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**Specific Physiotherapy Management for Subacromial
Shoulder Impingement**

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B.App.Sc. (Physiotherapy), Grad. Dip. Ergonomics

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

College of Healthcare Sciences

James Cook University

December 2017

Acknowledgements

Thank you to my principal advisor, Professor Susan Gordon, for mentoring me through this journey, both my personal and my professional journeys, with unfailing support and encouragement. You have given so much of your personal time and knowledge, patiently and enthusiastically throughout. I can only hope to emulate your example.

To my secondary advisor, Associate Professor Kerriane Watt, thank you for your patience and knowledge in guiding me through my statistical components and writing etiquette. The time we spent together always cleared my thoughts and created order to the chaos.

My gratitude goes to all my colleagues and students within Physiotherapy, in particular, Anne Jones, for your willingness to allow me time to complete writing of this thesis when staffing was not ideal and for the use of the musculoskeletal clinic, and Jade Williams, for your willingness to help with assessment when asked, as well as all the physiotherapy students who accommodated my need to do other duties within the clinic.

Thank you to my patient and supportive family, who have tolerated me throughout this journey, during which we have all grown together.

Statement of Contributions to Jointly Authored Works Contained in the Thesis

Land, H., & Gordon, S. (2011). What is normal isokinetic shoulder strength or strength ratios? A systematic review. *Isokinetics and Exercise Science, 19*, 231–241.

Helen Land was responsible for the design of the study, data collection, data analysis, and writing, editing and submitting the article. Susan Gordon supervised the design of the study, guided the data collection and analysis, reviewed progressive drafts of the paper and provided detailed feedback.

Land, H., & Gordon, S. (2017). Clinical assessment of factors associated with subacromial shoulder impingement: A systematic review. *Physical Therapy Reviews, 21*, 192–206.

Helen Land was responsible for the design of the study, data collection, data analysis, and writing, editing and submitting the article. Susan Gordon supervised the design of the study, guided the data collection and analysis, reviewed progressive drafts of the paper and provided detailed feedback.

Land, H., Gordon, S., & Watt, K. (2017). Clinical assessment of subacromial shoulder impingement—Which factors differ from the asymptomatic population?

Musculoskeletal Science and Practice, 27, 49–56.

Land, H., Gordon, S., & Watt, K. (2017). Isokinetic clinical assessment of rotator cuff strength in subacromial shoulder impingement. *Musculoskeletal Science and Practice, 27*, 32–39.

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Land, H., Gordon, S., & Watt, K. (2017) Effect of manual physiotherapy to the upper thoracic spine vs the posterior shoulder in a group of homogeneous individuals with SSI: A randomised controlled trial. Manuscript submitted for publication.

Helen Land was responsible for the design of the study, data collection, data analysis, and writing, editing and submitting the article. Susan Gordon and Kerrienne Watt supervised the design of the study, guided the data collection and analysis, reviewed progressive drafts of the paper and provided detailed feedback.

Statement of Contributions by Others to the Thesis as a Whole

Professor Susan Gordon and Associate Professor Kerrienne Watt assisted in the development of the research objectives, formulation of the research methodology and interpretation of the data. These members also provided thesis guidance through dedicated review of the manuscript, editorial assistance and detailed comments.

Elite Editing provided professional editorial services limited to the matters listed in Standards D and E of the *Australian Standards for Editing Practice* (Council of Australian Societies of Editors, 2001). This included proofreading; review of grammar, syntax, sentence structure and voice; identification of ambiguity, jargon and repetition; and suggestions to improve brevity and clarity. Elite Editing does not have academic expertise in the area of the thesis.

The candidate developed the research objectives, wrote the ethics applications, recruited the participants, conducted the research studies, conducted and interpreted the statistical analysis, and wrote and edited the thesis following feedback.

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**Statement of Parts of the Thesis Submitted to Qualify for the
Award of Another Degree**

None.

Published Works by the Author Incorporated into the Thesis

- Land, H., & Gordon, S. (2011). What is normal isokinetic shoulder strength or strength ratios? A systematic review. *Isokinetics and Exercise Science, 19*, 231–241.
- Land, H., & Gordon, S. (2017). Clinical assessment of factors associated with subacromial shoulder impingement: A systematic review. *Physical Therapy Reviews, 21*, 192–206.
- Land, H., Gordon, S., & Watt, K. (2017). Clinical assessment of subacromial shoulder impingement—Which factors differ from the asymptomatic population? *Musculoskeletal Science and Practice, 27*, 49–56.
- Land, H., Gordon, S., & Watt, K. (2017). Isokinetic clinical assessment of rotator cuff strength in subacromial shoulder impingement. *Musculoskeletal Science and Practice, 27*, 32–39.
- Land, H., Gordon, S., & Watt, K. (2017). Reply to the Letter to the Editor regarding ‘Clinical assessment of subacromial shoulder impingement—Which factors differ from the asymptomatic population?’ *Musculoskeletal Science and Practice, 29*, e14–e15.
- Land, H., Gordon, S., & Watt, K. (2017). *Effect of manual physiotherapy to the upper thoracic spine vs the posterior shoulder in a group of homogeneous individuals with SSI: A randomised controlled trial*. Manuscript submitted for publication.

Poster presentation

- Land, H. (2015, May). *Is rotator cuff strengthening necessary in the management of subacromial shoulder impingement?* Poster session presented at the World Congress of Physical Therapy, Singapore.

Abstract

Diagnostic labels for shoulder pain are frequently used, yet no standardised diagnostic criteria for any of the labels have been described. One such diagnostic label, subacromial shoulder impingement (SSI), is commonly used as an umbrella term for all subacromial pain with no indication of aetiology or mechanism of pain production. Indeed, the aetiology and specific mechanism of SSI remain robustly debated.

Physiotherapy is a common conservative treatment intervention in SSI. Current level II evidence (randomised controlled trials [RCTs]) for the effectiveness of physiotherapy in those with SSI has not provided information about targeted interventions linked to specific biomechanical factors. No clear judgements can be deduced from these RCT's due to limitations of heterogeneity in inclusion criteria, limitations in standardisation of interventions, the lack of matching of upper-limb dominance and not including objective outcomes within methodology. A major focus of physiotherapy is the identification of muscular, neuromuscular and joint impairments, with identified impairments targeted in the treatment programme. While several purported biomechanical factors have been suggested for extrinsic SSI, they have not been clearly described, and this has led to current use of nonspecific treatment interventions to embrace all possible impairments.

An initial literature review within this research programme identified four biomechanical factors purported to be associated with extrinsic SSI: posterior shoulder tightness, thoracic postural impairment, scapula impairment and rotator cuff impairment. Reliable and valid objective physiotherapy clinical tests for each of these four biomechanical factors were then identified, using a systematic literature review, prior to conducting a rigorous original case-control study to establish which, if any, were different between a group experiencing SSI

symptoms and an asymptomatic group, matched for age, gender, limb dominance and physical activity level.

Crude analyses revealed that 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. It is not known if these identified differences were contributing to or a result of SSI.

An RCT was conducted to determine if interventions focused on the upper thoracic spine and posterior shoulder were effective in the management of SSI. This original RCT, which followed the CONSORT statement and was a registered trial with the Australian New Zealand Clinical Trials Registry (12615001303538)¹, identified mobilisation of the upper thoracic spine or massage and mobilisation of posterior shoulder structures combined with a targeted single home exercise, in a homogeneous group with SSI, significantly improved function and passive internal rotation range, suggesting that manual therapy that addresses these extrinsic contributing factors decreases the signs and symptoms of SSI.

The outcomes of this research provide physiotherapists with a focused assessment and treatment pathway of the thoracic spine and posterior shoulder in those aged 40–60 years presenting with signs and symptoms of extrinsic SSI. This study is the first step in developing a physiotherapy clinical pathway for shoulder pain, which can be presented to health insurers and other health providers. Further rigorous research is required for a complete pathway for other causes of shoulder pain.

¹ Australian and New Zealand Standard Research Classifications (ANZSRC): 110699 Human movement and sports sciences not elsewhere classified 100%.

Keywords: subacromial shoulder impingement, thoracic, posterior shoulder, manual therapy, randomised controlled trial

Author's Confirmatory Statements

The opinions expressed in this study are those of the author. The National Statement on Ethical Conduct in Human Research (developed jointly by the National Health and Medical Research Council, the Australian Research Council and the Australian Vice Chancellors Committee, March 2007) has been adhered to during the conduct of this research.

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Abbreviations

ABD	Abduction
AC	Acromioclavicular
AP	Antero-posterior
AROM	Active range of motion
BMI	Body mass index
CINAHL	Cumulative Index of Nursing and Allied Health Literature
Con	Concentric
CONSORT	Consolidated Standards of Reporting Trials
CV	Costovertebral
CVA	Craniovertebral angle
D	Dominant
D&B	Downs and Black
DASH	Arm Shoulder Hand Disability Score
Ecc	Eccentric
EMG	Electromyography
ER	External rotation
F	Female
GH	Glenohumeral
ICC	Intraclass correlation coefficient
IPAQ	International Physical Activity Questionnaire
IR	Internal rotation
Jt	Joint
LHB	Long head of biceps

LSST	Lateral Scapula Slide Test
M	Male
Mobs	Mobilisations
MRI	Magnetic resonance imaging
MT	Manual Therapy
MWM	Mobilisation with movement
%MVIC	Percentage of maximum voluntary isometric contraction
ND	Non-dominant
NPRS	Numerical Pain Rating Scale
OR	Odds ratio
PA	Postero-anterior
Pec Min	Pectoralis minor
PT	Peak torque
RCT	Randomised Controlled Trial
ROM	Range of motion
RPT	Relative peak torque
SC	Sternoclavicular
SD	Standard deviation
SEM	Standard error of the mean
SF-36	36-item Short Form Health Survey
SPADI	Shoulder Pain and Disability Index
SPSS	Statistical Package for the Social Sciences
SS	Supraspinatus
SSI	Subacromial shoulder impingement

UTHSCSA University of Texas Health Science Center at San Antonio

VAS Visual analogue scale

Chapter 1: Introduction

1.1 Subacromial Shoulder Pain/Impingement

Shoulder pain, the third most common musculoskeletal condition (after back and knee) presenting to Australian general practitioners, has a reported prevalence of 22.3% (Charles, Britt, & Fahridin, 2007; Hill, Gill, Shanahan, & Taylor, 2010). Chronic painful shoulder conditions are frequent (Brox, 2003), affecting both quality of life and physical function (Hill et al., 2010) and resulting in expensive associated treatment costs (Mroz et al., 2014; Safe Work Australia, 2017).

Diagnostic labels for shoulder pain are frequently used, yet no standardised diagnostic criteria for any of the labels have been described (Schellingerhout, Verhagen, Thomas, & Koes, 2008). One such diagnostic label, subacromial shoulder impingement (SSI), is commonly used (Gebremariam et al., 2014; Linsell et al., 2006; Ostor, Richards, Prevost, Speed, & Hazleman, 2005; van der Windt, Koes, de Jong, & Bouter, 1995) as an umbrella term for all subacromial pain with no indication of aetiology or mechanism of pain production (Braman, Zhao, Lawrence, Harrison, & Ludewig, 2014; Lewis, 2011; Mackenzie, Herrington, Horlsey, & Cools, 2015). Indeed, the aetiology and specific mechanism of SSI remain robustly debated (Braman et al., 2014; Lewis, 2011; Mackenzie et al., 2015).

1.2 Physiotherapy Treatment of Subacromial Shoulder Impingement

Physiotherapy is a common conservative treatment intervention in SSI (Charles et al., 2007; Hill et al., 2010). Current level II evidence (randomised controlled trials [RCTs]) for the effectiveness of physiotherapy in those with SSI has not provided information about targeted interventions linked to specific biomechanical factors (Carmargo et al., 2015; Cook, Learman, Houghton, Showalter, & O'Halloran, 2014; Kachingwe, Phillips, Sletten, & Plunkett, 2008).

A major focus of physiotherapy is the identification of muscular, neuromuscular and joint impairments, with identified impairments targeted in the treatment programme (Banks & Hengeveld, 2014). While several purported biomechanical factors have been suggested for extrinsic SSI, they have not been clearly described, and this has led to the current use of nonspecific treatment interventions to embrace all possible impairments (Lewis & Ginn, 2015; Mackenzie et al., 2015; Seitz, McClure, Finucane, Boardman, & Michener, 2011).

The outcomes of RCTs investigating the effectiveness of physiotherapy in those with SSI have been limited by:

1. Heterogeneity in inclusion criteria. Participants aged 18–75 years or more were included without considering expected age-related significant variances in the type and intensity of daily activity and presence of age-related degenerative shoulder changes (Bennell et al., 2010; Kromer, de Bie, & Bastiaenen, 2013). In addition, there was a lack of gender matching, although differences in strength and flexibility were identified between males and females (Baskurt, Baskurt, Gelecek, & Ozkan, 2011).
2. Lack of standardisation of interventions preventing replication of therapy. Interventions have been prescribed in a pragmatic fashion, unique to each individual patient, based on their hypothesised underlying dysfunction and involving multiple mobilisation techniques and exercises (Carmargo et al., 2015; Cook et al., 2014). No reference or explanation has been given as to how the specific mobilisation technique or exercises used in the studies were chosen (Carmargo et al., 2015; Cook et al., 2014; Kachingwe et al., 2008).
3. Lack of matching of participants' upper-limb dominance. Internal and external rotation strength of the dominant shoulder is significantly stronger than that of the

non-dominant shoulder in an asymptomatic population (Roy, MacDermid, Boyd, et al., 2009), which might have confounded results.

4. Not objectively measuring clinical assessments which were included within methodology. Examples being painfree active range of shoulder motion and shoulder muscle strength. By not including these objective clinical assessments as study outcomes, interpretation of clinically meaningful effects of the manual therapy interventions was prevented (Cook et al., 2014; Kaya, Baltaci, Toprak, & Atay, 2014; Kromer et al., 2013).
5. Concomitant medical interventions. This included treatments such as corticosteroid injection along with physiotherapy exercise prescription (Holmgren, Bjornsson Hallgren, Oberg, Adolfsson, & Johansson, 2012).

No clear and effective physiotherapy treatment pathway for those experiencing SSI has been established, with a lack of homogeneity and objective outcome measures hampering previous studies. Identifying a sound and effective physiotherapy treatment pathway for those experiencing symptoms of SSI may ensure physiotherapy becomes the preferred treatment option for health insurers and other health providers.

1.3 Research Aims and Research Questions

Without rigorous research that includes reliable and valid objective assessment techniques, subjective outcomes and targeted interventions for established associated factors of extrinsic SSI, the use of physiotherapy will be unjustifiable and the outcomes sub-optimal.

Sequential studies informed this research and are described below (see Figure 1.1).

1.3.1 Study 1 (reported in Chapter 2)

Aim: To understand current knowledge regarding the aetiology of extrinsic SSI.

A literature review identified four biomechanical factors purported to be associated with extrinsic SSI:

1. posterior shoulder tightness (studied in asymptomatic sporting populations; Mackenzie, Herrington, Porter, & Funk, 2014; Maenhout, Van Eesel, & Van Dyck, 2012)
2. thoracic postural impairment (postulated from static measurement methods using healthy volunteers from standard radiographs and computed tomography [CT] scans; Gumina, Di Giorgio, Postacchini, & Postacchini, 2008)
3. scapula impairment (yet to be identified using physiotherapy clinical testing methods in those experiencing SSI)
4. rotator cuff impairment (identified as diminished rotator cuff electromyography [EMG] in subjects with SSI symptoms [Myers, Hwang, Pasquale, Blackburn, & Lephart, 2009; Reddy, Mohr, Pink, & Jobe, 2000] although it is uncertain whether this variation in activity is clinically significant in those with SSI or identifiable in a clinical assessment).

1.3.2 Study 2 (reported in Chapter 2)

Aim: To identify and determine the reliability and validity of clinical tests, and to assess if differences exist between those with SSI and an asymptomatic group, for each of the four biomechanical factors.

A systematic literature review titled ‘Clinical Assessment of Biomechanical Factors Associated with Extrinsic Subacromial Shoulder Impingement—A Systematic Review’ was conducted (Land & Gordon, 2017). This literature review has been published in *Physical Therapy Reviews* with permission received from the publisher, Taylor and Francis, to reproduce the full article in Appendix A.

1.3.3 Study 3 (reported in Chapter 4)

Aim: To compare a group experiencing SSI symptoms with an asymptomatic group to determine which, if any, of the four biomechanical factors differed between the two groups by using standard physiotherapy clinical tests.

The hypothesis was that there would be a difference in assessment outcomes, for each of the biomechanical factors, between the painful shoulder in the SSI group and the dominance-matched shoulder in the control group.

Clinical tests for this study were adopted from the outcomes of the systematic review described in Chapter 2. The specific clinical testing methods adopted—lateral scapula slide test (LSST; Kibler, 1998); active thoracic flexion/extension range and thoracic angle digitised from sagittal photographs (Edmondston et al., 2011); posterior shoulder range measured with participant in a side-lying position, scapula fully retracted and the humerus lowered to the end point, measured with a standard carpenter's square (Tyler, Roy, Nicholas, & Gleim, 1999); and isokinetic internal and external rotation testing (CSMi, 2006)—are reported in Chapter 3.

Further review of the literature established the demographic criteria and inclusion and exclusion criteria for this study, including age, gender, limb dominance, radiography and presence of other conditions (see Chapter 3).

This original research was written up as two separate papers, both published in the journal *Musculoskeletal Science and Practice* (Land, Gordon, & Watt, 2017a, 2017c).

This original case-control study identified with crude analysis that 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.

Differences in muscle strength were not clearly identified between the SSI cases and control group, with significant strength differences only found when the dominant SSI shoulder was symptomatic (peak torque [PT] of eccentric internal rotation at 60 deg/s). No strength differences were evident when comparing the non-dominant painful SSI shoulder and the non-dominant control shoulder. Posterior shoulder range was identified as a significant independent predictor of SSI using conditional logistical regression, showing for every centimetre reduction in posterior shoulder range there is a 5% increased likelihood of SSI.

It is not known whether these identified differences are contributing to or a result of SSI. Because no differences in muscle strength were identified, further research regarding rotator cuff strength was not warranted. However, further research was required to determine if interventions focused on the upper thoracic spine and posterior shoulder were effective in the management of SSI.

1.3.4 Study 4 (reported in Chapter 5)

Aim: To identify manual physiotherapy treatment protocols for SSI symptoms, including the frequency and total number of treatments performed, length of each individual treatment session, outcome measures used, specific techniques performed and effectiveness of each technique, to inform the methodology for an RCT investigating the effect of physiotherapy interventions to increase thoracic range of motion and increase posterior shoulder range in those presenting with SSI symptoms.

A systematic literature review informed the methodology for the RCT (see Chapter 5).

1.3.5 Study 5 (reported in Chapter 6)

Aim: To compare the effect of (1) passive mobilisation of the upper thoracic spine; (2) massage, passive mobilisation and stretching of the soft tissues of the posterior shoulder;

and (3) an active control intervention on pain, function and range of motion in a homogeneous SSI group.

The hypothesis was that there would be a significant improvement in pain, function and range of motion in the groups receiving passive mobilisation interventions, compared with the active control group.

This trial was conducted according to the CONSORT statement for reporting of RCTs (Moher et al., 2010). The paper reporting this RCT is currently under peer review for publication in an online journal.

This original research identified mobilisation of the upper thoracic spine or massage and mobilisation of posterior shoulder soft tissues combined with a targeted single home exercise, in a homogeneous group with SSI, significantly improved function and passive internal rotation range. The improvements remained significant 6 months after cessation of intervention. These findings suggest that manual therapy treatment that addresses these extrinsic contributing factors decreases the signs and symptoms of SSI.

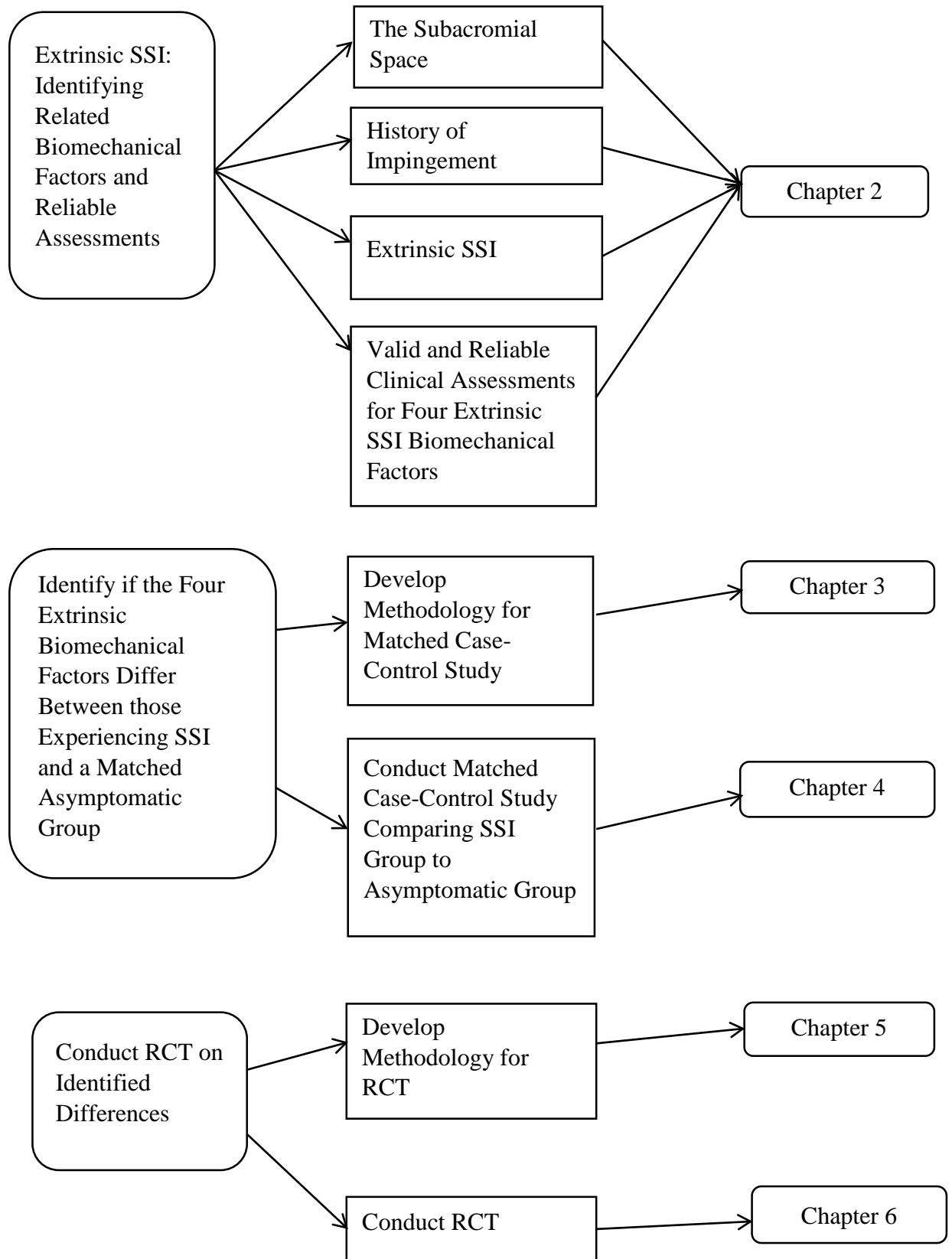


Figure 1.1 Thesis overview. SSI = subacromial shoulder impingement; RCT = randomised controlled trial

Chapter 2: Extrinsic Subacromial Shoulder Impingement: Identifying Related Biomechanical Factors and Reliable Assessment Methods

2.1 The Subacromial Space

The space between the acromion and proximal humerus is known as the subacromial space (Oatis, 2009). The normal linear distance between the acromion and proximal humerus, measured using radiographs and ultrasonography, is 7–17 mm (Azzoni, Cabitza, & Parrini, 2004). This space contains the subacromial bursa, the rotator cuff tendons, the superior portion of the glenohumeral joint capsule and the intraarticular tendon of the long head of the biceps brachii. All of these structures have the capacity to produce action potentials, via sensory receptors, that can be interpreted by the brain as antero-lateral glenohumeral joint or shoulder joint pain (Nijs, De Kooning, Beckwee, & Vaes, 2015). Glenohumeral joint movement occurs via a complex combination of rotation and gliding motions related to the asymmetrical articular areas of the humeral head and glenoid fossa, the pull of the capsuloligamentous complex, and forces from the surrounding muscles. Impairments in any of these structures potentially contribute to pain in the subacromial space (Oatis, 2009).

2.2 History of Impingement

Charles Neer, an orthopaedic surgeon, proposed the diagnosis of shoulder impingement in 1972. He based the diagnosis on his observations in the anatomy laboratory and in surgery of visible damage to tissues within the subacromial space against the anterior edge and undersurface of the anterior third of the acromion, the coracoacromial ligament and, at times, the acromioclavicular joint (Neer, 1983). This same impingement pattern was found in subsequent cadaver studies (Burns & Whipple, 1993). Neer proposed that repeated mechanical compression of the subacromial tissues, ‘impingement’, occurred as a result of

narrowing of the subacromial space during arm elevation. This resulted in a continuum of pathological changes, commencing with oedema and haemorrhage of the subacromial bursa, followed by thickening and fibrosis of the bursa, tendinitis of the rotator cuff and, finally, rotator cuff tears, biceps ruptures and bone changes (Budoff, Nirschl, & Guidi, 1998; Trampas & Kitsios, 2006).

The anatomical shape of the acromion was suggested as a contributing factor to this impingement mechanism. Three types of acromion were described according to radiological shape: type 1, flat; type 2, curved; and type 3, hooked (Bigliani & Levine, 1997). The hooked (type 3) acromion was suggested to impinge the structures within the subacromial space because, when present, a substantially higher prevalence of full-thickness rotator cuff tears were identified in cadaver studies (Bigliani & Levine, 1997). Neer developed and performed anterior acromioplasty surgery (removal of the undersurface of the anterior acromion) to relieve pain in the subacromial region (Neer, 1983). This procedure remains the surgical management for subacromial pain today (Braman et al., 2014; Lewis, 2011). Neer believed that this procedure prevented any further injury to the subacromial tissues; however, it was reported that 20% of people who underwent anterior acromioplasty developed rotator cuff tears within 9 years of surgery, suggesting that other factors contribute to pathological tissue changes in the subacromial space (Lewis, Green, & Dekel, 2001).

Since Neer's work, it has been shown that rotator cuff tears (partial) occur predominantly on the deep articular surface of the tendon, not on the surface against the acromion, as suggested by Neer's acromial compression impingement theory (Lewis, 2011; Reilly, Amis, Wallace, & Emery, 2003). Additionally, acromial shape is now considered an innate anatomic characteristic related to age (Gill et al., 2002), with the incidence of type 1 acromion decreasing with age, even in an asymptomatic population (Gill et al., 2002; Speer, Osbahr, Montella, Apple, & Mair, 2001), and the presence of degenerative acromial

osteophytes and spurs in both symptomatic and asymptomatic populations (Gill et al., 2002; Worland, Lee, Orozco, SozaRex, & Keenan, 2003).

Refuting Neer's acromial compression theory does not preclude an impingement mechanism occurring within the subacromial space. Recent technology, including 3-dimensional (3D) analysis using open magnetic resonance imaging (MRI), of the acromiohumeral distance revealed that significant narrowing of the subacromial space occurs with static shoulder abduction (not passive) at 60°, 90° and 120° in subjects with impingement syndrome (Graichen et al., 1999). A further open MRI study, using healthy volunteers, revealed that the humeral head remained more centred during static than passive abduction, revealing the importance of muscular action in maintaining the width of the subacromial space (Graichen et al., 2000). This was supported by digital video fluoroscopic studies in male subjects (18–43 years) experiencing shoulder impingement, which revealed increased superior translation of the humeral head (thereby narrowing the subacromial space) with rotator cuff fatigue (Royer et al., 2009). In addition, a small significant increase ($p \leq .05$) in anterior–posterior humeral translation during arm elevation, with and without load, was identified using 3D kinematic analysis. This caused narrowing of the subacromial space in subjects with shoulder impingement (Ludewig & Cook, 2002).

Glenohumeral instability can result in subacromial pain. However, impingement is not considered the primary mechanism producing this subacromial pain (Ellenbecker & Cools, 2010). Attenuation of the static stabilisers of the glenohumeral joint, including the capsular ligaments and labrum, allows an increased range of humeral head translation during arm movement, which results in irritation of the structures within the subacromial space (Ellenbecker & Cools, 2010). Therefore, subjects with glenohumeral laxity and instability should not be included in studies specifically investigating SSI.

Although not as simplistic as Neer originally proposed, differences in subacromial width were shown with variations in muscular and humeral head biomechanics in subjects with shoulder impingement (Graichen et al., 1999). A major focus of physiotherapy is the identification of muscular, neuromuscular and joint impairments to develop targeted treatment programmes (Banks & Hengeveld, 2014). Confirmation that those with SSI symptoms have biomechanical impairments suggests that physiotherapy may provide targeted interventions for those with this condition.

2.3 Extrinsic and Intrinsic SSI

Two types of SSI are described consistently in the literature—extrinsic and intrinsic (Lewis & Ginn, 2015; Mackenzie et al., 2015; Seitz et al., 2011), with extrinsic impingement the focus of this thesis.

2.3.1 Intrinsic impingement

Intrinsic impingement is subacromial pain originating within the tendon of the rotator cuff because of tensile loading exceeding the tendon's intrinsic healing and adaptive responses, resulting in degeneration (Seitz et al., 2011). Possible contributing pathology to this mechanism includes tendon vascularity, morphology, biology and potentially genetic predisposition (Lewis, 2016; Ludewig & Braman, 2011; Mackenzie et al., 2015; Seitz et al., 2011).

2.3.2 Extrinsic impingement

Extrinsic impingement occurs when anatomical or biomechanical factors external to the subacromial space decrease its relative width, causing compression of structures within the space (Ludewig & Braman, 2011; Mackenzie et al., 2015; Michener, McClure, & Karduna, 2003; Seitz et al., 2011). The concept of extrinsic subacromial impingement due to biomechanical movement impairment has been described extensively in the literature

(Mackenzie et al., 2015; Seitz et al., 2011). Four extrinsic biomechanical mechanisms have been consistently described:

1. Posterior shoulder tightness. Loss of flexibility in the posterior soft tissues of the glenohumeral joint has been suggested to interrupt optimal glenohumeral kinematics, causing increased translation of the humeral head, compromising the subacromial space (Mackenzie et al., 2015). This mechanism was proposed on the basis of studies confirming the loss of internal rotation range of motion on the dominant side in athletes performing overhead sports activity (Myers et al., 2007; Maenhout et al., 2012) with investigative studies measuring posterior shoulder range (Tyler et al., 1999; McClure et al., 2007) and static measurement of acromiohumeral distance (Maenhout et al., 2012) performed on asymptomatic athletes under 30 years of age. Throwing athletes have been shown to have increased external rotation range and decreased internal rotation range due to humeral torsion, a structural anomaly (Whiteley, Ginn, Nicholson and Adams, 2006). Only one study identifying increased posterior shoulder tightness in those with SSI has included non-athletes (Tyler et al., 2000). However, a previous study performed by the same authors recruited throwing athletes, so it is unclear how many throwing athletes were included in this study. Currently, it has not been established that posterior shoulder tightness is present in those with extrinsic SSI.
2. Thoracic postural impairment. This mechanism of SSI has been postulated on the basis of static measurement methods. A thoracic kyphosis of more than 50° resulted in significant narrowing of the subacromial space seen on standard radiographs and CT scans in healthy volunteers (Gumina et al., 2008). No difference in acromiohumeral distance, measured ultrasonically, was identified in subjects with subacromial pain when in a slouched thoracic posture or neutral

thoracic posture, but a significant increase in acromiohumeral distance was identified when a retracted thoracic posture was adopted (Kalra, Seitz, Boardman, & Michener, 2010). These reported variations in subacromial width continue to reinforce the concept of extrinsic subacromial impingement. Both studies used accurate measurement methods and adequate sample sizes, however, static measurements recorded with arms by side cannot be extrapolated to shoulder elevation.

3. **Scapula impairment.** Very small 3D scapula kinematic abnormalities have been identified in individuals with signs of shoulder impingement, compared with healthy individuals (Cools, Witvrouw, Declercq, Danneels, & Cambier, 2003; Ludwig & Cook, 2000; Lukisewicz, McClure, Michener, Pratt, & Sennett, 1999; McClure, Michener, Karduna, & Whitmans, 2006; Timmons et al., 2012). Electromagnetic or optical 3D motion laboratory analysis was used for all studies. This equipment is capable of revealing small alterations in scapula movement which may not be visible to the naked eye. The convexity of the thorax, together with muscular activity influences scapular positioning (Struyf, F et al., 2011) and, as such, scapula impairment may not be the primary source of these identified small kinematic abnormalities. Scapula impairments are yet to be identified using clinical assessments in subjects with SSI symptoms.
4. **Rotator cuff impairment.** Diminished rotator cuff EMG activation has been demonstrated in subjects with SSI symptoms (Myers et al., 2009; Reddy et al., 2000). Digital video fluoroscopy identified proximal migration of the humeral head with rotator cuff fatigue (Royer et al., 2009). These accurate methods of assessment can reveal differences which may not be identifiable in a clinical

assessment. In addition, it is uncertain if this variation in rotator cuff activity is clinically significant in subjects with SSI.

Having identified, from the literature, the four biomechanical factors purported to be associated with extrinsic SSI, investigation was needed to establish if each of these factors could be reliably assessed in a clinical environment. A systematic literature review was conducted to identify and determine the reliability and validity of clinical tests, and to assess if differences exist between those with SSI and an asymptomatic group, for each of these four biomechanical factors (Land & Gordon, 2017).

2.4 Clinical Assessment of Biomechanical Factors Associated with Extrinsic Subacromial Shoulder Impingement—A Systematic Review

This literature review has been published in *Physical Therapy Reviews* with permission received from the publisher, Taylor and Francis, to reproduce the full article in Appendix A.

The abstract, search strategy, study selection and outcomes are reproduced with adaptations in this chapter. The initial database search was completed prior to the commencement of the case-control study in 2011 but was updated in July 2016 before publication. The additional papers identified for inclusion, via the updated search, provided no outcomes which would have resulted in modification of the study method.

2.4.1 Abstract

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

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

Method: A scoping review identified tests for SSI. 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) two-dimensional (2D) scapula movement or (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 were identified in subjects with SSI, compared to a volunteer control group with no history of shoulder injury or disease, for posterior shoulder range (passive shoulder adduction and internal rotation and passive internal rotation in the supine position), isokinetic PT 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 LSST positions and resting pectoralis minor muscle length. These clinical tests should be considered for use in assessment of biomechanical factors related to extrinsic SSI.

2.4.2 Search strategy

An electronic database search was conducted in July 2016 of 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', 'SSI', 'SAIS'. The 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 using the same search terms. The reference lists of the final articles identified in these searches were hand searched.

2.4.3 Study selection

Studies with the following criteria were included:

- all types of primary studies that statistically analysed a group of individuals, male or female, aged 18 years and over
- studies in English
- studies published or 'in press' prior to 24 July 2016
- a diagnosis of SSI defined by a painful arc and positive impingement tests such as the Hawkins–Kennedy, Neer's or Jobe's test or obtained following an acceptable clinical assessment performed by an experienced clinician.

Studies with the following criteria were excluded:

- literature reviews
- studies not including a comparison group of asymptomatic controls
- studies investigating cadavers
- studies including participants with internal shoulder impingement
- studies including participants with glenohumeral instability
- studies including participants with surgical interventions.

The titles were screened for inclusion and exclusion criteria, then abstracts assessed.

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 eligibility, applying the inclusion and exclusion criteria, by two reviewers. A third reviewer was available for consultation in case of disagreements but was not required.

2.4.4 Quality assessment

The level of evidence of each included study was established using the Oxford Centre for Evidence Based Medicine categorisation (Portney & Watkins, 2009).

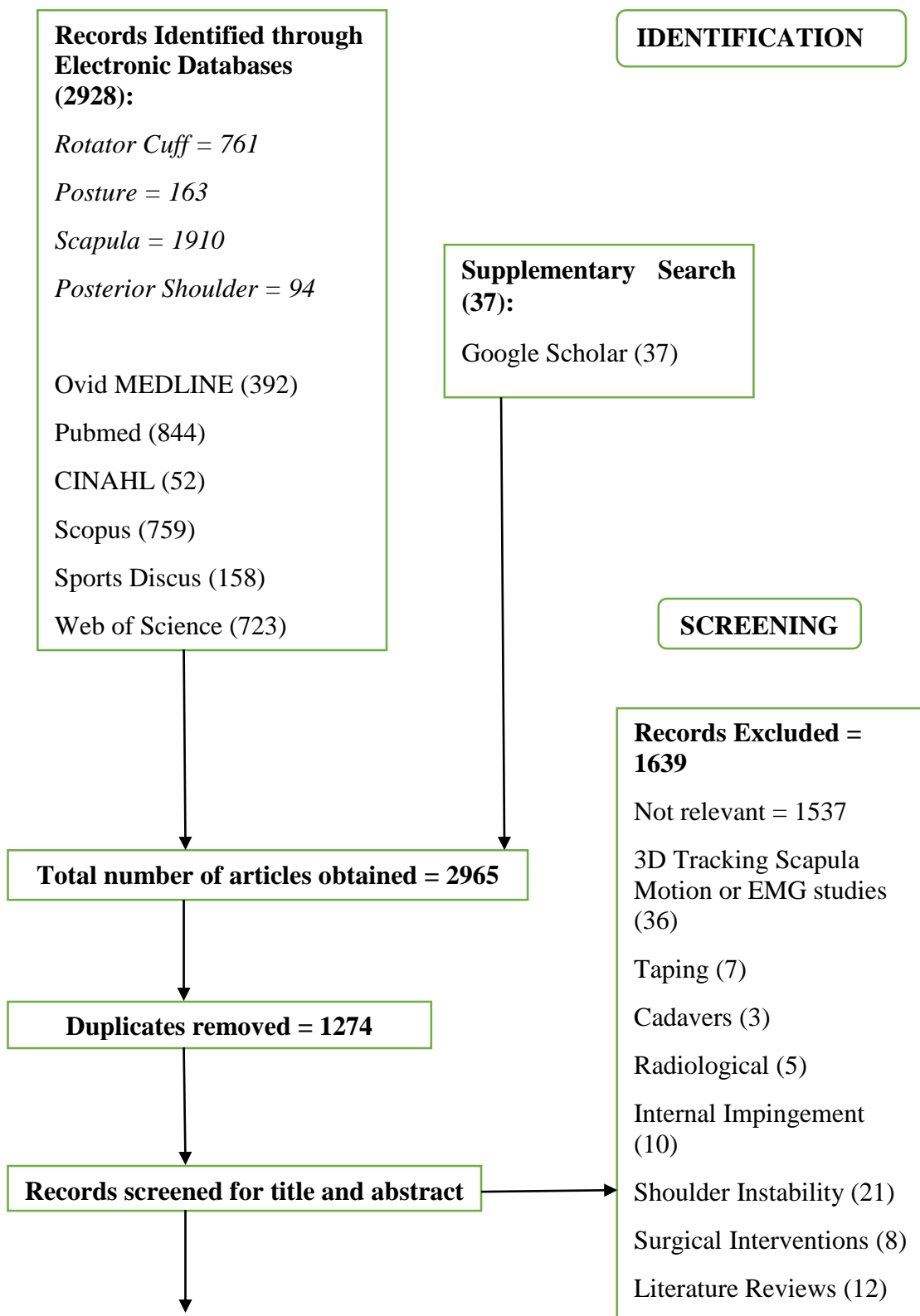
It was established that all included studies were case-control studies with critical appraisal performed using a quality checklist devised by Downs and Black (D&B; Downs & Black, 1998), which was assessed and reported as suitable for this purpose (Sanderson, Tatt, & Higgins, 2007). This checklist consists 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 5-point scale for rating the power to detect a clinically important effect. The D&B checklist was shown to have moderate to good inter-rater reliability (Downs & Black, 1998; Hootman, Driban, Sitler, Harris, & Cattano, 2011). For the purpose of this study, the final item was changed from a scale of 1–5 to a score of 0–1 because of limited information available. 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 observational studies and not intervention studies, the checklist was further modified, eliminating the items relating to intervention, patient follow-up and treatment location as these items do not contribute to the

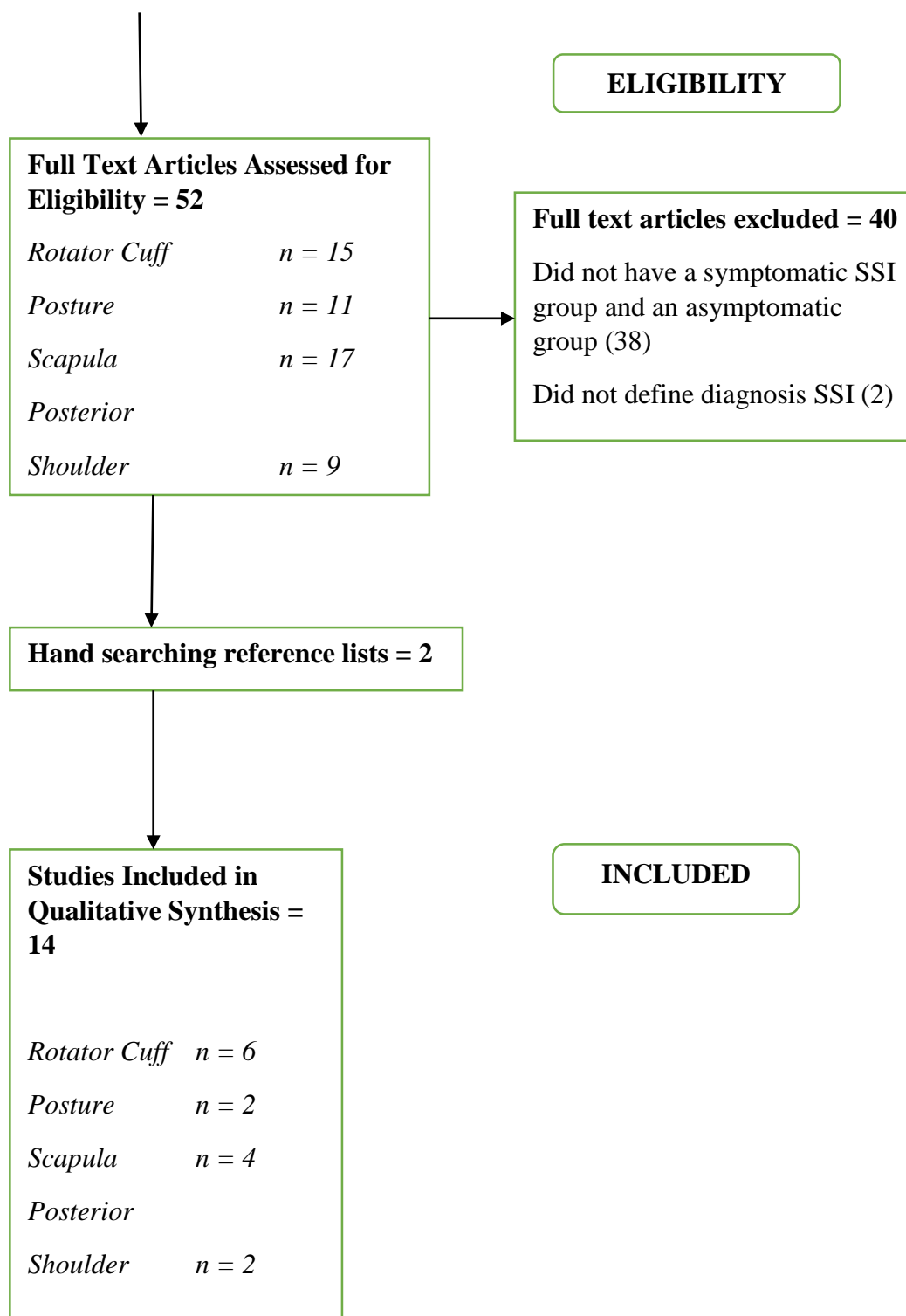
discriminant properties of the checklist (Downs & Black, 1998). The maximum score possible using this modified checklist was 23. Although overall scores may not provide adequate information regarding individual strengths and weaknesses of the studies (Wright, Brand, Dunn, & Spindler, 2007), this review assigned ordinal categories—low (≤ 7 ; 33% or less), moderate (8–15; 34%–68%) and high (≥ 16 ; 69% or more)—to rate the quality of the included studies while also reporting the strengths and weaknesses.

2.4.5 Results

The initial searches identified 2965 titles. Of these, 1274 were identified as duplicates and removed, and 1691 titles and abstracts were screened, with 1639 excluded because of not being relevant. Fifty-two full text articles were retrieved, 12 of which satisfied the inclusion and exclusion criteria and were included in this review. Two studies pertaining to scapula measurements required arbitration as they included subjects with not only a clear diagnosis of SSI but also other shoulder conditions (Curtis & Roush, 2006; Odom, Taylor, Hurd, & Denegar, 2001). 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 SSI (Curtis & Roush, 2006; Odom et al., 2001). One study included a control group, a non-operative SSI group and a postoperative SSI group (Leroux et al., 1994). The data regarding the postoperative group were not included in this review. A placebo crossover intervention using tape to adjust thoracic posture in subjects with SSI and an asymptomatic group was included as the outcomes of the clinical postural assessment tests were reported for both groups, allowing comparison (Lewis, Wright, & Green, 2005).

Details of each of the four searches are represented in Figure 2.1.





Note. SSI = subacromial shoulder impingement

Figure 2.1 PRISMA flow diagram.

2.4.5.1 Methodological quality

All studies provided level 3b or level 4 evidence according to the Oxford Centre for Evidence Based Medicine categorisation (Portney & Watkins, 2009).

The quality of the 14 included studies was evaluated by consensus of two reviewers (HL and SG) using the D&B checklist (Downs & Black, 1998). The quality scores ranged from 11/23 to 18/23 with three studies rated as high quality and the remaining as moderate quality. The following items consistently rated poorly: (1) reporting of adverse events that might have had a consequence on the measurements (item 8)—reported in only three of the 14 studies (Odom et al., 2001; MacDermid, Ramos, Drosdowech, Faber, & Patterson, 2004; Rosa, Borstad, Pires, & Carmargo, 2016); (2) blinding of study participants (item 14)—reported in one of the 14 studies (Lewis, Wright, & Green, 2005); (3) reporting whether cases and controls were recruited over the same period (item 22)—in only three of the 14 studies (Theisen et al., 2010; Dulgeroglu, Kirbiyik, Ersoz, & Ozel, 2013; Struyf, Meeus et al., 2014); (4) adequately adjusting for confounding in the analyses from which the main findings were drawn (item 25)—not reported in any of the studies; and (5) evidence that a power calculation was performed (item 27)—reported in two of the 14 studies (Lewis, Wright, & Green, 2005; Theisen et al., 2010).

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

2.4.5.2 Two-dimensional scapula measurement

Two methods of determining scapula position were identified: the resting pectoralis minor muscle length and the LSST.

Two studies investigated the reliability and validity of measuring the resting pectoralis minor muscle length (Rosa et al., 2016; Struyf, Meeus et al., 2014). The usefulness of the

resting pectoralis minor muscle length to establish alterations in scapula positioning is yet to be established (Struyf, Meeus et al., 2014). A change in pectoralis minor muscle length may cause alterations in scapula kinematics or be a result of these alterations (Rosa et al., 2016; Struyf, Meeus et al., 2014). Struyf, Meeus et al. (2014) used a vernier caliper with the participant positioned in the supine position, while Rosa et al. (2016) used a tape measure in a standing posture, with both studies reporting good to excellent reliability measurements.

Two studies investigated the reliability of the LSST (Curtis & Roush, 2006; Odom et al., 2001). The LSST is a semi-dynamic test that evaluates the position of the scapula in relation to a fixed point on the spine (Kibler, 1998). Three positions are used in this test procedure: (1) arms relaxed by side, (2) hands on hips with 10° shoulder extension and (3) arms at or below 90° abduction with maximum 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 LSST were high overall (Curtis & Roush, 2006; Odom et al., 2001). However, Odom et al. (2001) reported higher intra-rater reliability in the symptomatic group than the asymptomatic group. Inter-rater reliability was comparable for both the symptomatic and asymptomatic groups (Curtis & Roush, 2006; Odom et al., 2001).

All included scapula studies compared measurements between the scapulae of an individual experiencing unilateral or bilateral shoulder pain, with no studies identified that compared measurements between the matched scapulae of a symptomatic individual and an asymptomatic individual. Odom et al. (2001) and Curtis and Roush (2006) concluded that measurements of linear distance from the inferior angle of the scapula to the adjacent thoracic spine level using the LSST in symptomatic and asymptomatic groups were reliable.

2.4.5.3 Rotator cuff assessment

All studies ($n = 6$) compared within-group differences in mean strength between subjects with SSI and asymptomatic individuals.

Concentric PT for internal and external rotation was compared in four of the studies (Dulgeroglu et al., 2013; Erol, Ozcakar, & Celiker, 2008; Leroux et al., 1994; Tyler, Nahow, Nicholas, & McHugh, 2005), with MacDermid et al. (2004) testing both concentric and eccentric average PT.

Relative PT was compared in two studies (Dulgeroglu et al., 2013; Moraes, Faria, & Teixeira-Salmela, 2008). This value was calculated by dividing the PT by the subject's body weight and provides a comparator of muscular performance among individuals of different body mass and composition (Connelly Maddux, Kibler, & Uhl, 1989). Moraes et al. (2008) reviewed the work ratio between eccentric external rotation and concentric internal rotation and the work ratio between eccentric internal rotation and concentric external rotation.

The testing position adopted in four of the six studies was a seated position with the test shoulder positioned in the scapula plane (30° glenohumeral flexion and 45° glenohumeral abduction; Dulgeroglu et al., 2013; Erol et al., 2008; Leroux et al., 1994; MacDermid et al., 2004; Tyler et al., 2005). Testing was also performed at 90° glenohumeral abduction and 90° elbow flexion in the sitting (Tyler et al., 2005) and supine (Moraes et al., 2008) positions. No significant difference between groups was identified even with the variations in testing position.

The use of two or more velocities, with at least one being slow and the other fast, assists in establishing overall strength performance (Otis, Warren, Backus, Santner, & Mabrey, 1990); 60 deg/s and 180 deg/s were used in three of the studies (Leroux et al., 1994; Moraes et al., 2008; Tyler et al., 2005), and 90 deg/s and 180 deg/s by Dulgeroglu et al. (2013), while only 60 deg/s was used by Erol et al. (2008) and 75 deg/s by MacDermid et al.,

(2004). The variations in testing speed and testing position prevented comparison of results among studies.

Reliability of isokinetic testing was only reported by MacDermid et al. (2004) and was found to be adequate (intraclass correlation coefficient [ICC] of ≥ 0.75 for all tests). Two studies reported calibrating the machine prior to testing by using the standard instructions provided by the manufacturer (Leroux et al., 1994; Moraes et al., 2008).

2.4.5.4 Posture assessment

Lewis, Wright and Green (2005) used a lateral photograph to obtain the craniovertebral angle (CVA), a well-documented indicator of head on neck posture (Grimmer-Somers, Milanese, & Louw, 2008). The CVA is formed at the intersection of a horizontal line and a line drawn from the tragus of the ear to the spinous process of C7. It provides a gross measure of the amount of forward positioning of the head on the trunk.

Good intraphotographic reliability was reported with an ICC of 0.98 (Portney & Watkins, 2009).

Resting thoracic kyphosis angle was measured using two gravity-dependent inclinometers, 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 (Lewis, Wright, & Green, 2005). The intrarater reliability reported for this method was good, with an ICC of 0.96 for the asymptomatic group and 0.94 for the symptomatic group (Portney & Watkins, 2009). However, no significant difference in kyphosis angle was noted between the groups (J. S. Lewis, Wright, et al., 2005).

Theisen et al. (2010) measured thoracic range of motion and thoracic kyphosis in the erect seated posture, comparing Ott's sign and ultrasound tomography. Ott's sign is a measurement of thoracic range determined by marking the most prominent cervical spinous

process, C7, in relaxed sitting, and a distance 30 cm caudal to this measured with a tape. The distance participants bend maximally forward and back from relaxed sitting is used to calculate the range. Comparison of Ott's sign with ultrasound tomography yielded only a weak correspondence between the results (Theisen et al., 2010), suggesting 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 (Theisen et al., 2010). A significant difference in functional thoracic range was identified between the SSI group and the asymptomatic group for both the ultrasound tomography ($p \leq .01$) and Ott's sign ($p = .002$). Test-retest reliability for ultrasound tomography to measure thoracic ROM was reported to be good ($r = .87$).

2.4.5.5 Posterior shoulder assessment

Tyler, Nicholas, Roy and Gleim (2000) performed a study quantifying posterior shoulder tightness through a broad age range and gender in subjects with a diagnosis of shoulder impingement. Measurements of posterior shoulder tightness and passive internal rotation range of motion were made in 31 participants with shoulder impingement and in 33 controls without shoulder abnormalities (Tyler et al., 1999). Posterior shoulder range is measured with the participant in a side-lying position with the scapular fully retracted and the humerus lowered. A measurement is recorded when an end point is felt or the humerus starts to rotate (Tyler et al., 1999). Very high levels of intra- (ICC = 0.92–0.95) and inter- (ICC = 0.80) rater reliability were reported for this measurement method in asymptomatic shoulders (49 nonimpaired volunteers [25 male, 24 female] aged 11–59 years; Tyler et al., 1999). Further, it was established that passive internal rotation measured at 90° abduction in the coronal plane correlates with posterior shoulder tightness ($r = -.610$).

Borstad et al. (2007) investigated meaningful clinical changes in posterior shoulder range over an 8–12 week period in construction workers exposed to overhead work. Three

measures were used: (1) the method described by Tyler et al. (1999) to measure posterior shoulder range, (2) passive internal rotation in the supine position and (3) passive adduction in the supine position with the end range detected by palpating for scapula movement (Borstad et al., 2007). Reliability was determined by assuming no change in measurements should occur over the study period. This assumption of reliability was not valid as all workers continued to perform work duties, and were exposed to the use of force, static work activities and vibratory tools, which were shown to cause muscle fatigue (Bernard, 1997), thereby creating ongoing variability in extensibility of the posterior capsule and posterior shoulder muscles.

2.5 Discussion

Nine studies were identified that compared the findings of clinical tests in asymptomatic subjects and symptomatic SSI subjects. The remaining five studies reviewed only the reliability and validity of the assessment method in subjects with SSI and an asymptomatic group. Very small numbers of studies were found for each of the clinical tests, with the largest group of six studies 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 within-group values rather than the comparison of matched shoulders between the groups.

The majority of studies investigating scapula positioning in subjects with SSI used electromagnetic, optical or MRI 3D laboratory equipment, which is generally not available in a clinical setting (Ludewig & Cook, 2000; Lukisewicz et al., 1999; McClure et al., 2006; Ratcliffe, Pickering, McLean, & Lewis, 2014). This systematic review investigated 2D clinical scapula measurement methods used in subjects with SSI, compared with an asymptomatic group, with only two measurement methods identified (Land & Gordon, 2017). The first method used resting pectoralis minor muscle length, which is yet to be proven to

show alterations in scapular positioning and, being a static measurement performed with arms by the side, is not able to replicate the dynamic pattern of SSI, where pain is produced during shoulder elevation (Struyf, Meeus et al., 2014). The second method was a semi-dynamic test, the LSST, with comparisons made between the scapulae of individuals experiencing pain in resting and elevated scapular positions (Curtis & Roush, 2006; Odom et al., 2001). However, scapula resting position was shown to differ between dominant and non-dominant shoulders of individuals (Morais & Pascoal, 2013). This finding of hand dominance-related scapula asymmetry may explain why previous studies comparing subjects with SSI and an asymptomatic population did not identify any difference in resting scapula position, because they compared the scapulae of individuals (Lewis, Green, & Wright, 2005; Lukisewicz et al., 1999). Visual observation to identify scapular dyskinesis was reported as a clinical assessment but has not yet been shown to reliably identify differences between asymptomatic and SSI groups (Struyf, Nijs, et al., 2014).

The LSST is a semi-dynamic test that evaluates the position of the scapula in relation to a fixed point on the spine (Kibler, 1998), allowing the comparison of this measurement between the scapula of a symptomatic individual and the scapula of a matched asymptomatic individual. Reliability reports for the LSST were high overall to measure linear scapula position in subjects with SSI and an asymptomatic group (Land & Gordon, 2017), making it a suitable clinical scapula measurement test for use in this study.

Rotator cuff strength was assessed using isokinetic testing in all identified studies. Reliability and validity were reported in only one of the six identified studies (MacDermid et al., 2004), and only two studies reported calibration prior to testing (Leroux et al., 1994; Moraes et al., 2008). Standardisation of calibration is designed to minimise measurement error and improve reliability; if calibration is not performed prior to testing, outcome reliability needs to be questioned.

No study directly compared isokinetic strength of the painful shoulder in the symptomatic group with the dominance-matched shoulder in a similar asymptomatic group. Instead, the isokinetic strength between the shoulders of each individual was compared, with dominance of the painful shoulder not considered except in one study that only recruited subjects with a painful right shoulder (Erol et al., 2008). The dominant shoulder was proven significantly stronger than the non-dominant shoulder in an asymptomatic population (Roy, MacDermid, Boyd, et al., 2009). Hence, the matching of limb dominance is essential to establish differences between symptomatic and asymptomatic groups.

Only one study reported differences in isokinetic strength when comparing asymptomatic and symptomatic groups (Leroux et al., 1994). As all participants in this early study were presenting for surgical review and the methods of diagnosis available during the 1990s were clinical tests, radiographs and opaque arthrographs, these results might have been affected by the inclusion of some painful participants with undiagnosed rotator cuff tears.

Variations in testing speed and position as well as the use of only one testing speed in three of the six studies might have affected the validity of the outcomes in all of the isokinetic studies.

This review identified two clinical assessments for measuring resting thoracic angle in subjects with SSI compared with an asymptomatic group. No between-group differences were identified when using (1) two inclinometers or (2) ultrasound topometry (Land & Gordon, 2017). However, SSI symptoms are provoked with shoulder elevation, not with arms resting by the side, which is the position adopted for measuring resting thoracic angle. Shoulder elevation requires thoracic extension, making the assessment of available thoracic flexion/extension motion clinically relevant (Edmondston et al., 2011; Kebaetse, McClure, & Pratt, 1999). Differences in thoracic range of movement between an SSI group and an asymptomatic group were identified using ultrasound topometry, which is not readily

available in a clinical setting, and when using Ott's sign (Land & Gordon, 2017). However, the test–retest reliability of Ott's sign was not shown for SSI subjects and was reported to be poorly correlated with the measurements obtained using ultrasound tomography (Theisen et al., 2010). Investigating alternate methods suitable for measuring passive thoracic flexion/extension range is warranted.

Lateral photographs were shown to be reliable for measuring changes in thoracic angle and compared well with a two-inclinometer method (Perry, Smith, Straker, Coleman, & O'Sullivan, 2008). Reliability was shown using a computer software program to digitise thoracic angles from lateral photographs (Milanese & Grimmer-Sommers, 2010; Perry et al., 2008). The aim of the present study is to compare an asymptomatic group with an SSI group to establish if a difference in thoracic range of active flexion/extension motion exists, not to identify true angular thoracic range values for each group. Cameras and computers are readily available in a clinical setting, making this reliable method of digitising thoracic angles from lateral photographs suitable for this study. An identical method can be adopted for each group, allowing comparison of active flexion/extension range.

True measurement values for range of the posterior shoulder are difficult to establish because of the mobility of the scapula relative to the humerus. The method described by Tyler et al. (1999) was shown to be reliable when comparing SSI and asymptomatic subjects (Tyler et al., 2000), and is suitable for use in this study. The scapula is placed in full retraction to standardise this measurement position. This allows a difference, if it exists, to be detected between the groups, which is the aim of this study, although the value of the measurement cannot be considered the true length of these posterior structures.

High levels of intra-rater reliability and moderate to high levels of inter-rater reliability for 2D scapula assessment using the LSST (Curtis & Roush, 2006; Odom et al., 2001), isokinetic testing (MacDermid et al., 2004), photographic measuring of the CVA

(Lewis, Wright, & Green, 2005) and posterior shoulder range using the method described by Tyler et al. (2000) indicate that these assessments can be reliably applied in the clinical setting.

A limitation of this review was the small number of studies that compared each of the clinical assessments in SSI subjects with an asymptomatic group. This prevented definite conclusions being drawn about which clinical assessments reliably detect a difference in each of these factors between SSI and asymptomatic groups. A narrative approach was adopted because of the heterogeneity of the reviewed studies.

2.6 Conclusions

Subacromial shoulder impingement is a widely used diagnosis for those presenting with subacromial pain, although the aetiology remains unclear. Current management, both surgical and conservative, has evolved from Neer's shoulder impingement theorem reported in 1972. Currently, few studies have compared symptomatic SSI and asymptomatic subjects, with most having methodological limitations with respect to recruitment of subjects, matching of subjects for dominance and age, and comparison of values.

The concept of biomechanical subacromial impingement with related movement impairments has not yet been confirmed or refuted. Studies have identified that a decrease in the size of the subacromial space occurs in those with signs of SSI, yet the purported biomechanical factors associated with extrinsic SSI—including posterior shoulder tightness, thoracic postural impairment, scapula impairment and rotator cuff impairment—have not yet been investigated effectively.

In preparation for a study aimed at determining whether differences exist in any of these four biomechanical factors, in those with SSI compared with a matched group without shoulder pain, a first review of its kind was conducted to identify and report the reliability and validity of clinical tests used to assess each of these factors. The ability of each of the

identified tests to detect differences between people diagnosed with SSI and people without shoulder pain was also reported. This resulted in identification of the following clinical tests for use in the impending study: (1) assessment of posterior shoulder range (with the participant in a side-lying position, with the scapula fully retracted and the humerus lowered to the end point, measured with a standard carpenter's square) and passive internal rotation in the supine position (using a goniometer); (2) assessment of rotator cuff strength (isokinetic dynamometer); (3) assessment of 2D linear scapular position (LSST); and (4) assessment of active thoracic flexion/extension range and thoracic angle (digitising thoracic angles from lateral photographs).

The next chapter discusses the background of the development of the methodology for a case-control study investigating whether clinical measurement of the four purported biomechanical factors associated with extrinsic SSI differ between SSI and asymptomatic groups.

Chapter 3: Development of the Methodology for a Case-Control Study

3.1 Introduction

This chapter describes the development of the methodology for a case-control study to determine if clinical measurement of the four purported extrinsic SSI biomechanical factors (posterior shoulder range, active thoracic range of flexion/extension, scapula positioning and rotator cuff strength) differ between SSI and asymptomatic groups.

The clinical tests for this study were adopted from the outcomes of the systematic review described in Chapter 2.

3.2 Establishment of Inclusion and Demographic Criteria

3.2.1 History

Subacromial shoulder impingement has been described as sharp antero-lateral glenohumeral catching pain on elevation, which eases on lowering the limb, with no history of trauma and disturbed sleep patterns when lying on the affected shoulder (Bigliani & Levine, 1997; Hanchard, Cummins, & Jeffries, 2004; Walker-Bone, Palmer, Reading, Coggon, & Cooper, 2004). This reported history was adopted as an inclusion criterion for the SSI group in the study.

3.2.2 Age

Men over 60 years display a decline in strength (Roy, MacDermid, Boyd, et al., 2009) and a decrease in thoracic spine mobility (Edmondston et al., 2011). Limiting the upper age range in this study to 60 years for comparison of rotator cuff strength and thoracic range of motion minimised any age effect modification.

In addition, the peak incidence of patients presenting with SSI is 40–60 years (Ostor et al., 2005; van der Windt et al., 1995), suggesting this age range was optimal for inclusion in the study.

3.2.3 Gender

Anthropometric differences between males and females are well documented, with females generally shorter in stature (Côté, 2012) and males stronger (Roy, MacDermid, Boyd, et al., 2009). Females generally have greater flexibility of the shoulder joint (Côté, 2012; Roy, MacDermid, Boyd, et al., 2009), making gender a potential confounding variable. Hence, matching of gender in the SSI group and the asymptomatic group was required.

3.2.4 Physical activity level and occupation

Elevated arm position is a purported factor in the development of SSI, both from sports and work participation (Mackenzie et al., 2015). Frequent or sustained shoulder elevation at or above 60° in any plane while performing occupational tasks was identified as a risk factor for the development of shoulder tendinitis or nonspecific shoulder pain (Bernard, 1997). However, a single risk factor does not result in shoulder musculoskeletal symptoms, with evidence strongest for the exposure to multiple physical factors, such as holding a vibrating tool with the arm elevated (Bernard, 1997). Not all workers exposed to overhead working conditions develop shoulder symptoms, with prevalence ranging from 25% to 71% (Ludewig & Borstad, 2003). Therefore, it was not considered necessary to exclude participants with an occupation involving predominantly overhead work from a study comparing an SSI group with an asymptomatic group.

The incidence of sports-related shoulder pain directly correlates to the choice of sport, hand dominance and frequency of play, with injuries most common in those participating in elite or fulltime overhead sports (Mackenzie et al., 2015). Subjects participating in elite or fulltime overhead sports were excluded from the study.

Reduced activity levels were identified in 117 participants with reported shoulder impingement via the SF-36 Health Survey (Gartsman et al., 1998). To enhance the matching of the symptomatic and asymptomatic groups, a general physical activity outcome measure was included. The International Physical Activity Questionnaire (IPAQ), short form, has shown acceptable measurement properties for monitoring population physical activity levels in adults aged 18–65 years in diverse settings (Craig et al., 2003). The IPAQ short form asks about three specific types of activity—(1) walking, (2) moderate-intensity activities such as cycling for transport and yard work and (3) vigorous-intensity activities such as running and boxing—and computes using the duration (in minutes) and frequency (days). The resultant rating of low, medium or high physical activity was used for matching of the symptomatic and asymptomatic groups.

3.2.5 Limb dominance

Isometric internal and external rotation strengths of the dominant shoulder were reported to be significantly stronger (internal, $p = .002$; external, $p = .032$) than those of the non-dominant shoulder in an asymptomatic population (Roy, MacDermid, Boyd, et al., 2009). Hence, when assessing rotator cuff strength between groups, matching for limb dominance was required to reduce the risk of confounding.

On the basis of this review of demographic criteria in subjects presenting with SSI, an homogeneous group experiencing SSI and a group without shoulder pain, matched for age, gender, limb dominance and general physical activity level, were recruited to minimise the risk of confounding.

3.3 Objective Criteria

3.3.1 Provocation of subacromial pain

The orthopaedic special tests currently in use to reproduce subacromial pain have been found to have either high specificity (the proportion of those without subacromial pain

who test negative) or high sensitivity (the proportion of those with subacromial pain who test positive), but not both (Calis et al., 2000; Cleland, 2007; Hegedus et al., 2008; Park, Yokota, Gill, Rassi., & McFarland, 2005). Further, significant differences in sensitivity and specificity values for the same test have been identified using different standards. Calis et al. (2000) used plain radiography, MRI and the subacromial injection test for comparison, while Park et al. (2005) used the subacromial injection test and diagnostic arthroscopy (see Table 3.1). A combination of positive tests was shown to improve the reliability of identifying subacromial pain (Michener, Walsworth, Doukas, & Murphy, 2009), with three or more positive tests out of five confirming subacromial pain (Michener et al., 2009).

For a diagnosis of subacromial pain, the Hawkins–Kennedy (Hawkins & Kennedy, 1980) or Neer (Neer, 1983) test must reproduce subacromial pain along with two of the following: external rotation resistance test (Michener et al., 2009), horizontal (cross-body) adduction (Park et al., 2005), painful arc (Kessel & Watson, 1977), drop-arm test (Park et al., 2005) or Speed test (Dalton, 1989; Park et al., 2005).

Table 3.1

Orthopaedic Special Tests Identifying Subacromial Pain

Test	Sensitivity	Specificity	Reference	Description
Neer	*99.7% #68.0%	*30.5% #68.7%	Neer (1983)	Examiner stabilises the scapula with a downward force while flexing the humerus until pain is reported or full elevation reached. <i>A positive test is reproduction of pain in the superior shoulder.</i>
Hawkins– Kennedy	*92.1% #71.5%	*25.0% #66.3%	Hawkins and Kennedy (1980)	Examiner flexes the humerus and elbow to 90° and then internally rotates the shoulder. <i>A positive test is reproduction of pain in the superior shoulder.</i>
Horizontal (cross- body) adduction	*82.0% #22.5%	*27.7% #82.0%	Park et al. (2005)	Examiner flexes the humerus to 90° and then adducts the arm across the body. <i>A positive test is reproduction of pain in the superior shoulder.</i>
Painful arc	*32.5% #73.5%	*80.5% #81.1%	Kessel and Watson (1977)	The patient actively elevates then lowers the shoulder through abduction. <i>A positive test is pain or painful catching reported between 60° and 120° elevation of the arm.</i>
Drop-arm test	*7.8% #26.9%	*97.2% #88.4%	Park et al. (2005)	The patient fully elevates the arm and then slowly reverses the motion in the same arc. <i>If the arm is dropped suddenly or extreme pain is experienced, the test is considered positive.</i>
Speed test	*68.5% #38.3%	*55.5% #83.3%	Dalton (1989) Park et al. (2005)	Elbow is fully extended, and the arm elevated to 90° (passively or actively) and extended slightly horizontally. With the forearm supinated, the examiner applies a downward force to the arm. <i>A positive test is reproduction of pain in the bicipital groove.</i>
External rotation resistance test	#41.6%	#90.1%	Michener et al. (2009)	The arm is placed at the patient's side and the elbow flexed to 90°. A medially directed force is exerted on the distal forearm to resist shoulder external rotation. <i>A positive test is reproduction of pain.</i>

* Calis et al. (2000); # Park et al. (2005).

3.4 Exclusion Factors

3.4.1 Strength training

It is common to include shoulder external rotation strengthening within prescribed exercise programmes for patients with SSI (Carmargo et al., 2015; Holmgren et al., 2012; McClure et al., 2004; Tate, McClure, Young, Salvatori, & Michener, 2010). The exercises included in SSI strengthening programmes have been based on EMG studies (Cools et al., 2007; Cricchio & Frazer, 2011) and the results of clinical studies including athletic or college-aged populations and subjects with diagnosed shoulder instability (Ellenbecker & Cools, 2010). An 8%–10% increase in isokinetic shoulder internal and external rotator strength was reported after performing shoulder strengthening exercises (two sets of 15 repetitions, 5 days per week) for 4 weeks (Moncrief, Lau, Gale, & Scott, 2002). In the current study, subjects regularly participating in shoulder strength training for 4 weeks or more were excluded from the study to minimise any strength effect modification.

3.4.2 Other contributing factors to pain within the subacromial space

Other causes of pain that may mimic SSI include previous shoulder surgery, fracture of the shoulder girdle, having a known systemic or neurological condition, and having signs or symptoms of a spinal condition. Hence, these conditions were exclusion criteria in the study.

Assessment was needed to assist in differentiating the spine as a potential source of the painful symptoms (Ackerman & Newton, 2014). The following assessment, previously adopted in a study comparing a group with SSI and an asymptomatic group (Lewis, Wright, & Green, 2005), was used. In the sitting position, the patient actively (1) flexes the head and neck, (2) extends the head and neck, (3) rotates the head and neck to the left, (4) rotates the head and neck to the right, (5) side flexes the head and neck to the left, and (6) side flexes the head and neck to the right. Reproduction of local cervical and/or shoulder pain during these

tests is suggestive of a cervical component to the symptoms. If the active movements did not reproduce local or referred pain, then overpressure, when appropriate, was performed by the examiner at the end of range of the active movements to further stress the cervical structures. A subject was considered to have a positive response if local shoulder pain was reproduced during any of the cervical testing procedures, which excluded the participant from the study (Lewis, Wright, & Green, 2005). In addition, a primary test involving palpation, in a postero-anterior direction, centrally and unilaterally, to the lower cervical and upper thoracic levels was performed, with pain reproduction excluding the participant from the study (Ackerman & Newton, 2014).

3.4.2.1 Radiography

Radiographic assessment to measure subacromial space width revealed that subjects with thoracic hyperkyphosis greater than 50° (identified using Cobb's method) had a subacromial space significantly narrower than that measured in subjects with kyphosis less than 50° (Gumina et al., 2008). Because of the potential for spinal alignment to affect the subacromial space, subjects with thoracic hyperkyphosis or scoliosis (observed using the forward trunk flexion test; Bunnell, 2005) were excluded.

While there is increasing prevalence of rotator cuff tears in the subacromial space in individuals over 40 years of age, the presence of subacromial pain does not consistently occur when imaging demonstrates the presence of rotator cuff tears. Diagnostic subacromial ultrasound (Girish et al., 2011) and MRI (Gill, Shanahan, Allison, Alcorn, & Hill, 2014) have revealed identical shoulder pathology in both symptomatic and asymptomatic populations; hence, diagnostic imaging is not a predictor of pain. As no method exists to confirm if pathological changes identified on imaging are related to reported pain, subjects with pathological signs on scans, including osteophytes within the subacromial region, calcification of tendons and large rotator cuff tears, were excluded. No association has been

found between acromial morphology and the incidence of rotator cuff pathology, thereby allowing participants presenting with only these imaging findings to be included (Gill et al., 2002; Worland et al., 2003).

3.4.2.2 Glenohumeral instability

The reasoning for exclusion of people with glenohumeral instability from this study has been detailed in Chapter 2.

Common tests to identify glenohumeral instability include load and shift tests (anterior, posterior and inferior) and the sulcus test (Cleland, 2007; Ellenbecker & Cools, 2010). A grade II (humeral head translation to the glenoid rim) or grade III (humeral head translation past the glenoid rim) rating in any of these tests or a report of previous glenohumeral dislocation resulted in exclusion.

The potential effect of ligamentous laxity and postural changes associated with pregnancy can result in glenohumeral instability. Hence, pregnancy was also an exclusion criterion (Segal & Chu, 2015).

3.4.2.3 Chronicity of painful symptoms

Strength in subjects with rotator cuff tendinopathy was shown to be affected by a measurable decrease in central motor corticospinal excitability when symptoms were present for 12 months or more (Ngomo, Mercier, Bouyer, Sacoie, & Roy, 2015). To minimise the potential influence of this factor, participants were excluded when subacromial pain had been present for more than 12 months.

3.4.2.4 Frozen shoulder

Differential diagnosis between frozen shoulder and SSI can cause some confusion in practice, with tests for impingement being positive in the pain-dominant phase of frozen shoulder because stretching of the joint capsule is involved (Hanchard et al., 2011).

Guidelines recommend regarding signs of frozen shoulder as taking primacy over signs of

impingement, with pain produced on passive glenohumeral external rotation a strong diagnostic feature (Hanchard et al., 2011). In this study, reproduction of subacromial pain with passive external glenohumeral rotation, in neutral, resulted in exclusion.

3.4.3 Corticosteroid injections

Corticosteroid injections into the shoulder are common in the management of subacromial pain (Gruson, Ruchelsman, & Zuckerman, 2008). Properly placed injections can reduce inflammation within the bursa and rotator cuff tendons, thus reducing pain and improving participation in activities of daily living (Gruson et al., 2008). To minimise any modifying effect, participants who had received one or more subacromial injections were excluded.

3.5 Outcome Measures

3.5.1 Pain rating

The 11-point Numerical Pain Rating Scale (NPRS), ranging from 0 (*no pain*) to 10 (*worst imaginable*), was used to obtain pain measurements when the shoulder was at rest and when pain was provoked during assessment (Farrar, Young, LaMoreaux, Werth, & Poole, 2001; Jensen, Karoly, & Braver, 1986). A minimum clinically important difference of two points has been established for the NPRS (Childs, Piva, & Fritz, 2005; Farrar et al., 2001) and good test–retest reliability (ICC = 0.74) and responsiveness was shown in patients with shoulder pain (Mintken, Glynn, & Cleland, 2009). This was used as a secondary outcome measure in the study.

3.5.2 Functional outcome

The Shoulder Pain and Disability Index (SPADI) is a validated outcome measure measuring pain and disability associated with shoulder impairment (Roach, Budiman-Mak, Songsiridej, & Lertratanakul, 1991). It consists of 13 items in two domains—pain (5 items) and disability (8 items)—with each item scored. Pain scores range from 0 to 10 (0 = *no pain*

and 10 = *worst pain imaginable*) and disability scores range from 0 to 10 (0 = *no difficulty* and 10 = *so difficult, requires help*). Each item score is equally weighted, then added for a total percentage score from 0 to 100 (0 = *best* and 100 = *worst*). The SPADI was developed in 1991 and initially validated in a sample of 37 male patients with shoulder pathology recruited from an ambulatory care clinic (Roach et al., 1991). Since then, the SPADI has been validated in subjects referred to outpatient physiotherapy with shoulder pain and in the general community with self-reported shoulder pain (Heald, Riddle, & Lamb, 1997; Hill, Lester, Taylor, Shanahan, & Gill, 2011) and was found to be responsive and clinically sensitive for SSI subjects (Dogu, Sahin, Ozmaden, Yilmaz, & Kuran, 2013). A minimum clinically important difference of between 8 and 13 was established for the SPADI (Roy, MacDermid, & Woodhouse, 2009). This was used as a secondary outcome measure in the study.

3.5.3 Measurement of scapula position

The LSST was the only 2D clinical assessment method used to measure scapula position in SSI subjects compared with an asymptomatic population (see Chapter 2), and was used as a primary outcome measure in the study.

Three different glenohumeral positions are adopted in the LSST testing procedure: (1) arms relaxed by side, (2) hands on hips with 10° shoulder extension and (3) arms at or below 90° abduction in the coronal plane with maximum internal rotation of the glenohumeral joint (Kibler, 1998). A non-stretch tape measure was used to measure the distance from the inferior angle of the scapula to the adjacent thoracic spinous process as shown in Plate 3.1. Each participant stood with arms relaxed by his or her side for measurement of the first position of the LSST, in centimetres, using a standard non-stretch tape measure. The examiner then demonstrated the second position and asked the participant to place hands on hips before measuring in centimetres on each side, using the same tape measure. The examiner

demonstrated the third position and asked the participant to adopt this position before measuring in centimetres on each side, using the same tape measure. The side measured first was randomised for each participant, with the measurement value recorded immediately prior to measuring the second scapula.



Plate 3.1. Measurement in the lateral scapula slide test.

3.5.4 Measurement of thoracic range of movement and thoracic angle

The digitisation of thoracic angles from lateral photographs was discussed in Chapter 2 as a reliable method, suitable for use in this study to establish if a difference in thoracic range of active flexion/extension motion exists between SSI and asymptomatic individuals. This was a primary outcome measure in the study.

As previous studies had measured the CVA and resting thoracic angle, it was decided to record these measurements for comparison.

The photographic method used was as follows. Three lateral view photographs were taken (Edmondston et al., 2011): (1) relaxed resting posture, (2) thoracic flexion and (3) thoracic extension. For the relaxed resting posture, the participant stood at 90° 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 in front of the lens to confirm horizontal and vertical alignments of the camera, respectively. The camera distance from each subject was standardised to 2 metres with the tripod position maintained using tape on the floor. Floor markers standardised 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 the shoulders forward and back three times and then stand relaxed in his or her normal posture (Greenfield et al., 1995). The first photograph was taken. For thoracic flexion, the subject was instructed to round the back as much as possible and the second photograph was taken. For thoracic extension, the subject was instructed to extend the back as much as possible and the third photograph was taken. Files were downloaded directly from the JVC hard-drive camcorder to a laptop computer via a USB connecting cord. Each photograph was a .jpg individually numbered file. The digitising software UTHSCSA ImageTool was used to calculate the x,y plane coordinates (Wilcox, Dove, Doss, & Greer, 1997), from which postural angles were calculated as shown in Plate 3.2.

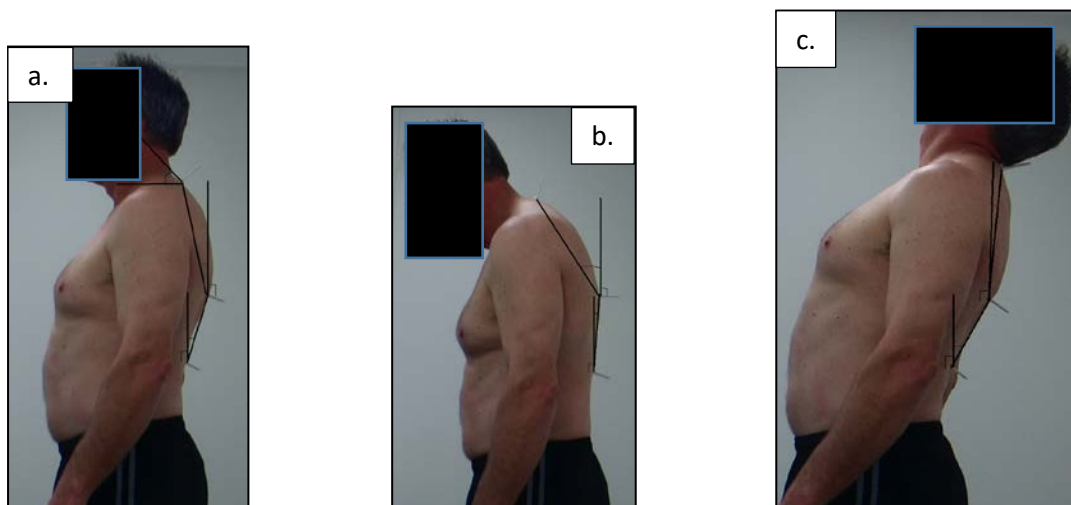


Plate 3.2. Three lateral photographs and associated angles. The subject has been photographed in the relaxed resting (a), thoracic flexion (b) and thoracic extension (c) positions.

The following postural measurements were calculated using the digital images in Plate 3.2:

1. The CVA was the angle, in degrees, of the horizontal line intersecting 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 the spinous process of C7 and true vertical.
3. Active movement of upper thoracic flexion through extension was calculated in degrees as the difference in upper thoracic extension and upper thoracic flexion.
4. Lower thoracic resting posture was measured in degrees from the T12 spinous process to the apex of the mid-thoracic curvature and true vertical.
5. Active movement of lower thoracic flexion through extension was calculated in degrees as the difference in lower thoracic extension and lower thoracic flexion.

All thoracic angles are calculated in relation to true vertical. Therefore a positive angle value represents flexion and a negative angle value represents extension.

3.5.5 Measurement of posterior shoulder range

The method described by Tyler et al. (1999) to measure posterior shoulder range was shown to be reliable when comparing SSI and asymptomatic groups (Tyler et al., 2000; see Chapter 2) and was adopted for this study. A moderate to good association (Portney & Watkins, 2009) was established between passive internal rotation measured at 90° abduction in the coronal plane and posterior shoulder tightness ($r = -.610$; Tyler et al., 1999). This passive measurement was included in this study for further comparison.

All measurements were taken with the subject side-lying on an electric physiotherapy plinth with a pillow beneath his or her 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° angle of the square ensured that a perpendicular line from the examination table to the medial epicondyle was measured.

Measurements were taken in the side-lying position. Male subjects removed their shirt while females wore only their bra. The subject lay with hips flexed to 90°, 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 assessor grasped the distal humerus and passively positioned it in 90° abduction and 0° internal/external rotation. The scapula was glided into a retracted position with the opposite hand. The humerus was lowered until motion ceased or rotation of the humerus was observed, indicating the end of posterior tissue flexibility(see Plate 3.3). A measurement in centimetres from the medial epicondyle to the plinth was then taken using the carpenter's square.

Passive internal rotation was measured with the subject lying supine with the humerus at 90° abduction in the coronal plane. A folded towel was placed under the humerus to ensure that it lay in the horizontal plane. The assessor 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.



Plate 3.3. Measurement of posterior shoulder range.

3.5.6 Measurement of rotator cuff strength

The rotator cuff muscles stabilise as well as move the glenohumeral joint. The subscapularis acts as an internal rotator, and the infraspinatus, teres minor and supraspinatus act as external rotators (Dark, Ginn, & Halaki, 2007; Reinold et al., 2004). The rotator cuff was shown to produce different activity levels dependent on the direction of movement (Lewis & Ginn, 2015). Electromyography (EMG) studies identified that, during internal rotation, muscle activity, expressed as a percentage of maximum voluntary isometric contraction (%MVIC), was greatest in the pectoralis major followed by the subscapularis then the latissimus dorsi at low, medium and high exercise intensities (Dark et al., 2007). During external rotation, infraspinatus, teres minor and supraspinatus muscle activity (%MVIC) levels are much greater than that of the deltoid muscle at all exercise intensities and when the arm is positioned in the scapular plane (Dark et al., 2007; Reinold et al., 2004). These findings are consistent with internal and external rotation being used to assess rotator cuff strength (Ludewig & Cook, 2000; Reddy et al., 2000). The choice of isokinetic testing of internal and external rotation for this study was discussed in Chapter 2.

A systematic review of the literature, conducted in 2010, was used to guide the isokinetic methodology. This review titled ‘What is Normal Isokinetic Shoulder Strength or Strength Ratios? A Systematic Review’ has been published in *Isokinetics and Exercise Science* with the accepted full copy for publication in Appendix B (Land & Gordon, 2011).

3.5.6.1 ‘What is Normal Isokinetic Shoulder Strength or Strength Ratios? A Systematic Review’

The abstract of the above article is reproduced here with adaptations.

Purpose: To systematically review the literature regarding isokinetic testing to identify values for isokinetic shoulder strength and agonist/antagonist ratios in the general

population that may be used as reference values when assessing, planning and implementing shoulder rehabilitation.

Methods: Electronic databases were systematically searched and reference lists of all retrieved papers were hand searched; nine relevant studies were identified. Two independent reviewers assessed methodological quality and extracted data.

Results: Seven studies reported the effect of limb dominance on strength, with four reporting no significant difference between the dominant and non-dominant limbs. The studies that compared muscle strength with gender concluded that men were significantly stronger than women at all speeds in all directions. Age was reported to have no significant effect on muscle strength. Four studies agreed that muscle strength was greater in adduction and extension than other directions, and that flexion, abduction, internal rotation and external rotation were the next strongest in that order.

Conclusions: Nine low- and moderate-quality research papers have attempted to establish isokinetic shoulder strength in a general population. Poor consistency with respect to sample size, randomisation and selection of testing velocities and positions did not allow direct comparison of the results. Future research is warranted involving symptomatic subjects matched to a group of subjects from the general population of the same age, gender and physical profile, with adequate sample sizes representative of the symptomatic population.

This study addresses the gaps in the research identified by this review.

3.5.6.2 Isokinetic testing method

On the basis of the systematic review, the following methodology for isokinetic testing was adopted.

Isokinetic testing was performed using a HUMAC NORM computerised dynamometer (CSMi, 2006). Calibration was completed prior to testing. The asymptomatic group was randomly allocated by drawing a piece of paper, stating right or left, from a box to

determine the arm to be tested first. The asymptomatic limb was consistently tested first in the SSI group, with this familiarisation encouraging maximal effort when testing the symptomatic limb.

The participant was seated in the standardised position, ensuring the seat position allowed the testing arm to be positioned at 45° abduction in the scapular plane (see Plate 3.4). This set-up was consistent with that provided in the HUMAC NORM manufacturer instructions (CSMi, 2006, pp. 5–34). The chair was rotated to 35°, and the dyna tilt was set to 45° and the dyna rotation to 5°. The zero rotation position was established using a spirit level resting on the fixed arm attachment of the machine. A heat-moulded wrist splint was attached before the arm was positioned and strapped into place to standardise the wrist position. Standardised instructions were given by the examiner, explaining which direction the movement was to occur, to provide maximum effort and to maintain the pressure throughout the entire movement. Three practice repetitions were carried out before each test. The examiner advised not to provide maximum effort in the practice session but just to become accustomed to the machine. A 1-min rest was provided between the practice and trial sessions. Five trials were performed in each direction. They were reciprocal concentric/eccentric external rotation and concentric/eccentric internal rotation at 60 deg/s. A 1-min rest was then followed by reciprocal concentric/eccentric external rotation and concentric/eccentric internal rotation at 120 deg/s. All tests were completed on one arm before adjusting the seat set-up to allow testing with the other arm. All five repetitions at each speed were included in the analysis.

Isokinetic PT, glenohumeral internal rotation and glenohumeral external rotation were measured separately using continuous reciprocal concentric and eccentric contraction cycles at speeds of 60 deg/s and 120 deg/s. Testing was performed through a total range of 60° from neutral rotation—from neutral rotation to 30° internal rotation and from neutral rotation to

30° external rotation. Gravity correction was not applied as the range of motion tested in the seated position results in gravity affecting both internal and external rotation movements equally. Further, as significant error and variability were found when applying gravity correction because of the inability of the person to relax, it was not considered advantageous (Bygott, McMeeken, Carroll, & Story, 2001).



Plate 3.4. HUMAC NORM set-up.

The measurements included in isokinetic analyses were:

1. PT of isokinetic concentric and eccentric external and internal rotation measured in newton metres (Nm)
2. relative PT of isokinetic concentric and eccentric external and internal rotation, calculated as PT divided by individual's body weight
3. ratio of PT of eccentric external rotation to PT of concentric internal rotation
4. ratio of PT of concentric external rotation to PT of concentric internal rotation.

3.6 Conclusion

The available evidence was highlighted and methodology formulated to conduct a case-control study comparing the four purported biomechanical factors associated with extrinsic SSI—posterior shoulder range, active thoracic range of flexion/extension and thoracic angle, scapula positioning and rotator cuff internal and external rotation strength—in a homogeneous asymptomatic group with a group experiencing SSI.

The following chapter reports the outcomes of this study and, to the author's knowledge, is an original contribution to our understanding in this field.

Chapter 4: Clinical Comparison of Posterior Shoulder Range, Active Thoracic Flexion/Extension Range, Scapula Position and Rotator Cuff Strength in Subjects With and Without Subacromial Shoulder Impingement

4.1 Introduction

This original contribution to knowledge reports the outcomes of a case-control study investigating the differences between a group of people with SSI and an asymptomatic group, matched for age, gender, limb dominance and physical activity level, for each of the biomechanical factors purported to be associated with extrinsic SSI:

- posterior shoulder range
- active thoracic flexion/extension range in standing and resting thoracic angle
- scapula positioning
- glenohumeral isokinetic internal and external rotation strength.

This original research was written up as two separate papers, both published in the journal *Musculoskeletal Science and Practice* (Land, Gordon, & Watt, 2017a, 2017c).

This original study identified that the SSI group had significantly increased resting thoracic flexion, as well as significantly reduced upper thoracic active flexion/extension motion and reduced posterior shoulder range, compared with the asymptomatic group (Land et al., 2017a).

4.2 Hypothesis

The hypothesis was that there would be a difference in assessment outcomes for each of the biomechanical factors between the painful shoulder in the SSI group and the dominance-matched shoulder in the control group.

4.3 Reliability Testing

Pilot reliability studies were completed prior to commencement of the study by using an unrelated asymptomatic population. All measurements were shown to have a good to excellent level of intra-rater reliability (Portney & Watkins, 2009; see Table 4.1). The following pilot studies were performed:

1. measurement of posterior shoulder range, using the method described by Tyler et al. and shown to be valid and reliable (Tyler et al., 1999)
2. passive glenohumeral internal rotation in the supine position, with shoulder abducted to 90° and using a plastic universal goniometer (Tyler et al., 2000)
3. scapula linear measurements using a standard tape measure in the three test positions described for the LSST (Kibler, 1998)
4. measurement of cervical and thoracic postural angles using ImageTool software
5. isokinetic internal and external rotation using the HUMAC NORM computerised dynamometer (CSMi, 2006).

In pilot study 4, inter-rater reliability was determined, compared with two other musculoskeletal physiotherapists with more than 15 years' experience. In pilot study 5, initial recruits displayed visible flexion and extension occurring at the wrist during testing. A small pilot study was then conducted, using asymptomatic young participants performing the same protocol with a wrist splint in situ. No significant difference in PT values was found at either speed when the splint was or was not in situ. However, it was decided to use the heat-moulded splint for all participants to standardise the wrist joint position.

Table 4.1

Outcomes of Reliability Testing for Clinical Assessments of Biomechanical Factors in Extrinsic Subacromial Shoulder Impingement

Intra-rater reliability study	Number of measurements	Measurement one <i>M ± SD</i>	Measurement two <i>M ± SD</i>	Intraclass correlation coefficient	95% confidence interval
1.	16 Repeated on same day, 1 hr apart	21.88 ± 8.55	22.48 ± 8.84	0.893	[0.722, 0.961]
2.	16 Repeated on same day, 1 hr apart	65.50 ± 11.94	65.31 ± 12.08	0.933	[0.867, 0.967]
3.	48 Repeated on same day, 1 hr apart	8.60 ± 2.30	8.33 ± 1.98	0.889	[0.810, 0.936]
4.	Digitise 30 photographs: 10 in relaxed resting, 10 in thoracic flexion and 10 in extension	20.50, 20.21 and 20.41	15.6, 15.6 and 15.7	0.997	[0.995, 0.998]
5.	110 Repeated 4 days later			0.948	[0.992, 0.965]

4.4 Methods

4.4.1 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 email 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 reception area of the JCU Physiotherapy Clinic. The advertisement stated ‘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?’ Volunteers contacted the investigator, who arranged an assessment to determine eligibility. Controls were recruited of 40–60 years of age; with no history of shoulder, neck or upper back injuries; and with no reports of painful symptoms in any of these areas in the previous 12 months. Both groups were required to meet the inclusion criteria (see section 4.4.3).

Subacromial shoulder impingement cases and asymptomatic controls were recruited and assessed during the same period, independently of each other. Matching was not performed until data collection was completed, thereby ensuring random selection of participants.

4.4.2 Power analysis

A pre-study sample size calculation was performed on the basis of shoulder passive internal rotation range in subjects with and without SSI. The required sample size was a minimum of 45 cases and 45 controls to detect a between group difference of 9° ([Tyler et al., 2000]; standard deviation [*SD*], 12° [Borstad et al., 2007]) with 80% power and $\alpha = 0.05$ (Altman, 1991). This sample size was also sufficient to detect a between group difference of 10 Nm; *SD*, 2 Nm [Leroux et al., 1994]) in rotator cuff strength (PT external rotation at 60 deg/s). Values for the postural and scapula measurements were not available in the literature so sample size calculations were not able to be completed for these variables.

4.4.3 Inclusion and exclusion criteria

Participants of 40–60 years of age 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, with:

- history of participating in intense shoulder strength training for at least 4 weeks prior to entering the study (defined as high-load upper-body weight training two or more times per week)
- recent (within the previous 2 years) or current pregnancy
- previous shoulder surgery or 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
- participation in elite or fulltime overhead sports
- scoliosis (by observing posture and the forward trunk flexion test [Bunnell, 2005])
- current cervical or thoracic pain or positive outcome from testing described in section 3.4.2
- diagnosed systemic or neurological condition (screening for type 2 diabetes was not performed)
- shoulder corticosteroid injection at any time in the past.

If the questionnaire indicated that a participant was eligible, a physical assessment was conducted. Volunteers eligible for inclusion in the SSI group were reported to have:

- a minimum of three positive orthopaedic special tests for subacromial pain reproduction (Michener et al., 2009; Park et al., 2005), including a positive Hawkins–Kennedy test (Hawkins & Kennedy, 1980) and/or Neer test (Neer,

1983) together with two of the following: external rotation resistance test (Michener et al., 2009), tendon palpation (Hanchard et al., 2004), horizontal (cross-body) adduction (Park et al., 2005), painful arc (Kessel & Watson, 1977), drop-arm test (Park et al., 2005) and Speed test (Dalton, 1989; Park et al., 2005)

- ‘catching’ or aching pain without appreciable joint stiffness (Hanchard & Handoll, 2008)
- a painful arc elicited on elevation with pain eased on lowering the arm (Hanchard et al., 2004)
- pain localised to the anterior or antero-lateral-superior shoulder (Lewis, Green, & Dekel, 2001)
- insidious onset of symptoms with a possible history of gradual progression over time but without history of trauma (Bigliani & Levine, 1997)
- alterations in acromial shape and bursal thickening were noted but did not prevent inclusion. However, volunteers with radiographic or ultrasound scans revealing osteophytes within the subacromial region, calcification of tendons or large rotator cuff tears were excluded from the study

4.4.4 Outcome measures

The SPADI was completed by both groups to further describe the SSI group. An NPRS was used to obtain pain measurements when at rest and when pain was provoked during assessment (Jensen et al., 1986), and was checked in the matched asymptomatic group. Physical activity level was established by completing the short form of the IPAQ (Craig et al., 2003). The height and weight of all participants was recorded to allow calculation of body mass index (BMI).

Both shoulders of all participants were measured by an experienced musculoskeletal physiotherapist with over 20 years' clinical experience. The physical assessment order for all participants was as follows:

- Lateral linear measurements of both scapulae, in each participant, were completed, in standing, using the three positions described for the LSST (Kibler, 1998; detailed in section 3.4.3).
- Passive range of glenohumeral internal rotation was measured in the supine position by using a universal plastic goniometer (Clarkson, 2000; Riddle, Rothstein, & Lamb, 1987; detailed in section 3.4.5).
- Posterior shoulder tightness was assessed using Tyler's method with randomisation of the side measured first (Tyler et al., 1999; detailed in section 3.4.5).
- Three sagittal-view photographs were obtained, from which the thoracic flexion/extension range and thoracic angle were digitised (Edmondston et al., 2011; detailed in section 3.4.4).
- Isokinetic glenohumeral internal and external rotation strengths were assessed using a HUMAC NORM computerised dynamometer (CSMi, 2006; detailed in section 3.4.6).

4.4.5 Data analysis

Data for SSI cases and controls were collected and then matched for gender, hand dominance, physical activity level and age (within a bracket of 3 years) (Webb, Bain, & Page., 2017; Watt, Purdie, Roche, & McClure, 2004; Rothman & Greenland, 1998).

Postural angles were calculated from lateral photographs by using digitising software, UTHSCSA ImageTool (Wilcox et al., 1997), as detailed in section 3.4.4.

Data were analysed using IBM Statistical Package for the Social Sciences (SPSS) Version 22. Calculations for ratios and relative PT were performed in SPSS using the raw data. All data were tested and found to be normally distributed. Descriptive statistics (mean, standard deviation and standard error) were calculated for each physical assessment variable (CVA, resting thoracic angle, active thoracic flexion/extension range, passive internal rotation, posterior shoulder range, three positions of the LSST and all isokinetic tests).

Comparisons between matched SSI cases and controls were completed using independent-samples *t* tests, with $\alpha \leq 0.01$, to minimise the chance of a type I error occurring because of multiple comparisons. When the dominant shoulder was painful in the SSI group, it was compared with the dominant shoulder in the control group, and when the non-dominant shoulder was painful in the SSI group, it was compared with the non-dominant shoulder in the control group.

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 et al., 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 (OR) 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 SSI, taking into account relevant confounders, were identified. The strengths of association were expressed as ORs with 95% confidence intervals. Pearson's correlation was used to establish whether postural variables were correlated with each other 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 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. Pearson's correlation was used to establish if an association was present between significant isokinetic and significant postural variables.

4.5 Results

Data for 73 SSI cases and 91 controls were collected and then matched for gender, hand dominance, physical activity level and age. Matching resulted in 51 complete matches of cases and controls. A description of participants is found in Table 4.2, with no significant differences in BMI or physical activity between the groups and a moderate activity level the most prevalent in each group. SSI cases reported symptom duration of 4–12 months. As expected, significant differences in the SPADI and NPRS scores were present between the cases and controls and no significant differences were present for the matched descriptors.

Table 4.2

Description and Comparison of Participants

	SSI <i>M ± SD</i> <i>n = 51</i>	Asymptomatic <i>M ± SD</i> <i>n = 51</i>	<i>p</i> 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	
Dominance			1.0
Right	45	45	
Left	6	6	
IPAQ			.282
Low	27%	30.2%	
Moderate	42.9%	38.1%	
High	30.2%	31.7%	
NPRS			
Rest	0.3 ± 0.8	0	<.001
Activity	5.8 ± 2.8	0	<.001
SPADI	26.2 ± 17.9	0	<.001

Note. SSI = subacromial shoulder impingement; BMI = body mass index; IPAQ = International Physical Activity Questionnaire; NPRS = Numerical Pain Rating 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. Occupations that involved overhead work were not predominant in either group.

4.5.1 Cervical and thoracic resting posture, thoracic active flexion/extension range of motion, posterior shoulder and passive internal rotation range and scapula position

4.5.1.1 Cervical and thoracic resting posture

The CVA was significantly smaller in the SSI group (cases) than the asymptomatic group (controls; $p \leq .001$). This suggests that the amount of forward positioning of the head on the trunk is significantly greater in individuals with SSI. In addition, the SSI group (cases) rested with significantly greater upper thoracic flexion ($p \leq .001$) and significantly less lower thoracic extension than did the asymptomatic group (controls; $p \leq .001$; see Table 4.3).

There was an inverse association in the SSI group between increased forward head posture (i.e., smaller CVA) and increased upper thoracic flexion ($r = -.50, p \leq .001$). There was a weak association between increased upper thoracic flexion posture and reduced lower thoracic extension posture ($r = .31, p = .025$). Therefore, overall the thoracic spine was more flexed in the SSI group (cases) than the asymptomatic group (controls).

No association was found in the asymptomatic group (controls) between upper and lower thoracic resting postures ($r = .19, p = 0.18$), but a weak association was present between forward head posture and resting upper thoracic posture ($r = -.30, p = .031$).

4.5.1.2 Thoracic range of motion

The SSI group had significantly less range of upper thoracic active flexion/extension motion than did the asymptomatic group ($p \leq .001$; see Table 4.3).

4.5.1.3 Posterior shoulder and passive internal rotation range

There was significantly less passive internal rotation and passive posterior shoulder range in the painful shoulder in the SSI group (cases) than the matched shoulder in the asymptomatic group (controls; $p \leq .001$; see Table 4.3). A weak correlation was found between passive posterior shoulder range and passive internal rotation in the SSI group ($r = .37, p = .008$), which was not present in the asymptomatic group ($r = .04, p = .78$).

4.5.1.4 Scapula position

No significant differences were found in scapula position between the asymptomatic and symptomatic groups by using the LSST method (see Table 4.3).

Table 4.3

Between-Group Comparison of Cervical and Thoracic Resting Posture, Thoracic Active Flexion/Extension Range of Motion, Posterior Shoulder and Passive Internal Rotation Range, and Scapula Position, Matched for Age, Gender, Dominance and Physical Activity

	SSI <i>M ± SD (SEM)</i> <i>n = 51</i>	Asymptomatic <i>M ± SD (SEM)</i> <i>n = 51</i>	<i>p</i> value
CVA (degrees)	46.29 ± 6.72 (0.94)	51.73 ± 5.63 (0.79)	≤.001*
Upper thoracic resting posture (degrees)	18.59 ± 6.29 (0.88)	13.22 ± 4.81 (0.67)	≤.001*
Range of upper thoracic motion (degrees)	32.71 ± 14.09 (1.97)	42.16 ± 14.95 (2.09)	≤.001*
Lower thoracic resting posture (degrees)	-8.48 ± 5.99 (0.84)	-12.50 ± 3.97 (0.56)	≤.001*
Passive internal rotation (degrees)	38.39 ± 13.98 (1.96)	56.24 ± 12.46 (1.74)	≤.001*
Posterior shoulder range (degrees)	38.89 ± 7.93 (1.11)	24.61 ± 6.47 (0.91)	≤.001*
Lateral slide test position 1 (cm)	9.22 ± 1.32 (1.84)	9.29 ± 1.57 (2.19)	.811
Lateral slide test position 2 (cm)	9.59 ± 1.39 (1.94)	9.34 ± 1.44 (2.02)	.384
Lateral slide test position 3 (cm)	12.06 ± 2.19 (3.06)	12.65 ± 1.87 (2.62)	.147

Note. SSI = subacromial shoulder impingement; CVA = craniovertebral angle. A positive postural value represents flexion and a negative value represents extension (see section 3.4.4.).

* Significant finding.

4.5.2 Isokinetic testing: Subacromial shoulder impingement cases versus control analysis

4.5.2.1 Dominant shoulder

For these analyses, an alpha value of 0.01 was used to minimise the risk of a type I error due to multiple comparisons. Only PT of eccentric internal rotation at 60 deg/s ($p = .01$) was significantly less in the dominant symptomatic SSI shoulder (cases) than the dominant control shoulder (see Table 4.4). While no other statistical differences were identified, all measures of the dominant SSI shoulder were lower than those of the dominant control shoulder.

4.5.2.2 Non-dominant shoulder

No significant difference in isokinetic strength was identified between the non-dominant symptomatic SSI shoulder (cases) and the non-dominant control shoulder. It is noted, however, that non-dominant shoulder PT values were greater than the dominant shoulder PT values in the SSI group (cases), whereas non-dominant shoulder PT values were slightly lower than those of the dominant shoulder in the control group (see Table 4.4).

This suggests that rotator cuff strength is reduced more when the dominant limb is affected than when the non-dominant limb is affected.

Table 4.4

*Isokinetic Testing for the Symptomatic Shoulder in the Subacromial Shoulder Impingement**Group (Cases) and the Matched Shoulder in the Control Group*

		SSI	Control	<i>p</i> value
		<i>M ± SD (SEM)</i>	<i>M ± SD (SEM)</i>	
PT ER Con				
60 deg/s	D ^a	12.7 ± 6.6 (1.2)	17.2 ± 8.4 (1.5)	.03
	ND ^b	16.0 ± 6.6 (1.5)	14.6 ± 6.8 (1.5)	.51
120 deg/s	D	10.7 ± 6.1 (0.1)	13.6 ± 7.8 (1.4)	.10
	ND	11.7 ± 6.1 (1.4)	11.1 ± 6.0 (1.3)	.78
PT ER Ecc				
60 deg/s	D	21.6 ± 10.7 (1.9)	26.1 ± 11.0 (2.0)	.11
	ND	25.5 ± 12.9 (3.0)	23.2 ± 9.1 (2.0)	.53
120 deg/s	D	21.3 ± 7.0 (1.2)	27.2 ± 11.1 (2.0)	.02
	ND	29.1 ± 17.0 (3.8)	25.5 ± 9.4 (2.1)	.41
Rel PT ER Con				
60 deg/s	D	0.16 ± 0.08 (0.01)	0.20 ± 0.09 (0.02)	.06
	ND	0.18 ± 0.07 (0.01)	0.17 ± 0.07 (0.01)	.64
120 deg/s	D	0.14 ± 0.07 (0.01)	0.16 ± 0.09 (0.02)	.21
	ND	0.14 ± 0.07 (0.01)	0.14 ± 0.07 (0.01)	.99
Rel PT ER Ecc				
60 deg/s	D	0.28 ± 0.12 (0.02)	0.31 ± 0.10 (0.02)	.24
	ND	0.30 ± 0.18 (0.04)	0.28 ± 0.08 (0.02)	.61
120 deg/s	D	0.27 ± 0.09 (0.02)	0.32 ± 0.10 (0.02)	.04
	ND	0.35 ± 0.26 (0.06)	0.31 ± 0.09 (0.02)	.48
PT IR Con				
60 deg/s	D	31.9 ± 11.9 (2.1)	36.2 ± 13.6 (2.4)	.20
	ND	33.1 ± 11.8 (2.6)	34.4 ± 14.3 (3.2)	.76
120 deg/s	D	31.1 ± 11.6 (2.1)	33.6 ± 14.1 (2.5)	.45
	ND	32.2 ± 11.5 (2.6)	30.9 ± 15.1 (3.4)	.78
PT IR Ecc				
60 deg/s	D	39.9 ± 13.4 (2.4)	49.3 ± 15.7 (2.8)	.01*
	ND	45.8 ± 15.6 (3.5)	48.6 ± 17.7 (4.0)	.59
120 deg/s	D	41.8 ± 11.5 (2.1)	49.8 ± 16.6 (3.0)	.03
	ND	47.2 ± 16.1 (3.6)	49.6 ± 18.3 (4.1)	.67
Rel PT IR Con				
60 deg/s	D	0.41 ± 0.16 (0.03)	0.44 ± 0.14 (0.02)	.59
	ND	0.40 ± 0.17 (0.04)	0.43 ± 0.17 (0.04)	.61

120 deg/s	D	0.40 ± 0.14 (0.03)	0.40 ± 0.15 (0.03)	.93
	ND	0.39 ± 0.11 (0.04)	0.38 ± 0.18 (0.04)	.90
Rel PT IR Ecc				
60 deg/s	D	0.52 ± 0.18 (0.03)	0.60 ± 0.15 (0.03)	.06
	ND	0.54 ± 0.20 (0.05)	0.60 ± 0.19 (0.04)	.41
120 deg/s	D	0.54 ± 0.15 (0.03)	0.60 ± 0.16 (0.03)	.14
	ND	0.55 ± 0.18 (0.04)	0.61 ± 0.19 (0.04)	.37
ER Ecc/IR Con				
60 deg/s	D	0.72 ± 0.32 (0.06)	0.74 ± 0.23 (0.04)	.69
	ND	0.81 ± 0.44 (0.10)	0.71 ± 0.23 (0.05)	.36
120 deg/s	D	0.72 ± 0.22 (0.04)	0.91 ± 0.58 (0.10)	.09
	ND	0.97 ± 0.58 (0.13)	0.94 ± 0.50 (0.11)	.82
ER Con/IR Con				
60 deg/s	D	0.41 ± 0.19 (0.03)	0.48 ± 0.17 (0.03)	.16
	ND	0.52 ± 0.24 (0.05)	0.43 ± 0.14 (0.03)	.16
120 deg/s	D	0.34 ± 0.12 (0.02)	0.41 ± 0.15 (0.03)	.06
	ND	0.38 ± 0.19 (0.04)	0.38 ± 0.16 (0.03)	.95

Note. SSI = subacromial shoulder impingement; D = dominant; ND = non-dominant; PT = peak torque; Rel PT = relative peak torque; ER = external rotation; IR = internal rotation; Con = concentric; Ecc = eccentric.

^a $n = 31$; ^b $n = 20$.

No significant differences were identified when the asymptomatic shoulder of the SSI group (cases) was compared with the matched shoulder of the control group (dominant = 20, non-dominant = 31; see Table 4.5). Overall, non-dominant shoulder PT values were less than dominant shoulder PT values in both groups.

Table 4.5

Isokinetic Testing for the Asymptomatic Shoulder in the Subacromial Shoulder Impingement Group and the Matched Shoulder in the Control Group

		SSI	Control	<i>p</i> value
		<i>M ± SD (SEM)</i>	<i>M ± SD (SEM)</i>	
PT ER Con				
60 deg/s	D ^a	17.0 ± 7.2 (1.6)	16.5 ± 6.7 (1.5)	.82
	ND ^b	12.3 ± 5.6 (1.0)	14.1 ± 6.5 (1.2)	.26
120 deg/s	D	13.5 ± 7.3 (1.6)	11.7 ± 6.7 (1.5)	.42
	ND	10.9 ± 5.7 (1.0)	11.0 ± 6.2 (1.1)	.98
PT ER Ecc				
60 deg/s	D	26.8 ± 9.3 (2.1)	24.5 ± 9.0 (2.0)	.42
	ND	21.6 ± 8.9 (1.6)	22.8 ± 8.7 (1.6)	.61
120 deg/s	D	28.8 ± 9.8 (2.2)	27.3 ± 12.4 (2.8)	.67
	ND	22.1 ± 8.2 (1.5)	24.1 ± 9.3 (1.7)	.38
Rel PT ER Con				
60 deg/s	D	0.19 ± 0.07 (0.01)	0.20 ± 0.07 (0.02)	.69
	ND	0.16 ± 0.07 (0.01)	0.17 ± 0.07 (0.01)	.57
120 deg/s	D	0.15 ± 0.07 (0.02)	0.14 ± 0.07 (0.02)	.55
	ND	0.14 ± 0.07 (0.01)	0.13 ± 0.06 (0.01)	.61
Rel PT ER Ecc				
60 deg/s	D	0.31 ± 0.08 (0.02)	0.30 ± 0.09 (0.02)	.71
	ND	0.28 ± 0.12 (0.02)	0.27 ± 0.09 (0.02)	.88
120 deg/s	D	0.33 ± 0.09 (0.02)	0.33 ± 0.12 (0.03)	.93
	ND	0.28 ± 0.10 (0.02)	0.29 ± 0.09 (0.02)	.81
PT IR Con				
60 deg/s	D	34.9 ± 10.3 (2.3)	35.5 ± 18.3 (4.1)	.91
	ND	34.3 ± 13.3 (2.4)	34.2 ± 13.2 (2.4)	.96
120 deg/s	D	30.9 ± 11.8 (2.6)	32.5 ± 15.8 (3.5)	.73
	ND	32.5 ± 12.9 (2.3)	32.0 ± 14.4 (2.6)	.45
PT IR Ecc				
60 deg/s	D	49.5 ± 14.4 (3.2)	50.3 ± 21.6 (4.8)	.89
	ND	43.3 ± 14.7 (2.6)	44.0 ± 15.0 (2.7)	.86
120 deg/s	D	50.6 ± 12.3 (2.8)	52.1 ± 18.3 (4.1)	.76
	ND	44.7 ± 14.3 (2.6)	45.9 ± 15.3 (2.7)	.75
Rel PT IR Con				
60 deg/s	D	0.41 ± 0.12 (0.03)	0.44 ± 0.21 (0.05)	.55
	ND	0.44 ± 0.17 (0.03)	0.41 ± 0.13 (0.02)	.39

120 deg/s	D	0.36 ± 0.14 (0.03)	0.40 ± 0.17 (0.04)	.47
	ND	0.42 ± 0.16 (0.03)	0.38 ± 0.14 (0.03)	.33
Rel PT IR Ecc				
60 deg/s	D	0.57 ± 0.14 (0.03)	0.61 ± 0.22 (0.05)	.48
	ND	0.56 ± 0.17 (0.03)	0.53 ± 0.14 (0.03)	.52
120 deg/s	D	0.59 ± 0.13 (0.03)	0.64 ± 0.19 (0.04)	.31
	ND	0.57 ± 0.17 (0.03)	0.55 ± 0.14 (0.03)	.59
ER Ecc/IR Con				
60 deg/s	D	0.78 ± 0.20 (0.04)	0.81 ± 0.50 (0.11)	.81
	ND	0.66 ± 0.28 (0.05)	0.69 ± 0.19 (0.03)	.67
120 deg/s	D	1.0 ± 0.39 (0.09)	0.92 ± 0.47 (0.10)	.57
	ND	0.71 ± 0.25 (0.04)	0.84 ± 0.41 (0.07)	.16
ER Con/IR Con				
60 deg/s	D	0.48 ± 0.14 (0.03)	0.52 ± 0.21 (0.05)	.59
	ND	0.36 ± 0.10 (0.02)	0.41 ± 0.14 (0.02)	.09
120 deg/s	D	0.42 ± 0.14 (0.03)	0.36 ± 0.17 (0.04)	.23
	ND	0.33 ± 0.12 (0.02)	0.35 ± 0.13 (0.02)	.53

Note. SSI = subacromial shoulder impingement; D = dominant; ND = non-dominant PT = peak torque; Rel PT = relative peak torque; ER = external rotation; IR = internal rotation; Con = concentric; Ecc = eccentric.

^a $n = 20$; ^b $n = 31$.

4.5.3 Conditional logistic regression analysis

Any variables for which a significant difference between the painful shoulder in the SSI group (cases) and the matched shoulder in the control group was identified were included in a conditional logistic regression analysis to identify independent predictors of SSI. These variables included the CVA, upper thoracic resting posture, range of upper thoracic motion, lower thoracic resting posture, passive internal rotation, posterior shoulder range and PT of eccentric internal rotation at 60 deg/s. Lower thoracic resting posture, PT of eccentric internal rotation at 60 deg/s, range of upper thoracic motion, passive internal rotation, upper thoracic resting posture and the CVA were progressively 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 4.6. Posterior shoulder range was identified as a

significant independent predictor of SSI using this model. This model shows that, for each centimetre reduction in posterior shoulder range, there is a 5% increased likelihood of SSI.

Table 4.6

*Association Between Significant Variables and Subacromial Shoulder Impingement
(Conditional Logistic Regression)*

Variable	Odds ratio	95% confidence interval	p value
Posterior shoulder range	1.047	[1.013, 1.083]	.007*

* Significant finding.

Within-group analysis was performed to identify if an association was present between posterior shoulder range and the significant isokinetic variable PT for eccentric internal rotation at 60 deg/s (see Table 4.7).

Posterior shoulder range consistently showed a moderate to good significant association with isokinetic strength in the asymptomatic (control) group only (Portney & Watkins, 2009). There was no significant association between these variables in the SSI group (cases).

Table 4.7

Association Between Posterior Shoulder Range and Isokinetic Strength

Significant variables	SSI r value, p value	Control r value, p value
PT IR Ecc 60 deg/s Posterior shoulder range	-.051, 0.78	.632, ≤.001*

Note. SSI = subacromial shoulder impingement; PT IR Ecc = peak torque for eccentric internal rotation.

In summary, the hypothesis that there would be a difference in assessment outcomes between the painful shoulder in the SSI group and the dominance-matched shoulder in the control group was true for the CVA, resting thoracic angle, active thoracic flexion/extension

range, passive internal rotation range and posterior shoulder range, as well as for one isokinetic test in the dominant shoulder only (PT for eccentric internal rotation at 60 deg/s; see Table 4.8).

Table 4.8

Summary of Identified Significant Variables

	SSI <i>M ± SD (SEM)</i> <i>n = 51</i>	Asymptomatic <i>M ± SD (SEM)</i> <i>n = 51</i>	<i>p</i> value
CVA (degrees)	46.29 ± 6.72 (0.94)	51.73 ± 5.63 (0.79)	≤.001
Upper thoracic resting posture (degrees)	18.59 ± 6.29 (0.88)	13.22 ± 4.81 (0.67)	≤.001
Range of upper thoracic motion (degrees)	32.71 ± 14.09 (1.97)	42.16 ± 14.95 (2.09)	≤.001
Lower thoracic resting posture (degrees)	-8.48 ± 5.99 (0.84)	-12.50 ± 3.97 (0.56)	≤.001
Passive internal rotation (degrees)	38.39 ± 13.98 (1.96)	56.24 ± 12.46 (1.74)	≤.001
Posterior shoulder range (degrees)	38.89 ± 7.93 (1.11)	24.61 ± 6.47 (0.91)	≤.001
PT IR Ecc 60 deg/s dominant limb (Nm)	39.9 ± 13.4 (2.4)	49.3 ± 15.7 (2.8)	0.01

Note. SSI = subacromial shoulder impingement; CVA = craniovertebral angle; PT IR Ecc = peak torque for eccentric internal rotation.

4.6 Discussion

This original study confirmed measurable, clinical differences in biomechanical factors associated with extrinsic SSI in a group experiencing SSI compared to an asymptomatic group matched for age, gender, hand dominance and physical activity. Previously, each of these factors have been described independently for subjects with SSI, compared with an asymptomatic group—that is, only posterior shoulder range (Tyler et al., 2000), cervical and thoracic posture (Lewis, Green, & Wright, 2005), scapula positioning (Lukisewicz et al., 1999) or isokinetic rotational strength (Dulgeroglu et al., 2013). This study

considered the multifactorial contributors considered part of SSI and assessed all of these factors in each of the groups, in addition to ensuring that the groups were well matched.

It is uncertain if these biomechanical factors which are significantly different between the groups actually contribute to the development of SSI symptoms or occur as a consequence of SSI symptoms. An example is the significant difference in forward head position (CVA) identified between groups, with an increased CVA measurement in the SSI group correlated with increased resting thoracic flexion posture. This flexed posture may be adopted to relieve the painful symptoms or may be contributing to their development.

As the shoulder moves actively into elevation, each level of the thoracic spine extends and side flexes to varying degrees (Oatis, 2009). It was shown that when the ability of the thoracic spine to extend is limited, the range of active shoulder elevation is consequently reduced (Kebaetse et al., 1999). Impingement pain occurs during shoulder elevation, and it was hypothesised that a reduction in the range of upper thoracic extension may be associated with the presence of SSI. Two previous trials that compared an SSI group with an asymptomatic group assessed the resting thoracic angle in standing and found no difference between the groups (Greenfield et al., 1995; Lewis & Valentine, 2010). However, this provided no information about the range of thoracic flexion or extension that occurs during dynamic movement. Ultrasound topometric measurement calculated sagittal plane thoracic range and recorded maximal thoracic flexion and extension, identifying significantly less thoracic flexion/extension range in subjects with SSI (Theisen et al., 2010).

This present study calculated upper thoracic range by measuring end-range upper thoracic flexion and extension from digitised sagittal photographs, and found significantly reduced active thoracic range in the SSI group. This reduction in total active thoracic range in the SSI group along with resting in significantly more thoracic flexion than in the asymptomatic group, suggests thoracic extension is limited. Interventions to reduce thoracic

restriction may be indicated for SSI management, and inclusion of thoracic spine examination in all SSI assessments is warranted.

Lateral linear measurements using the three positions of the 2D LSST found no difference in scapula positioning between the SSI and asymptomatic groups. Position 1 of the LSST is with the arms resting by the side, thereby measuring the resting scapula position. No difference between the groups for resting scapula position is consistent with previous 2D and 3D scapula studies (Greenfield et al., 1995; Ludewig & Cook, 2000; Lukisewicz et al., 1999; McClure et al., 2006; Rufa, 2014). Position 2 of the LSST (hands resting on the hips) and position 3 (arms internally rotated and abducted to 90°) were not significantly different between the groups. This indicates no difference in the linear positioning of the scapulae between groups. However, the LSST is not able to measure changes in scapula tilt or rotation that are identified in 3D kinematic studies in subjects with SSI (Ludewig & Cook, 2000; Lukisewicz et al., 1999; McClure et al., 2006). However, no clinical tests have yet been identified that reliably identify scapula dyskinesia and the 3D kinematic variations identified to date in subjects with SSI may not be clinically relevant.

This study supports previous findings that showed both the range of passive internal rotation and the passive posterior shoulder range are correlated and significantly reduced in subjects with SSI (Tyler et al., 2000). Further research is needed to inform clinicians whether recovering either or both of these ranges results in decreased symptomatology in subjects with SSI.

The hypothesis that a significant difference in internal and external rotation strengths would be found in the painful shoulder in the SSI group (cases), compared with the dominance-matched shoulder in the control group, has not been supported by this study. No concentric variables differed between the two groups. Concentric testing was shown to be more reliable than eccentric testing when comparing an SSI group to an asymptomatic group

(MacDermid et al., 2004). A concentric contraction produces less force than an eccentric contraction, thereby reducing the influence of pain on performance (Anderson, Bialocerkowski, & Bennell, 2006).

Only one previous study compared concentric isokinetic external rotation and internal rotation PT in an SSI symptomatic shoulder with a control group (Dulgeroglu et al., 2013), with all values found to be significantly lower for concentric internal rotation and concentric external rotation, at 90 deg/s and 180 deg/s, in the SSI symptomatic shoulder compared with the dominant shoulder of the control group. However, of the 22 symptomatic shoulders assessed only 14 were the dominant shoulder (Dulgeroglu et al., 2013). The remaining eight shoulders were non-dominant, but were compared with the dominant shoulders of the control group. This analytical and methodological anomaly, together with the relatively small sample size and the testing speeds of the study, may explain why the findings of the current study differ from these previous results (Dulgeroglu et al., 2013).

Differences in eccentric strength in this study were only present when the dominant shoulder was the affected shoulder in the SSI group and only with eccentric internal rotation. Significantly less eccentric internal rotation PT at 60 deg/s was found when compared with the matched control shoulder. EMG studies identified that pectoralis major muscle activity (expressed as %MVIC) is greatest during internal rotation, suggesting this significant finding may not indicate rotator cuff dysfunction but result from pain inhibition (Dark et al., 2007).

No differences were found between the non-painful shoulder of the SSI group and the matched shoulder of the control group, with less strength recorded in the non-dominant shoulder compared with the dominant shoulder in both groups, consistent with the normal population (Roy, MacDermid, Boyd, et al., 2009).

Mean isokinetic values for all measurements of the painful dominant shoulder in the SSI group (cases) were consistently lower than those of the matched dominant shoulder in the

control group. However, when the non-dominant shoulder was the painful shoulder in the SSI group (cases), the isokinetic values were very similar or slightly higher than those of the control group. This may suggest overall activity of the dominant shoulder is reduced when painful symptoms are present. However, when the non-dominant shoulder is painful, its overall activity level may not vary significantly.

Within-group analysis of the significant isokinetic variable, eccentric internal rotation PT at 60 deg/s, and posterior shoulder range revealed a moderate association in the asymptomatic (control) group only. The lack of association between these variables in the SSI group (cases) may be attributed to the identified significant restriction in posterior shoulder range.

4.7 Limitations of the Study

Limitations of this study include the availability of only one assessor (primary investigator), leading to a lack of blinding and potential bias. This lack of assessment blinding is a significant limitation and occurred because no funding was available to employ an assistant for this study. However, the assessor has postgraduate training, more than 20 years' experience as a musculoskeletal physiotherapist and completed quality reliability studies in preparation, suggesting the results can be considered credible.

Another limitation was the participants not being familiar with the use of the isokinetic dynamometer, which is common to other isokinetic studies. Although instructions were clear before commencing the trial, reminders to apply maximum effort throughout and which direction to apply resistance were sometimes needed for subjects in both the SSI group and the control group. However, this was true for both cases and controls, so the measurement bias is likely to be non-differential, and therefore any impact on the results would be an underestimate of the true association. The effect of pain was minimised by the position and range chosen for isokinetic testing. Further, selection bias (volunteer bias) might

have been present because of the snowball recruitment strategy. In addition, this study only included participants aged 40–60 years. While this is the primary age of SSI, these findings should only be applied to this age group.

A strength of this study is the matching of cases and controls by age, gender, hand dominance and physical activity level.

4.8 Conclusion

An SSI group was compared with 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.

Differences in muscle strength were not clearly identified between the SSI cases and control group, with significant strength differences only found when the dominant SSI shoulder was symptomatic (eccentric internal rotation PT at 60 deg/s). No strength differences were evident when comparing the non-dominant painful SSI shoulder and the non-dominant control shoulder. Posterior shoulder range was identified as a significant independent predictor of SSI using conditional logistical regression, showing for every centimetre reduction in posterior shoulder range, there is a 5% increased likelihood of SSI.

It is not known if these identified differences were contributing to or a result of SSI. As no differences in muscle strength were identified, further research regarding rotator cuff strength was not warranted. However, further research was required to determine if interventions focused on the upper thoracic spine and posterior shoulder were effective in the management of SSI.

The following chapter explores the background to establishing the methodology for an RCT investigating the effect of physiotherapy interventions to increase thoracic range of motion and increase posterior shoulder range in patients presenting with SSI symptoms.

Chapter 5: Developing Methodology to Conduct a Randomised Controlled Trial

5.1 Introduction

No previous study has investigated the effect of physiotherapy interventions to increase thoracic range of motion or increase posterior shoulder range on SSI symptoms. A RCT has been suggested as a powerful research tool for evaluating effectiveness of interventions (Koes & Hoving, 1998; Littlewood, 2011).

5.2 Randomised Controlled Trials

In 1998, increasing attention was being placed on evidence-based practice, with reports that knowledge about the efficacy of physiotherapeutic interventions was important for all clinicians, highlighting the methodological problems in clinical RCT's at that time (Koes & Hoving, 1998). The problems included (1) the lack of prognostic homogeneous study populations; (2) limitations in standardisation of interventions, with the need to include the type, intensity, frequency and duration of treatment, thereby making it possible to replicate the therapy elsewhere; and (3) ensuring blinding of patients, therapists and outcome measurement. Therapists were reminded to be equally positive in the delivery of all treatments, including the control treatment, with extensive practice required before the trial (Koes & Hoving, 1998). Recent RCT reporting has become increasingly standardised because of the requirement of journal editors to publish articles that follow the CONSORT statement (Moher et al., 2010) and trial registration prior to commencement.

However, although the RCT is an appropriate design, the manner in which the trial is conducted can alter the internal or external validity of the findings (Littlewood, 2011). The principles recommended to minimise this possibility were applied in this RCT, being (1) recruit a justified sample size from a specified clinical population, (2) utilise and report

appropriate methods of random allocation, (3) use validated outcome measures and (4) have an appropriate length of follow-up (Littlewood, 2011). Although an RCT may not be representative of clinical practice (Milanese, 2011), the standardisation of the treatments provided to determine the efficacy of each intervention makes it possible to replicate the therapy. Once each treatment has been proven effective, or otherwise, it can be incorporated into clinical practice.

5.3 Manual Therapy to Increase Range

The biomechanical effects associated with mobilisation techniques were reported to be transient and very difficult to assess because of variations in force applied by clinicians, variable identification of the area to be treated and variations in chosen technique (Bialosky, Bishop, Price, Robinson, & George, 2009). In addition to the biomechanical effect from the mechanical stimulus, it is suggested that the mechanical force from mobilisation techniques results in a cascade of neurophysiological responses from the peripheral and central nervous system, which are responsible for the clinical outcome, and should be considered in future mechanistic studies (Bialosky et al., 2009).

Manipulative and movement-related therapies (mobilisations) no longer adhere to well-established formulas and instead rely on clinical reasoning for the selection and application of techniques (Banks & Hengeveld, 2014). A literature review was conducted to identify if manual physiotherapy techniques have been used on patients experiencing SSI symptoms and the effectiveness of these techniques, to develop the methodology for the RCT.

5.4 Literature Review

5.4.1 Aim

To identify manual physiotherapy treatment protocols for SSI symptoms including (1) the frequency and total number of treatments performed, (2) the length of each individual

treatment session, (3) outcome measures used, (4) specific techniques performed and (5) the effectiveness of each technique.

5.4.2 Search strategy

An electronic database search was conducted in July 2015 using the following databases: MEDLINE Ovid, CINAHL, Cochrane and Web of Science. All keywords were searched independently and then combined using relevant Boolean terms, including ‘shoulder impingement’, ‘SAIS’, ‘SIS’, ‘SI’, ‘SSI’, ‘shoulder joint’, ‘shoulder pain’, ‘tendinopathy’, ‘rotator cuff’, ‘bursitis’, ‘physical therapy’, ‘physiotherapy’, ‘rehabilitation’, ‘mobilisation’, ‘manual therapy’, ‘massage’, ‘soft tissue therapy’, ‘range of motion’, ‘kinematics’ and ‘outcome assessment’.

An additional search of Google Scholar was conducted using the same search terms. The reference lists of the final articles identified in these searches were hand searched, including previously published systematic reviews (Desjardins-Charbonneau et al., 2015; Dong et al., 2015).

5.4.3 Study selection

Studies meeting the following criteria were included:

- RCTs and quasi-RCTs that evaluated manual physiotherapy techniques in subjects with SSI, compared with other treatment, including placebo or sham treatment
- reported results with at least 2 weeks follow-up
- published or ‘in press’ prior to July 2015
- in English
- studies conducted on males or females aged 18 years and older
- a clear diagnosis of SSI defined by a painful arc and positive impingement tests such as the Hawkins–Kennedy test and Neer’s test or following an acceptable clinical assessment performed by an experienced clinician.

Studies were excluded if they:

- involved surgical or postoperative interventions
- involved other shoulder conditions (such as calcific tendinitis, partial or full-thickness rotator cuff tears, adhesive capsulitis, osteoarthritis and nonspecific shoulder/neck pain)
- evaluated physiotherapeutic techniques without manual application, such as injections, electrophysical agents, hot/cold therapy and exercises.

The titles were screened, then abstracts assessed to determine if studies met the inclusion criteria. Full text copies were obtained for the selected studies and for those where relevance was not clearly identifiable in the abstract and title. One reviewer (HL) performed the selection process.

5.4.4 Quality assessment

All studies were assessed using the critical appraisal tool PEDro by one assessor. This critical appraisal tool is based on the Delphi list for quality assessment of systematic reviews using randomised clinical trials (Verhagen et al., 1998). PEDro has been shown to be reliable for scoring RCTs pertaining to physiotherapy (Maher, Sherrington, Herbert, Moseley, & Elkins, 2003). It contains eight criteria for assessing internal validity and two criteria for assessing sufficiency of the statistical information displayed. Each criterion is answered as 'yes' or 'no', with 'yes' scoring one point and no scoring zero. The maximum score is 10 points. PEDro scores for each study are included in Table 5.1.

5.4.5 Data extraction

One reviewer (HL) extracted data using a standardised form that documented types of outcome measures, participants and specifics of manual physiotherapy protocols adopted, including frequency of treatments, length of individual treatment sessions and techniques used (see Table 5.1).

5.4.6 Results

The initial searches identified 3872 titles; of these, 753 were identified as duplicates and were removed. Subsequently, 3119 titles and abstracts were screened with 3067 excluded because of not being relevant. Finally, 52 full text articles were retrieved, eight of which satisfied the inclusion and exclusion criteria and were included in this review. Results are displayed in the flow diagram (see Figure 5.1).

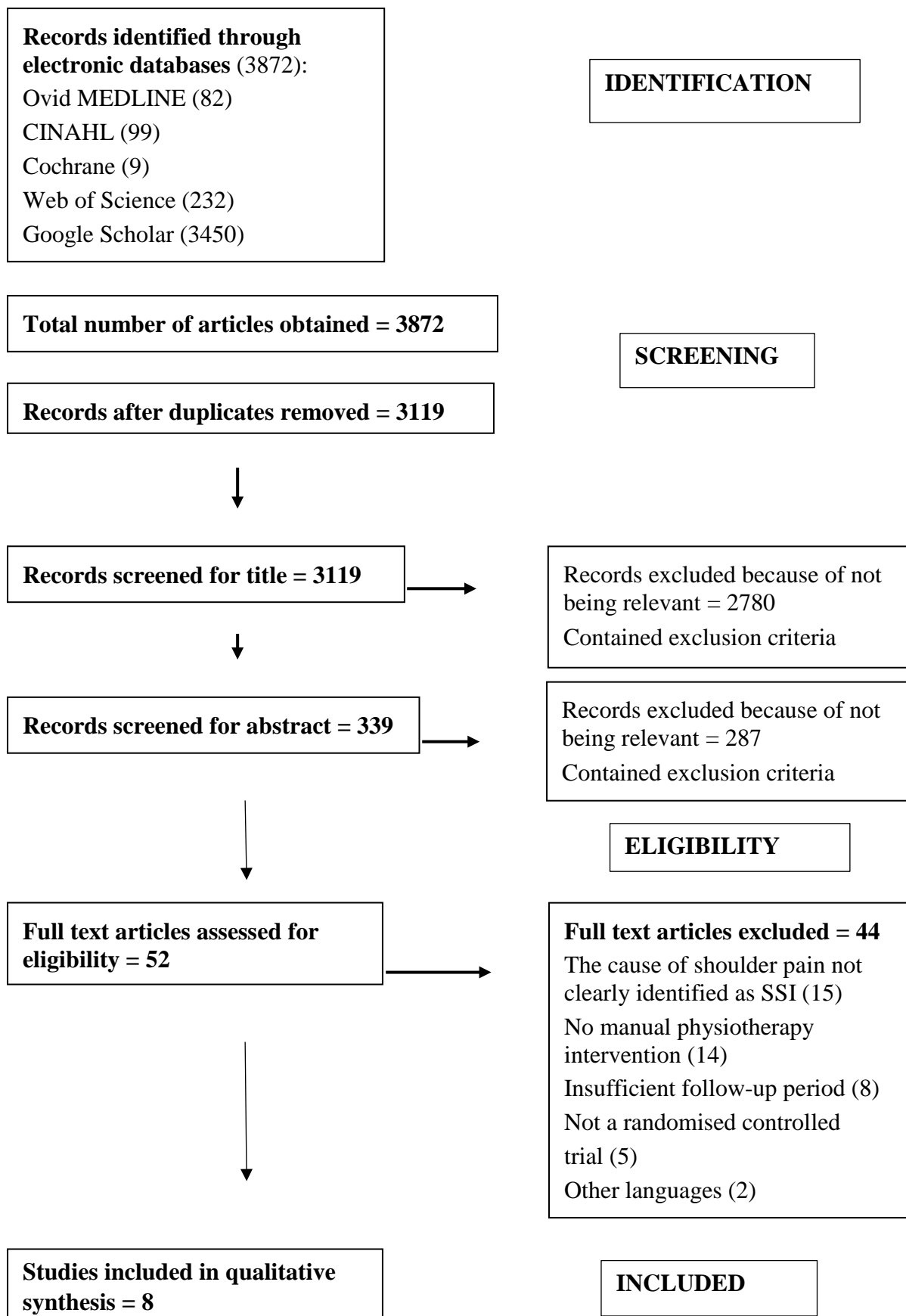


Figure 5.1. PRISMA flow diagram.

Eight RCTs were identified for inclusion in this review, published between 1998 and 2015, with data extracted for each study detailed in Table 5.1. All eight studies scored eight or above on the PEDro scale, revealing them to be internally valid and having interpretable results (Maher et al., 2003). Four RCTs were conducted in the United States (Bang & Deyle, 2000; Conroy & Hayes, 1998; Kachingwe et al., 2008; Cook et al., 2014) and one each from Australia (Bennell et al., 2010), the Netherlands (Kromer et al., 2013), Turkey (Kaya et al., 2014) and Brazil (Carmargo et al., 2015).

Table 5.1

Comparison of Manual Therapy Protocols in Randomised Controlled Trials Involving Subacromial Shoulder Impingement

Study, appraisal score, outcome measures used and result	Participants	Frequency	Manual therapies	Passive stretches
Conroy and Hayes (1998) USA PEDro score 8/10 VAS Subacromial compression AROM shoulder flexion, abduction, IR and ER Three graded reaching tasks All outcomes improved in Group 1 AROM and reaching tasks improved in Group 2	14 subjects: <ul style="list-style-type: none"> • 8 M • 6 F Randomised into 1 of 2 groups: <ul style="list-style-type: none"> • Group 1: Mobilisation • Group 2: Control Conducted at 1 site; 3 assessors and 1 treating therapist	Both groups: 3×/week for 3 weeks = 9 Both groups received soft-tissue mobilisation, hot packs, active ROM, stretching, strengthening and education Session length not reported.	Soft-tissue mobilisation for 10 min including effleurage, friction and kneading—sitting, arm in loose packed position MT used varied for each subject but included: <ul style="list-style-type: none"> • Maitland described techniques—GH posterior glide, GH anterior glide, GH inferior glide, GH long axis traction • 2 to 3 oscillations per second, grade I–IV • applied 2 to 4×, 30 s each • total of 15 min 	Physiologic stretching: Cane-assisted flexion and external rotation Towel-assisted internal rotation Cross-body adduction stretch
Bang and Deyle (2000) USA	52 subjects: <ul style="list-style-type: none"> • 30 M • 22 F 	Both groups: 2×/week for 3 weeks = 6	Directed at relevant movement limitations found in the upper quarter	Both groups: <ul style="list-style-type: none"> • anterior pectoral stretch • posterior cross-body

<p>PEDro score 7/10</p> <p>Functional assessment questionnaire VAS</p> <p>Isometric strength of IR, ER and abduction using a stabilised electronic dynamometer</p>	<p>Randomised into 1 of 2 groups:</p> <ul style="list-style-type: none"> • Group 1: Exercise • Group 2: MT <p>Conducted at 4 sites, with 1 assessor and 1 treating therapist at each site</p>	<p>Each session = 30 min</p>	<p>Primarily aimed at shoulder, may have been at shoulder girdle, cervical and upper thoracic, including CV joints</p> <p>Passive accessory or physiological Maitland grades I–V</p>	<p>adduction stretch</p> <p>Held 30 s, 3×, with 10 s rest. Once daily at home</p> <p>MT group had additional exercises aimed at reinforcing the effect of MT (e.g., cervical or thoracic postural exercises)</p>
<p>All outcomes improved in both groups with a greater decrease in pain and increase in strength in Group 2</p>				
<p>Kachingwe et al. (2008) USA</p> <p>PEDro score 9/10</p> <p>VAS for previous 24 hr period; Neer test and Hawkins–Kennedy test</p> <p>Active pain-free ROM for flexion and scaption</p> <p>SPADI</p>	<p>33 subjects:</p> <ul style="list-style-type: none"> • 17 M • 16 F <p>Randomised into 1 of 4 groups:</p> <ul style="list-style-type: none"> • Group 1: Exercise only • Group 2: Exercise and mobilisation • Group 3: Exercise and MWM • Group 4: Control 	<p>Groups 1 to 3: 1×/week for 6 weeks = 6</p>	<p>MT used varied for each subject but included: GH posterior glide, GH anterior glide, GH inferior glide, GH long axis traction.</p> <p>1 to 2 oscillations per second, grade I–IV</p> <p>Applied 3×, 30 s each with 30 s rest, followed by a cold pack applied for 10–15 min</p>	<p>Posterior capsule stretch = cross-body adduction stretch</p>
<p>All outcomes improved in</p>				
<p>One assessor and one</p>				

all groups.	treating therapist		
<p>Bennell et al. (2010) Australia</p> <p>PEDro score 9/10</p> <p>SPADI NPRS for pain with movement Perceived global rating of change overall SF-36 Isometric strength of IR, ER and abduction using manual muscle tester</p> <p>No immediate difference between groups was found. However, at follow-up, Group 1 outcomes were significantly improved.</p>	<p>120 subjects:</p> <ul style="list-style-type: none"> • 64 M • 56 F <p>Randomised into 1 of 2 groups:</p> <ul style="list-style-type: none"> • Group 1: Physiotherapy • Group 2: Placebo <p>Conducted over 10 sites with a treating therapist at each</p>	<p>Both groups:</p> <p>Individual sessions</p> <p>2×/week for 2 weeks 1×/week for 4 weeks 1×/fortnight over 4 weeks = 10</p> <p>Each session = 30–45 min</p>	<p>Physiotherapy group had standardised treatment:</p> <ul style="list-style-type: none"> • soft-tissue massage for 6 min each in 2 positions: (1) side-lying—posterior joint capsule and shoulder muscles, (2) supine—SS, LHB and pec min • GH Jt mobs, grade IV (50% resist), 30 s, 4×: AP glides and inferior glides at 45° and at 90° ABD • spinal joint mobs, grade IV, 4 min in total for each: (1) unilateral PAs C5–7, both sides; (2) central PAs T 1–8 • scapula and rotator cuff <p>Placebo group: Sham ultrasound + gel</p>
<p>Kromer et al. (2013) Netherlands</p> <p>PEDro score 7/10</p>	<p>90 subjects:</p> <ul style="list-style-type: none"> • 44 M • 46 F <p>Randomised into 1 of 2</p>	<p>Both Groups:</p> <p>2×/week for 5 weeks = 10</p> <p>20–30 min each for intervention group</p>	<p>Control group: Standard exercise protocol using band and dumbbell resistance + stretches</p> <p>Intervention group: Perform the same standard</p> <p>Cross-body adduction stretch</p> <p>Lateral neck stretch in standing (upper trap)</p>

SPADI Global impression of change Generic patient-specific scale Average weekly pain score No differences identified between groups	groups: <ul style="list-style-type: none"> Group 1: Individual Physio Group 2: Control Conducted at 6 sites using 12 therapists	15–20 min for control group Continue home exercises 3×/week for further 7 weeks	exercise protocol as a home programme Between 6 to 10 individual physiotherapy sessions with treatment based on a decision tree. Techniques and frequency not described apart from MT concepts of Maitland, Kaltenborn, Evjenth, and Hamberg and Butler	Thoracic spine extension lying on towel in supine
Cook et al. (2014) USA PEDro score 8/10 QuickDASH NPRS Patient Acceptable Symptom State (PASS) Both groups improved	68 subjects: <ul style="list-style-type: none"> 37 M 31 F Randomised into 1 of 2 groups: <ul style="list-style-type: none"> Group 1: Shoulder treatment + neck mobs Group 2: Shoulder treatment only Conducted at 9 sites using 10 therapists	Discharge, treatment length, frequency of treatment determined by treating therapist	Grade III PA mobs, prone 30 reps, 3 sets Performed to the stiffest or most painful segment If no joint signs present, performed to either C5–6 or C6–7 on same side as symptomatic shoulder Clinical and home treatments and dosage modified for all subjects according to examination, included MT, stretching, isotonic strengthening	
Kaya et al. (2014) Turkey PEDro score 8/10	60 subjects Randomised into 1 of 2 groups:	Both groups: 1×/week for 6 weeks = 6 Each session = 90 min	Combination as detailed below according to individual requirements: <ul style="list-style-type: none"> Superior–inferior gliding, rotations and 	Cross-body adduction stretch Upper thoracic extension

VAS DASH	<ul style="list-style-type: none"> • Group 1: Taping • Group 2: MT 		<ul style="list-style-type: none"> • distractions to the scapula—3 to 5× • GH joint mobs • long axis traction and posterior or inferior glide • soft-tissue massage, cervical, thoracic or elbow mobilisation • friction massage to SS 	<p>stretch</p> <p>Active ROM stretching for GH flexion and ABD</p> <p>3 reps, held 30 s each</p>
Both groups improved, with Group 1 recording more decrease in pain	Conducted at 1 site, using 1 assessor and 2 treating therapists			
Carmargo et al. (2015) Brazil	46 subjects: <ul style="list-style-type: none"> • 24 M • 22 F 	Each session 45 min	MT only applied to affected side	Lateral neck /upper trapezius stretch
PEDro score 9/10	Randomised into 1 of 2 groups:	Progression and specific treatments varied at each session	Grade III and IV GH Jt, scapulothoracic, AC jt, SC jt and cervical spine	Anterior shoulder pec stretch
DASH VAS Pressure pain threshold (PPT) 3D scapula motion	<ul style="list-style-type: none"> • Group 1: Exercises only • Group 2: Exercises + MT 		Implemented according to clinical presentation of each individual	Posterior shoulder cross-body stretch
No difference between groups	Conducted at 1 site, 1 treating therapist			3 reps of 30 s, with 30 s rest between

Note. M = male; F = female; ROM = range of motion; VAS = visual analogue scale; MT = manual therapy; AROM = active range of motion; IR = internal rotation; ER = external rotation; GH = glenohumeral; CV = costovertebral; SPADI = Shoulder Pain and Disability Index; MWM = mobilisation with movement; NPRS = Numeric Pain Rating Scale; SS = supraspinatus; LHB = long head of biceps; pec min = pectoralis minor; Jt = joint; mobs = mobilisations; AP = antero-posterior; SF-36 = 36-item Short Form Health Survey; ABD = abduction; PA = postero-anterior; DASH = Arm Shoulder Hand Disability Score; AC = acromioclavicular; SC = sternoclavicular.

5.4.6.1 Manual therapy protocols

Only one of the eight RCTs used a standardised manual therapy protocol (Bennell et al., 2010). This protocol was based on a review of the literature and on the results of a formal written survey completed by 10 Australian musculoskeletal physiotherapists, considered to be experts in treating shoulder conditions (Bennell et al., 2007). The survey asked participants to indicate which interventions they would use at three stages of a 10-week programme for patients with chronic rotator cuff symptoms. The trial was multimodal in nature with all treating therapists trained to provide both the physiotherapy and placebo interventions (Bennell et al., 2010). In addition to the manual physiotherapy techniques and stretches (detailed in Table 5.1), education and scapula and rotator cuff interventions were included in this standard protocol, but these additional techniques are not relevant to this review. No immediate benefit was shown using this standard treatment protocol for pain and function, compared with the placebo group, but a definite improvement in the treatment group was identified at follow-up, suggesting time was needed for the effect to become evident. The remaining seven RCTs allowed the treating therapist to individualise the treatment protocol according to the clinical presentation (Bang & Deyle, 2000; Carmargo et al., 2015; Conroy & Hayes, 1998; Cook et al., 2014; Kachingwe et al., 2008; Kaya et al., 2014; Kromer et al., 2013). These seven RCTs provided no detail regarding impairments identified during the assessment by the therapist or which specific interventions were then chosen to address this, with only a list of interventions given. The lack of a standardised protocol for these seven RCTs, along with the application of several techniques within a treatment session, makes the efficacy of individual techniques impossible to establish.

All studies reported an improvement in outcome measures in all groups, with the exception of Kromer et al., (2013) who identified no difference between manual therapy and exercise (see Table 5.1).

5.4.6.2 Outcome measures

Subjective outcome measures were used almost exclusively in the included RCTs. They included change in pain, assessed using a visual analogue scale (VAS) or NPRS (Farrar et al., 2001; Jensen et al., 1986); functional scores such as the SPADI; and global impression of change (ten Klooster, Drossaers-Bakker, Taal, & van de Laar, 2006). Objective measurements included isometric strength (Bang & Deyle, 2000; Bennell et al., 2010), active pain-free shoulder range of motion (Kachingwe et al., 2008) and pain pressure thresholds (Carmargo et al., 2015).

5.4.6.3 Length of intervention

Three RCTs did not report treatment length (Conroy & Hayes, 1998; Cook et al., 2014; Kachingwe et al., 2008), while a 90-min session, which included performing the exercise regime, was reported in another (Kaya et al., 2014). Two RCTs reported 20 or 30 min sessions, which included the supervision of exercises for the exercise group or manual therapy for the other group (who then performed their exercises as a home programme; Bang & Deyle, 2000; Kromer et al., 2013). One RCT conducted sessions of 30–45 min, performing education, several physiotherapy techniques and allotting exercises as a home programme (Bennell et al., 2010), and the remaining RCT reported 45-min sessions including the supervision of exercises (Carmargo et al., 2015).

5.4.6.4 Frequency of intervention

The reported frequency of treatment sessions was variable and appeared to be related to the individuality of each session. Treatments were provided over a period of 3–6 weeks, with total treatments equalling 10 (Bennell et al., 2010; Kromer et al., 2013), nine (Conroy & Hayes, 1998) and six (Bang & Deyle, 2000; Kachingwe et al., 2008; Kaya et al., 2014), with two RCTs leaving the total of number of treatments (with this total not being reported) at the discretion of the treating therapist (Carmargo et al., 2015; Cook et al., 2014).

5.4.6.5 Mobilisation techniques

The RCTs published prior to 2009 reported mobilisation prescription such as the speed and length of oscillations, and number of sets performed, consistent with the era of well-established formulas, which have been replaced by clinical reasoning for the selection and application of techniques (Banks & Hengeveld, 2014). Six RCTs reported using grade III or grade IV mobilisations (Bang & Deyle, 2000; Bennell et al., 2010; Carmargo et al., 2015; Conroy & Hayes, 1998; Cook et al., 2014; Kachingwe et al., 2008), with the remaining two not providing this detail (Kromer, de Bie, & Bastiaenen, 2010). All RCTs reported the use of passive anterior, posterior or inferior glenohumeral glides, and two RCTs reported cervical and/or thoracic spine passive mobilisation on the same side as the symptomatic shoulder (Carmargo et al., 2015; Cook et al., 2014).

Soft-tissue massage was reported in three RCTs (Bennell et al., 2010; Conroy & Hayes, 1998; Kaya et al., 2014).

Mobilisation and massage were not performed in isolation; hence, interpretation of the specific effect of these manual physiotherapy techniques was not possible.

5.4.6.6 Stretches

A description of the cross-body adduction stretch performed in standing, to stretch the posterior aspect of the shoulder (McClure et al., 2007), was included in six out of the eight RCTs (Bang & Deyle, 2000; Carmargo et al., 2015; Conroy & Hayes, 1998; Kachingwe et al., 2008; Kaya et al., 2014; Kromer et al., 2010).

A stretch for thoracic extension, lying supine on a rolled towel, was described in two RCTs (Kaya et al., 2014; Kromer et al., 2010). A study that reported prescribing postural exercises to complement passive treatment gave no detail of the exercise or which technique it was prescribed for (Bang & Deyle, 2000).

5.4.6.7 Treating therapists

Six of the eight included RCTs used one treating therapist for each site at which the study was conducted (Bang & Deyle, 2000; Bennell et al., 2010; Carmargo et al., 2015; Conroy & Hayes, 1998; Cook et al., 2014; Kachingwe et al., 2008), with the remaining using two treating therapists per site (Kaya et al., 2014; Kromer et al., 2013).

Half the RCTs used only one treatment site (Carmargo et al., 2015; Conroy & Hayes, 1998; Kachingwe et al., 2008; Kaya et al., 2014), with the remaining using between 4 and 10 locations (Bang & Deyle, 2000; Bennell et al., 2010; Cook et al., 2014; Kromer et al., 2013).

5.4.7 Conclusion

This literature review identified eight RCTs, shown to be internally valid and having interpretable results, scoring eight or above on the PEDro scale. The lack of standardised protocols along with the application of several techniques within a treatment session, makes the efficacy of individual techniques reported impossible to establish. However, components of each protocol were consistent across all the RCTs and can be used to guide the methodology for this RCT.

Treatment lengths of 30–45 min were common, which included more than two manually applied techniques; therefore, a 20-min treatment session can be used for the application of one or two manually applied techniques. Treatment should be maintained for at least 6 weeks, with longer follow-up recommended for effect to be observed. Passive anterior posterior glides of the glenohumeral joint, massage and the prescription of the cross-body adduction posterior shoulder stretch have been consistently applied to patients with SSI. Grade III and grade IV mobilisation are consistently used along with a thoracic extension stretch performed in the supine position by using a rolled towel.

5.5 Treatment Interventions

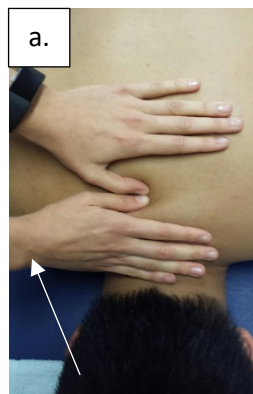
5.5.1 Interventions to increase thoracic range of motion

Treatment cannot be isolated to joints alone, but to increase thoracic range of motion, the clinician is predominantly attempting to affect the joints (McCreesh & O'Connor, 2012). Mobilisations are passive joint movements performed at all times within the control of the patient and within the physiological range of the joint (McCreesh & O'Connor, 2012). Accessory movements are accepted mobilisation techniques for use in the thoracic spine to increase range, including central posterior–anterior (PA), unilateral PA and transverse to the spine (Exelby, 2011). Accessory mobilisation to the ribs (costovertebral) are needed to effect a change in thoracic spine range because of their strong attachment to the thoracic spine (Exelby, 2011) and the mechanical interaction between thoracic motion segments and rib joints (Edmondston et al., 2007). Axial thoracic rotation is coupled with lateral flexion in the mid to upper thoracic levels (Edmondston et al., 2007); hence, a transverse mobilisation technique is considered effective to improve range in this region of the spine. Unloaded positions of the thoracic spine appear to allow greater range of thoracic extension, supporting adoption of a lying position for mobilisation and the accompanied supine passive extension stretch (Edmondston et al., 2011).

The upper thoracic intervention for this current RCT was established from the results of the literature review and this background knowledge. It consisted of upper thoracic transverse mobilisations (T1–T6), grade III, approximately 60 repetitions at each level, performed from the side of the painful shoulder, and costovertebral mobilisations (T1–T6), grade III, approximately 60 repetitions each, on the side of the painful shoulder (Wells & Banks, 2014; see Plate 5.1). The total session time was 20 min (Banks & Hengeveld, 2014). The home exercise of passive thoracic extension was localised to the area of treatment by participants lying supine on a rolled towel positioned longitudinally from T1 along the

thoracic spine for 5 min, twice a day (McClure et al., 2004; Tate et al., 2010; see Plate 5.1).

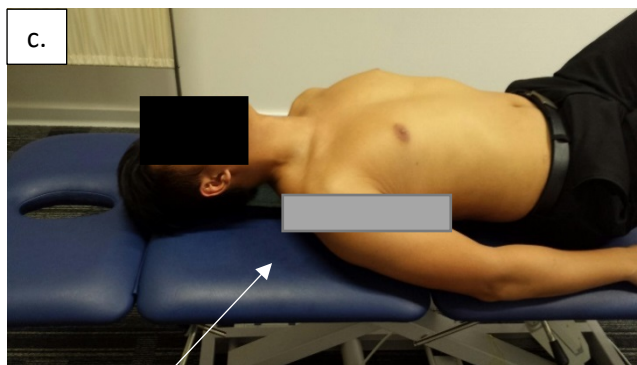
Compliance with the exercise was recorded by participants in an exercise diary.



Painful shoulder



Painful shoulder



Positioning of rolled towel

Plate 5.1. Upper thoracic treatments. Positioning of the patient and therapist is shown for thoracic transverse mobilisations (a), costovertebral mobilisations (b) and the thoracic towel stretch (c).

5.5.2 Interventions to increase posterior shoulder range

Massage (Yang, Chen, Hsieh, & Lin, 2012), and stretching and glenohumeral anteroposterior glide mobilisation (Manske, Meschke, Porter, Smith, & Reiman, 2010), have been shown to be effective in reducing posterior shoulder tightness. In a clinical setting, it is impossible to selectively isolate the tension exercised by the posterior capsule from the tension exercised by the infraspinatus and teres minor muscles. This makes it impossible to exactly identify the source of the joint restriction (Poser & Casonato, 2008), and suggests treatment can be directed at both the muscles and the capsule. A review of manual techniques

used in previous RCTs in patients with SSI (see section 5.4) revealed all studies that reported successful outcomes used an anteroposterior glenohumeral glide and a cross-body adduction posterior shoulder stretch (Bang & Deyle, 2000; Conroy & Hayes, 1998; Kachingwe et al., 2008).

The posterior shoulder intervention for this current RCT was established from the results of the literature review and this background knowledge. It consisted of massage of the posterior shoulder soft tissues, focusing along the lengths of the infraspinatus and teres minor, parallel to the muscle fibres, performed for 15 min with the participant lying on the non-symptomatic side, the painful shoulder supported in 90° elevation (see Plate 5.2). This is the same soft-tissue technique described by Bennell et al. (2007). The participant was then positioned in the supine position, and anteroposterior glenohumeral mobilisations, grade III, were performed to the painful shoulder for approximately 20 repetitions (Hengeveld & Banks, 2005). The total session time of massage and mobilisation was 20 min. The participant was instructed to perform a passive cross-body adduction stretch in standing twice for the count of 20, two times during the day (McClure et al., 2007; see Plate 5.2). Compliance with the exercise was recorded by participants in an exercise diary.



Plate 5.2. Posterior shoulder treatments. Positioning is shown for massage to the posterior shoulder (a), mobilisations (b) and the cross adduction stretch (c).

To enhance the internal validity of the study, all participants were asked to decline any other form of treatment for their shoulder during the course of the study, including additional physiotherapy, chiropractic, acupuncture and massage therapy to the shoulder, neck or upper back. They were instructed to remain on current levels of medication and not to begin any new medications during the course of the study and to continue all activities they usually participated in but not to begin new activities (Portney & Watkins, 2009).

5.5.3 Control intervention

Ultrasound has been reported to have no superior effect, compared with placebo, in the short-term treatment of shoulder pain (Ainsworth et al., 2007; Haik et al., 2016; Nykanen, 1995). However, ultrasound has been, and continues to be, used regularly in a physiotherapy clinical setting, predominantly in soft-tissue lesion management (Watson, 2008), making it suitable as an active control. Participants randomised to this group received ultrasound (1 MHz, 50% pulsed, 0.5 wcm² for 8 min) directed at the subacromial area while lying supine (<http://www.electrotherapy.org>).

5.6 Randomised Controlled Trial Criteria and Outcome Measures

The inclusion of treatment to the upper thoracic spine and posterior shoulder was a result of the outcomes of the initial study, which identified differences in these factors in a group experiencing SSI compared with an asymptomatic group (Land et al., 2017a; see Chapter 4). The same recruitment strategy, and exclusion and inclusion criteria, were therefore applied to this RCT as for the initial study (detailed in Chapter 3). The same outcome measures were adopted: NPRS (see section 3.4.1), SPADI (see section 3.4.2), thoracic range and thoracic angle (calculated from digitised lateral photographs; see section 3.4.4), posterior shoulder range and passive internal glenohumeral rotation (see section 3.4.5).

5.7 Conclusion

The available evidence was gathered and the methodology formulated to conduct an RCT comparing the effect of (1) passive mobilisation to the upper thoracic spine; (2) massage, passive mobilisation and stretching to the posterior shoulder; and (3) an active control intervention (ultrasound) in a homogeneous SSI group.

The following chapter reports the outcomes of this trial and is an original contribution to knowledge.

Chapter 6: Effect of Manual Physiotherapy to the Upper Thoracic Spine Versus the Posterior Shoulder in a Group of Homogeneous Individuals with Extrinsic Subacromial Shoulder Impingement: A Randomised Controlled Trial

6.1 Introduction

This original contribution to knowledge reports the outcome of a randomised controlled trial (following CONSORT guidelines) to compare the effect of (1) passive mobilisation to the upper thoracic spine; (2) massage, passive mobilisation and stretching to the posterior shoulder; and (3) an active control intervention (ultrasound) in a homogeneous extrinsic SSI group.

6.2 Methodology

6.2.1 Study design

This study was a single-centre prospective double-blinded RCT. The duration of intervention was 12 consecutive weeks, with email follow-up 6 months after commencement of intervention. Data were collected at baseline and at 3, 6, 9 and 12 weeks. Participants were asked to reattend for reassessment at these intervals as 3, 6, 9 and 12 weeks are common reattendance timeframes for physiotherapy. The participants were randomised into three parallel groups: (1) an active control group, which received ultrasound for 6 weeks (see section 5.5.3); (2) an intervention group, which received treatment to thoracic levels 1–6 for 6 weeks along with a daily thoracic home exercise performed for the entire 12-week period (see section 5.5.1); and (3) an intervention group, which received treatment to the soft tissues of the posterior shoulder for 6 weeks along with a daily posterior shoulder home stretch performed for the entire 12-week period (see section 5.5.2).

6.2.2 Setting and ethics

Ethical approval was granted by the JCU Human Ethics Committee (approval: H6129). Written informed consent was obtained from each of the eligible participants. All assessments and treatments were performed at the JCU Musculoskeletal Physiotherapy Clinic, Townsville, Australia.

Participants were recruited from the Townsville community via emails and word of mouth. In addition, an advertisement was placed in the local Townsville press on three occasions.

6.2.3 Recruitment

Recruitment commenced in August 2015 and continued through to September 2016. Final follow-up of participants at Week 12 was completed in November 2016, with email follow-up to provide pain rating and functional score (SPADI) completed in March 2017. The trial ended once 60 participants (20 in each group) had completed the 12-week trial period. The trial was registered with the Australian New Zealand Clinical Trials Registry (12615001303538).

6.2.4 Sample size

Sample size calculations were completed for each of the three outcome measures. To detect a between-group difference of 18° (*SD*, 14; Land et al., 2017a; see Chapter 4) for passive range of internal shoulder rotation with 90% power and an alpha value of 0.05, a total sample size of 25 was estimated. To detect a between-group difference of 3 (*SD*, 2.5; Childs et al., 2005) on the NPRS with 90% power and an alpha value of 0.05, a total sample of 30 was estimated. To detect a between-group difference of 30 (*SD*, 20; Heald et al., 1997) in the SPADI total score with 90% power and an alpha value of 0.05, a total sample of 20 was estimated. (Altman, 1991). Therefore, it was estimated that a sample size of 20 per group

would be more than sufficient. Some loss to follow-up was allowed for by increasing the recruitment target from 60 to 69 people.

6.2.5 Inclusion and exclusion

Inclusion and exclusion criteria, to ensure homogeneity of the study population, were the same as a previous study (Land et al., 2017a, 2017c; see section 4.3.3). An assessment with the principal investigator (HL) determined eligibility.

Inclusion criteria included:

- age of 40–60 years
- testing positive to a minimum of three out of five orthopaedic special tests, including Hawkins–Kennedy (Hawkins & Kennedy, 1980) and/or Neer (Neer, 1983) along with two of the following: external rotation resistance test (Michener et al., 2009), tendon palpation (Hanchard et al., 2004), horizontal (cross-body) adduction (Park et al., 2005), painful arc (Kessel & Watson, 1977), drop-arm test (Park et al., 2005) and Speed test (Dalton, 1989; Park et al., 2005); experiencing ‘catching’ or aching pain without appreciable joint stiffness (Hanchard & Handoll, 2008); pain localised to the anterior or antero-lateral-superior shoulder (Lewis et al., 2001); and the insidious onset of symptoms with a possible history of gradual progression over time but without history of trauma (Bigliani & Levine, 1997).

Exclusion criteria included:

- recent (within the past 2 years) or current pregnancy
- previous shoulder surgery or 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 (by observing posture and the forward trunk flexion test [Bunnell, 2005])

- current cervical or thoracic pain or positive outcome from testing described in section 3.4.2
- diagnosed systemic or neurological condition (type 2 diabetes was not screened for)
- radiographic or ultrasound scans revealing osteophytes within the subacromial region, calcification of tendons or large rotator cuff tears.

6.2.6 Randomisation

Randomisation was performed prior to the commencement of the trial by a research assistant using computerised sequence generation from <https://www.randomizer.org>. The research assistant placed the randomised treatment number on a piece of paper, in order, in a separate opaque envelope in a storage box. The treating therapist would select the next envelope in the box upon presentation of each new consenting participant. If a participant ceased to continue the study, their allocation was re-recorded and placed back in an opaque envelope for re-use.

6.2.7 Interventions

The frequency of treatment, manual therapy techniques and prescribed exercises simulate current Australian clinical practice (Bennell et al., 2010) and closely resemble similar international practice (Bang & Deyle, 2000; Kromer et al., 2013). All three treatment groups attended treatment for six consecutive weeks. In the initial 3-week period, each participant attended for treatment twice a week, then once a week for 3 weeks immediately thereafter. After 6 weeks, all manual therapy ceased and participants were advised to continue the same exercise as prescribed at their initial treatment. All participants were assessed at 9 weeks and 12 weeks.

6.2.7.1 Active control group

The full description of this intervention is in section 5.5.3.

6.2.7.2 Modifications to the study design

Modifications were made to the trial design after commencement of the study because of concerns with retaining participants in the active control ultrasound group. Recruitment commenced in August 2015 and continued through to September 2016. By July 2016, the active control ultrasound group had four participants cease participation because of dissatisfaction with the intervention. This trend was a concern with all participants needing to complete the trial by the end of 2016. To enhance completion of the remaining control group participants, the home exercises given to the two treatment groups were prescribed following completion of their ultrasound treatment at 6 weeks.

6.2.7.3 Upper thoracic intervention

The full description of this intervention is in section 5.5.1.

6.2.7.4 Posterior shoulder intervention

The full description of this intervention is in section 5.5.2.

6.2.7.5 Other treatments

All participants were asked to decline any other form of treatment during the course of the study, including additional physiotherapy, chiropractic, acupuncture and massage therapy to the shoulder, neck or upper back. They were instructed to maintain current levels of medication and not to begin any new medication during the course of the study and to continue all usual activities but not to begin new activities.

6.2.7.6 Treating therapists

Two treating registered musculoskeletal physiotherapists provided all interventions. Both physiotherapists were instructed by the primary investigator (HL) and demonstrated each intervention to the satisfaction of the primary investigator, ensuring all participants were provided with the same treatment and exercise regime.

6.2.8 Outcome measures

The reliability of the assessor (HL) for all methods of assessment was established prior to commencement of this study (see section 4.3).

6.2.8.1 Outcome 1 (primary): Thoracic range of motion

Postural angles were calculated from sagittal photographs by using the digitising software UTHSCSA ImageTool (Wilcox et al., 1997). Very high inter-rater reliability was established for this method prior to the study (ICC = 0.997; see section 4.3). Full details of this measurement method are in section 3.4.4.

Upper thoracic resting posture was measured in degrees from the apex of the mid-thoracic curvature to the spinous process of C7 and true vertical (detailed in section 3.4.4).

Active movement of upper thoracic flexion through extension was calculated in degrees as the difference in upper thoracic extension and upper thoracic flexion (detailed in section 3.4.4).

6.2.8.2 Outcome 2 (primary): Passive glenohumeral internal rotation range and posterior shoulder range.

Only a weak association between internal rotation and posterior shoulder range was found in an initial study (Land et al., 2017a; see Chapter 4), with other studies reporting a definite correlation (Myers et al., 2007; Tyler et al., 2000). This further research was expected to assist in establishing if increasing thoracic active flexion/extension range or posterior shoulder range or both results in decreased symptomatology in patients with SSI (Land et al., 2017a).

Passive glenohumeral internal rotation was measured in the supine position by using a plastic goniometer. Full details of this measurement method are described in section 3.4.5. A minimum clinically important difference of 10° for passive glenohumeral internal rotation

was reported (Manske et al., 2010). Very high intra-rater reliability was established for this method prior to the study (ICC = 0.933; see section 4.3).

Posterior shoulder range was measured using the method described by Tyler et al. (1999) performed in side-lying and using a carpenter's square to measure the distance from the medial epicondyle of the elbow to the plinth in centimetres (Tyler et al., 1999). Full details of this measurement method are in section 3.4.5.

6.2.8.3 Outcome 3 (secondary): Pain rating (numerical rating scale)

An 11-point NPRS ranging from 0 (*no pain*) to 10 (*worst imaginable*) was used to measure pain (Farrar et al., 2001; Jensen et al., 1986). A minimum clinically important difference of two has been established for the NPRS (Childs et al., 2005; Farrar et al., 2001).

6.2.8.4 Outcome 4 (secondary): Shoulder Pain and Disability Index

This validated outcome measure was developed to measure pain and disability associated with shoulder impairment (Roach et al., 1991) and was found to be suitable for assessment of SSI syndrome (Dogu et al., 2013). A minimum clinically important difference of between 8 and 13 was established for the SPADI (Roy, MacDermid, & Woodhouse, 2009).

6.2.9 Blinding

Each participant and the treating therapist were unaware of the treatment to be performed until presenting for the initial treatment. The assessor (principal investigator) was blinded to treatment allocation. Participants were instructed by the treating therapist not to discuss their treatment when presenting for assessment. In turn, each participant was instructed by the assessor not to discuss any change in their condition with the treating therapist. The assessor recorded outcome measures on a paper template. A research assistant entered this data into an Excel spreadsheet. The completed spreadsheet was de-identified before being returned to the principal investigator for data analysis.

6.2.10 Statistical analysis

Data were analysed using IBM SPSS Version 22. Data were assessed for normality and all variables were found to be normally distributed. Descriptive statistics (mean, standard deviation and standard error for numerical variables) were calculated for each physical assessment variable. One-way ANOVA tests were performed for numerical variables or chi-square tests for categorical variables to determine whether there were any between-group differences at baseline.

Between-group differences were assessed at baseline and at Week 6 and Week 12 time points only. New variables were computed to represent the differences in each variable from baseline to Week 6, from Week 6 to Week 12 and from baseline to Week 12. After data were checked for normality, it was determined that parametric tests were appropriate for testing between-group differences. However, because the group sizes were small, non-parametric tests were also completed. The results did not differ; therefore, parametric analyses are presented. Between-group differences in each of these new variables were then assessed using one-way ANOVA tests with post hoc Bonferroni adjustment. The modification in study design resulted in the final eight participants randomised into the active control group being prescribed home exercises following completion of their ultrasound treatment at 6 weeks, which continued through to Week 12. These variables were not included in the final analysis.

Only results of participants who remained in the study were analysed (i.e., data were not analysed on 'intention to treat').

6.3 Results

One hundred fifty-two volunteers were assessed for eligibility. Seventy-nine failed to meet the eligibility criteria and four elected not to participate (see Figure 6.1).

Sixty-nine volunteers who consented to participate in the trial were randomly allocated, 23 to the upper thoracic intervention, 22 to the posterior shoulder intervention and 24 to the active control group (see Figure 6.1).

Dropouts occurred in each of the groups, resulting in 20 participants completing the intervention in each group. Baseline characteristics of participants who dropped out did not differ significantly from those of participants who completed the trial (see Table 6.1).

Home exercise compliance was consistent in all groups, with home exercises reportedly performed 60% to 75% of the total time advised.

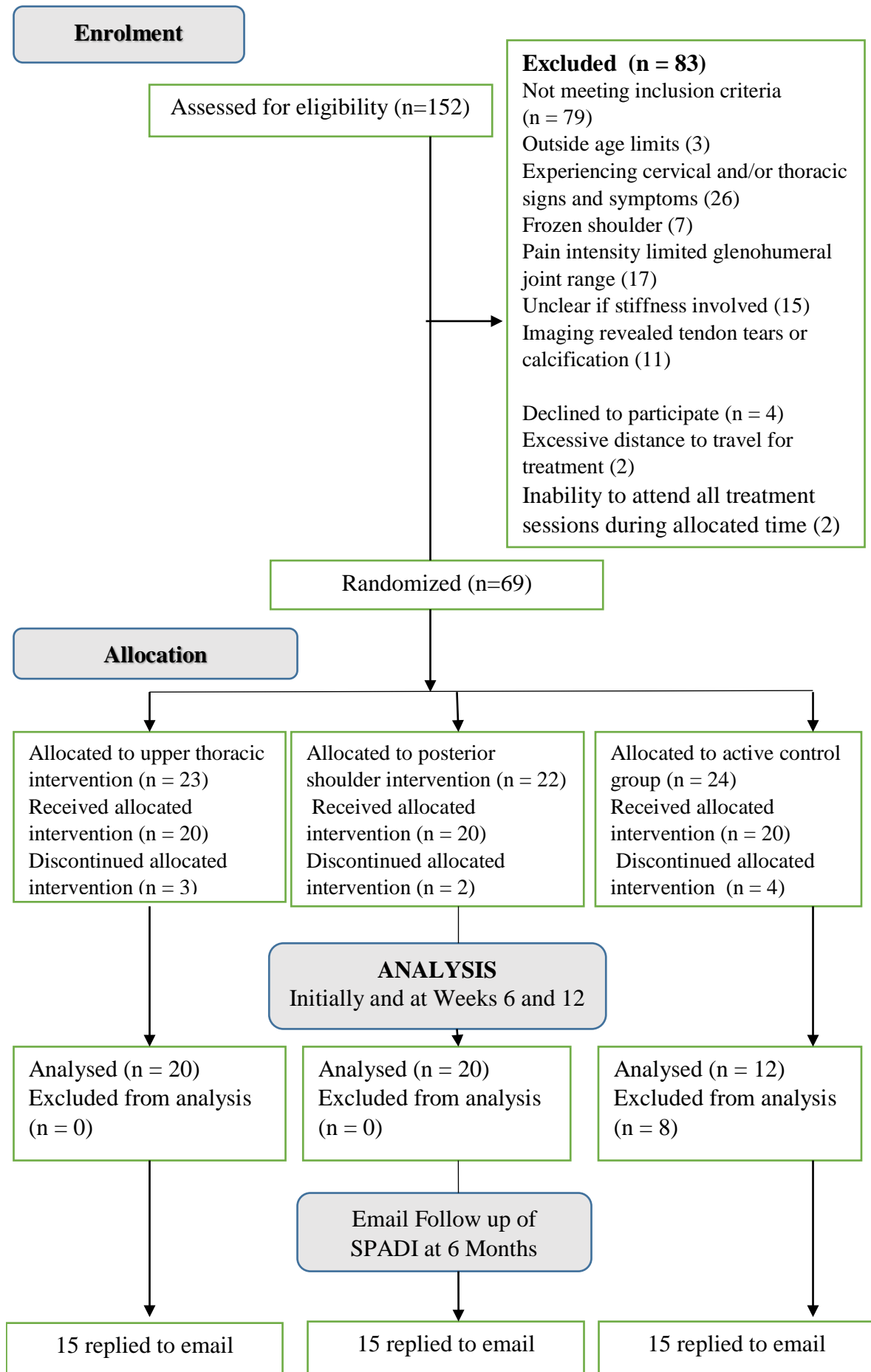


Figure 6.1. Flow diagram of participant recruitment.

No significant differences in baseline group characteristics were identified (see Table 6.1).

Table 6.1

Baseline Participant Characteristics by Group

Treatment group	Age (years) <i>M ± SD</i>	Gender Male:Female	Dominance Right:Left	Duration of symptoms (months) <i>M ± SD</i>	Dominance of injured limb Dominant:Non-Dominant
Upper thoracic intervention	51 ± 4.4	11:9	18:2	8.1 ± 4.0	10:10
Posterior shoulder intervention	51 ± 5.4	12:8	17:3	9.0 ± 4.0	14:6
Active control group (ultrasound)	51 ± 6.0	7:13	18:2	8.3 ± 4.1	7:13
	<i>p</i> = .991	<i>p</i> = .247	<i>p</i> = .851	<i>p</i> = .764	<i>p</i> = .085
Dropouts <i>n</i> = 9	51 ± 6.0	5:4	5:4	9.0 ± 5.5	8:1

No significant differences in baseline outcome measures were identified (see Table 6.2).

Table 6.2

Baseline Outcome Measures by Group

Measurement (number of participants)	Baseline <i>M ± SD (SEM)</i>	<i>p</i> value
NPRS		
Thoracic (20)	6.90 ± 1.8 (0.40)	.73
Shoulder (20)	6.55 ± 1.5 (0.34)	
Ultrasound (20)	6.95 ± 1.9 (0.42)	
SPADI		
Thoracic (20)	41.27 ± 17.3 (3.87)	.53
Shoulder (20)	36.46 ± 11.1 (2.48)	
Ultrasound (20)	41.38 ± 17.9 (4.00)	
Passive internal rotation		
Thoracic (20)	44.3 ± 12.8 (2.86)	.86
Shoulder (20)	44.5 ± 12.7 (2.83)	
Ultrasound (20)	46.3 ± 12.1 (2.71)	
Posterior shoulder		
Thoracic (20)	3.5 ± 6.9 (1.55)	.52
Shoulder (20)	3.7 ± 5.1 (1.14)	
Ultrasound (20)	3.5 ± 6.5 (1.45)	
Thoracic resting		
Thoracic (20)	20.4 ± 4.7 (1.00)	.43
Shoulder (20)	20.8 ± 3.4 (0.75)	
Ultrasound (20)	22.2 ± 5.3 (1.19)	
Active thoracic range		
Thoracic (20)	23.8 ± 11.1 (2.47)	.12
Shoulder (20)	26.1 ± 9.9 (2.22)	
Ultrasound (20)	19.7 ± 8.2 (1.83)	

Note. NPRS = Numerical Pain Rating Scale; SPADI = Shoulder Pain and Disability Index.

Analysis was performed, comparing the change in each outcome measure, in each group for each 6-week assessment period (see Table 6.3 and Figure 6.2). When comparing all three groups, significant improvements in the SPADI scores, passive internal rotation and posterior shoulder range were found between baseline and Week 6 (see Table 6.3). Post hoc analysis identified that passive internal rotation, posterior shoulder range and SPADI scores significantly improved in the group receiving upper thoracic treatment and in the group receiving posterior shoulder treatment, compared with the active control group, with no differences detected between the posterior shoulder treatment and the thoracic treatment groups (see Table 6.4). The mean scores for change in the SPADI score and passive internal rotation range were greater than the pre-defined minimum clinically important differences of these measurements. This indicates that both manual therapy interventions had a positive effect on reducing pain, improving function and increasing posterior shoulder range after 6 weeks in this homogeneous group with external SSI.

Significant improvements in the SPADI score and passive internal rotation were found between baseline and Week 12 (see Table 6.3). Post hoc analysis showed that the SPADI scores significantly improved in the group receiving upper thoracic treatment, compared with the active control group, and that passive internal rotation significantly improved in the groups receiving upper thoracic treatment and posterior shoulder treatment, compared with the active control group (see Table 6.4), with both having a mean score greater than the pre-defined minimum clinically important differences. These improvements were maintained across the 12 weeks, with no further significant improvement found from Weeks 6 to 12. This indicates that the benefit gained from manual therapy to the posterior shoulder for 6 weeks along with continuing the cross-body adduction stretch for a further 6 weeks, maintains an objective increase in posterior shoulder range. Active treatment to the upper thoracic region for 6 weeks, and 6 weeks of continued home stretches, maintained

reduced pain, improved function and an objective increase in passive internal rotation at 12 weeks in this homogeneous SSI group.

Only the SPADI functional outcome scores and posterior shoulder range were significantly improved in each of the three groups from Weeks 6 to 12, but the measurements recorded were not clinically important.

Upper thoracic flexion/extension range and thoracic resting angle revealed no significant differences between groups from baseline to Week 6, from Week 6 to Week 12 or from baseline to Week 12.

The SPADI outcome measure was emailed to all participants 6 months after the completion of treatment. Fifteen participants from each group replied. A significant improvement in SPADI scores was maintained 6 months after intervention had ceased in the thoracic intervention, compared with the active control group ($p = .05$), and posterior shoulder intervention, compared with the active control group ($p = .02$). The change in SPADI scores between Week 12 and 6 months was not significantly different among the three groups, which is consistent with maintaining treatment improvements.

Table 6.3

Identification of Groups with Significant Change in Outcome Values from Baseline to Week 6, from Week 6 to Week 12 and from Baseline to Week 12

Measurement (number of participants)	Baseline to Week 6		Week 6 to Week 12		Baseline to Week 12	
	$M \pm SD$ (SEM)	<i>p</i> value	$M \pm SD$ (SEM)	<i>p</i> value	$M \pm SD$ (SEM)	<i>p</i> value
NPRS						
Thoracic (20)	2.35 ± 2.6 (0.59)		1.25 ± 1.9 (0.42)		3.60 ± 3.2 (0.71)	
Shoulder (20)	1.95 ± 2.6 (0.58)		1.70 ± 2.0 (0.45)		3.65 ± 2.5 (0.56)	
Ultrasound to Week 6 (20)	0.65 ± 2.4 (0.54)	.10	0.75 ± 2.2 (0.64)	.52	.83 ± 2.6 (0.74)	.04*
Ultrasound Week 7 to 12 (12)						
SPADI						
Thoracic (20)	21.04 ± 19.5 (4.36)		11.08 ± 10.6 (2.38)		32.12 ± 17.4 (3.88)	
Shoulder (20)	18.31 ± 11.1 (2.45)	.005**	7.42 ± 8.5 (1.89)	.005**	25.73 ± 9.4 (2.10)	.007**
Ultrasound to Week 6 (20)	5.18 ± 15.8 (3.53)		3.43 ± 17.2 (5.0)		9.25 ± 20.2 (5.84)	
Ultrasound Week 7 to 12 (12)						
Passive IR						
Thoracic (20)	17.0 ± 14.6 (3.27)		2.8 ± 13.2 (3.0)		19.8 ± 18.5 (4.13)	
Shoulder (20)	14.0 ± 10.3 (2.31)	≤.001***	4.3 ± 6.7 (1.51)	.24	18.3 ± 9.5 (2.12)	.01*
Ultrasound to Week 6 (20)	2.0 ± 8.3 (1.86)		-1.25 ± 10.5 (3.02)		2.5 ± 14.9 (4.29)	
Ultrasound Week 7 to 12						

(12)

**Posterior
shoulder**

Thoracic (20)	7.3 ± 5.4 (1.20)		0.80 ± 3.6 (0.80)		8.1 ± 5.9 (1.32)	
Shoulder (20)	6.8 ± 4.9 (1.11)		0.6 ± 3.6 (0.80)		7.4 ± 4.6 (1.02)	
Ultrasound to Week 6 (20)	2.2 ± 4.2 (0.94)	.002**	-0.4 ± 3.6 (0.10)	.05*	3.3 ± 3.6 (1.04)	.07

Ultrasound
Week 7 to 12
(12)

**Thoracic
resting**

Thoracic (20)	- .65 ± 3.4 (0.74)		.45 ± 3.6 (0.80)		-.20 ± 3.4 (0.77)	
Shoulder (20)	.75 ± 3.3 (0.74)		-.55 ± 2.3 (0.52)		.20 ± 2.6 (0.58)	
Ultrasound to Week 6 (20)	.90 ± 4.8 (1.06)	.38	-1.50 ± 3.2 (0.93)	.31	-.42 ± 3.5 (1.01)	.62

Ultrasound
Week 7 to 12
(12)

**Active thoracic
range**

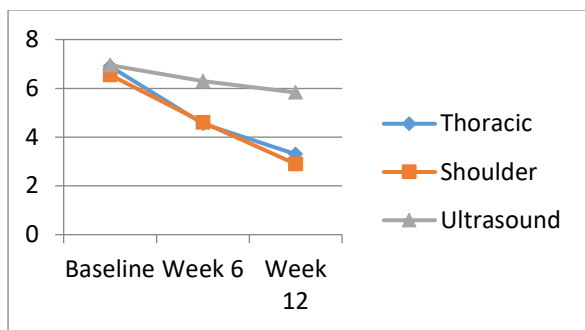
Thoracic (20)	1.0 ± 9.1 (2.04)		.15 ± 9.2 (2.1)		1.15 ± 10 (2.23)	
Shoulder (20)	3.6 ± 6.6 (1.49)		1.95 ± 6.9 (1.55)		5.55 ± 8.3 (1.9)	
Ultrasound to Week 6 (20)	0.2 ± 7.6 (1.69)	0.36	0.83 ± 7.3 (2.12)	.58	0.08 ± 10 (2.9)	.24

Ultrasound
Week 7 to 12
(12)

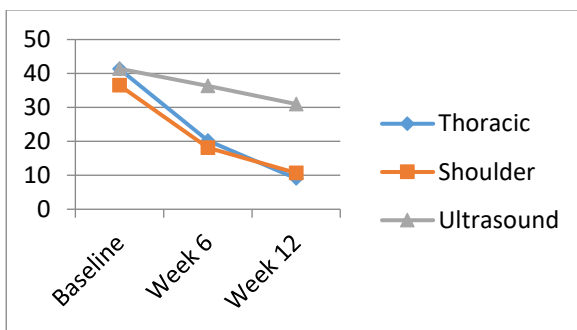
Note. NPRS = Numerical Pain Rating Scale; SPADI = Shoulder Pain and Disability Index; IR = internal rotation.

* $p < .05$; ** $p < .01$; *** $p < .001$.

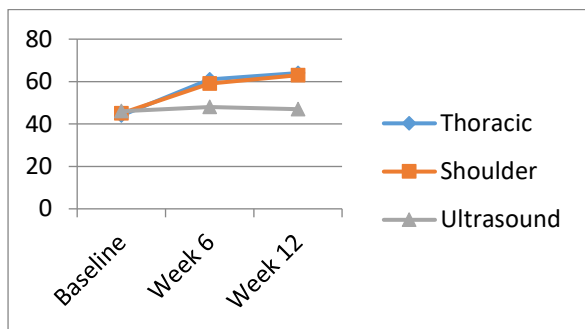
Figure 6.2. Graphical representation of mean scores for each outcome measure at Baseline, Week 6 and Week 12



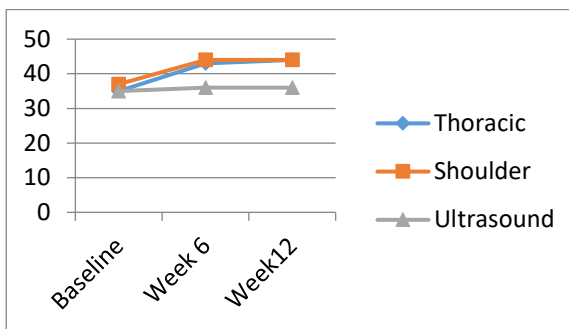
NPRS



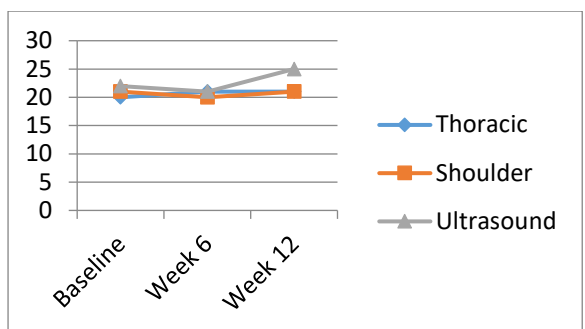
SPADI



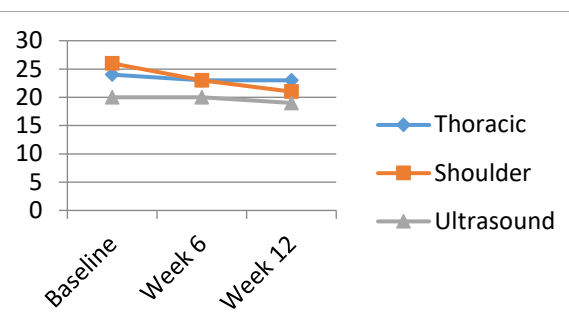
Passive IR



Posterior shoulder



Thoracic Resting



Active Thoracic Range

Table 6.4

Post Hoc Bonferroni Adjustment

Intervention	Weeks 6 to 12		Baseline to Week 6			Baseline to Week 12	
	SPADI	Posterior shoulder	SPADI	Passive IR	Posterior shoulder	SPADI	Passive IR
Upper thoracic Posterior shoulder	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upper thoracic Active control	.88	1.00	.007**	≤.001***	.004**	.006**	.02*
Posterior shoulder Active control	1.00	1.00	.03*	0.005**	.01*	.09	.04*

Note. SPADI = Shoulder Pain and Disability Index; IR = internal rotation.

* $p < .05$; ** $p < .01$; *** $p < .001$.

6.4 Discussion

Previous studies investigating the effect of manual physiotherapy treatment in SSI have chosen to use a range of techniques concurrently, allowing the treating therapist to choose from a group of treatments or choose their own, dependent on the presentation, with no standardised treatment protocol implemented (Bang & Deyle, 2000; Carmargo et al., 2015; Conroy & Hayes, 1998; Cook et al., 2014; Kaya et al., 2014; Kromer et al., 2013). Treatments have included hot packs; stretching of the shoulder or neck; scapular, rotator cuff or postural strengthening; massage; mobilisation to the cervical spine, thoracic spine or shoulder girdle joints; and education (Bang & Deyle, 2000; Carmargo et al., 2015; Conroy & Hayes, 1998; Cook et al., 2014; Kaya et al., 2014; Kromer et al., 2010). This study showed specific targeted treatment can have a positive effect.

Previous studies that investigated exercises versus manual treatment reported manual therapy was superior to exercises in improving pain and function scores along with improvements in isometric strength (Bang & Deyle, 2000) and pain-free range of shoulder flexion (Kachingwe et al., 2008). These reported outcome improvements may be attributed to the individual attention and improvement in mood provided by the attending therapist (Woolf, 2010), or may be attributed to the mechanical stimulus provided through the manual techniques initiating a number of potential neurophysiological effects from the peripheral and central nervous systems (Bialosky et al., 2009). This study provides evidence that clinically meaningful improvements in objective measures of passive internal rotation and posterior shoulder range occur alongside subjective improvements in function with thoracic mobilisation and posterior shoulder treatment in extrinsic SSI.

Studies that previously reported that manual therapy had no superior effect to exercise to improve pain and function scores in subjects with SSI included the same supervised

exercise regime for each group, making the isolated effect of the manual techniques difficult to establish (Carmargo et al., 2015; Kromer et al., 2013).

This study chose to prescribe only one home exercise specific to the maintenance of gains from the intervention provided. In contrast, previous studies have prescribed both rotator cuff and scapular strengthening as well as anterior and posterior shoulder and neck stretching (Carmargo et al., 2015; Kromer et al., 2010), suggesting a targeted exercise achieves a more efficient benefit.

The current study identified a significant improvement in posterior shoulder range irrespective of upper thoracic treatment or posterior shoulder treatment, with neither group showing a greater degree of benefit. It is possible that either thoracic mobilisation or posterior shoulder stretching and direct humeral head mobilisation can alter humeral head position and potentially reduce any compressive effect within the subacromial space. It is also possible that the prone position adopted to perform the passive thoracic mobilisations evoked an effect on humeral head position. It is not known if the techniques used directly affected the humeral head position or if the effect was via the muscles that maintain humeral head positioning (Oatis, 2009). However, the outcome of this study supports the hypothesis that biomechanical factors contribute to pain production in extrinsic SSI.

The range of upper thoracic flexion/extension and thoracic resting angle was not found to significantly change in any of the groups during the trial. It may be possible that treatment to the upper thoracic spine does not have a biomechanical effect on the thoracic spine but instead on the posterior shoulder range and that, via this mechanical stimulus, a neurophysiological cascade may produce a positive effect (Bialosky et al., 2009). Small mean differences in upper thoracic flexion/extension range were recorded along with large standard deviations and standard errors, which may suggest the method of measurement used may not

be sufficiently accurate for detecting these ranges but is more likely a reflection of the small sample sizes.

6.5 Limitations

There were some limitations in this study. Difficulty was experienced in retaining participants in the active control group. This led to participants randomised to the active control group from July 2016 being given exercises at 6 weeks. In addition, there was a possible lack of sensitivity of the upper thoracic measurement method to detect small changes in range. Finally, selection bias (specifically volunteer bias), may also affect the generalisability of these findings to the general population. It is unlikely that sample size was a limitation in this study. Reverse power calculations were completed (using passive range of internal shoulder rotation [mean difference, 10°; *SD*, 5°] and the SPADI total score [mean difference, 20; *SD*, 17]). These calculations revealed that there was 90% power to detect the described differences with $\alpha = 0.05$ (Altman, 1991).

6.6 Conclusion

Mobilisation of the upper thoracic spine or massage and mobilisation of posterior shoulder structures combined with a targeted single home exercise, in a homogeneous group with SSI, significantly improved function and passive internal rotation range. The improvements continued to be significant 6 months after cessation of intervention. These findings suggest that manual therapy treatment that addresses these extrinsic contributing factors decreases the signs and symptoms of SSI.

Chapter 7: Conclusion: Implications for Practice and Research

7.1 Aim of Current Research Programme

The Australian Physiotherapy Association (APA) defines physiotherapists as 'highly skilled health professionals who use advanced techniques and evidence-based care, who assess, diagnose, treat and prevent a wide range of health conditions and movement disorders' (APA, 2017). Manual therapy, including mobilisation and massage techniques, is regularly performed by physiotherapists for treatment (APA, 2017). Shoulder pain is one of the most frequently referred conditions to physiotherapy, particularly SSI.

Physiotherapists have had limited high-quality evidence to inform the clinical care of those presenting with SSI. In particular, previous physiotherapy studies used a pragmatic non-standardised treatment approach, included participants of any adult age without considering the implications of age-related degenerative shoulder changes; did not match for variances in the type and intensity of daily activity, gender or limb dominance; and did not provide clear rationale or evidence for the selected treatment and exercise interventions. Rigorous research was needed that included reliable and valid objective assessment techniques and targeted interventions, thereby justifying the use of physiotherapy to provide optimal outcomes.

This programme of research conducted a matched case-control study on a homogeneous group experiencing SSI symptoms, identified significant biomechanical impairments present in the SSI group, and used an RCT to determine effective and appropriate manual therapy physiotherapy interventions that can confidently and immediately be used in clinical practice. To the authors knowledge, these findings are an original contribution to our understanding in this field.

7.2 Limitations of the Current Programme of Research

The limitations specific to each study were detailed in Chapters 4 and 6. The initial matched case-control study comparing biomechanical factors between an SSI group and an asymptomatic group had the significant limitation of only one assessor being available, leading to lack of blinding and potential bias. However, the significant outcomes related to targeted interventions applied to these biomechanical factors appear to justify the outcomes of the study.

A limitation of the RCT was the difficulty in retaining participants in the active control group which led to participants randomised to the active control group from July 2016 being given exercises at 6 weeks. Pre- and post-trial sample size calculations consistently revealed the study had a power of 0.9, with $\alpha = 0.05$, showing a robust outcome.

Objective outcome measures used in both studies have not been extensively investigated to confirm their reliability and validity to determine differences, particularly when small differences are significant, as in thoracic range of motion. This lack of sensitivity may have contributed to significant differences not being identified.

Both studies only included participants aged 40–60 years. Although this is the primary age of SSI, these findings should only be applied to this age group.

7.3 Implications for Practice

A major focus of physiotherapy is the identification of muscular, neuromuscular and joint impairments, with identified impairments targeted in the treatment program (Banks & Hengeveld, 2014). The outcomes of this research provide physiotherapists with targeted interventions linked to such impairments of the thoracic spine and posterior shoulder in patients aged 40–60 years, presenting with signs and symptoms of extrinsic SSI. This study is the first step in developing a sound and effective physiotherapy clinical pathway for shoulder pain, which can be presented to health insurers and other health providers. Further rigorous

research is required on other causes of shoulder pain to continue the development of this clinical pathway.

Physiotherapy clients presenting with extrinsic SSI will be satisfied to learn that physiotherapy treatment in addition to regular performance of one targeted home exercise each day, instead of performing several exercises, achieves effective, efficient and lasting symptom relief.

7.4 Implications for Research

Past research has based treatment protocols on expert, experienced physiotherapists opinions (Bennell et al., 2007, Cook et al., 2014, Carmargo et al., 2015) without confirming the factors targeted in these treatment protocols had been identified as measurable, clinical impairments. This is reflected in current evidence, from RCTs, for the effectiveness of physiotherapy interventions for SSI being hampered by the use of variable treatment protocols within the same study, including the provision of several exercises in addition to performing manual techniques. The methodologies adopted in this programme of research, including: conducting an initial study involving those with the defined musculoskeletal condition matched to an asymptomatic group to identify measurable impairments; and the identification, confirmation and use of objective outcome measures for use with these impairments, should be considered in further research investigating the efficacy of physiotherapy treatment techniques in other defined musculoskeletal conditions. This can assist in substantiating the value of physiotherapy manual techniques in the treatment of other musculoskeletal conditions.

This research identified the limited evidence available confirming the reliability and validity of clinical tests used by physiotherapists to accurately determine if differences exist in those with a defined symptomatic musculoskeletal condition and a matched asymptomatic

population. Further investigation is required to; determine the reliability and validity of physiotherapy clinical assessments and inform improved sensitivity and specificity of assessment techniques to ensure small but significant differences can be identified between those experiencing symptoms and those without. It is uncertain if the biomechanical factors associated with extrinsic SSI identified through this research actually contribute to the development of SSI symptoms or occur as a consequence of SSI symptoms. Enhancing the sensitivity and specificity of assessment techniques may assist in identifying this fact.

Other subgroups of SSI, such as those with intrinsic SSI or those experiencing glenohumeral instability, need to be defined with similar case-control studies conducted to establish objective differences from the asymptomatic population, which may respond to targeted physiotherapy intervention.

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Appendix A

'Clinical Assessment of Factors Associated with Subacromial Shoulder Impingement: A Systematic Review' by Helen Land and Susan Gordon
Physical Therapy Reviews Vol 21:6 pp. 192-206 (2017).

This is the authors accepted manuscript of an article published as the version of record in *Physical Therapy Reviews* 9th January 2017.

<http://www.tandfonline.com/> <http://dx.doi.org/10.1080/10833196.2016.1274355>

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.

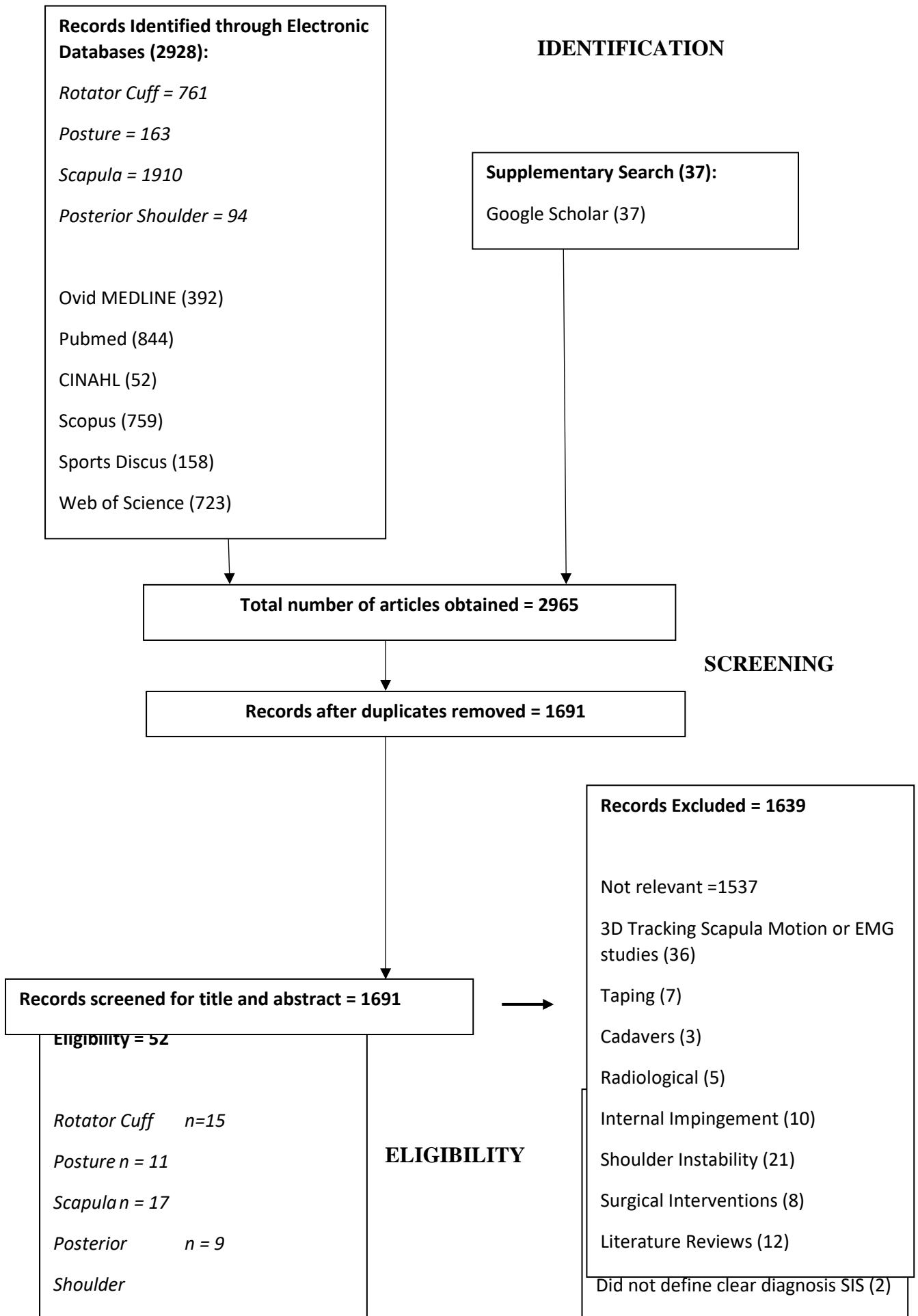
Results

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.

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

Figure 1 PRISMA flow diagram





Hand searching reference lists = 2



**Studies Included in Qualitative
Synthesis = 14**

Rotator Cuff *n = 6*

Posture *n = 2*

Scapula *n = 4*

Posterior *n = 2*

INCLUDED

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

Study	Posterior Shoulder		Posture				Rotator Cuff				Scapula			
	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 D&B Item	3b	3b	3b	3b	4	3b	3b	3b	3b	3b	3b	3b	3b	4
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. LSST using Scoliometer.	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	Total 33 Males Mean age 25.5yrs ± 5.69 Recruited from Phoenix Arizona metropolitan area, no specific demographic detailed.	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

		scoliosis			
			Asym: 18		Position 1: 0.96 Position 2: 0.93 Position 3: 0.84
			Sym: 15 – unilateral or bilateral shoulder. Multiple diagnoses of shoulder pain in group.		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 4 th 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	Total 100 18-35yrs 25 Asym. For intra and inter rater reliability	Tape measure with 0.10cm resolution used to measure pectoralis minor muscle length.	Intra-rater: Both groups – ICC 0.95-0.97 SEM 0.30-0.42 Inter-rater:

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

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 (30⁰ GH flexion and 45⁰ GH abduction) was adopted in all studies except Moraes et al. (2008).^{20, 35, 36, 37, 39} Testing was also done at 90⁰ glenohumeral abduction and 90⁰ elbow flexion in sitting³⁶ 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 uninjured 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	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	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).

			volunteers.	tested. 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° abduction with handgrip 2) 90° GH abduction, 90° elbow flexion, 90° GH ER. Test speeds 60° and 180° 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° sec & 15 reps at 180° sec. Testing was performed from 0° to 90°, with the test initiated with arm in 90° 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° GH abduction & elbow flex Test speeds 60° and	Calibration performed before testing Warm-up: 5 submaximal reps at each test speed Isokinetic test – 5 max reciprocal reps at each speed. Testing was	. 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

		asymptomatic subjects.	10 asymptomatic Mean age 29 ± 5.35yrs (21-36 yrs)	180 ⁰ per sec. 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	performed in an arc 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.	ratios.
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	Biodex (Not identified further) Test position: sitting, plane of scapula 45 ⁰ GH abduction, 30 ⁰	4 trial reps advised not to use max effort at each test speed as warm up. 30 secs rest between	Between group analysis: No significant difference identified in: 1.PT/BW ratios & Total Work for Sym GH of SIS group vs D Asym GH

		weight. 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	GH flex & 30 ⁰ GH fwd flex with handgrip. Test speeds 90 ⁰ and 180 ⁰ per sec. Both GH tested, through maximum arc of painless motion (20 ⁰ - 120 ⁰)	each speed. Isokinetic test – 5 reps at 90 ⁰ sec & 5 reps at 180 ⁰ sec. After 5 minute rest, other shoulder tested.	2. PT and TW for within group analysis of SIS Group 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	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.	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
			60 subjects with SIS Protocol A Age 47.9 ±15.3yrs (22-72) M:F 17:13 Dominance: 25 Right 5 Left	FSP measured as the angle between horizontal line passing through C7 & a line extending from the lateral midpoint of the humeral head to C7	
			Protocol B Age 49.9 ±15.1yrs (19-75) M:F 18:12 Dominance: 27 Right 3 Left	Kyphosis angle measured using inclinometers. Placed tip of inclinometer on T1&2 and T12&L1	
			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		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 90⁰ 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	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-

			daily 30.6±21.2	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

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	Standard Carpenter’s Square in side lying Goniometer	No	Excellent intra Good inter	No	Yes	Yes
Borstad et al. (2007)	Passive Internal Rotation Posterior shoulder range Passive Internal Rotation	Standard Carpenter’s Square Goniometer	No	No	No	No	NA

Table 6

Reliability and Validity

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 reliability⁴⁰ and posterior shoulder range⁴² 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 measurements³⁵ (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 reliable²⁸, 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 assignment 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?

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What is normal isokinetic shoulder strength or strength ratios?

A systematic review

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Abstract

Purpose: To systematically review the literature regarding isokinetic testing to identify values for isokinetic shoulder strength and agonist/antagonist ratios in the general population which may be used as reference values when assessing, planning and implementing shoulder rehabilitation.

Methods: Electronic databases were systematically searched and reference lists of all retrieved papers were hand searched and nine relevant studies were identified. Two independent reviewers assessed methodological quality and extracted data.

Results: Seven studies reported the effect of limb dominance on strength with four reporting no significant difference between the dominant and non-dominant limbs. The studies which compared muscle strength with gender concluded that men were significantly stronger than women at all speeds in all directions. Age was reported to have no significant effect on muscle strength. Four studies agreed that adduction and extension muscle strength were greater than other directions and flexion, abduction, internal rotation and external rotation were the next strongest in that order.

Conclusions: Nine low and moderate quality research papers have attempted to establish isokinetic shoulder strength in a general population. Poor consistency with respect to sample sizes, randomization and selection of testing velocities and positions did not allow direct comparison of the results. Future research involving symptomatic subjects will need to be matched to a group of subjects from the general population of the same age, gender and physical profile with adequate sample sizes representative of

the symptomatic population.

Keywords: isokinetic, shoulder strength, strength ratios

1. Introduction

1.1 Background

Muscle strength is commonly assessed and reassessed for diagnostic purposes and to assess the outcome of therapeutic interventions and rehabilitation. Three methods used for performing muscle strength assessment are manual muscle testing (MMT), hand held dynamometry and isokinetic dynamometry. MMT is widely used for assessment of muscle strength in the clinical setting as it is cheap and easy to perform. A number of MMT protocols are in wide clinical use but all use similar criteria to assign grades based on the ability of the muscles to contract through range and against gravity or manual resistance [1,2]. MMT has limited usefulness as a tool for assessing the response to therapeutic interventions as it is not sufficiently sensitive or reliable to detect subtle weakness or small changes in strength [3,4,5]. Hand held dynamometry is popular for its portability and has been shown to be highly reliable in measuring isometric strength but it is not clear how well inferences can be made from tests of this type to the ability of muscle to generate tension for task performance [6]. It has been shown to be influenced by the testers force generating capacity [5,7]. Isokinetic dynamometers enable measurement of muscle torque production during the performance of a constant-velocity movement. Studies of most isokinetic devices have shown that the measurements obtained from them have good test reliability, particularly after proper patient instruction and familiarization with the equipment and testing procedure [8,9,10,11].

In summary, strength values obtained using isokinetic dynamometry in a clinical setting are considered the most reliable, valid and safe strength measurements used by therapists, when compared with MMT and hand held dynamometry, even when recorded by different therapists and with different subjects.

1.2 Rationale and Review Question

Judgements about the extent of impairment require comparison with some reference value. A common reference used are normative values [7]. Normative values assist clinicians to establish rehabilitation programs following specific surgical procedures, general injury and dysfunction. Establishment of normative strength values allows strength to be assessed relative to a matched population and to assess strength deficits relative to the individuals own strength [12]. Extensive isokinetic testing has been performed on knee flexion and extension with 'normal values' rated as the unaffected limb based on the assumption that the muscle torque of both lower limbs are equal [13]. Discussion continues in the literature as to the value of comparing asymptomatic upper limb isokinetic strength values to symptomatic upper limb strength values. Arm dominance and regular participation in physical activities favouring one limb may result in significant isokinetic strength differences between limbs with bilateral involvement also presenting difficulties in comparison [6,11]. Another reference value used for comparison are unilateral isokinetic strength ratios between the agonist and antagonist muscles used to identify particular weaknesses in a muscle group [11].

This systematic review was undertaken to identify values for isokinetic shoulder strength and agonist/antagonist ratios in the general population which may be used as reference values when assessing, planning and implementing shoulder rehabilitation.

2. Method

Identification and selection of studies

Ovid Medline was searched by the reviewer for studies published between 1950 to week 1 of March 2010. Although this initial date falls outside the commencement of isokinetic research it was the only default parameter available for selection which ensured early research would be captured. Additional searches were performed in Cinahl, The Cochrane library, PEDro, sportDiscus and Google. The search strategy included:

1. Isokinetic
2. Strength testing
3. Shoulder or glenohumeral
4. 2 and 3
5. 1 and 4
6. Dynamometer
7. Cybex
8. Kin-Com or kincom or kinetic communicator
9. 6 or 7 or 8
10. 5 and 9

Reference lists of all retrieved papers were hand searched for relevant studies. This was performed by one reviewer (HL).

2.1 Inclusion Criteria

Any journal article that referred to shoulder isokinetic strength testing was included in the review.

2.2 Exclusion Criteria

Articles with no statistical analysis were excluded. Populations with specific pathologies such as cystic fibrosis, paraplegia or with painful shoulder conditions such as impingement were excluded along with specific studies investigating post-shoulder

surgery. Studies which exclusively reviewed isokinetic strength of glenohumeral internal and external rotators were excluded as these would not provide an indication of overall shoulder strength. Specific populations exclusively assessed such as baseball pitchers were also excluded. Papers that contained no data and book chapters were also excluded from the review. The search was limited to humans and to studies published in English.

2.3 Data Extraction

The results of the electronic database search are detailed in Figure 1

The included studies are summarized in Table 1.

The variables extracted from these studies have been detailed in the results and include:

- Sample characteristics including size, age, gender, health status, activity level, limb dominance and inclusion/exclusion criteria
- Isokinetic instrumentation including the model used and the range of motion and velocities used for testing
- The purpose and findings of each of the studies

3.0 Description of Studies/Results

Nine studies met the inclusion criteria of this search. All studies were stand alone projects. A description of each of the reviewed studies is presented alphabetically in Table 1.

All studies identified were rated as level 4 and level 5 evidence according to the categorization described by the Oxford Centre for Evidence Based Medicine [14].

A published specific rating scale for evaluation of isokinetic studies was not identified. The author designed a quality rating procedure based on modification of a generic evaluation tool developed by the Cochrane Group (Table 2). Full text articles were rated by the two independent reviewers (SG and HL) using the ten question rating procedure. When they felt the question was dealt with extensively in the paper it received a rating of two, when it was briefly mentioned it received a rating of one and when not mentioned or adequate details were not available a rating of zero was given.

Studies were considered of high quality if they received a quality score of 16 or higher, of moderate quality if they scored between 12 and 16, and of low quality if they scored 12 or less. As seen in Table 3, four papers were rated as moderate quality and five as low quality.

There was an 8% disagreement between the reviewers. There was complete agreement on questions five, eight and nine. Differences between raters related to consideration of gravity compensation and the references in the remaining papers being appropriate and comprehensive at the time the paper was written. Consensus was achieved by the reviewers through discussion and the results were tabulated (Table 3).

3.1 Sample Size

Seven of the nine studies reviewed considered strength measurements of the general population yet the age and gender of the participants were not representative of this. Studies included very few female participants and the majority of participants were aged

between 18 and 40 years. Sample sizes averaged 30 to 45 subjects which did not allow effective statistical power to provide convincing or generalisable data.

3.2 Age and Gender

Two of the studies included subjects over 40 years of age. One study included a wide age range (21 to 50 years) which was used in the statistical analysis [15]. This study did not report the exact number of subjects used for calculations involving age. As the sample size was already inadequate the number of older subjects must be assumed to be very small. Another used nine males and nine females over 50 years but did not use age as a separate factor in the statistical analysis [16]. Sex was used in the statistical analysis which implies a sampling error as only nine of the 39 subjects were females.

Two of the studies concluded men were significantly stronger than women for all motions and speeds tested [3,17]. Another reported age had no general effect [15]. One found fairly strong relationships in men but not in women [18].

3.3 Description of Participants

3.3.1 Health Status and Activity Level

Subjects were described as “normal, healthy volunteers” in three studies [12,18,19]. General activity level of the subjects was not controlled for in three of the studies [15,17,20] or not detailed at all in four of the studies. Activity level descriptions varied: ‘12 participants did no upper extremity exercise; seven exercised occasionally and 12 exercised regularly’ [15]. “Moderately fit athletic individuals from a variety of sporting backgrounds” [20]. “None participated in recreational sports regularly” [16]. This variance in regular muscular activity is likely to affect the internal validity of these studies. Strength measurements recorded may have been affected by the regular

participation in upper body exercise rather than just being influenced by dominance, gender or age. Only one study chose to group participants according to their athletic activity: college baseball pitchers, swimmers and non-athletes [21].

3.3.2 Limb Dominance

Some studies did not detail the limb dominance of participants [3,19] others included only right handed participants [16,21] which contributed to sample bias.

A representative sample with 10% left hand dominant participants was achieved in one of the studies [17]. Another included a sufficient number of right and left hand participants but did not detail the number of male and female [15]. Another used 36 males of which 34 were right handed [12]. Using this assumption, they should have had four left hand dominant subjects.

Seven of the studies reported the effect of limb dominance. Four of these reported no significant difference between the dominant and non-dominant limbs [12,15,17,20]. Only one reported a significant difference in peak torque between dominant and non-dominant limbs for extension [21]. However, they identified bilateral strength differences of up to 10% for pitchers and 5% for swimmers and non-athletes. One reported significant bilateral strength differences in shoulder flexion and extension [19] whereas another commented that torque production tended to be greater on the dominant side [3].

3.4 Inclusion and Exclusion Criteria

The current condition of subjects' shoulders was not clearly described in all reviewed studies. Overall, the studies included subjects with full active shoulder range of motion who reported they were currently asymptomatic. However, clear differentiation between those with shoulder instability or laxity was not provided.

Only two studies provided a description of subjects who were excluded from their studies [16,17].

3.5 Purpose of Study

The purpose of the studies was not homogeneous. Three studies aimed to obtain normal values of isokinetic strength of shoulder Flexion/Extension (FI/Ext); Abduction/Adduction (Abd/Add) and Internal Rotation (IR)/External Rotation (ER) [3,15,18]. One aimed to establish normal values of Abd/Add and IR/ER [20]. Another tested shoulder FI and Ext [19]. Both these studies aimed to collate normal values for the populations tested and then develop a method/model for determining the strength of the opposite limb [19,20].

3.6 Range of Motion Tested

The total range of motion (ROM) through which the limb was tested was not consistent between studies. Two studies have not detailed the range through which testing was conducted [3,19]. Ranges used for testing varied from 120 degrees [16,18], 180 degrees [15,20], 165 degrees [21] and 135 degrees [12].

3.7 Positions for Testing and Equipment Used

Three different types of isokinetic dynamometer were used in the studies. Six of the studies used Cybex II with the upper limb exercise table. This machine is defined as a passive machine as it offers resistance exclusively to concentric muscle work [[8], p240]. It requires testing of shoulder IR and ER to be performed in supine and Abd in the reclined seated position. One study used the Kin-Com [18] which measures concentric and eccentric muscle activity in a sitting position. The third machine used was the Lido [16] which measured concentric isokinetic and isometric muscle force. Abd was tested in sitting and ER in supine.

The studies using a seated test position have used the scapula plane as a test position. ([18], for IR/ER, [3],for Abd/Add, [16], for Abd, [17], for modified Abd/Add). The test position has been standardised in each investigation however there is wide variation between studies. This prevents meaningful comparison between their outcomes.

Reliability and validity for the Cybex II and the Kin-Com have been established. Face validity can be assumed for both these devices assuming they are regularly maintained and gravity compensation has been applied when testing. However, only three of the studies reviewed reported using gravity compensation [12,18,19].

3.8 Velocity

No apparent consistency was used when choosing velocities. As can be seen in Table 3, 60°/s was used in all but one of the studies where the velocity was detailed. The remaining velocities varied between 90°/s, 120°/s, 180°/s, 210°/s, 240°/s and 300°/s. One study [20] chose to do testing at only 60°/s, another only at 48°/s [12] with all other studies using two or more velocities.

3.9 Findings

Four of the studies reported on the descending order of muscle strength according to the direction of movement as FI, Abd, IR followed by ER [12,15,18]. Ext and Add were included in some of the studies in which the order of strength varied [3,15,18]. This inconsistency may be due to the variation in factors discussed previously.

Three of the studies reported their purpose was to collect normal isokinetic values, thereby creating a normal strength database which may become a reference [3,15,20]. Reviewing the strength results obtained showed wide variance. However a comparison could be made with three studies which tested younger males at a velocity of 60°/s through shoulder FI and Ext [3,18,19]. On reviewing these results normal concentric

shoulder FI peak torque in this group is about 50Nm and Ext 85Nm on the dominant side. (FI results were 47.5, SD 7.9; 50, SD 12; 61.2, SD 13.3 and Ext results were 66.7, SD 12.9; 87 SD 18; 84.9, SD 20.5).

Comparison was made with four studies which tested young males and females at a velocity of 60°/s through shoulder Abd and Add [3,17,18,20]. Normal concentric shoulder Abd peak torque on the dominant side in this group for males is about 45Nm and Add 65Nm. (Abd results were 39,SD19; 50,SD14; 39,SD9; 50.5,SD13 and Add results were 63,SD14; 86, SD19; 80,SD 16; 72.9, SD19.6). Normal concentric shoulder Abd peak torque on the dominant side in this group for females is about 23Nm and adduction 38Nm. (Abduction results were 19,SD4; 23,SD5; 20,SD4; 28.4,SD4.6 and Add results were 32,SD7; 46,SD 9; 39,SD6; 32.4, SD6.9).

Gravity correction was not applied in each of these studies which affects the comparison of this data.

4. Discussion

The limited quality of research available regarding isokinetic shoulder strength and agonist/antagonist ratio values in the general population must be addressed before appropriate goals for shoulder rehabilitation can be established. Many of the shortcomings of previous research such as ensuring adequate sample sizes, representative of the general population and testing at functional velocities can easily be addressed in future research.

Standardization of the unit of strength used for reporting muscle strength is required. Some studies report peak torque and others the average peak torque. When considering comparisons between healthy subjects and those with a painful condition however,

bilateral comparison of the peak torque has been shown to be the most appropriate outcome parameter [22].

It may be argued an individual's body mass and body composition vary making comparison within the general population of the absolute maximal muscular performance or peak torque impractical [17]. To compare muscular performance between differing individuals of different body mass and composition, a relative peak torque can be calculated by dividing the peak torque by the individual's lean body mass. Three studies took skinfold measurements and weighed the subjects enabling them to use relative peak torque for comparison [3,15,17]. Other studies reported either peak torque or the average peak torque. Comparing data from these studies is difficult with this variation in reporting.

The joint position in which strength is measured alters the muscle strength values by altering both the stretch and moment arm of a muscle [12]. Computer modeling has identified that shoulder muscle function varies as the humeral position changes [23]. Further, significant differences in lines of action and stabilizing capacities when measuring the lines of action of 18 major muscles and muscle sub-regions crossing the glenohumeral joint in cadaver specimens mounted on a dynamic testing apparatus have been reported [24]. Hence, variations in the normal muscle strength values can be partly attributed to variations in joint position during testing.

The literature describes two positions for shoulder rotation isokinetic assessment, the frontal plane and the scapula plane. Those who favour the plane of the scapula theorize the joint capsule is relaxed or loose packed in this position. The loose packed position presumably allows normal unrestricted joint gliding and rolling or arthrokinematic motion during shoulder rotation [25]. Other proposed advantages for testing with the humerus in the plane of the scapula include optimal length-tension relationships of the humeral

abductors and rotators, a relaxed inferior capsule, maximum conformity between the humeral head and the glenoid, and more comfort during testing [[16], p1320]. The opposing view to this is that “although there may be issues of stability and comfort that are optimized by measuring strength of the shoulder in the plane of the scapula, there is no support at the present time for the notion that this position enhances strength complexities affecting muscle performance.” [26]. It could be argued that functionally both FI/ Ext and Abd/ Add are performed outside the scapula plane. However, any investigation which seeks to establish normal strength values must standardize the test position.

Considering these findings, limited comparisons in strength of the same muscle group can be made when the testing position is not identical. However, three studies have attempted to directly compare their results despite significant variation in the test positions used. Ivey et al tested in a supine testing position, through 180 degrees, with IR/ER tested at 90 degrees of Abd [15]. Cahalan et al used a seated testing position with FI/Ext in the sagittal plane, Abd/Add in the plane of the scapula and IR/ER in the transverse plane but only at 15 degrees Abd [3]. Shklar and Dvir tested in sitting but IR/ER was tested in the scapular plane [18]. The effects of gravity differ between supine lying and sitting. When relating results to function, sitting provides a more functional test position than supine lying.

Comparison of isokinetic strength data measured on different isokinetic dynamometers is not recommended. Significant differences have been obtained for testing measurements of the same variable with the same subjects using different devices [27,28].

The need to include gravity correction in dynamometric measurements continues to be argued in the literature. It has been shown that applying the gravitational procedure when testing shoulder IR and ER strength has a significant influence. When not corrected the IR strength is significantly lower and ER significantly higher [29]. When testing trunk isokinetics significant error was found when the gravity correction procedure was applied due to the inability of the subjects to completely relax [30]. The torque registered by the dynamometer is not actual muscular torque but the resultant of muscular and gravitational forces. The influence of gravity varies throughout the range of testing being performed. This potential for error suggests direct comparisons should only be made between values obtained using the same testing procedure.

Contraction velocity and level of fibre recruitment alter measured muscle strength [26]. Hence using two or more velocities with at least one being slow and the other fast, would assist in establishing overall strength performance. No standardization of velocity between the studies is evident. No reasoning is provided to support the choice of certain velocities. It has been reported that peak torques decrease as testing velocity increases from 60°/s through 180°/s to 300°/s [31]. When muscles contract at a higher velocity they do not have the time to develop maximal tension. At faster velocities, a greater range of movement is needed to give the limb time to catch up to the speed of the dynamometer [[8], p244]. It has been suggested velocities above 180 °/s are not to be considered isokinetic due to the range of motion needed to obtain an isokinetic movement. At 300°/s a range of 60° is needed [6]. In summary, differing velocities and differing positions will result in different measures of isokinetic strength. Comparison between research findings should only be made when assessed in the same position and at the same velocity. Currently there are no reports which have identified the velocity of shoulder motion for normal activities of daily living. The velocity of testing should be matched to

the velocity of functional activities so that the strength measurements are applicable to functional rehabilitation outcomes.

During isokinetic concentric shoulder elevation in the coronal and sagittal planes it has been reported that the centre of rotation of the glenohumeral joint was displaced 8cm vertically relative to the centre of rotation of the dynamometer's actuator arm [32]. The effect of isokinetic velocity on this displacement was not significant. The authors attributed this effect to normal kinematics of shoulder elevation that requires synchronous function of both the scapulothoracic and glenohumeral joints. Therefore, when testing isokinetic strength standardization of both scapula and glenohumeral joint position must be ensured.

The studies reviewed primarily investigated strength measurements in participants under the age of 40 years, with two of the studies including participants up to 50 years. It is unknown whether this was due to participant availability or to exclusion due to current or past history or symptoms. The presence of rotator cuff degeneration and tears are known to be more prevalent in the older population and may alter strength measurements. A recent study revealed a high prevalence of rotator cuff tears in elderly asymptomatic individuals using ultrasonography [33]. They concluded studies establishing normative values for isometric shoulder strength may have been skewed by the presence of asymptomatic rotator cuff tears in elderly subgroups. The same should be considered when undertaking isokinetic testing. However, a large number of older people present for rehabilitation with shoulder dysfunction and establishing data for strength in all age groups is needed to assist in the assessment and rehabilitation of shoulder dysfunction.

Since the completion of this systematic review, a large study with 438 participants has recently been published producing isokinetic normative values for the ankle, knee, shoulder and forearm in a subset of the normal population group. The specific cohort included fit South African males aged between 16 to 20 yrs (average 19yrs) who were applying to become pilots in the airforce. Testing of the non-dominant side was performed on a Cybex, concentrically at 60°/sec without gravity correction. Shoulder tests, performed in supine consisted of flexion, extension, horizontal abduction and adduction and internal and external rotation. The shoulder results varied when compared to previous studies most likely due to the variability in sample size, population and testing procedures used. The data generated from this study may be useful for clinical evaluations within this group [29].

5. Summary

This systematic review identified nine low and moderate quality research papers which have attempted to establish isokinetic shoulder strength in the general population. Poor consistency with respect to selection of testing velocities and positions did not allow direct comparison of the results.

Future research involving symptomatic subjects will need to be matched to a group of subjects from the general population of the same age, gender and physical profile with adequate sample sizes representative of the symptomatic population. The velocities tested should be based on functional activities and in functional positions, with standardized glenohumeral and scapulothoracic positions.

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TABLE 1

Study	Subjects	Limb Dominance and Incl/Excl Criteria	Brand of Isokinetic Dynamometer	Test Position	Test Protocol	Statistics Used	Results
Cahalan et al. (1991) [3]	50 healthy, adult volunteers 21 - 40 yrs 26 men and 24 women	Not detailed Subjects had no history of any upper extremity symptoms and active shoulder motion was normal.	Cybex II Used splint to maintain elbow in 90 deg	Fl/ext in saggital plane Abd/add in plane of scapula IR/ER in transverse plane at 15 deg abd Warmup using machine only. Well stabilised	Test side randomised. Tested sequentially No gravity correction Velocities: 60; 180 and 300 deg/sec Concentric Used skinfold calipers	Peak torque means and SD were calculated for each test. Paired t-test :to determine differences in strength as a factor of dominance. Two sample t-test: to test significance related to gender.	Mean peak torque values generally decreased as speed increased. Men significantly stronger than women for all motions & speeds tested. Shoulder extension torque was greatest followed by adduction, flexion, IR, abduction and ER. Torque production tended to be greater on the dominant side.
Chi-hung So et al (1995) [19]	30 normal, healthy volunteers Mean age 21 yrs +- 2.3yrs All male	Dominance not detailed Subjects had no shoulder pain or injury at the time of the study.	Cybex II with U.B.X.T. (upper body exercise and testing table).	Supine Shoulder Fl/Ext Warmup on machine only at 60 deg/sec. Well stabilised	The two muscle groups were randomised. Gravity correction applied. Velocities: 60 and 240deg/sec Concentric	Paired t-tests: to test for bilateral differences set at two tailed($p < 0.01$). Correlation used to determine the linear relationship between dominant and non-dom for the same measurement.	Significant bilateral differences. Concluded "it would be inappropriate to use uninjured limb for comparison"

Connelly Maddux et al (1989) [17]	Different subjects for IR/ER and Mod Abd/Add Max. 40 subjects 21 males 34yrs±10yrs 19 females 26yrs± 6 yrs 79% Males 47% Fem exercised regularly	16 right handed males 17 right handed females No history of shoulder pain/ injury at the time of testing. 10 subjects reported injury > 12 months previous. 3 Excl listed: 2 females insuff torque & 1 male discomfort	Cybox II isokinetic with U.B.X.T. (upper body exercise and testing table).	IR/ER supine with shoulder at 90 deg abd through range of 180 deg. Modified Abd/Add seated reclined through range of 90 deg. No warmup described	Not reported if gravity adjusted or randomised. Velocities: 60 and 180deg/sec Used skinfold callipers	Means and SD: determined for peak torques & normalised for weight/lean body mass. Paired t-tests(p<0.05) : for differences between dom and non-dom. Independent t-test (p<0.05): for differences between males and females & when normalised for body weight the peak torque between sexes for dom & non-dom. Pearson product correlation coefficient : for the angle of peak torque between dom & non-dom	No significant difference in peak torques between dom & non-dom. A significant difference was found between sexes for peak torque, total work and power. No difference when comparing agonist/antagonist peak torque and work values. Large SD's.
Ivey et al(1985) [15]	31 volunteers 21 to 50 yrs Av. 27yrs 18 males 13 females 12= no upper limb exercise 12= regular exercise 7 = occ. exer	24 subjects were right dominant Excluded if pregnant; had shoulder complaints; or previous injury or surgery.	Cybox II with U.B.X.T. (upper body exercise and testing table).	Supine. Abd/Add FI/Ext IR/ER at 90 deg abd Through range of 180 deg Warmup	Not detailed if randomised or gravity compensated for. Suggest unlikely. Velocities: 60 and 180deg/sec Concentric Used skinfold calipers	Specific tests used not detailed. Described that the average and SD for the group as a whole and then the sub-groups were analysed. Also analysed for correlation with variables and variance.	Descending order of muscle strength for both genders was: Add, Ext, FI, Abd, IR. ER Ratios: IR>ER (3:2) Add>abd(2:1) Ext>FI(5:4) Age and dominance had no general effect

Kuhlman et al (1992)	39 subjects in 3 group	All right handed.	Lido 2.0	ER= supine with shoulder in scapula plane	Not detailed if randomised or gravity compensation used.	Average peak torque produced by each subject was used as the value of isokinetic peak torque. Average values were used for work angle at which peak torque was produced.	All subjects tolerated testing in the plane of the scapula without discomfort.. Isokinetic peak torque was greater at 90 deg/sec.
[16]	1. 19-30 yrs (av. 24yrs) males = 21 subjects. All participated regularly in athletics	No history of major trouble with the shoulder. No asymptomatic function of the shoulder and no previous injury or treatment to the upper extremity or neck		Abd= seated, in scapula plane	Velocities: 90 and 120 deg/sec		Repeat testing demonstrated high reliability at angles within range of production of peak torque.
	2. 51-65 yrs (av. 58 yrs) males = 9 subjects	2 were excluded due to a history of problems with shoulder.		Range: 120 deg		2 way ANOVA with each test group (by age and sex) and mode of testing at each speed	
	3. 50-65 yrs (av. 56 yrs) females = 9 subjects			Grasped handle			
				Warmup on machine only			
				Well stabilised			
Otis et al (1990)	"Normal, healthy volunteers"	34 right handed	Cybox II modified with strain gauge torque cell	Shoulder flexion and IR/ER tested in supine.	Gravity adjusted. Order of testing each function, sequence of isometric, isokinetic within each function were randomised.	Means and SD: for every combination of side, speed and joint angle. Students paired t-tests: for differences at specific angles and between dom & non-dominant.	Descending order of muscle strength: FI, Abd, IR,ER.
[12]	21 to 35 yrs (av. 25.8yrs ±3.4yrs)		with U.B.X.T. (upper body exercise and testing table).	Shoulder abduction sitting reclined.			Isokinetic values: not significantly different with respect to dominance
	36 males			For IR/ER in supine shoulder at 90 deg abd	Velocity: 48 deg/sec		
				Range: 135deg	Concentric		
				Grasped handle			
				Warmup on machine			
				Well stabilised			
Perrin et al (1987)	45 subjects	All right handed	Cybox II	Supine. Shoulder at 90 degrees for IR/ER and	No gravity correction for shoulder	12 2 way ANOVA computed for measures at both 60 and	No significant difference in peak torque found between right and left
	18 to 27 yrs	Subjects were	with U.B.X.T.				

[21]	(Av. 19yrs) All males. 15 intercollegiate baseball pitches 15 intercollegiate swimmers 15 non-athletic college students	medically screened for previous injury to knee or shoulder.	(upper body exercise and testing table). Warmup	from 0 – 165 for ext/fl. Also tested the knee	assessment. Velocities: 60 and 180 deg/sec. Concentric Order of muscle groups tested randomised. Order of side to be tested was restricted randomised.	180deg/sec. Peak torque identified at both speeds.	sides for shoulder IR/ER and FI. Right>left ($p<0.05$) for shoulder ext at both speeds. Bilateral differences approached 10% for pitchers and within 5% for swimmers and non-athletes
Reid et al (1989) [20]	40 subjects described as 'moderately fit athletic individuals with a variety of sporting backgrounds' 15-36yrs (Av. 25yrs) = 20 males 19-34yrs (Av. 27yrs) = 20 females	16 males right handed. All females right handed Subjects had no shoulder pain or dislocations	Cybox II with U.B.X.T. (upper body exercise and testing table).	Abd/Add in reclined sitting through 0 to 180 deg. IR/ER in supine at 90 deg IR/ER in standing Range: 180deg No warmup described Stabilised in supine NOT standing	No gravity correction reported. Velocity: 60 deg/sec No randomisation reported. Concentric	Comparison of selected means using independent t-test for comparison between sexes and dependent t-test for comparisons within a sex. Non-directional 5% significance level	Ratios: Add>abd IR > ER Men twice as strong as women in this population. No differences in means for dom & non-dom within a sex. No difference in peak torque of IR/ER in standing and lying

Shklar & Dvir (1995)	30 Healthy Volunteers	Limb Dominance Not detailed	Kin-Com II	Seated. Abd/Add – elbow extension and forearm pronated. Fl/Ext –forearm in mid-position. IR/ER – scapular plane, supported at elbow Range: 120 deg Warmup Well stabilised	Order of testing randomised. Within same muscle group, order of velocity randomised. Velocities: 60;120 and 180deg/sec Gravity correction applied. Concentric and Eccentric	No statistical analysis performed. Analysis using kin-com software only.	Descending order of muscle strength at both contraction modes and for both genders was: extensors, adductors, flexors, abductors, IR's and ER's. Strength correlation co-efficients have indicated significant. Moderate-fairly strong relationships in men but not women.
[18]	22-35 years 15 males 15 females	Subjects were without history of shoulder pathology established through interview and general physical examination following the Maitland protocol					

Table 1 **Quality Evaluation Questions**

Questions	Extensively	Briefly
Not at all		
1. Is the purpose of the study clearly stated?		
2. Are the references appropriate and comprehensive?		
3. Are participant demographics adequately described?		
4. Were inclusion/exclusion criteria stated?		
5. Was the sample size adequate?		
6. Was the design appropriate to the research question?		
Consider was a randomization procedure used and were threats to internal validity controlled?		
7. Was instrumentation described, including the specific procedure used, in sufficient detail? Consider if gravity was corrected for as part of the procedure.		
8. Were appropriate statistical procedures used?		
9. Was the external validity of the results discussed?		
10. Were the limitations of the study described?		

Extensively = E = 2

Briefly = B = 1

Not at all = N

TABLE 3 QUALITY EVALUATION RESULTS

<u>STUD</u>	<u>Q1</u>	<u>Q2</u>	<u>Q3</u>	<u>Q4</u>	<u>Q5</u>	<u>Q6</u>	<u>Q7</u>	<u>Q8</u>	<u>Q9</u>	<u>Q10</u>	<u>Score</u>
[3]	2	2	1	1	0	1	1	2	0	0	10
[5]	2	1	2	2	0	2	1	2	0	1	13
[8]	1	2	1	1	0	1	1	0	0	0	7
[11]	2	2	1	1	0	2	2	2	1	1	14
[14]	2	1	1	0	0	2	2	2	0	0	10
[15]	2	2	2	1	0	1	1	1	0	0	10
[4]	2	2	1	1	0	2	2	2	1	1	14
[18]	1	2	1	1	0	2	1	1	0	2	11
[19]	2	2	1	1	0	2	2	-	1	1	12

Extensively = 2**High Quality 16 and above****Briefly = 1****Moderate Quality 12 to 16****Not at all or minimally = 0****Low Quality 12 and under**

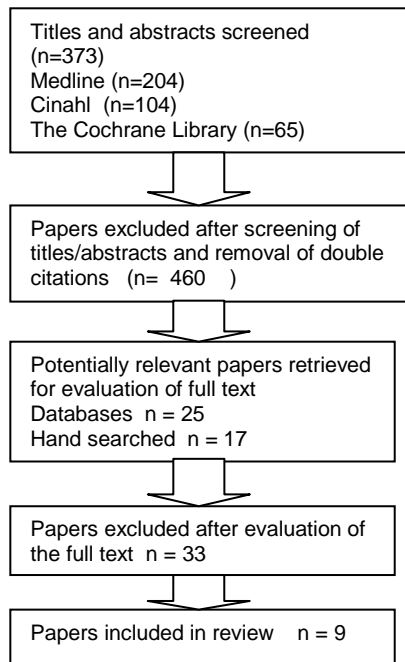


Figure 1 Flow Diagram of Search Results