989), Speed test (Dalton, 1989; Park et al., 2005)
- ‘catching’ or aching pain without appreciable joint stiffness (N. C. A. Hanchard & Handoll, 2008)
- a painful arc elicited with pain easing on lowering the arm (N. Hanchard et al., 2004)
- pain localized to the anterior or antero-lateral-superior shoulder (Jeremy. S Lewis et al., 2001)
- insidious onset of symptoms with a possible history of gradual progression over time but without history of trauma (Bigliani & Levine, 1997)

- xray or ultrasound scans revealing osteophytes within the subacromial region, calcification of tendons or large rotator cuff tears . Alterations in acromial shape and bursal thickening were noted but did not prevent inclusion

**Procedure**

Prior to commencing the assessment the shoulder pain and disability index (SPADI) was completed to further describe the SSI group. This validated outcome measure was developed to measure pain and disability associated with shoulder impairment (Roach, Budiman-Mak, Songsiridej, & Lertratanakul, 1991) and has been found to be suitable for assessment of SSI syndrome (Dogu, Sahin, Ozmaden, Yilmaz, & Kuran, 2013). The visual analogue scale (VAS) was used to obtain pain measurements when at rest and when pain was felt (Jensen, Karoly, & Braver, 1986). Physical activity level was established by completing the short form of The International Physical Activity Questionaire (IPAQ)  (Craig et al., 2003). The IPAQ assesses three specific types of activity (1) walking (2) moderate-intensity activities such as cycling for transport and yard work (3) vigorous intensity activities such as running and boxing. Duration (in minutes) and frequency (days) of activity is recorded, combined with a rating of low, medium or high physical activity.

All testing was performed by an experienced musculoskeletal physiotherapist with over 20 years clinical experience, with both shoulders being measured in all participants.

The physical assessment order for all participants was as follows:

1. Assessment of scoliosis by observing the forward trunk flexion test (Bunnell, 2005).

2. Lateral linear measurements of each scapulae, in each participant, were taken in standing using the three positions described for the lateral scapula slide test (Kibler, 1998). (Detailed in Appendix B)
3. Passive range of glenohumeral internal rotation in supine was measured using a universal plastic goniometer(Clarkson, 2000; Riddle, Rothstein, & Lamb, 1987)(Clarkson, 2000; Riddle, Rothstein, & Lamb, 1987). (Detailed in Appendix B)
4. Posterior shoulder tightness was assessed using Tyler's Method, in centimetres, with randomization of the side measured first (Tyler , Roy, Nicholas, & Gleim, 1999). (Detailed in Appendix B)
5. Three sagittal view photographs were taken for the posture and thoracic range assessment (Edmondston et al., 2011). *(a)* relaxed resting posture: The participant stood at 90 degrees in a direct line to a JVC hard disc camcorder positioned on a tripod. A spirit level was used on top of the camera and the front of the lens to confirm horizontal and vertical alignments of the camera respectively. The camera distance from each subject was standardized to 2 metres with the tripod position maintained using tape on the floor. Floor markers were used to standardize the participant position. Markers were attached to the spine using double sided tape. Markers were placed overlying C7, the apex of the mid thoracic curve and overlying T12 (Edmondston et al., 2011). The assessor demonstrated to the participant the postures to be adopted. The subject was instructed to roll their shoulders forward and back three times and then stand relaxed in their normal posture (B. H. Greenfield et al., 1995). The first photo was taken. *(b)* thoracic flexion: The subject was then instructed to round their back as much as possible and

the second photo was taken. *(c)* thoracic extension: The subject was then instructed to extend their back as much as possible and the third photo was taken. (Detailed in Appendix B)

An intra-rater reliability study, completed with eight unrelated asymptomatic volunteers, was conducted in preparation for this study and included:

1. Measurement of posterior shoulder range
2. Scapula linear measurements
3. Goniometry measurement of internal rotation in supine

These measurements were recorded bilaterally for each volunteer one week apart, on the same day of the week and the same time of the day.

An inter-rater reliability study, using two experienced musculoskeletal physiotherapists, was conducted for measurement of postural angles using Image Tool software.

**Data Analysis**

The following postural measurements were calculated using the digital images:

1. Craniovertebral angle (CVA) is a gross measure of the amount of forward positioning of the head on the trunk. The CVA is the angle, in degrees, of the horizontal line intersecting with a line drawn from the tragus of the ear to the spinous process of C7 (Grimmer-Somers, Milanese, & Louw, 2008).
2. *Upper thoracic resting posture was measured in degrees from the apex of the mid-thoracic curvature to spinous process of C7 and true vertical (Details in Appendix C).
3. Active movement of upper thoracic flexion through extension was calculated in degrees as the difference in upper thoracic extension – upper thoracic flexion.

4. *Lower thoracic resting posture was measured in degrees from T12 spinous process to the apex of the mid-thoracic curvature and true vertical. (Details in Appendix C).
5. Active movement of lower thoracic flexion through extension was calculated in degrees as the difference in lower thoracic extension – lower thoracic flexion.

* = A positive angle denotes a flexion angle. A negative angle denotes an extension angle.

Postural angles were calculated from lateral photographs using digitising software UTHSCSA Image Tool (Wilcox, Dove, Doss, & Greer, 1997).

Data were analysed using IBM SPSS Statistics Version 22. All data were normally distributed. Descriptive statistics (mean, standard deviation, range, standard error) were calculated for each physical assessment variable.

Reliability analysis was conducted using intra-class correlation (Detailed in Appendix A).

Comparisons between the painful shoulder in the cases and the matched shoulder in the control group were completed using independent t-tests or chi-squared tests, with significance at $p \leq 0.05$.

Any variables for which a significant difference between the painful shoulder in the cases and the matched shoulder in the control group was identified, were then included in a conditional logistic regression analysis to identify independent predictors of SSI (Watt, Purdie, Roche, & McClure, 2004). Variables that were significant in crude analysis were entered into the model, then removed one by one, and the impact on the odds ratio of the variables remaining in the model assessed. If the OR of the remaining variables changed more than 10%, the variable was retained in the model. In this way, factors that were independent predictors of those with SSI, taking into account relevant confounders, were identified. The strengths of association were expressed as odds ratios (OR), with -95% Confidence Intervals. Pearson's correlation was used to establish whether postural variables were correlated with each other, in order to determine whether multicollinearity was an issue for the logistic regression model. Any variables for which a correlation greater than 0.5 was observed, were considered to be highly correlated. No correlations greater than 0.5 were observed so multicollinearity was not an issue in these analyses, and all relevant variables were included in the model.

**RESULTS**

Intra class correlation coefficients for the pilot reliability studies indicated very high intra-rater reliability for all measures (ICC > 0.88).

SSI cases and asymptomatic controls were recruited and assessed during the same time period, independently of each other. Matching was not performed until data collection was completed. Data for 73 SSI cases and 91 controls were collected and then matched for gender, hand dominance, physical activity level and age (within a bracket of three years). SSI cases reported symptoms being present between 4 weeks to 12 months. This resulted in 51 complete matches in each group. A description of participants is found in Table 1, with no significant differences in body mass index or physical activity between the groups, with moderate activity level being the most prevalent in each group. Significant differences in SPADI and VAS scores were present.

**TABLE 1:** DESCRIPTION AND COMPARISON OF PARTICIPANTS

| | SSI MEAN ± SD N = 51 | ASYM MEAN ± SD N =51 | P VALUE |
|---|---|---|---|
| Age (years) | 51.24 ± 5.71 | 50.80 ± 4.66 | .074 |
| BMI | 28.14 ± 5.61 | 28.17 ± 4.65 | .393 |
| Gender | | | 1.0 |
| Male | 28 | 28 | |
| Female | 23 | 23 | |
| Dom | | | 1.0 |
| Right | 45 | 45 | |
| Left | 6 | 6 | |
| IPAQ | | | .282 |
| Low | 27% | 30.2% | |
| Mod | 42.9% | 38.1% | |
| High | 30.2% | 31.7% | |
| VAS Rest | 0.25±0.77 | 0 | .000 |
| VAS Activity | 5.82±2.81 | 0 | .000 |
| SPADI | 26.21±17.92 | 0 | .000 |

Abbreviations: BMI, body mass index; Dom, dominance; asym, Asymptomatic; VAS, Visual Analogue Scale; SPADI, Shoulder Physical Activity Disability Index

Occupations were recorded for each participant. The greatest number of participants in each group were professionals including high school teachers, police officers, librarians and university lecturers and researchers with occupations involving overhead work not predominant in either group.

The craniovertebral angle (CVA) was significantly smaller in the SSI group compared to the asymptomatic group (p<.001). This suggests the amount of forward positioning of the head on the trunk is significantly greater in the SSI group, with this group resting in significantly greater upper thoracic flexion (p<.001) and significantly less lower thoracic extension (p<.001) (table 2). There was an inverse association in the SSI group between increased forward head posture (smaller CVA) and increased upper thoracic flexion (r=-.503, p<.001), and a weak association between increased upper thoracic flexion posture and reduced lower thoracic extension posture (r=.314, p=.025) That is, overall the thoracic spine was more flexed.  No association was found in the asymptomatic group between upper and lower thoracic resting postures (r=.193, p=0.175) but a weak association was present in forward head posture and resting upper thoracic posture (r=-.302, p=.031). Cases in the SSI group had significantly less range of upper thoracic spine motion than the asymptomatic group (p=.001) (table 2).

There was significantly less passive internal rotation and passive posterior shoulder range in the painful shoulder in the SSI group than the matched shoulder in the asymptomatic group (p<.001) (table 2). A weak correlation was found between passive posterior shoulder range and passive internal rotation in the SSI group (r=.368, p =.008) which was not present in the asymptomatic group (r=.040, p=.779). No significant differences were found in scapular position between the asymptomatic and symptomatic groups using the lateral scapular slide test method (Table 2).

**TABLE 2:** BETWEEN GROUP COMPARISON OF CERVICAL AND THORACIC POSTURE AND RANGE OF MOTION, SHOULDER RANGE OF MOTION, POSTERIOR SHOULDER RANGE AND SCAPULA POSITION MATCHED FOR AGE, GENDER, DOMINANCE AND PHYSICAL ACTIVITY

| | SSI MEAN ± SD (SEM) N = 51 | ASYM MEAN ± SD (SEM) N = 51 | 95%CI | P VALUE |
|---|---|---|---|---|
| CVA (degrees) | 46.29 ± 6.72 (0.94) | 51.73 ± 5.63 (0.79) | -7.9 to -3.0 | <.001 |
| Upper Thoracic Resting Posture (degrees) | 18.59 ± 6.29 (0.88) | 13.22 ± 4.81 (0.67) | 3.2 to 7.6 | <.001 |
| Range of Upper Thoracic Motion (degrees) | 32.71 ± 14.09 (1.97) | 42.16 ± 14.95 (2.09) | -15.2 to -3.7 | .001 |
| Lower Thoracic Resting Posture (degrees) | -8.48 ± 5.99 (0.84) | -12.50 ± 3.97 (0.56) | 2.0 to 6.0 | <.001 |
| Passive Internal Rotation (degrees) | 38.39 ± 13.98 (1.96) | 56.24 ± 12.46 (1.74) | -23.0 to -12.6 | <.001 |
| Posterior Shoulder Range (degrees) | 38.89 ± 7.93 (1.11) | 24.61 ± 6.47 (0.91) | 11.4 to 17.1 | <.001 |
| Lateral Slide Test Position 1 (cm) | 9.22 ± 1.32 (1.84) | 9.29 ± 1.57 (2.19) | -6.4 to 5.0 | .811 |
| Lateral Slide Test Position 2 (cm) | 9.59 ± 1.39 (1.94) | 9.34 ± 1.44 (2.02) | -3.1 to 8.0 | .384 |
| Lateral Slide Test Positon 3 (cm) | 12.06 ± 2.19 (3.06) | 12.65 ± 1.87 (2.62) | -13.9 to 2.1 | .147 |

Abbreviations: asym, asymptomatic; CVA, craniovertebral angle

A positive postural value represents flexion and a negative value represents extension.

Any variables for which a significant difference between the painful shoulder in the cases and the matched shoulder in the control group was identified, were then included in a conditional logistic regression analysis to identify independent predictors of SSI. These variables were: CVA, upper thoracic resting posture, range of upper thoracic motion, lower thoracic resting posture, passive internal rotation and posterior shoulder range. Lower thoracic resting posture and range of upper thoracic motion were removed from the model as taking them out of the model did not alter the OR of the remaining variables in the model by more than 10%. The final model is shown in table 3. No significant independent predictors of SSI were identified using this model. It is possible that this is likely due to the small numbers in this study.

**TABLE 3:** ASSOCIATION BETWEEN SIGNIFICANT VARIABLES AND SSI (CONDITIONAL LOGISTIC REGRESSION)

| VARIABLES | ODDS RATIO | 95% CI | P VALUE |
|---|---|---|---|
| CVA | 0.894 | 0.707 to 1.131 | 0.352 |
| Upper Thoracic Resting Posture | 1.055 | 0.902 to 1.233 | 0.505 |
| Passive Internal Rotation | 0.941 | 0.854 to 1.037 | 0.218 |
| Posterior Shoulder Range | 1.016 | 0.997 to 1.035 | 0.098 |

Abbreviations: CVA, craniovertebral angle

## DISCUSSION

This study has identified a significant increase in resting thoracic flexion and forward head posture, as well as a significant reduction in upper thoracic active motion, posterior shoulder range and passive internal rotation range in a SSI group compared to an asymptomatic group matched for age, gender, hand dominance and physical activity level in crude analyses. However, no significant independent predictors of SSI were identified in conditional logistic regression analyses, most likely due to small numbers in this study. Occupations and physical activity levels were similar between the groups and those involved in frequent overhead work were not dominant.

Previously, only posterior shoulder range (Tyler et al., 2000) or cervical and thoracic posture (Jeremy. S. Lewis et al., 2005) or scapula positioning (Lukisewicz et al.,

1999) have been assessed in both a SSI group and an asymptomatic group. This study has considered the multifactorial contributors considered part of SSI and assessed all of these factors in each of the groups, ensuring the groups are well matched.

This study found a significant difference in forward head position (CVA) between groups. The forward head position is a static sagittal plane measurement, which may alter with shoulder elevation. This increased measurement in the SSI group may be a consequence of the increased resting thoracic flexion posture as this variable was found to be correlated with forward head posture. It is uncertain if this increase in resting thoracic flexion contributes to the development of symptoms or is a consequence of the symptoms being present.

During shoulder elevation the thoracic spine extends and side flexes to varying degrees at each level (Oatis, 2009). Due to this, observation and measurement of thoracic spine extension mobility is considered an important part of the shoulder physical examination (Edmondston et al., 2011). Previous trials comparing a SSI group to an asymptomatic group which assessed static erect thoracic posture identified no difference between the groups (B. H. Greenfield et al., 1995; Jeremy S Lewis & Valentine, 2010). However, static postures do not consider thoracic spine extension as suggested. A significant restriction in sagittal plane thoracic range has been identified in those with SSI using ultrasound topometric examination (Theisen et al., 2010).This study also found significantly reduced range of active upper thoracic spine movement in the SSI group. This reduction in active upper thoracic range may have a significant impact on the position and movement of the scapula via bony and muscular attachments (Struyf et al., 2014). Interventions to increase thoracic extension may be indicated for SSI management and inclusion of the examination of the thoracic spine in all SSI assessments is warranted.

Lateral linear measurements using the three semi-dynamic positions of the 2D lateral scapular slide test (LSST) were used to identify differences in scapula positioning in this study. Positon 1 of the LSST is with the arms resting by the side thereby measuring the resting scapula position. No difference was identified between groups in this position which is consistent with previous 2D and 3D scapula studies (B. Greenfield et al., 1995; P.M. Ludewig & Cook, 2000; Lukasiewicz, McClure, Michener, Pratt, & Sennett, 1999; McClure, Michener, Karduna, & Whitmans, 2006; Rufa, 2014). Position 2 of the LSST (hands resting on the hips) and position 3 (arms internally rotated and abducted to $90^0$) were not significantly different between the groups. This indicates no difference in the linear positioning of the scapulae between groups but does not take into account changes in scapula tilt or rotation which have been identified in 3D kinematic studies to differ in those with SSI (P.M. Ludewig & Cook, 2000; Lukasiewicz et al., 1999). Clinically, observation of scapulae movement may detect scapular dyskinesis, however this observation method has been reported to be altered by the velocity of the arm movement (Struyf et al., 2014).

The findings of this study support previous findings showing both the range of passive internal rotation and passive posterior shoulder range are correlated and significantly reduced in those with SSI (Tyler et al., 2000). Further research is needed to inform clinicians if both these ranges need to be recovered when measurements identify they are reduced compared to the unaffected shoulder.

This study reveals cervical and thoracic movement and positioning and posterior shoulder range are significant indicators of potential SSI but scapula positioning is not predictive in those without signs of instability, without any injury history and without prolonged performance of overhead activity.

Limitations of this study include the availability of only one assessor leading to lack of blinding and potential bias. This lack of assessment blinding is a significant limitation and occurred due to no funding being available to employ an assistant for this study. However, the assessor has post graduate training, more than 20 years experience as a musculoskeletal physiotherapist and completed quality reliability studies in preparation, suggesting the results can be considered credible. Selection bias (volunteer bias) is also likely to be present with a snowballing effect occurring from the initial promotion for volunteers. While associations were observed in descriptive (crude) analyses, no significant independent predictors of SSI were identified in conditional logistic regression analyses. This is mostly likely due to the sample size (and consequent increase in type 1 error). That is, the sample was insufficiently powered to detect identification of multiple independent predictor variables, after adjusting for relevant confounders.

## CONCLUSION

A SSI group were compared to an asymptomatic group, matched for age, gender, hand dominance and physical activity level. In crude analysis, the SSI group had significantly increased resting thoracic flexion and forward head posture, as well as a significant reduction in upper thoracic active motion, posterior shoulder range and passive internal rotation range.  No independent predictors of SSI were identified in conditional logistic regression analysis

These findings indicate that further research is required to determine if interventions focused on these factors are effective in the management of SSI.

**APPENDIX A:** OUTCOMES OF RELIABILITY TESTING

| Intra-rater Reliability Study | Number of Measurements | Measurement One Mean | Measurement Two | Intraclass Correlation Coefficient ICC | 95% Confidence Interval |
|---|---|---|---|---|---|
| Tyler's Method Posterior Shoulder | 16 Repeated on same day, one hour apart | 21.88+/-8.55 | 22.48+/-8.84 | 0.893 | 0.722 to 0.961 |
| Kibler's Scapula Measurements | 48 Repeated on same day, one hour apart | 8.60+/-2.30 | 8.33+/-1.98 | 0.889 | 0.810 to 0.936 |
| Universal Goniometer to Measure Shoulder ROM | 16 Repeated on same day, one hour apart | 165.50+/-11.94 | 165.31+/-12.08 | 0.933 | 0.867 to 0.967 |
| Inter-rater reliability of UTHSCSA Image Tool Software compared to two experienced therapists | Digitise 30 photos, being 10 photos in relaxed resting, 10 photos in thoracic flexion and 10 in extension | Mean<br>1. 20.50<br>2. 20.21<br>3. 20.41 | Standard Deviation<br>1. 15.6<br>2. 15.6<br>3. 15.7 | 0.997 | 0.995-0.998 |

**APPENDIX B:**

**Methodological Detail**

*Scapula Assessment*

The lateral scapular slide test is a semidynamic test which evaluates the position of the scapula in relation to a fixed point on the spine (Kibler, 1998). Three positions are chosen for this testing procedure 1. arms relaxed by side 2. hands on hips with about 10 degrees shoulder extension 3. arms at or below 90 degrees abduction with maximal internal rotation of the glenohumeral joint. A tape measure is used to measure the distance from the inferior angle of the scapula to the adjacent thoracic spinous process as shown in Figure 1. Each participant was asked to stand with arms relaxed by their side and the first position of the lateral slide test was measured in centimetres on both sides using a standard plastic tape measure. The examiner then demonstrated the second position and asked the participant to place their hands on their hips before a measurement in centimetres was taken on each side, using the same tape measure. The examiner demonstrated the third position before the participant adopted this position and measurements were again taken using the same tape measure.  The side measured first was randomised for each participant.

**Figure 1**

*Assessment of posterior shoulder tightness*

Tyler performed a study quantifying posterior capsule tightness and motion loss through a broad age range of both genders in those with a diagnosis of shoulder impingement (Tyler  et al., 2000). This was a follow up to Tyler's original study which quantified posterior shoulder tightness using a broad age range of subjects of both genders. Posterior shoulder tightness was correlated with passive internal rotation in supine in both of these studies (Tyler  et al., 1999). The measurement technique used is as follows:

All measurements were taken with the subject lying on an electric physiotherapy plinth with a pillow beneath their head. A standard carpenter's square was used for marking the location of the elbow medial epicondyle in relation to the non indented surface of the plinth. The 90 degree angle of the square ensured that a perpendicular line from the examination table to the medial epicondyle was measured.

Measurements were taken in side lying. Male subjects had removed their shirt while females were in their bra only. The subject lay with hips flexed to 90 degrees, stabilising the lower back, close enough to the edge of the plinth so the hand could be lowered unhindered by the plinth surface. Both acromion processes were perpendicular to the plinth, with the arm not being tested positioned so as not to hinder the movement of the test arm. The spine was maintained in neutral flexion, extension and rotation. The medial epicondyle of the humerus was marked with a black dot. The tester grasped the distal humerus and passively positioned it in 90 degrees abduction and 0 degrees internal/external rotation. The scapula was glided into a retracted position with the opposite hand. The humerus was lowered until the motion ceased or if rotation of the humerus was observed, indicating the end of posterior tissue flexibility. A measurement in centimetres was then taken using the carpenters square from the medial epicondyle to the plinth by a second examiner.

Passive internal rotation was measured with the subject lying in supine with the humerus at $90^0$ of abduction in the coronal plane. A folded towel was placed under the humerus to ensure it rested in the horizontal. The tester palpated the spine of the scapula while passively internally rotating the humerus with the end range determined as palpable movement of the scapula. A measurement in degrees was then taken using a plastic universal goniometer positioned with its axis level with the olecranon process and the fixed arm vertical.

*Posture Assessment*

Three photos were taken as per the instructions detailed previously. Files were downloaded directly from the JVC Hard Drive Camcorder to a lap top computer via a USB connecting cord. Each photo was a .jpg individually numbered file. Relative motion of the upper thoracic and lower thoracic spines was to be established. Digital photograph measurements have been shown to be reliable and valid for postural measurements (Grimmer-Somers et al., 2008; van Niekerk, Louw, Vaughan, Grimmer-Somers, & Schreve, 2008). Digitising software UTHSCSA Image Tool was used to calculate the x,y plane coordinates, from which postural angles were calculated as shown in Figure 2.

Relaxed Resting Thoracic Flexion Thoracic Extension

**FIGURE 2**


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