Clinical Assessment of Factors Associated with Subacromial Shoulder Impingement: A Systematic Review

Background Physiotherapists commonly use orthopaedic special tests to reproduce subacromial shoulder impingement (SIS) pain by increasing compression or tension within the subacromial space. However, these tests do not differentiate between purported extrinsic and intrinsic mechanisms associated with SIS.

Objective To identify, and determine the reliability and validity of clinical tests used to assess extrinsic factors associated with SIS.

Method A scoping review identified tests for extrinsic SIS. A systematic approach was then used to search six electronic databases in July 2016 to identify clinical tests used to measure (1) posterior shoulder range (2) cervical and/or thoracic posture (3) 2D scapula movement (4) rotator cuff strength. The 14 articles included in the review were assessed using a modified Downs and Black quality assessment tool.

Results Moderate quality studies investigated 2D scapula measurements (N=2), resting pectoralis minor length (N=2) and rotator cuff strength (N=5). High quality studies measured forward head position and/or thoracic posture (N=2) and rotator cuff strength (N=1).

Conclusion A good level of assessment reliability and significantly less range and strength was identified in those with SIS for: posterior shoulder range (passive shoulder adduction and internal rotation and passive internal rotation in supine); isokinetic peak torque values for internal and external shoulder rotation (isokinetic testing); forward head position (lateral photograph) and; thoracic range of motion (tape measure or ultrasound tomography). Good to excellent reliability was reported for lateral scapular slide test positions and resting pectoralis minor muscle length. These clinical tests should be considered for use in SIS assessment.

Key Words *shoulder, impingement, measurement, posture, scapula, rotator cuff*

Introduction

Subacromial shoulder impingement (SIS) is the term used to describe pain within the subacromial space, emanating from the rotator cuff tendons, subacromial bursa, biceps tendon and shoulder capsule or a combination of these structures. [1, 2] The term SIS is a description of the painful signs found on assessment which include no history of trauma, a localised catching or aching pain without appreciable joint stiffness and/or a painful arc through glenohumeral elevation. [3, 4] Current literature varies widely regarding the classification, diagnosis and terminology of SIS. However it is agreed that the mechanisms include extrinsic or intrinsic factors or a combination of both, with the aetiology being poorly understood. [2] SIS accounts for 44-60% of all shoulder related symptoms presenting for assessment and is most common between 40 and 60 years. [5, 6]

Clinical trials and systematic reviews have reported a combination of orthopaedic special tests (Neer test, Hawkins-Kennedy test, horizontal adduction test, painful arc test, drop arm test, Yergasons test, Speed test and infraspinatus muscle strength test (also named external rotation resistance test)) [7 - 12] are most likely to reproduce pain associated with SIS. [13] While these tests are commonly used to reproduce SIS pain by increasing compression or tension within the subacromial space they do not identify the specific painful structure or the degree of injury to that structure.[7, 14, 15] Further they do not differentiate between extrinsic and intrinsic mechanisms purported to be associated with SIS which include restriction of the posterior shoulder [1, 4], altered cervical and/or thoracic posture [1, 2, 4], altered scapula movement [16, 17, 18] and dysfunctional or weak rotator cuff musculature. [1, 4, 19 - 22]

Several literature reviews have presented the evidence for use of special orthopaedic tests in the diagnosis of SIS [7, 15] but no previous reviews have identified the clinical tests used to assess external factors in those with SIS. These clinical tests guide the therapist to provide the most appropriate advice and treatment. [14]

This review identified current clinical tests used to assess purported extrinsic factors associated with SIS being:

(1) posterior shoulder range
(2) cervical and/or thoracic posture
(3) 2D scapula movement (as 3D assessment is not clinically available)
(4) rotator cuff strength.

The quality of the research was appraised, and in particular the ability of the clinical tests to detect differences between people with and without shoulder pain due to SIS has been reported. As well, where possible, this review reports the reliability and validity of these tests.

Method

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed when conducting this systematic review. [23]

This systematic review has been registered with Prospero. Registration number CRD42015024529.

Eligibility Criteria

All types of primary studies which statistically analysed a group of individuals, male or female, aged 18 years or older, diagnosed with a clear medical or clinical diagnosis of SIS and were compared with a group of asymptomatic individuals.

Search Strategy

An electronic database search was conducted in July 2016 by the primary investigator. Searches of the following databases were performed: Ovid MEDLINE, Pubmed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), SCOPUS, SportDiscus and Web of Science from their inception to present.

Four searches were conducted in each database, one for each factor being investigated. The terms for each factor were: (1) “posterior shoulder”, “posterior capsule”, “tight*”, “restrict*, “limit* (2) “scapula” 3. “posture”, “thoracic”, “cervical” 4. “rotator cuff”, “RC”, “strength”. These terms were combined with “shoulder impingement”, “SI”, “SIS”, “SAIS”. Boolean connectors “OR” and “AND” were used to combine these search terms within and between each area respectively.

An additional search of Google Scholar was conducted. The reference lists of the final articles identified in these searches were hand-searched.

Study Selection

Inclusion Criteria

- Study must have been published or ‘in press’ prior to 24th July 2016
- Published research in English only
- Studies conducted on humans, over the age of 18 years
- A clear diagnosis of SIS defined by a painful arc and positive impingement tests such as the Hawkins-Kennedy test, Neer’s test or Jobe’s test or following an acceptable clinical assessment performed by an experienced clinician

Exclusion Criteria

- Literature reviews
- Studies without a comparison group of asymptomatic controls
- Studies involving cadavers
- Studies involving internal shoulder impingement
- Studies involving glenohumeral instability (this was necessary as the clinical presentation for instability related SIS is different, resulting in differing conservative and operative treatments and should be considered as a separate discussion. [24])
- Studies involving surgical interventions

The titles were screened by the first reviewer (HL) to exclude studies that were clearly not relevant. Then, abstracts of the selected titles were analysed by the first reviewer (HL) regarding study design, participants, interventions and outcomes. Full text copies were obtained for the selected studies and for those where relevance was not clearly identifiable in the abstract and title. The reference lists were screened for identification of additional relevant publications not retrieved during the electronic search. The selected articles were further assessed in a standardised manner for their eligibility, applying the inclusion and

exclusion criteria, by the first and second reviewers (HL and SG). A third reviewer was available for consultation in case of disagreements but was not required.

Quality Assessment

The level of evidence of each included study was established using The Oxford Centre for Evidence Based Medicine categorization. [25]

Critical appraisal of each of the included studies was performed using a quality checklist devised by Downs and Black (D&B). [26] This tool was deemed suitable for critical appraisal of case control studies. [27] This checklist consists of 27 items divided into five subsections. (1) Reporting (10 items) (2) External Validity (3 items) (3) Internal validity – bias (7 items) (4) Internal validity – confounding (selection bias) (6 items) and (5) Power (1 item). Each item, apart from one, scores 1 = yes, 0 = no or 0 = unable to determine. The remaining item scores 2 for clearly describing principal confounders in each group of subjects, 1 for partially describing and 0 when not described. The maximum score totals 32 as the final item is a five point scale for rating the power to detect a clinically important effect. The D&B Checklist has been shown to have moderate to good inter-rater reliability. [26, 28] For the purpose of this study, the final item was changed from a scale of 1-5 to a score of 0-1. A score of 1 was recorded if a power calculation or sample size calculation was provided and a score of 0 if not provided. As all included studies were case-control outcome studies and not intervention studies, the checklist was further modified, eliminating the items relating to intervention, patient follow up and treatment location. [28] The maximum score possible using this modified checklist is 23 (D&B Checklist detailed in Appendix 1).

Each included study was initially assessed by two independent reviewers (HL and SG). Any differences in scores between the reviewers was discussed and a consensus in scoring achieved.

Various quality rating categories have been suggested. This review has assigned the following ordinal categories: low (≤ 7), moderate ($8 – 15$) and high (≥ 16) to describe the quality of the included studies. [26]

Data Extraction and Synthesis

Data extraction was carried out by the first reviewer (HL) and checked by the second reviewer (SG), using standardized forms. [29]

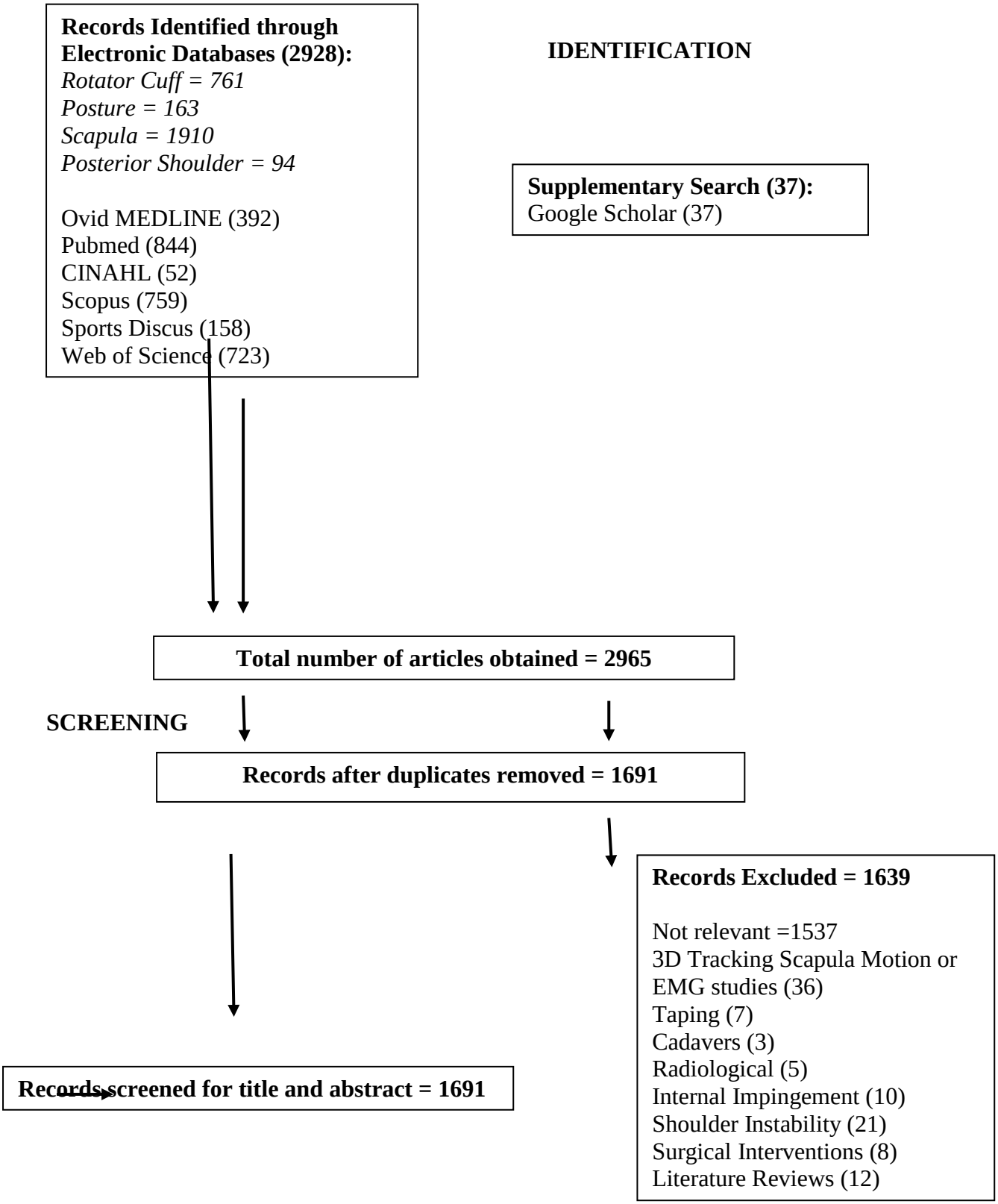
The information is provided in table form with highlighted similarities and differences within the study design, aim of the study, subjects, measurements, outcome measures and results. A separate table is used to detail this information for each physical factor. Due to the heterogeneity in the outcomes of the primary studies, it was not possible to perform a meta-analysis.

Results

The initial searches identified 2965 titles, and of these 1274 were identified as duplicates and were removed. 1691 titles and abstracts were screened with 1639 excluded due to not being relevant. 52 full text articles were retrieved, twelve of which satisfied the inclusion and exclusion criteria and were included in this review. Two studies required arbitration as they included not only those with a clear diagnosis of SIS but other shoulder conditions.[30, 31] Both articles pertained to scapula measurements. The reviewers decided to include these studies in the review as more than half of the symptomatic participants in each study met the description of SIS. [30, 31] One study included a control group, a non-operative SIS group and a post- operative SIS group. [20] The post-operative group was not included in this review. One study was a placebo crossover intervention using tape to adjust thoracic posture in those with SIS and an asymptomatic group. The reviewers decided to include this study as the clinical postural assessment tests were performed on both groups, allowing comparison of these tests. [40]

Details of each of the four searches are represented in Figure 1.

Figure 1 PRISMA flow diagram



ELIGIBILITY

Full Text Articles Assessed for Eligibility = 52

Rotator Cuff n=15
Posture n = 11
Scapula n = 17
Posterior Shoulder n = 9

Full text articles excluded = 40

Did not have both a symptomatic SIS group and an asymptomatic group (38.)
Did not define clear diagnosis SIS (2)

Hand searching reference lists = 2

INCLUDED

Studies Included in Qualitative Synthesis = 14

Rotator Cuff n = 6
Posture n = 2
Scapula n = 4
Posterior n = 2

Methodological Quality

All studies provided level 3b or level 4 evidence according to The Oxford Centre for Evidence Based Medicine categorization (Table 1). [25]

The quality of the fourteen included studies was evaluated by consensus of two reviewers (HL and SG) using the D&B checklist. [26] Results are shown in Table 1.

The quality scores ranged from 11/23 to 18/23 with three studies rated as high quality and the remaining as moderate quality. The items which consistently rated poorly were: (1) Reporting of adverse events which may have had a consequence on the measurements (item 8) (2) Blinding of study participants (item 14) (3) Blinding of those measuring main outcomes (item 15) (4) Reporting if cases and controls were recruited over the same time period (item 22) (5) Evidence a power calculation was performed (item 27).

The four eligible scapula studies were rated as moderate quality, the two posterior shoulder studies were moderate quality, the rotator cuff studies were high (1) and moderate (5) quality and the posture studies were rated as high quality.

TABLE 1 Results of Quality Index Score

	Posterior Shoulder		Posture			Rotator Cuff					Scapula			
Study	Tyler et al. (2000)	Borstad et al. (2007)	Lewis et al. (2005)	Thiesen et al. (2010)	Leroux et al. (1994)	MacDermid et al. (2004)	Tyler et al. (2005)	Erol et al (2008)	Moraes et al. (2008)	Dulgeroglu et al. (2013)	Odom et al. (2001)	Curtis & Roush. (2006)	Struyf et al. (2014)	Rosa et al. (2016)
OLoE	3b	3b	3b	3b	4	3b	3b	3b	3b	3b	3b	3b	3b	4
D&B Item														
1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	0	1	0	1	1	1	0	1	0	1	1	1	1	1
5 (/2)	1	1	2	1	1	1	1	2	1	1	1	1	2	0
6	1	0	1	1	1	1	1	1	1	0	1	1	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	0	0	0	0	0	1	0	0	0	0	1	0	0	1
10	1	0	1	1	0	1	1	1	1	1	1	0	0	1
11	0	1	0	1	1	1	0	1	0	1	0	0	1	1
12	0	1	0	1	1	0	0	1	0	1	0	1	0	1
14	0	0	1	0	0	0	0	0	0	0	0	0	0	0
15	0	0	1	0	0	0	0	0	0	0	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	0	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	0	1	1	0	1	1	1	1	0	1	1	0	0
21	0	1	0	1	0	1	0	1	0	0	1	1	0	0
22	0	0	0	1	0	0	0	0	0	1	0	0	1	0
23	0	1	1	1	0	0	0	0	0	0	0	0	1	1
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27 (/1)	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Total/23	11	13	16	18	12	15	11	16	11	12	14	14	14	14
Quality	M	M	H	H	M	M	M	H	M	M	M	M	M	M

OLoE=Oxford Level of Evidence M=Moderate H=High

Study Characteristics

Two studies investigated 2D scapula measurements to determine linear differences in scapula position in those with and without SIS. [30, 31] Two studies measured resting pectoralis minor length in those with and without SIS (Table 2). [32, 33] Six articles used isokinetic testing to assess rotator cuff strength in those with and without SIS (Table 3). [20, 35-39] Two articles measured forward head position and/or thoracic posture in those with and without SIS (Table 4).[40, 41] The remaining two articles measured posterior shoulder restriction in those with and without SIS (Table 5). [42, 43]

Five of the included studies only reported the reliability and sometimes the validity of a specific measurement approach and did not investigate if measurement differences were detected in those with SIS compared to the asymptomatic group. [30-33, 43]
Two studies had significant variance in the recruitment age of the SIS group compared to the asymptomatic group. The asymptomatic group participants mean age was 21 in both studies and the SIS groups mean age was 37 and 51 respectively.[32, 36] The remaining studies included participants who were matched or very similar in age and gender and all selected participants were close to the peak age incidence for SIS of 40 to 60 years.
Matching of upper limb dominance between the SIS group and the asymptomatic group was not consistently performed or not reported in the majority of studies.
The measurement method used for each study was the same but the tool used to obtain the measurements was different. Measurement of 2D linear scapula position used the lateral scapular slide test (LSST) [30, 31], pectoralis minor resting muscle length measurement used identical anatomic landmarks [32, 33], rotator cuff strength assessment used isokinetic dynamometers and posterior shoulder measurements were obtained using the same technique. [42, 43] Posture measurements differed in both the method of measurement and the tool used. [40, 41]

Statistical analysis was appropriate for each study method.

2D Scapular Measurement (Table 2)
All included scapular studies compared measurements between the scapulae of an individual experiencing unilateral or bilateral shoulder pain but did not compare measurements between matched scapulae of a symptomatic individual and an asymptomatic individual. Odom et al. (2001) and Curtis & Roush. (2006) concluded that measurements of linear distance from the inferior angle of the scapula to the adjacent thoracic spine level using the lateral scapula slide test in a symptomatic and asymptomatic group were reliable.[30, 31] However, the bilateral difference comparison measurements of both scapulae were unreliable for determining the degree of scapular asymmetry.
The use of resting pectoralis minor muscle length to establish alterations in scapular positioning is yet to be established. [32] A change in pectoralis minor muscle length may cause alterations in scapula kinematics or be a result of these alterations. [32, 33] Struyf et al. (2014) used a Vernier caliper with the participant positioned in supine while Rosa et al. (2016) used a tape measure in a standing posture with both studies reporting good to excellent reliability measurements (table 6). [32, 33]

The lateral scapular slide test is a semi-dynamic test which evaluates the position of the scapula in relation to a fixed point on the spine. [34] Three positions are used in this test 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. The distance from the inferior angle of the scapula to the adjacent thoracic spinous process is measured.
Reliability reports for the lateral scapular slide test were high overall. [30, 31] However Odom et al. (2001) reported higher intra-rater reliability in the symptomatic group than the asymptomatic group. [30] Inter-rater reliability was comparable for both the symptomatic and asymptomatic groups (Table 6). [30, 31]

Table 2 Summary of articles – 2 Dimensional Scapula Assessment

Author	Study Design	Aim of Study	Subjects	Outcome Measure	Results
Odom et al. (2001)	Case Control Study	Aim: 1. Investigate intrarater and inter-rater reliability of measurements obtained with LSST in those with and without diagnosed shoulder pathology 2. Examine validity of LSST for classifying shoulder impairment	Total 46 Mean age 30.0 ± 11.1yrs M&F Asym: 26 being treated at Centre Sports Medicine for medical diagnoses other than shoulder. Dom not reported Sym: 20 - symptoms unilateral or bilateral. Multiple diagnoses of shoulder pain in group. 19 Right Dom 1 Left Dom 11 Right Sym 9 Left Sym	LSST using unmarked sections of string. Assessors: 6 physical therapists at the Centre for Sports Medicine (min. 1 year exp.) Linear measurements in each test position were obtained bilaterally but these were not reported. From these bilateral measurements a difference measurement was derived: uninjured side - injured side in those with symptoms and(left side – right side) in those without (P>0.05). Paired t tests also performed on linear measurements of injured & uninjured sides in those with symptoms.	Aim1: Asym: Intra-rater : 0.91 to.0.97 (SEM = 0.31 - 0.63cm) Inter-rater : 0.70 to 0.95 (SEM = 0.31 – 1.15cm) Subjects with shoulder dysfunction: Intra-rater 0.81 to 0.93 (SEM = 0.52 – 0.79cm) Inter-rater 0.71 to 0.91 (SEM = 0.45 – 1.02cm) Aim2: Difference measurements cannot be used to reliably assess the presence or magnitude of scapular asymmetry P>0.05 for mean difference measurements in both symptomatic and asymptomatic. LSST was found to be not useful for identifying the injured side based on the derived difference in scapular distance measurements.
Curtis & Roush. (2006)	Case Control Study	Aim: Test reliability of the LSST using a scoliometer. A scoliometer is described as a caliper attached to two movable points, used for measuring scoliosis	Total 33 Males Mean age 25.5yrs ± 5.69 Recruited from Phoenix Arizona metropolitan area, no specific demographic detailed.	LSST using Scoliometer. Assessors: Physical therapists 3 years of experience (22.67 ± 2.52 yrs). Familiar with LSST but not scoliometer	Asym: ICC Position 1: 0.96 Position 2: 0.93 Position 3: 0.83 Subjects with shoulder sym: ICC Position 1: 0.96

			Asym: 18 Sym: 15 – unilateral or bilateral shoulder. Multiple diagnoses of shoulder pain in group.		Position 2: 0.93 Position 3: 0.84 A large range of error when using measurements to calculate the difference measurement between sides.
Struyf et al. (2014)	Case Control Study	Investigate reliability of pectoralis minor muscle length measurement in patients with and without SIS	Total 50 Asym: 25 20.8yrs ±1.5 16M 9F Sym SIS: 25 50.8yrs ±16.3 8M 17F	Vernier Caliper used to measure pectoralis minor length. Assessors: 2 x physiotherapists with one year clinical experience. Training given. Testing order randomised. Measurement performed in supine from caudal edge 4th rib at sternum to inferomedial aspect of coracoid process.	Intra-rater: Asym. D ICC 0.76 SEM 0.29-0.32% ND ICC 0.87 SEM 0.21-0.32% SIS: Sym ICC 0.87 SEM 0.21-0.27% Asym. ICC 0.93 SEM 0.19-0.30% Inter-rater: Asym. D ICC 0.67 SEM 0.38% ND ICC 0.64% SEM 0.45% SIS: Sym. ICC 0.65 SEM 0.46% Asym. ICC 0.72 SEM 0.61%
Rosa et al. (2016)	Case Control Study	Evaluate intra-rater, inter-rater and between day reliability of using a tape measure to assess pectoralis minor	Total 100 18-35yrs 25 Asym. For intra and inter rater reliability 13F 12M 10D 15ND	Tape measure with 0.10cm resolution used to measure pectoralis minor muscle length. Assessors: Two	Intra-rater: Both groups – ICC 0.95-0.97 SEM 0.30-0.42 Inter-rater: Asym.

	resting length in asymptomatic individuals and individuals with signs of SIS	25 Asym. For between day reliability 13F 12M 13D 12ND 25 SIS for intra and inter rater reliability 12F 13M 10D 15ND 25 SIS for between day reliability 14F 11M 17D 8ND	Training given. Intra and inter rate reliability: two trials, two minutes part. Five minutes between evaluators. Between day reliability: one rater, seven days apart Measurement performed in standing from caudal edge 4th rib at sternum to inferomedial aspect of coracoid process.	ICC 0.86 SEM 0.70 SIS: ICC 0.87 SEM 0.84 Between Day: Asym. ICC 0.95 SEM 0.40 MDC 1.13cm SIS: ICC 0.95 SEM 0.41 MDC 1.14cm

M = males F = females D = dominant ND = non-dominant Sym = symptomatic

LSST = lateral scapular slide test Asym = asymptomatic

Rotator Cuff Assessment (Table 3)

All studies compared the within group difference in mean strength values of the symptomatic group to within group difference in the mean strength values of the asymptomatic group. No study directly compared the painful shoulder in the symptomatic group with the matched shoulder in the asymptomatic group.

Concentric peak torque for internal and external rotation was compared in four of the studies [20, 36, 37, 39] with MacDermid et al. (2004) testing both concentric and eccentric average peak torque. [35]

Relative peak torque was reviewed in two studies.[38, 39] This value is calculated by dividing the peak torque by the individuals body weight and is considered a comparator of muscular performance between individuals of different body mass and composition. [44] Moraes et al. (2008) reviewed the work ratio between eccentric external rotation/concentric internal rotation and the work ratio between eccentric internal rotation and concentric external rotation. [38]

A seated position with the test shoulder positioned in the scapula plane (30^0 GH flexion and 45^0 GH abduction) was adopted in all studies except Moraes et al. (2008).[20, 35, 36, 37, 39] Testing was also done at 90^0 glenohumeral abduction and 90^0 elbow flexion in sitting [36] and in supine. [38] No significant difference between groups was identified even with the variation in testing positions.

The use of two or more velocities with at least one being slow and the other fast, assists in establishing overall strength performance. [45] Sixty degrees per second and 180 degrees per second were used in three of the studies [20, 36, 38], with only 60 degrees per second being used by Erol et al. (2008) [37], 75 degrees per second by MacDermid et al. (2004) [35] and 90 degrees per second and 180 degrees per second by Dulgeroglu et al. (2013). [39] The variation in testing speeds and testing positions prevents the comparison of results between studies.

Reliability of isokinetic testing was only reported by MacDermid et al. (2004) and was found to be adequate. [35] Two studies calibrated the machine prior to testing using the standard instructions provided by the manufacturer.[20, 38] This standardization of calibration is designed to minimize measurement error and improve reliability.

Table 3 Summary of articles – Rotator Cuff Assessment

Author	Study Design	Aim of Study	Subjects	Outcome Measure	Testing	Results
Leroux et al. (1994)	Case Control Study	Compare shoulder internal and external rotation strength	45 subjects – no demographic detail. Dominance not reported. 15 random age-matched asym volunteers. Average age 47.6 Range 28-57 M:F 10:5 15 chronic SIS nonoperative Average age 48.8 Range 28-65 M:F 5:10 sym side: 10 right/5 left	Biodex Multi-joint System. Test position sitting, arm in plane of scapula & 45^0 GH abduction with handgrip. Test speeds 60^0 and 180^0 per sec. IR & ER peak torque reported and average power and ratios calculated. Both shoulders tested. One examiner.	Effect of gravity & machine calibrated before each test. 5 submaximal reps at each test speed as warm up. 1 minute rest between warm-up and testing. Isokinetic test – 2 submax reps & a set 5X at each speed. Dominant shoulder asym and uninvolved shoulder of SIS group tested first. 30 seconds rest between speed changes and approx. 2 mins rest when changing sides	1.Within Asym group – D vs ND 2.Within Sym group – Involved vs Uninvolved 3.PT % deficit: Involved Sym vs D Asym Not significant: - Control Group D/ND, IR/ER PT - Involved & Uninvolved shoulders with SIS IR/ER PT ratio Significant: - Non –operative SIS vs Control Mean IR and ER PT ($p< 0.01$) Non-operative SIS lower IR/ER PT ratio ($p<0.005$)
MacDermid et al. (2004)	Case Control Study	Determine reliability of strength and self report measures; relationship of strength measures to function & quality of life self reports	84 subjects 24M & 12F Mean age 43.6 yrs diagnosed with chronic RC tendinitis or SI > 3 months 28M & 20F. Mean age 40.8 yrs asymptomatic volunteers.	Lido Computerised Dynamometer. Test position sitting, arm in plane of scapula & 45^0 GH abduction with handgrip. Test speed 75^0 per sec. Both shoulders tested.	1 maximal rep practice. 3 maximal reps used for test. Continuous reciprocal conc & ecc contraction cycle through 90^0 motion i.e. from 45^0 IR to 45^0 ER.	Average PT and IR/ER ratios significantly lower in Sym compared Asym ($p<0.005$).

				Concentric & Eccentric IR & ER average peak torque reported. Values reported appear to be the mean of both shoulders.		
Tyler et al. (2005) .	Case Control Study	Determine strength deficits between SIS and asymptomatic groups	39 subjects Details of dominance not reported. 13 M & 4 F Mean age 37 ± 12 yrs (19-63 yrs) with SIS 10 M & 12 F. Mean age 21 ± 5 yrs (14-34 yrs) asymptomatic All participants recorded normal strength bilaterally according to manual muscle tests	Biodex System 3 Multi-joint Testing & Exercise Dynamometer. 2 x test positions 1) sitting, plane of scapula & 45^0 abduction with handgrip 2) 90^0 GH abduction, 90^0 elbow flexion, 90^0 GH ER. Test speeds 60^0 and 180^0 per sec. Both shoulders tested. IR & ER PT reported in each position and at each speed.	Warm-up: 2 trial reps at each test speed 30 secs rest between each speed. Isokinetic test – 5 reps at 60^0 sec & 15 reps at 180^0 sec. Testing was performed from 0^0 to 90^0, with the test initiated with arm in 90^0 ER. No reliability or validity reported.	Analysis compared the strength deficit between the D and ND shoulders in the asym group to the strength deficit between the involved and uninvolved shoulders in the SIS group. No significant difference was found between SIS and asym group for any isokinetic testing.
Moraes et al. (2008)	Case Control Study	Compare isokinetic performance of shoulder internal and external rotators between unilateral SIS and	20 subjects matched by age, gender & hand dominance. 10 with unilateral SIS 4 M & 6 F, mean age 28.6 ± 5.89yrs (20-38 yrs)	Biodex Medical System 3 Dynamometer. Test position – supine, 90^0 GH abduction & elbow flex Test speeds 60^0 and 180^0 per sec.	Calibration performed before testing Warm-up: 5 submaximal reps at each test speed Isokinetic test – 5 max reciprocal reps at each speed. Testing was performed in an arc	. Between group analysis: Sym (Sym group) vs ND (Asym group) Asym (Sym group) vs D (Asym group) No significant difference was identified in IR and ER work ratios.

		asymptomatic subjects.	10 asymptomatic Mean age 29 ± 5.35yrs (21-36 yrs)	Both shoulders tested. Strength data normalised by body weight. Work ratio between Ecc ER and Conc IR and work ratio between Ecc IR & Conc ER reported	of 90^0 GH rotation, between 40^0 IR & 50^0 ER. Conc followed by Ecc. D GH Asym and uninvolved GH of SI group tested first.	
Erol et al. (2008)	Case Control Study	Determine rotator cuff strength between SIS and Asym groups & explore relationship with pain, disability & quality of life	38 subjects All right D 13 diagnosed with SIS > 4 weeks All right side Sym 3 M & 10 F, mean age 37.8 ± 9.4yrs (26-52 yrs) who presented to Physical Med & Rehab Dept 25 Asym 5 M & 25 F, mean age 37.1 ± 9.0yrs (24-53 yrs) from clinical staff & patient escorts for same Dept.	Biodex System 3 Dynamometer. Test position was sitting, plane of scapula & 45^0 GH abduction. Test speed 60^0 per sec. Both GH tested. ER & IR peak torque values noted and peak torque deficit calculated as: (uninvolved – involved side) / Uninvolved side x 100	1 set of submaximal reps for familiarisation. 1 maximal practice rep before data. Isokinetic test – 5 max reciprocal reps. Conc/Conc IR & ER. Testing was performed with an arc of 90^0, between 45^0 IR & 45^0 ER.	Within group Sym: Involved vs Uninvolved Asym: D vs ND These values then compared between groups. Median ER PT, IR PT and ratios not significantly different between groups. No difference between D and ND in SIS group.
Dulgeroglu et al. (2013)	Case Control Study	Establish if GH rotation strength deficits in patients with SIS	48 subjects No significant difference between groups in gender, age or height but there was in weight.	Biodex (Not identified further) Test position: sitting, plane of scapula 45^0 GH abduction, 30^0 GH flex & 30^0 GH fwd flex with handgrip.	4 trial reps advised not to use max effort at each test speed as warm up. 30 secs rest between each speed.	Between group analysis: No significant difference identified in: 1.PT/BW ratios & Total Work for Sym GH of SIS group vs D Asym GH 2. PT and TW for within group analysis of SIS Group

		All right side dominant in both groups. 22 volunteers, diagnosed with SI 16 F & 6 M Mean age 46.09 ± 8.22 yrs. Presented to same hospital in Ankara,Turkey. 26 Asym 19F & 7M Mean age 42.77± 9.13 yrs	Test speeds 90^0 and 180^0 per sec. Both GH tested, through maximum arc of painfree motion (20^0-120^0)	Isokinetic test – 5 reps at 90^0 sec & 5 reps at 180^0 sec. After 5 minute rest, other shoulder tested.	Involved GH vs SIS group uninvolved GH Significantly lower PT/body weight ratios for IR, ER at both speeds (P<0.001). Significantly lower total work mean values for IR and ER at 90 ^{0} sec (P<0.001) and IR at 180 ^{0} sec (P=0.043) and ER at 180 ^{0} sec (P=0.003).

SIS = Shoulder Impingement	Conc = Concentric	Ecc= Eccentric	M=males
IR=Internal Rotation	ER=External Rotation	RC = Rotator Cuff	F=females
D=Dominant	ND=Non-Dominant	PT = Peak Torque	BW= body weight
Sym = Symptomatic	Asym = Asymptomatic		TW-total work

Posture Assessment (Table 4)

Lewis et al. (2005) used a lateral photograph to obtain spinal postural measurements and reported good intraphotographic reliability with an intraclass correlation coefficient (ICC) of 0.98. [25, 40] The craniovertebral angle (CVA), a well documented indicator of head on neck posture [40, 46] was identified via these lateral photographs and recorded as forward head posture. [40] The CVA is formed at the intersection of a horizontal line and a line drawn from the tragus of the ear and the spinous process of C7 and provides a gross measure of the amount of forward positioning of the head on the trunk.

Resting thoracic kyphosis angle was measured in both studies with no significant difference between groups identified in any of them. An inclinometer was used by Lewis et al. (2005). [40] Two gravity dependent inclinometers were used with the feet of the first inclinometer placed over the spinous processes of T1/2 and of the second over the spinous processes of T11/12. The thoracic kyphosis angle was calculated by the summation of these two angles. [40] The intra-rater reliability reported for this method was good with an intraclass correlation coefficient of 0.96 for the asymptomatic group and 0.94 for the symptomatic group. [25]

Theisen et al. (2010) reviewed the range of thoracic motion by measuring the thoracic kyphosis in the erect seated posture, sitting in maximal flexion and sitting in maximal extension. [41] Ott's sign was used to measure the degree the thoracic spine unfolds. It is measured by detecting and marking the most prominent cervical spinous process, C7, in relaxed sitting, then marking 30cm caudal to this, with the length bending maximally forward and back measured with a tape. This method was compared to ultrasound tomography with only a weak correspondence found between these results. [41] The authors stated that Ott's sign can be used as an indicator of restriction in the mobility of the thoracic spine but cannot be relied on to determine the amplitude of thoracic motion or the total range of thoracic motion. [41] A significant difference in functional thoracic range was identified between groups for both the ultrasound tomography and Ott's sign. Test-retest reliability for ultrasound tomography to measure thoracic ROM was reported to be good using Pearson correlation coefficient. [25]

Table 4 Summary of articles – Posture Assessment

Author	Study Design	Aim of Study	Subjects	Outcome Measure	Results
Lewis et al. (2005)	Case Control Study – placebo controlled cross-over trial	Investigate effect of changing posture on ROM GH flexion and abduction in scapular plane in SIS and Asym subjects.	120 subjects 60 subjects with SIS Protocol A Age 47.9 ±15.3yrs (22-72) M:F 17:13 Dominance: 25 Right 5 Left Protocol B Age 49.9 ±15.1yrs (19-75) M:F 18:12 Dominance: 27 Right 3 Left 60 subjects Asym Protocol A Age 32.8 ±9.9yrs (19-59) M:F 13:17 Dominance: 29 Right 1 Left Protocol B Age 35.3 ±10.0yrs (23-65) M:F 16:14 Dominance: 29 Right 1 Left	FHP measured on a lateral view photograph as the angle between horizontal line passing through C7 & a line extending from the tragus of the ear to C7 = CVA. FSP measured as the angle between horizontal line passing through C7 & a line extending from the lateral midpoint of the humeral head to C7 Kyphosis angle measured using inclinometers. Placed tip of inclinometer on T1&2 and T12&L1	Six variables were considered for analysis – FHP, FSP, thoracic kyphosis angle, normalized scapular protraction, and ranges of sagittal-plane GH flexion and abduction in plane of scapula Postural taping effects were statistically significant (P<0.001) for all postural measures for both Sym and Asym groups. Standard error reported in Sym group identified greater FHP (mean, 4.1°), less FSP (mean, 3.9°), smaller kyphosis (mean, 5.8°), less lateral scapular displacement (mean, 1.8 cm), less elevated scapula position (mean, 1.7 cm), less forward sagittal position (mean, 2.5 cm), increased pain-free range of shoulder flexion (mean 16.2°), and increased painfree range of scapular plane abduction (mean 14.7°), as compared to

					when measured with placebo taping.
Thiesen et al. (2010)	Case Control Study	Compare ROM thoracic spine in the sagittal plane in SIS and Asym groups	78 subjects 39 confirmed SIS 16M 23F Mean age 56.6yrs (38-77 yrs) Dominant 37 Right 2 Left 39 Asym 16M 23F Mean age 56.1yrs (38-79 yrs) Dominant 36 Right 3 Left	Ott's signs (Seventh cervical vertebrae (C7) located and marked in relaxed sitting and 30 cm caudal marked). Measured ROM thoracic spine in sagittal plane (maximal forward and backward) using tape measure. Tape measure compared to ultrasound topometry. ROM of thoracic spine in sagittal plane using Ott's sign and ultrasound topometry.	Static kyphosis measurement not statistically different between groups ($p>0.66$). Functional thoracic range statistically different between groups ($p<0.01$) Mean ±standard deviation Sym = 28.0 ±12.7 Asym = 34.6 ± 9.6

FHP=Forward Head Position FSP=Forward Shoulder Position M=males F=females ROM=Range of Motion Sym = Symptomatic

Asym = Asymptomatic

Posterior Shoulder Assessment (Table 5)

Tyler et al. (2000) performed a study quantifying posterior capsule tightness and motion loss through a broad age range and gender in those with a diagnosis of shoulder impingement. [42] Very high levels of intra and inter-rater reliability were reported for the posterior shoulder measurement in asymptomatic shoulders (49 nonimpaired volunteers (25 male, 24 female) aged 11 to 59 years) (Refer to Table 5). [47] Further, it was established passive internal rotation measured at 90^0 abduction in the coronal plane is correlated with posterior shoulder tightness (see further comment in Table 5).

A study by Borstad et al. (2007) aimed to detect meaningful clinical changes in posterior shoulder range over an 8 to 12 week period in construction workers exposed to overhead work. [43] Three measures were used: (1) Method as described by Tyler et al. (1999) to measure posterior shoulder range (detailed in Table 5) [47] (2) passive internal rotation in supine and (3) passive adduction in supine with the end range detected by palpating for scapula movement. [43] Reliability was determined by assuming no change in measurements should occur over this time period. This assumption of reliability is not valid as all workers continued to perform work duties throughout this period. The extensibility of the posterior capsule and posterior shoulder muscles would vary during this period as they were exposed to the use of force, static work activities and vibratory tools which have been shown to cause muscle fatigue. [48]

Table 5 Summary of articles – Posterior Shoulder Assessment

Author	Study Design	Aim of Study	Subjects	Outcome Measure	Measurement	Results
Tyler et al. (2000)	Case Control Study	Document changes in range of motion and posterior capsule tightness between SIS and asym groups	64 subjects 31 SIS Mean age 44 ± 16.5 yrs (19-74) 33 asym 20M 13F Mean age 33 ± 9.3 yrs (21-57)	All measurements made on a standard examination table. A standard carpenters square was used for marking the location of the medial epicondyle in relation to the surface of the examination table. Standard goniometers used to measure IR and ER.	The subject was positioned in neutral spine side lying with shoulders (acromions) positioned directly above each other. The scapula was stabilised by the examiner in the retracted position, with the humerus in 90^0 abduction. The humerus was lowered until the motion ceased or there was rotation of the humerus. Measurement recorded from medial epicondyle to examination table.	SIS D significant loss of IR ($p<0.001$) & greater posterior tightness ($p=0.011$) compared with asym. SIS ND significant loss of IR ($p=0.04$) & greater posterior tightness ($p=0.03$) compared with asym. ↓ IR range correlated to ↑ posterior shoulder tightness ($r=-0.50$, $P=0.006$. Least squares regression analysis).
Borstad et al. (2007)	Case Control Study	Compare three measurements used to quantify posterior shoulder flexibility for intra rater reliability over an 8-12 week period	59 subjects 37 SIS of at least 1 week Age 47.8 ± 11.6yrs %time spent working overhead daily 36.3±26.5 Years in trade 23.2 ± 11.4 22 asymptomatic Age 51.0 ± 11.7yrs %time spent working overhead daily 30.6±21.2	Measurement taken from the sym shoulder or the dominant asym shoulder. Goniometer measured passive internal rotation in supine and horizontal adduction in supine. 60cm carpenters square measured adduction in side lying.	Passive IR measured in supine with an assistant preventing scapular movement. Horizontal adduction measured in supine with the point being the palpable onset of scapular motion away from the plinth. Sidelying adduction was recorded using a carpenters square as per Tyler's method (Tyler , Roy, Nicholas, & Gleim, 1999)	Two way ANOVA (subject and trial) used to calculate ICC. Standard error of measurement (SEM) and smallest real difference (SRD) values reflected high test-retest variability in all three measurements. None of the three measures were proven to be highly stable indicators of posterior shoulder range over 8-12 weeks.

				Years in trade 23.8 ± 13.9 Recruited from construction workers with overhead work exposure of at least 1 year

SIS=shoulder impingement M=males F=females ICC=Intraclass Correlation Coefficient

D=Dominant ND = Non-Dominant IR= Internal Rotation

Table 6 Reliability and Validity

Study	Factor Being Assessed	Clinical Assessment Performed	Reliability		Validity		Consistent Differences Identified Between Groups
			SIS	Asymptomatic	SIS	Asymptomatic	
Odom et al. (2001)	2D Scapula	LSST – String and tape measure	Good to excellent	Good to excellent	Yes	Yes	NA
Curtis & Roush. (2006)	2D Scapula	LSST - Scoliometer	Excellent for positions 1 and 2	Excellent for positions 1 and 2	No	No	NA
Struyf et al. (2014)	Pec Minor Length	Vernier Caliper	Excellent intra Moderate inter	Good intra Moderate inter	No	No	NA
Rosa et al. (2016)	Pec Minor Length	Tape Measure	Excellent intra Good inter	Excellent intra Moderate inter	No	No	NA
Leroux et al. (1994)	Rotator Cuff Strength	Computerised Dynamometer	No	No	No	No	Yes
MacDermid et al. (2004)	Rotator Cuff Strength	Computerised Dynamometer	Good to excellent	Good to excellent	Yes	Yes	Yes
Tyler et al. (2005)	Rotator Cuff Strength	Computerised Dynamometer + Hand held dynamometer	No	No	No	No	No
Moraes et al. (2008)	Rotator Cuff Strength	Computerised Dynamometer	No	No	No	No	No
Erol et al. (2008)	Rotator Cuff Strength	Computerised Dynamometer	No	No	No	No	No
Dulgeroglu et al. (2013)	Rotator Cuff Strength	Computerised Dynamometer	No	No	No	No	Yes
Lewis et al. (2005)	CVA Resting thoracic kyphosis Angle	Lateral Photograph Inclinometer	Good to Excellent	Good to Excellent	Unknown		Yes No
Thiesen et al. (2010)	Thoracic range	Otts sign – tape measure Ultrasound Tomography	Yes	Yes	Unknown		Yes
Tyler et al. (2000)	Posterior shoulder range Passive Internal Rotation	Standard Carpenter's Square in side lying Goniometer	No	Excellent intra Good inter	No	Yes	Yes
Borstad et al. (2007)	Posterior shoulder range Passive Internal Rotation	Standard Carpenter's Square Goniometer	No	No	No	No	NA

LSST = lateral scapula slide test CVA = craniovertebral angle NA = not applicable

Discussion

Nine studies were identified that compared the findings of clinical tests in asymptomatic subjects and symptomatic SIS subjects. The remaining five studies reviewed only the reliability and validity of the assessment method in those with SIS and an asymptomatic group. Very small numbers of studies were found for each of the clinical tests, with the largest group of six studies being identified for rotator cuff strength assessment. The included studies ranged in quality but many had methodological limitations with respect to recruitment of subjects, matching of subjects for dominance and comparison of values calculated from both shoulders within each group prior to comparison between groups. High levels of intra-rater reliability and moderate to high levels of inter-rater reliability for 2D scapula assessment [30, 31] photographic reliability [40] and posterior shoulder range [42] indicate that these assessments can be reliably applied in the clinical setting (Table 6).

Static measurements of resting scapula positioning and cervical and thoracic angles were used in some assessments. [40] While this is useful, static values are of questionable value in the assessment of SIS as it is a dynamic condition occurring during shoulder elevation and requires an adequate range of thoracic extension which should be assessed. [49] Further research regarding the reliability and validity of dynamic tests which may be used in the clinical setting is required.

Thiesen et al. (2010) measured the thoracic range between segments using ultrasound topometry but this is not readily available in a clinical setting. [41] Photographic measurement was used by Lewis et al. (2005) to measure forward head posture but neither used this method to measure the thoracic angle. [40] Photographs have been shown to be reliable for measuring changes in thoracic angle. [50] None of the eligible studies used computer software programs to digitise thoracic angles from the lateral photographs although this method has been shown to be reliable. [51]

True measurement values for range of the posterior shoulder are difficult to establish due to the mobility of the scapula relative to the humerus. Tyler et al. (2000) positioned the scapula in full retraction thereby tensioning the posterior structures and reported that glenohumeral internal rotation measured in this position is a reliable indicator of posterior shoulder tightness. [42] Full scapula retraction standardises this position across all subjects being measured to allow a difference, if it exists, to be detected although the value of the measurement cannot be considered the true length of these posterior structures.

Only one study assessing rotator cuff strength reported specific validity and reliability measurements [35] (Table 6), however all identified studies used isokinetic testing. Isokinetic equipment requires calibration prior to testing ensuring an adequate level of reliability. No consistent differences in isokinetic strength of the rotator cuff were identified when comparing asymptomatic and symptomatic groups, despite variation in testing speed and position. Only Leroux et al. (1994) identified a significant difference (lower in symptomatic

group) in peak torque between groups suggesting weakness of the rotator cuff. [20] As all participants in this early study were presenting for surgical review and the methods of diagnosis available were clinical tests, radiographs and opaque arthrographs, these results may have been affected by the inclusion of some painful participants with undiagnosed rotator cuff tears.
Tyler et al. (2005) suggested hand held dynamometry was more sensitive than isokinetic dynamometry for detecting shoulder strength deficits. [36] However, hand held dynamometry is an isometric test performed at one point within the range of shoulder motion and can be affected by the skill and strength of the tester. [52, 53] As shoulder impingement is a dynamic condition with variation expected through range, a measurement taken at one point in range provides limited information about function and rotator cuff strength.

Posterior shoulder restriction, cervical and thoracic posture, scapula motion and rotator cuff strength have all been reported as factors associated with SIS yet no studies were identified which assessed a combination or all of these factors. Lewis et al. (2005), a high quality study, included range of motion, posture and static scapula assessment with all other studies comparing only a single factor in the symptomatic and asymptomatic groups. [40] Consistent differences in presentation between the asymptomatic group and the SIS group have not been identified when measuring 2D scapula position, static thoracic curves or isokinetic rotator cuff strength, with only static forward head position, functional thoracic range and posterior shoulder tightness being consistently identified as significantly different in those with SIS (Table 6).

The limitations of this study include the small number of studies which met the inclusion criteria for each factor being considered. This prevented definite conclusions being drawn regarding which clinical assessments are able to detect a difference in each of these factors in those with SIS and an asymptomatic group; a narrative approach was taken due to the heterogeneity of the reviewed studies; and the choice of a quality assessment tool for this type of study. Although the Downs and Black checklist has previously been modified and shown to be reliable [28], it may be considered to lack rigour.

Conclusion

This is the first review of clinical tests used to assess SIS associated extrinsic factors and their ability to detect differences between people diagnosed with SIS and people without shoulder pain.

Assessment of posterior shoulder range (passive shoulder adduction and internal rotation (using a standard carpenters square in side lying) and passive internal rotation in supine (using a goniometer)) identified significant loss of internal rotation and greater posterior tightness in those diagnosed with SIS. High reliability for this assessment was reported in the

asymptomatic group but not the SIS group. Further studies are needed to determine the preferred test position which may ensure reliability in those with SIS.

Assessment of thoracic range of motion (tape measure and ultrasound tomography) was found to be significantly reduced in those with SIS. Assessment using the tape measure (Ott's sign) was shown to identify the restriction in thoracic mobility but was unable to reliably report the true amplitude of motion as with ultrasound tomography. Ott's sign can be considered for use in the clinical setting with ultrasound tomography not being readily available. Cervical posture or forward head position (lateral photograph) and static thoracic kyphosis angle (inclinometer) identified significantly greater change in range in those with SIS with this assessment having good reliability. However, clinicians should take note that static thoracic values are of questionable value in the assessment of SIS as it is a dynamic condition occurring during shoulder elevation.

Assessment of rotator cuff strength (isokinetic dynamometer) identified significantly lower peak torque and mean peak torque values for internal and external shoulder rotation in the SIS group in half of the reviewed studies, with good reliability found, suggesting therapists can use this test in a clinical setting, when available.

Good to excellent reliability was reported for the lateral scapular slide test positions to assess 2D linear scapular position and resting pectoralis minor muscle length. As clinical differences were not assessed between groups further research is needed to determine if these tests are able to identify differences between those diagnosed with SIS and asymptomatic shoulders.

In a clinical setting, physiotherapists can consider using these tests which have identified clinical differences to aid them in their provision of advice and treatment for SIS. However, further research of these clinical tests needs to consider controlling for age, upper limb dominance and gender between a group diagnosed with SIS and an asymptomatic group.

APPENDIX 1

Downs and Black Checklist (1998)

1	Is the hypothesis/aim/objective of the study clearly described?
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section?
3	Are the characteristics of the patients included in the study clearly described?
4	~~Are the interventions of interest clearly described?~~
5	Are the distributions of principal confounders in each group of subjects to be compared clearly described?
6	Are the main findings of the study clearly described?
7	Does the study provide estimates of the random variability in the data for the main outcomes?
8	Have all important adverse events that may be a consequence of the intervention been reported?
9	~~Have the characteristics of patients lost to follow up been described?~~
10	Have actual probability values been reported (e.g. 0.035, not <0.05) for the main outcomes except where the probability value is less than 0.001?
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited?
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?
13	~~Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive?~~
14	Was an attempt made to blind study subjects to the intervention they have received?
15	Was an attempt made to blind those measuring the main outcomes of the intervention?
16	If any of the results of the study were based on 'data dredging', was this made clear?
17	In case control studies, is the time period between the intervention and the outcome the same for cases and controls?
18	Were the statistical tests used to assess the main outcomes appropriate?
19	Was compliance with the intervention/s reliable?
20	Were the main outcome measures used accurate (valid and reliable)?
21	Were the cases and controls recruited from the same population?
22	Were the cases and controls recruited over the same time period?
23	Were study subjects randomised to intervention groups?
24	~~Was the randomised intervention aSISgnment concealed from both subjects and assessors until recruitment was complete and irrevocable?~~
25	Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?
26	~~Were losses of patients to follow up taken into account?~~
27	Was there evidence of a power calculation?

1. Michener, L.A., P.W. McClure, and A.R. Karduna, *Anatomical and biomechanical mechanisms of subacromial impingement syndrome.* Clinical Biomechanics, 2003. **18**: p. 369-379.
2. Lewis, J.S., A.S. Green, and S. Dekel, *The aetiology of subacromial impingement syndrome.* Physiotherapy, 2001. **87**(9): p. 458-469.
3. Bigliani, L.U. and W.N. Levine, *Subacromial Impingement Syndrome.* Journal of Bone and Joint Surgery, 1997. **79**(12): p. 1854-1868.
4. Hanchard, N., J. Cummins, and C. Jeffries *Evidence-based clinical guidelines for the diagnosis, assessment and physiotherapy management of shoulder impingement syndrome*. 2004.
5. Ostor, A.J.K., et al., *Diagnosis and relation to general health of shoulder disorders presenting to primary care.* Rheumatology, 2005. **44**: p. 800-805.
6. van der Windt, D.A.W.M., et al., *Shoulder disorders in general practice: incidence, patient characteristics and management.* Annals of the Rheumatic Diseases, 1995. **54**: p. 959-964.
7. Park, H.B., et al., *Diagnostic accuracy of clinical tests for the different degrees of subacromial impingement syndrome.* Journal of Bone and Joint Surgery, 2005. **87-A**(7): p. 1446-1455.
8. Neer, C.S.I., *Impingement Lesions.* Clinical Orthopaedics and Related Research, 1983. **173**(March): p. 70-77.
9. Hawkins, R.J. and J.C. Kennedy, *Impingement syndrome in athletes.* American Journal of Sports Medicine, 1980. **8**(3): p. 151-158.
10. Kessel, L. and M. Watson, *The painful arc syndrome. Clinical classification as a guide to management.* The Journal of Bone and Joint Surgery, 1977. **59-B**(2): p. 166-172.
11. Dalton, S.E., *Clinical examination of the painful shoulder.* Ballieres Clinical Rheumatology, 1989. **3**(3): p. 453-474.
12. Michener, L.A., et al., *Reliability and diagnostic accuracy of 5 physical examination tests and combination of tests for subacromial impingement.* Archives of Physical Medicine and Rehabilitation, 2009. **90**(November): p. 1898-1903.
13. Cleland, J., ed. *Orthopaedic Clinical Examination: An Evidence-Based Approach for Physical Therapists*. 2007, Saunders.
14. Sorohan, A. and K. Mc Creesh, *Assessment of subacromial impingement syndrome in the primary care setting: development of an evidence based clinical framework.* Physiotherapy Ireland, 2009. **30**(1): p. 16-22.
15. Calis, M., et al., *Diagnostic values of clinical diagnostic tests in subacromial impingement syndrome.* Annals of the Rheumatic Diseases, 2000. **59**: p. 44-47.
16. Borstad, J.D. and P.M. Ludewig, *Comparison of scapular kinematics between elevation and lowering of the arm in the scapular plane.* Clinical Biomechanics, 2002. **17**: p. 650-659.
17. Ludewig, P.M. and T.M. Cook, *Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement.* Physical Therapy, 2000: p. 276-291.
18. McClure, P.W., et al., *Shoulder Function and 3-Dimensional Scapular Kinematics in People With and Without Shoulder Impingement Syndrome.* Physical Therapy, 2006. **86**(8): p. 1075-1090.

19. Brox, J.I., et al., *Arthroscopic surgery versus supervised exercises in patients with rotator cuff disease (stage II impingement syndrome): A prospective, randomised, controlled study in 125 patients with a 2 1/2 year follow-up.* Journal of shoulder and elbow surgery, 1999. **8**(2): p. 102-111.
20. Leroux, J.-L., et al., *Isokinetic evaluation of rotational strength in normal shoulders and shoulders with impingement syndrome.* Clinical Orthopaedics and Related Research, 1994: p. 108-115.
21. Reddy, A.S., et al., *Electromyographic analysis of the deltoid and rotator cuff muscles in persons with subacromial impingement.* Journal of shoulder and elbow surgery, 2000. **9**: p. 519-523.
22. Warner, J.J., et al., *Patterns of flexibility, laxity and strength in normal shoulders and shoulders with instability and impingement.* American Journal of Sports Medicine, 1990. **18**: p. 366-375.
23. Moher, D., et al., *Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement.* Annals of Internal Medicine, 2009. **151**(4): p. 264-269.
24. Braman, J., P., et al., *Shoulder impingement revisited: evolution of diagnostic understanding in orthopedic surgery and physical therapy.* Medical & Biological Engineering & Computing, 2013.
25. Portney, L.G. and M.P. Watkins, eds. *Foundations of Clinical Research: Applications to Practice*. Third ed. 2009, Pearson Prentice Hall. 892.
26. Downs, S.H. and N. Black, *The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions.* Journal of Epidemiology and Community Health, 1998. **52**: p. 377-384.
27. Sanderson, S., I.D. Tatt, and J.P.T. Higgins, *Tools for assessing quality and susceptibility to bias in observational studies in epidemiology: a systematic review and annotated bibliography.* International Journal of Epidemiology, 2007. **36**: p. 666-676.
28. Hootman, J., M., et al., *Reliability and validity of three qualitative instruments for systematic reviews of observational studies.* Research Synthesis Methods, 2011. **2**(2): p. 110-118.
29. Wright, R.W., et al., *How to write a systematic review.* Clinical Orthopaedics and Related Research, 2007. **455**: p. 23-29.
30. Odom, C.J., et al., *Measurement of scapular asymmetry and assessment of shoulder dysfunction using the lateral scapular slide test: A reliability and validity study.* Physical Therapy, 2001. **81**(2): p. 799-809.
31. Curtis, T. and J.R. Roush, *The lateral scapular slide test: A reliability study of males with and without shoulder pathology.* North American Journal of Sports Physical Therapy, 2006. **1**(3): p. 140-146.
32. Struyf, F., et al., *Interrater and intrarater reliability of the pectoralis minor muscle length measurement in subjects with and without shoulder impingement symptoms.* Manual Therapy, 2014. **19**: p. 294-298.
33. Rosa, D.P., et al., *Reliability of measuring pectoralis minor muscle resting length in subjects with and without signs of shoulder impingement.* Brazilian Journal of Physiotherapy, 2016. **20**(2): p. 176-183.
34. Kibler WB. *The Role of the Scapula in Athletic Shoulder Function*. American Journal of Sports Medicine, 1998. **26**: p. 325-337.
35. MacDermid, J.C., et al., *The impact of rotator cuff pathology on isometric and isokinetic strength, function and quality of life.* Journal of shoulder and elbow surgery, 2004. **13**(6): p. 593-598.

36. Tyler, T.F., et al., *Quantifying shoulder rotation weakness in patients with shoulder impingement.* Journal of Shoulder and Elbow Surgery, 2005. **14**(6): p. 570-574.
37. Erol, O., L. Ozcakar, and R. Celiker, *Shoulder rotator strength in patients with stage I-II subacromial impingement: Relationship to pain, disability and quality of life.* Journal of shoulder and elbow surgery, 2008. **17**(6): p. 893-897.
38. Moraes, G.F.S., et al., *Sacpular muscle recruitment patterns and isokinetic strength ratios of the shoulder rotator muscles in individuals with and without impingement syndrome.* Journal of shoulder and elbow surgery, 2008. **17**(15): p. 48S-53S.
39. Dulgeroglu, D., et al., *Evaluation of shoulder rotational strength in patients with subacromial impingement syndrome using a computerized isokinetic dynamometer.* Journal of musculoskeletal pain, 2013. **21**(1): p. 23-30.
40. Lewis, J.S., C. Wright, and G. Ann, *Subacromial impingement syndrome: The effect of changing posture on shoulder range of movement.* Journal of Orthopaedic & Sports Physical Therapy, 2005. **35**(2): p. 72-87.
41. Thiesen, C., et al., *Co-occurrence of outlet impingement syndrome of the shoulder and restricted range of motion in the thoracic spine - a prospective study with ultrasound-based motion analysis.* BMC Musculoskeletal Disorders, 2010. **11**(135).
42. Tyler , T.F., et al., *Quantification of Posterior Capsule Tightness and Motion Loss in Patients with Shoulder Impingement.* American Journal of Sports Medicine, 2000. **28**(5): p. 668-673.
43. Borstad, J.D., et al., *Clinical measurement of posterior shoulder flexibility.* Manual Therapy, 2007. **12**: p. 386-389.
44. Connelly Maddux, R.E., W.B. Kibler, and T. Uhl, *Isokinetic peak torque and work values for the shoulder.* Journal of Orthopaedic and Sports Physical Therapy, 1989(January): p. 264-268.
45. Otis, J.C., et al., *Torque production in the shoulder of the normal young adult male: The interaction of function, dominance, joint angle and angular velocity.* Journal of Orthopaedic and Sports Physical Therapy, 1990. **18**(2): p. 119-123.
46. Grimmer-Sommers, K., S. Milanese, and Q. Louw, *Measurement of cervical posture in the sagittal plane.* Journal of Manipulative and Physiological Therapeutics, 2008. **31**(7): p. 509-517.
47. Tyler , T.F., et al., *Reliability and validity of a new method of measuring posterior shoulder tightness* Journal of Orthopaedic and Sports Physical Therapy, 1999. **29**(5): p. 262-274.
48. Bernard, B.P., *Musculoskeletal Disorders and Workplace Factors: A critical review of epidemiologic evidence for work related musculoskeletal disorders of the neck, upper extremity and low back.*, N.I.o.O.S.a.H. (NIOSH), Editor. 1997, NIOSH.
49. Edmondston, S.J., et al., *Thoracic Spine Extension Mobility in Young Adults: Influence of Subject Position and Spinal Curvature.* Journal of Orthopaedic & Sports Physical Therapy, 2011. **41**(4): p. 266-273.
50. Perry, M., et al., *Reliability of Sagittal Photographic Spinal Posture Assessment in Adolescents.* Advances in Physiotherapy, 2008. **10**: p. 66-75.
51. Milanese, S. and K. Grimmer-Somers, *Backpacks and body posture in children*, in *Load Carriage in School Children*, Y. Hong, Editor. 2010, Nova Science Publishers Inc.
52. Refshauge, K.M. and E.M. Gass, eds. *Muculoskeletal Physiotherapy. Clinical Science and Evidence-Based Practice*. Second ed. 2004, Butterworth-Heinemann. 305.
53. Andrews, A.W., M.W. Thomas, and R.W. Bohannon, *Normative values for isometric muscle force measurements obtained with hand-held dynamometers.* Physical Therapy, 1996. **76**(3).