THE DIAGNOSIS OF SUBACROMIAL IMPINGEMENT SYNDROME AND ASSOCIATED PATHOLOGY IN THE PRIMARY CARE SETTING

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This thesis is dedicated to my wife, Tasha, and my daughters, Charlotte and Madeline, thank you, all my love.

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Attestation of Authorship

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or institute of higher learning."

Daniel Harvey
29/06/2009

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Ethical approval

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Abstract

Diagnosing shoulder pain conditions is a challenging area of musculoskeletal practice. Subacromial impingement syndrome (SIS) is a clinical syndrome that indicates pain and pathology involving the subacromial bursa and rotator cuff tendons within the subacromial space. The three stages of SIS are subacromial bursitis, partial thickness and full thickness rotator cuff tears. The cause of SIS is believed to be multi-factorial with both extrinsic and intrinsic factors involved in its pathogenesis. Clinicians have traditionally diagnosed SIS using a clinical examination including a subjective history followed by confirmatory clinical tests.

A review of the evidence for diagnostic accuracy of clinical tests highlights that individual tests have poor diagnostic accuracy. A combination of clinical tests or a clinical examination *per se* may be useful at ruling out rotator cuff tears, but is less accurate at detecting rotator cuff tears when it is present. There is consensus in the literature that particular combinations of signs and clinical features may be useful in diagnosing rotator cuff tears but not for diagnosing SIS. The vast majority of research to date examining the clinical diagnosis of SIS has been focused on individual clinical tests carried out by medical practitioners in specialist and tertiary care settings. This review has established that the majority of diagnostic accuracy studies for SIS and rotator cuff tears have had poor methodological design.

This exploratory study was conducted with subjects undergoing a standardized clinical examination (index test) by a physiotherapist. The decision as to which specific tests were chosen for this research was based on supporting research within the literature and the test's actual use within the New Zealand clinical setting. This included subjective history questions, active and passive shoulder movement tests and eleven SIS tests. Subjects were referred for a diagnostic ultrasound scan immediately following the clinical examination and results from the scan stood as the criterion reference standard. Thirty eight individuals (males n=23, females n=15) with new onset shoulder pain, who met the inclusion criteria, were assessed by a participating physiotherapist. Sensitivity, specificity, positive likelihood ratios, negative likelihood ratios and respective 95% confidence intervals were calculated for all variables of the examination. Individual variables from the clinical examination

were tested for their association with the diagnostic ultrasound scan reference criterion using Pearson Chi-Squared Exact test. Potential predictor variables were retained as potential predictors for use in the logistic regression analysis to determine the most accurate set of clinical examination variables for diagnosing SIS and the individual pathological stages of SIS.

The results indicate that no historical, subjective or objective features from the clinical examination are accurate in diagnosing SIS or rotator cuff tears. The presence of night pain demonstrated a significant correlation (P<0.02) with the criterion reference standard for the presence of subacromial bursa fluid/bunching. Night pain and pain with overhead activity has a high sensitivity for subacromial bursa fluid/bunching being present. The absence of night pain and the absence of pain with overhead activity are two subjective phenomena from a clinical examination that are useful in ruling out subacromial bursa fluid/bunching being present. Night pain was also found to be the best predictor of subacromial bursa fluid/bunching being present (P<0.012). Male gender (P<0.034) was the best predictor of partial thickness rotator cuff tears while being 60 years of age or older (P<0.01) significantly correlated with full thickness rotator cuff tears. The Drop Arm Sign (P<0.01) and External Rotation Lag Sign (P<0.01) were significantly correlated with SIS and full thickness rotator cuff tears. Clinical tests for all three pathological stages of SIS and subacromial bursa fluid/bunching being present, had equivalent or if not greater diagnostic accuracy than previous report studies in the literature. The Hawkins-Kennedy Test and Neer Sign can be used in the primary care setting to rule out the presence of subacromial bursa fluid/bunching or SIS if the tests are negative. For mid to end stage SIS (rotator cuff tears) the Empty Can Test and Drop Arm Sign with their high sensitivity can be used to rule out rotator cuff tears especially to the supraspinatus tendon when the tests are negative.

Despite the small sample size and other limitations of this study, the findings are an important addition to the current literature surrounding the diagnostic accuracy of clinical tests for SIS and rotator cuff tears. This is the first study to use physiotherapists as examiners and to be set in a primary care setting. The study is also the first to examine the diagnostic accuracy of a range of historical and

subjective features from the clinical examination. The results found in the current study could be used by future studies as a starting point in the development of a clinical decision or prediction rule to assist clinicians in the diagnosis of SIS and rotator cuff tears.

Keywords: subacromial impingement syndrome, clinical examination, physiotherapy

1 Introduction

The differential diagnosis of conditions that cause shoulder pain is a challenging and complex area of musculoskeletal practice. Pathologies and their clinical presentation can vary from person to person. Clinicians have historically diagnosed shoulder pain conditions using a clinical examination that includes a subjective history followed by clinical tests (Cyriax & Cyriax, 1983).

Subacromial impingement syndrome (SIS) is a clinical syndrome that indicates pain and pathology within the subacromial space of the shoulder. The cause of SIS is believed to be multi-factorial with both extrinsic and intrinsic factors involved in its pathogenesis.

Dozens of clinical tests have been described that are proposed to aid in the diagnosis of SIS. Most clinical studies have focused on mid to end stage SIS (partial and full thickness rotator cuff tears). The diagnostic accuracy of the clinical examination and individual clinical tests for the different pathological stages of SIS is poor. Recent meta-analyses, systematic reviews and clinical guidelines clearly demonstrate that individual clinical tests for SIS (and in particular rotator cuff tears) lack specificity (ACC, 2004; Dinnes, Loveman, McIntyre, & Waugh, 2003; Hegedus et al., 2007; Hughes, Taylor, & Green, 2008). The current literature demonstrates that clinicians are not able to accurately diagnose SIS and particularly rotator cuff tears using positive clinical tests. However, the literature does suggest that a combination of clinical tests and historical features for rotator cuff tears has high sensitivities when carried out by specialist clinicians in tertiary or specialist settings (Park et al., 2005).

Tests that are highly sensitive are likely to provoke or reproduce the patient's symptoms and help screen for a particular pathology (Davidson, 2002; Lewis, 2009). To date there appear to be no clinical diagnostic accuracy study for SIS and rotator cuff tears that have been carried out by physiotherapists in a primary care or private practice setting. Recent reviews have stated that although physiotherapists see a large number of shoulder pain conditions, their ability as non-specialist primary care clinicians, to accurately diagnose SIS using a clinical examination is unknown (ACC, 2004; Dinnes et al., 2003; Hegedus et al., 2007; Hughes et al., 2008).

2 Literature review

2.1 Shoulder pain

Shoulder pain is a common musculoskeletal complaint with wide variation in the reported incidence and prevalence. Studies report that shoulder pain has an estimated lifetime incidence of between 6.9% and 34% in the general population (Green, Buchbinder, Glazier, & Forbes, 1999; Kuijpers, van Tulder, van der Heijden, Bouter, & van der Windt, 2006; Luime et al., 2004; Stevenson, 2006). Shoulder pain incidence increases with age with a peak prevalence of 56-60 years (Anderson-Ingemar, Ejlertsson, Leden, & Rosenberg, 1993; Green et al., 1999). The lifetime prevalence of shoulder pain in the adult population is approximately 10% (van der Heijden, van der Windt, Kleijnen, Koes, & Bouter, 1996).

There is a worldwide shift toward assessing and treating patients in a primary care setting. In the Netherlands approximately 95% of all shoulder pain patients are treated in primary care (Stevenson, 2006; van der Heijden et al., 1996). In New Zealand for the 2007/2008 year under the Accident Compensation Corporation insurance scheme, there were 82,934 new and existing shoulder/upper arm soft tissue injuries reported. The vast majority (94%) of these claims were registered and initially assessed in the primary care setting (ACC, 2008). The total cost of these soft tissue shoulder injuries was $285 748 000, accounting for 36% of all registered soft tissue body injuries. With most shoulder pain being assessed and treated in the primary care there is a clear need for accurate assessment of the shoulder by primary care clinicians.

There are many sources of shoulder pain. However, pathology of the periarticular soft tissues of the rotator cuff and subacromial bursa are considered to be the principal source of shoulder pain in comparison to pain originating from the cervical or thoracic spine, viscera, neurological structures or neoplasm (ACC, 2004; Stevenson, 2006; van der Heijden et al., 1996). Due to the anatomy of the shoulder, the rotator cuff and subacromial bursa have been reported to be more vulnerable to injuries, repetitive loading and age-related tissue changes (ACC, 2004; Lewis, 2009; Matava, Purcell, & Rudzki, 2005).

2.2 Anatomy of the shoulder

The shoulder is the most mobile joint in the body. This mobility is facilitated by its bony structure that provides very little in the way of structural stability. The anatomical representation of the shoulder has been likened to a ball balancing on a plate (ACC, 2004; Murrell, 2004). The joint consists of the head of the humerus articulating with the glenoid fossa of the scapula (Figure 1). The glenoid labrum is a fibro cartilaginous rim that increases the joint surface of the glenoid fossa. The labrum turns the relatively flat surface of the glenoid into a more secure curved saucer type structure.

The shoulder joint gains its passive stability from the joint capsule and the surrounding glenohumeral, coracohumeral and coracoacromial ligaments. The coracoacromial ligament, acromion and coracoid process of the scapula collectively form the coracoacromial arch. This coracoacromial arch forms the superior border or roof of the subacromial space which sits above the glenohumeral joint. The superior aspect of the humeral head and the greater tuberosity of the humerus form the floor of the subacromial space. Within this space lies the rotator cuff tendons and subacromial/subdeltoid bursa (Hyvonen, 2003; Murrell, 2004).

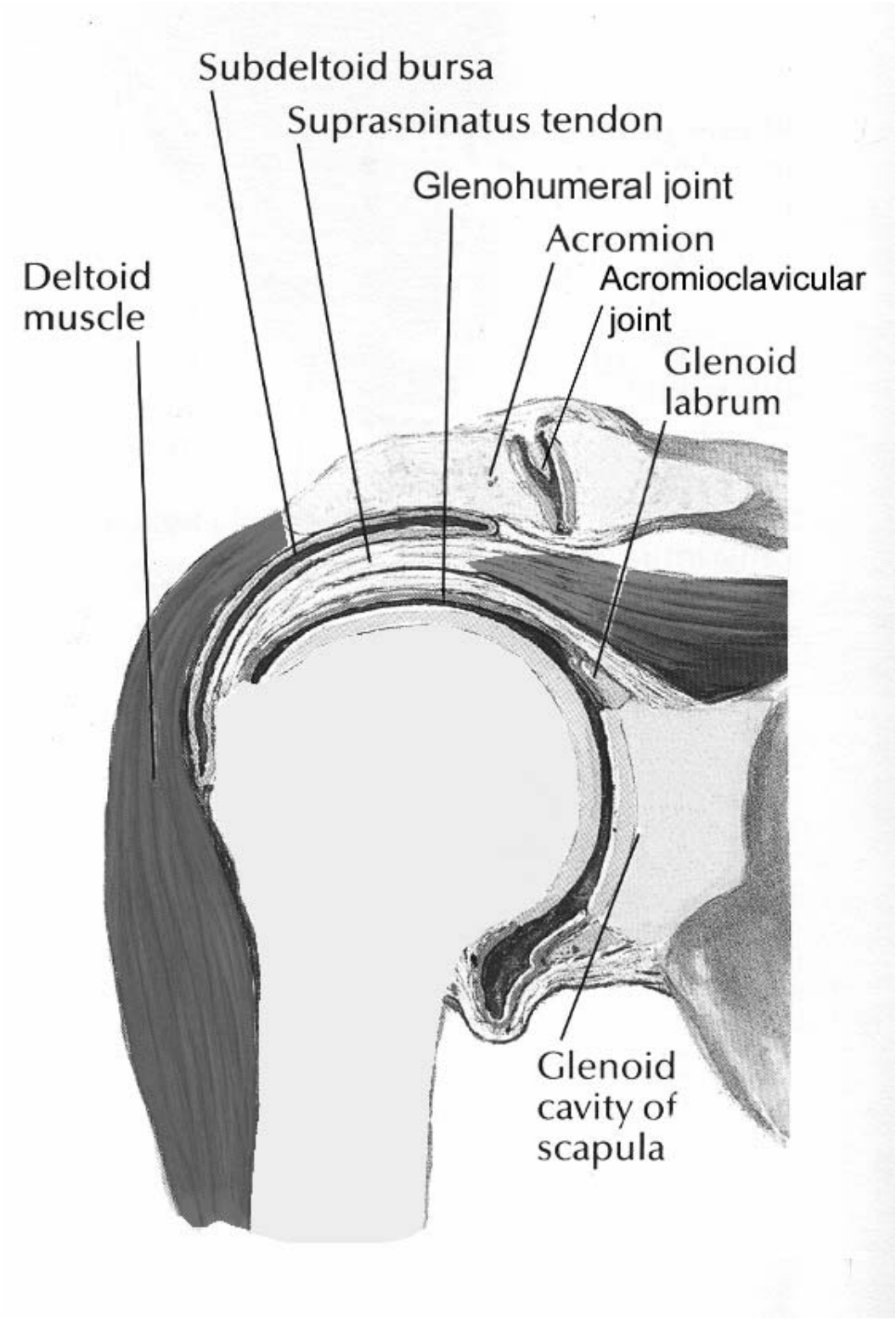

Figure 1: Anatomy of the shoulder
(From Hyvonen, (2003). *The pathogenesis of subacromial impingement syndrome.* University of Oulu, Oulu).

2.2.1 Subacromial bursa

The subdeltoid or more commonly called subacromial bursa (SAB) is a large potential space lined by synovial tissue. It is attached superiorly to the coracoacromial ligament, acromion and deltoid muscle laterally while it's under surface is adherent to the rotator cuff and greater tuberosity of the humerus. It is thought that the SAB facilitates or regulates the gliding of the humeral head under the coracoacromial arch and dissipates potential friction. The SAB is highly innervated with nociceptor receptors, mechanoreceptors, pressure receptors and proprioceptors. The various receptors of the SAB may be activated during clinical tests or manoeuvres for the rotator cuff or subacromial space. The SAB can become filled with fluid and thickened with injury or compression. Bunching or distension by fluid within subacromial bursa may also occur during arm movements causing impingement (Lew et al., 2007; Papatheodorou et al., 2006) (Figure 2).

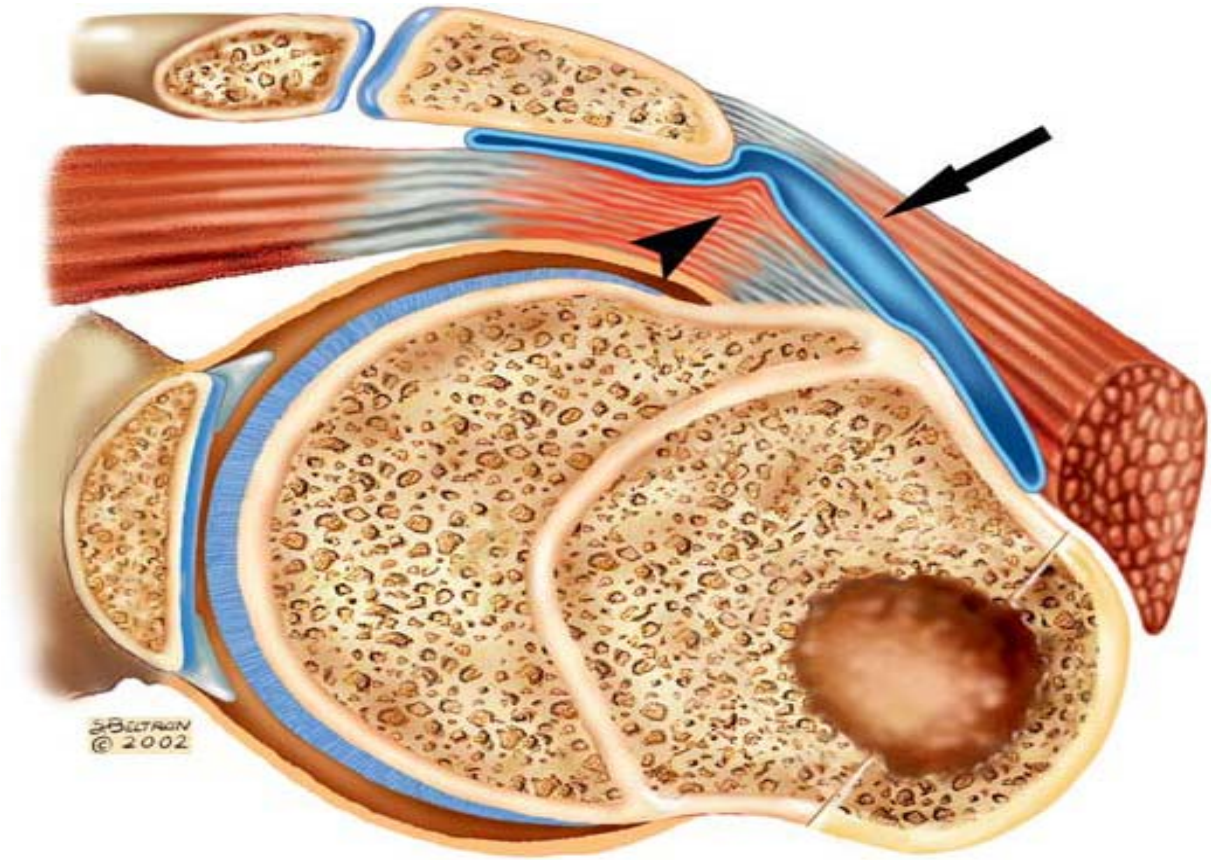

Figure 2: Subacromial bursa
(From Bureau, Beauchamp, Cardinal, & Brassard (2006). Dynamic sonography evaluation of shoulder impingement syndrome. *American Journal of Roentgenology, 187*, 216-220)

2.2.2 Rotator cuff

The rotator cuff is the merged distal tendons of four muscles (supraspinatus, infraspinatus, teres minor and subscapularis) that are layered and blend together before attaching to the humeral head (Figure 3). The rotator cuff tendons do not act individually but instead are made up of multiple confluent tissue layers functioning and acting in concert (Clark & Harryman, 1992).

The infraspinatus and teres minor tendons merge near their musculotendinous junctions whereas the supraspinatus and subscapularis tendons join as a sheath surrounding the long head of biceps tendon at the entrance of the bicipital groove. The roof of this sheath consists of a portion of the supraspinatus tendon, whereas a sheet of the subscapularis tendon serves as the floor. The relationship is relevant to the frequent and statistically significant coexistence of subscapularis tears with lesions of the long head of biceps (Flatow et al., 1996; Matava et al., 2005).

The rotator cuff acts functionally to depress the humeral head and stabilize it within the glenoid fossa with overhead activities. The rotator cuff forms a force couple with the deltoid muscle to allow elevation of the arm. This force couple is responsible for 45% of abduction strength and 90% of external rotation strength (Hertel et al, 1996). Injury or fatigue to the rotator cuff results in the decreased ability to keep the humeral head depressed in the glenoid fossa. This then allows the larger deltoid muscle to elevate the humeral head upward, creating one common cause of impingement of the SAB and rotator cuff tendons during arm movements (Hyvonen, 2003; Murrell, 2004).

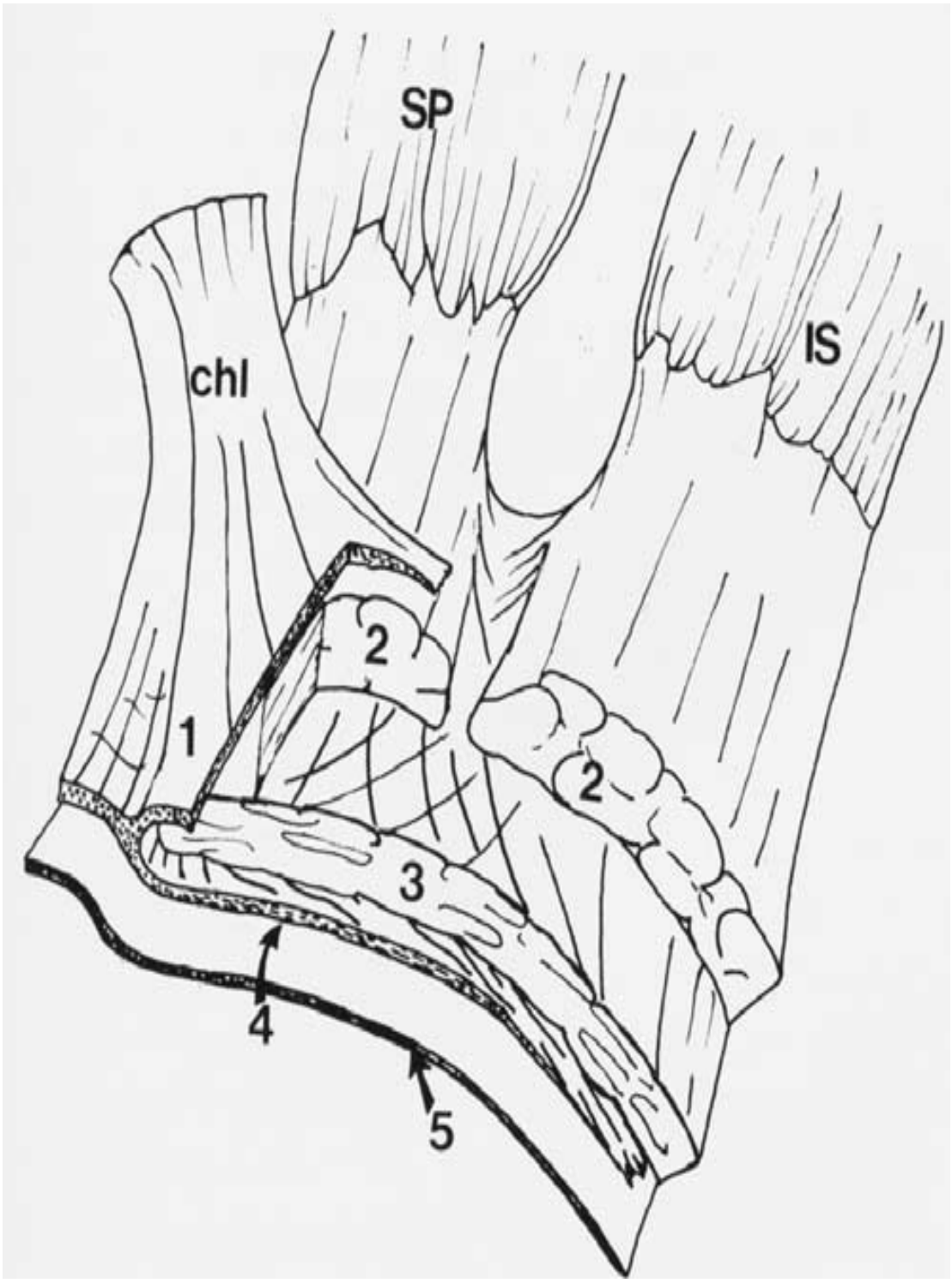

Figure 3: Schematic diagram of a rotator cuff dissection sectioned transversely showing confluent layers of tissue. SP, supraspinatus; IS, infraspinatus; chl, coracohumeral ligament (From Matava et al. (2005). Partial-thickness rotator cuff tears. *American Journal of Sports Medicine, 33*, 1405-1417).

2.2.3 Subacromial impingement syndrome

Subacromial impingement syndrome (SIS) is the abnormal mechanical compression of the rotator cuff and subacromial bursa within the subacromial space (Bigliani & Levine, 1997; Hyvonen, 2003; Neer 1983). The cause of SIS is multi-factorial but can be broadly classified into the degenerative/intrinsic theory or the mechanical/extrinsic theory. The key factors of the intrinsic theory are muscle overload and weakness, shoulder overuse and tissue microtrauma and rotator cuff degeneration. The key factors of the extrinsic theory are shape of the acromion, glenohumeral instability, disturbed scapulothoracic rhythm, os acromiale and degeneration of the AC joint (Bigliani and Levine, 1997; Hyvonen, 2003).

Osteophytes that protrude inferiorly from the undersurface of a degenerative acromioclavicular joint can contribute to SIS as the rotator cuff passes beneath the joint during arm movements. Stiffness and thickening of the coracoacromial ligament may also contribute toward SIS (Hyvonen, 2003). Coracoid impingement along the more medial aspect of the coracoacromial arch is less common, but it has been reported as a cause of SIS. The long head of bicep tendon in concert with the rotator cuff act to stabilize the shoulder through depression of the humeral head. Lesions to the long head of biceps can contribute toward the development of SIS (Bigliani & Levine, 1997; Hyvonen, 2003).

These extrinsic and intrinsic factors create repetitive and excessive compression of the rotator cuff and SAB against the bony under surface of the anterior one third of the acromion. Superior translation of the humeral head on the glenoid fossa creates impingement that is centred primarily on the supraspinatus tendinous insertion at the greater tuberosity. Shoulder pain in patients with SIS appears to be caused by compression of the inflamed and irritated SAB, or pressure ischemia in the rotator cuff tendons (Hyvonen, 2003). Local pressures in the subacromial space are also elevated in SIS patients, supporting the mechanical/extrinsic theory (Bigliani and Levine, 1997; Lewis, 2009).

These factors combine to create tissue trauma and distinct pathology within the subacromial space. Tissue pathology begins with the presence of fluid and thickening

of the subacromial bursa. The rotator cuff can become degenerative and fatigued, leading to tendinosis/tendinopathy developing. With trauma or increased tissue loading and subsequent tissue fatigue, intrasubstance and partial thickness rotator cuff tears can occur. This can progress to tendon failure with full thickness and massive rotator cuff tendon tears developing (Lewis, 2009). The symptoms and clinical presentation of the different pathological stages of SIS and can vary greatly from patient to patient.

2.2.4 Stages of subacromial impingement syndrome

Originally, Neer (1972, 1983) introduced and described three stages of shoulder impingement that clinically can have similar symptoms and physical signs which include pain, crepitus, loss of movement, weakness and a painful arc (Table 1). The most common reported symptoms of SIS are pain especially at night, stiffness, loss in ranges of motion, weakness and loss of function which all contributes to the cause of shoulder disability (Silva et al., 2008; Stevenson, 2006; van der Heijden et al., 1996).

Table 1: Original stages of subacromial impingement syndrome

Stage One- Oedema & haemorrhage	Oedema and haemorrhage of the rotator cuff tendons may result from excessive use and are reversible. Dull ache with palpable tenderness and positive impingement signs (including Neer Sign) are the usual findings. They occur most commonly in individuals <25 years of age (Neer, 1972, 1983).
Stage Two- Fibrosis & tendinitis	With repeated episodes of mechanical inflammation, the supraspinatus tendon, biceps tendon and/or SAB may become fibrotic and thickened. The age group affected is usually between 25-40 years of age. Impingement signs are always present. Crepitus as well as mild limitation in active and passive movements are also present (Neer, 1972, 1983).
Stage Three- Tear of the rotator cuff, bicep tendon rupture and bony changes	With further progression, there will be bony alterations of the anterior acromion of the scapula and greater tuberosity of the humerus. Limited shoulder range of motion, weakness in abduction and external rotation and a positive impingement sign are the typical findings. Pain becomes more severe and will prohibit vigorous use of the affected arm. Night pain is also a typical complaint. The age group is usually above forty and often requires surgical anterior acromioplasty and rotator cuff repair.

Neer describes very similar signs and symptoms across all three original stages of impingement and believed that 95% of rotator cuff tears occur as a consequence of SIS (Neer, 1972, 1983). Since Neer's original description, there has been a better understanding and improved validity of the descriptors of the different degrees and stages of SIS pathology. It is currently believed that SIS encompasses a spectrum of pathologies with different aetiologies within the subacromial space including subacromial bursitis, partial thickness and full thickness rotator cuff tears. Recently researchers have investigated the different stages of SIS (Çalis et al., 2000; Park, Yokota, Gill, Rassi, & McFarland, 2005; Zlatkin et al., 1989). Park et al. (2005) described SIS with three discrete entities or stages based primarily on the treatment and surgical management of SIS patients. Stage one defines subacromial bursitis with no rotator cuff tear. Stage two defines partial thickness rotator cuff tears only, including intrasubstance tears. Stage three defines full thickness rotator cuff tears. Most authors are in agreement that thickening/presence of fluid in the SAB is the dominant clinical feature of stage one SIS and thus should be labelled subacromial bursitis (Lewis, 2009; Murrell, 2004; Park et al., 2005).

Neer did not differentiate between partial thickness and full thickness rotator cuff tears in the original classification of the stages of impingement syndrome (Neer, 1972, 1983). The improvement in both non-invasive imaging modalities and arthroscopic surgical techniques has been accompanied by an increase in the recognition of partial thickness rotator cuff tears (Matava et al, 2005). Partial thickness rotator cuff tears are now recognized as a separate pathological entity from full thickness tears. Partial thickness tears can be defined as tears to the bursal or articular side of the rotator cuff without extending through the full thickness of the tendon (Figure 4, 5 & 6) (Fukuda, 2003; Yen et al., 2004). Full thickness rotator cuff tears are classified as tears that extend through the full thickness of the tendon. Massive rotator cuff tears have been defined as tears greater than 5 cm in diameter and usually affecting two or more of the rotator cuff tendons (ACC, 2004).

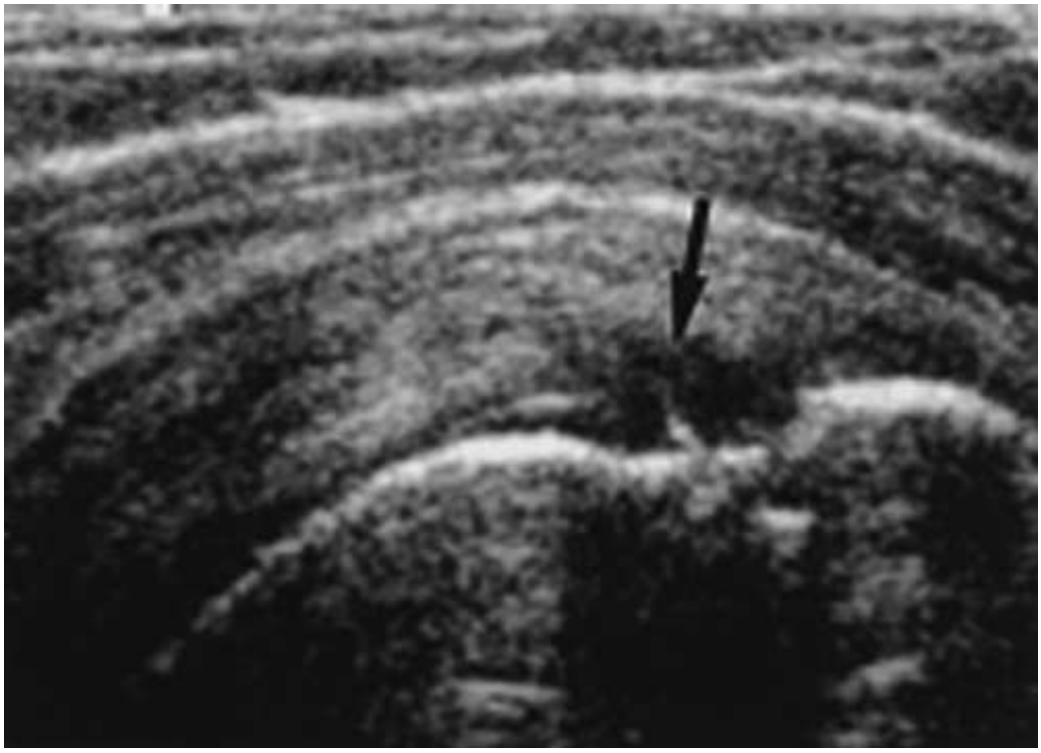

Figure 4: Partial thickness rotator cuff tear on Diagnostic Ultrasound
(From Matava et al. (2005). Partial-thickness rotator cuff tears. *American Journal of Sports Medicine, 33*, 1405-1417).

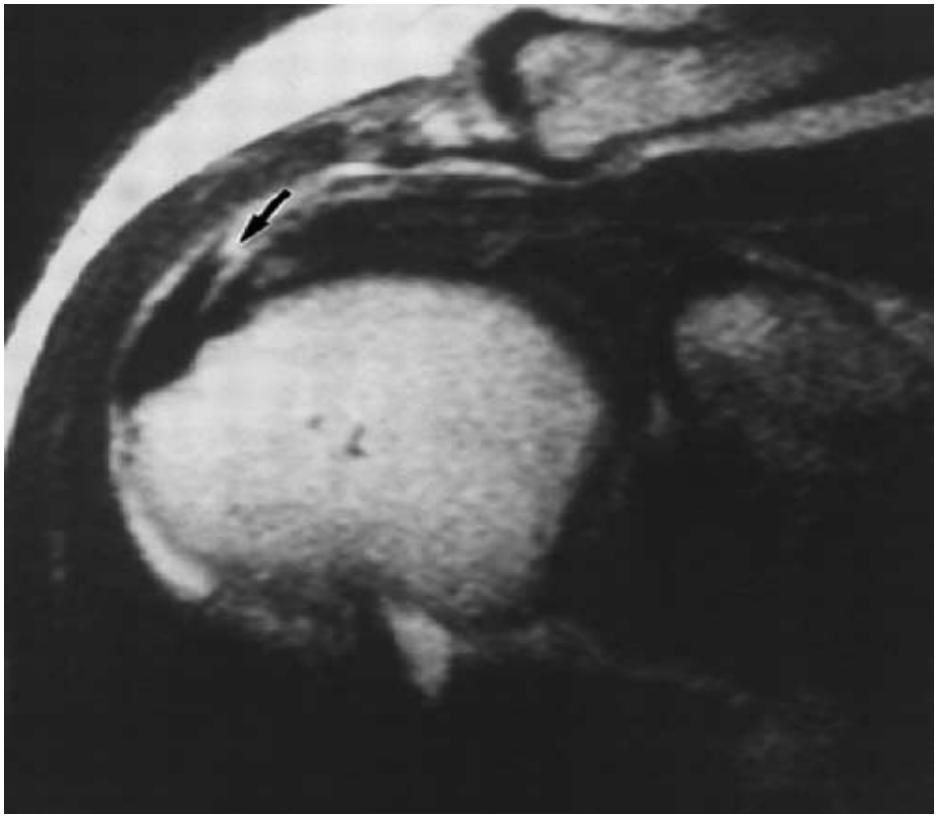

Figure 5: Supraspinatus tendon tear on Magnetic Resonance Imaging
(From Matava et al. (2005). Partial-thickness rotator cuff tears. *American Journal of Sports Medicine, 33*, 1405-1417).

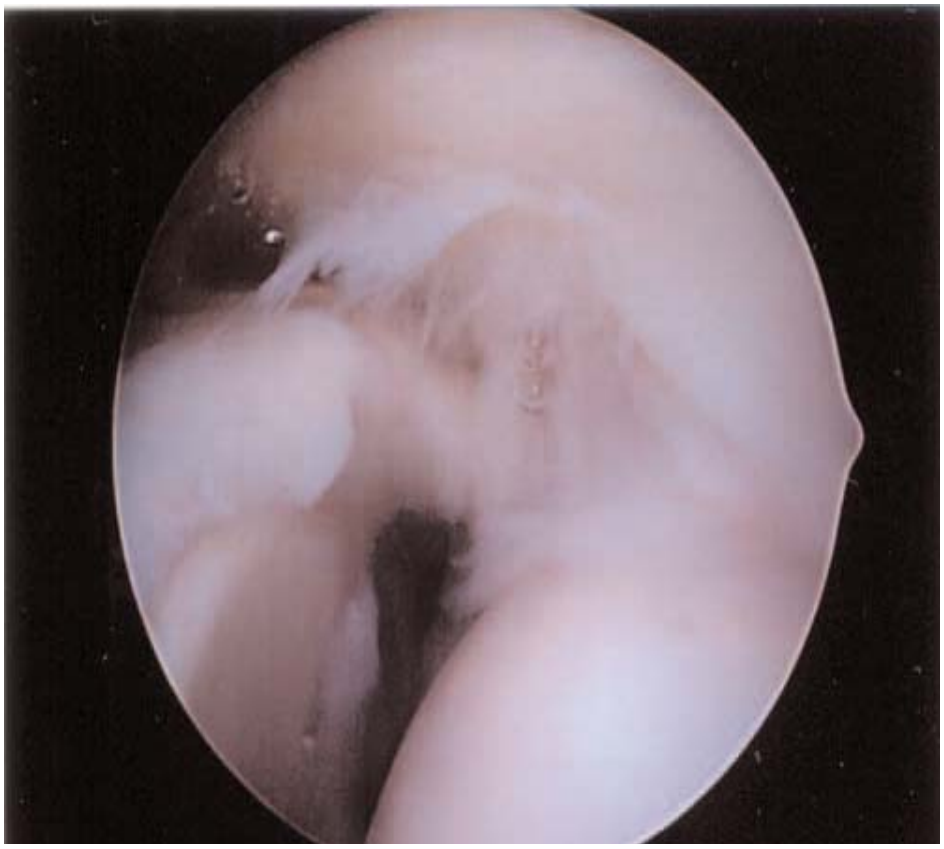

Figure 6: Supraspinatus tendon tear with Arthroscopy
(From Matava et al. (2005). Partial-thickness rotator cuff tears. *American Journal of Sports Medicine, 33*, 1405-1417).

2.3 Diagnosis of subacromial impingement syndrome

The diagnosis of shoulder pathology is often challenging and complex. The signs and symptoms associated with most pathologies affecting the structures of the shoulder, especially those linked to SIS, are very similar. Also complicating the diagnosis is the fact that patients can present with a combination of SIS pathologies such as a rotator cuff tear and subacromial bursitis. The ACC guidelines recommend that an accurate diagnosis of painful and disabling SIS will ultimately guide the treatment and management options of the patient (ACC, 2004; Matava et al., 2005). Patients with mild to moderate SIS (subacromial bursitis and partial thickness rotator cuff tear) are advised to carry out a supervised exercise rehabilitation programme by a recognised treatment provider such as a physiotherapist (ACC, 2004). Patients with end stage SIS (full thickness rotator cuff tear) and significant structural damage

to the rotator cuff require urgent referral for a surgical opinion (ACC, 2004). Identifying full thickness rotator cuff tears early, especially in those patients who are active and physiologically young is very important in the surgical management of these patients (ACC, 2004; Matava et al., 2005; Yen et al., 2004).

Diagnostic imaging such as Magnetic Resonance Imaging (MRI) and Diagnostic Ultrasound (DUS), have been demonstrated to be highly accurate at identifying and confirming full thickness rotator cuff tears (ACC, 2004; Dinnes et al., 2003). However, diagnostic imaging can be very expensive and not always readily available to clinicians especially in the primary care setting. Therefore, if it can be shown that a clinical examination could accurately diagnose and or aid in identifying patients with a rotator cuff tear that would benefit from DUS or MRI, this may lead to reduced costs and faster implementation of appropriate treatment and management options. A clinical examination may also allow clinicians to diagnose mild or early stage SIS to facilitate timely and appropriate rehabilitation or non-operative management (ACC, 2004; Green, Shanley, Taylor, & Perrot, 2008; Lewis, 2009).

2.3.1 Clinical examination of subacromial impingement syndrome

Physiotherapists routinely use a detailed clinical examination in the diagnosis of SIS (Cyriax & Cyriax, 1983). During the initial subjective history interview the physiotherapist uses clinical reasoning skills to develop hypotheses about possible causes or diagnoses for the patient with shoulder pain (Davidson, 2002; Lewis, 2009; Magarey & Jones, 1992). These hypotheses are then tested using a clinical examination including movement and clinical tests. Many tests currently exist and it is commonly believed that positive findings from these clinical tests will accurately identify specific underlying shoulder pathologies. Historically these clinical tests have been based on the principle that it is possible to isolate individual tissue structures and apply mechanical stress to test the tissue's integrity or compress them in order to provoke pain (Hertel, Ballmer, Lambert, & Gerber, 1996; Hyvonen, 2003; Lewis, 2009; Tennent, Beach, & Meyers, 2003).

2.3.2 Clinical tests

There are a number of specific tests that are utilized to assess SIS. These can be described under two main types of tests used in clinical practice.

2.3.3 Impingement tests

The first type of clinical test is the impingement or pain provocation tests (Table 2). These impingement tests were historically intended to reproduce symptoms or pain by compressing the greater tuberosity against the acromion (Bak & Fauno, 1997; Lewis; 2009; Neer 1983; Tennent, Beach & Meyers, 2003).

Table 2: Clinical tests for impingement

Shoulder pathology	**Clinical tests for the pathology**
Subacromial impingement syndrome	Neer Sign, Hawkins-Kennedy Test, Horizontal Adduction Test

Historically a positive Neer Sign was believed to reproduce pain in patients with SIS (Neer, 1983). A recent systematic review on the anatomical basis of clinical tests assessing musculoskeletal function of the shoulder found conflicting evidence on anatomical basis for the Neer Sign and Hawkins-Kennedy Test (Green et al., 2008). Studies investigating the Neer Sign come to conflicting conclusions: one study found no anatomical basis, whereas another indicated that there was some anatomical basis (Green et al., 2008). Discrepancies between the findings of the two studies may be explained by the fact that their methodologies differed with regard to participant positioning (seated versus supine). In addition, one study used a more detailed three-dimensional distance analysis, and investigated the presence of subacromial impingement. The authors in the review concluded that an alternative anatomical basis of internal impingement may exist for the Neer Sign; however, this basis does not support the test developer's hypothesis (Green et al., 2008). Despite SIS being a common clinical diagnosis there is a lack of consensus about the anatomical basis of the clinical tests designed to diagnose SIS.

2.3.4 Rotator cuff integrity tests

The second type of test assesses the integrity of the individual rotator cuff tendons and their respective musculotendinous units (Table 3). These clinical tests are also commonly referred to as rotator cuff power or strength tests. Specifically there are active movement, resisted/strength tests as well as 'lag' signs that determine if a passive position of the shoulder or arm can be maintained (Hertel et al., 1996; Hughes et al., 2008; Tennent et al., 2003).

Table 3: Clinical tests for the integrity of the rotator cuff

Shoulder pathology	Clinical tests for the tear
Supraspinatus tear	Drop Arm Test, Full Can Test, Empty Can Test, Painful Arc Test, Supraspinatus palpation
Infraspinatus & teres minor tear	Infraspinatus/Resisted External Rotation Test, External Rotation Lag Sign, Patte's Test, Hornblower's Sign
Subscapularis tear	Bear-Hug Test, Belly-Press Test, Napoleon Test, Lift Off Test
Biceps tear	Speed's Test

2.4 Diagnostic accuracy

A clinician uses a clinical test to help determine if a patient does or does not have the particular pathology. A positive or negative clinical test will often lead the clinician to either accept or refute a particular shoulder pathological hypothesis. The extent to which a positive or negative clinical test result can confirm or disprove a diagnostic hypothesis is based upon its diagnostic accuracy (Davidson, 2002).

2.4.1 Diagnostic accuracy of clinical tests

Diagnostic accuracy is defined as the proportion of patients who are correctly identified as either having or not having the particular disorder. Diagnostic tests are rarely 100% accurate as false positives and false negatives can occur (Davidson, 2002). Estimates of diagnostic accuracy are determined using a 2 x 2 contingency

table where the findings of a clinical test (positive or negative) are plotted against the actual diagnosis as determined by a criterion reference standard such as surgery or imaging scan (Figure 7).

		Criterion reference standard diagnosis	
		Present	*Absent*
Diagnostic (index) test result	*Positive*	True positives **A**	False positives **C**
	Negative	False negatives **B**	True negatives **D**
		A+B	**C+D**

Figure 7: The 2 x 2 contingency table
(From Davidson (2002). The interpretation of diagnostic tests: A primer for physiotherapists. *Australian Journal of Physiotherapy, 48*, 227-233).

2.4.1.1 Sensitivity and specificity

Sensitivity is defined as the proportion of the population who has the disorder that test positive (true positive rate) and is calculated from the 2 x 2 table with the formula A / (A+C). When the sensitivity is high (90-100% or 0.90-1.00) we can be confident that a negative clinical test result will rule the particular disorder out (Davidson, 2002; Dinnes et al., 2003; Hegedus & Stern, 2009).

Specificity is defined as the proportion of people who do not have the disorder that test negative (true negative rate) and is calculated from the 2 x 2 table with the formula D / (B+D). When the specificity is high (90-100% or 0.90-1.00) we can be confident that a positive clinical test result will rule the particular disorder in (Davidson, 2002; Dinnes et al., 2003; Hegedus & Stern, 2009).

Sackett, Haynes, Guyatt and Tugwell (1992), introduced the mnemonics of SpPIN (when specificity is high, a positive test result rules in the diagnosis) and SnNout (when sensitivity is high, a negative test rules out the diagnosis) for clinicians to easily apply diagnostic accuracy characteristics to clinical tests.

Sensitivity and specificity informs the clinician how often a clinical test is positive and negative in patients who have the particular disorder. Clinically they are an estimate of certainty (Davidson, 2002). Underpowered studies with small sample sizes have wide confidence intervals that indicate a less precise measure of accuracy than the estimates (Hegedus & Stern, 2009; Lewis, 2009). There is potential for inappropriate diagnostic conclusions if sensitivity or specificity values have wide confidence intervals or if clinicians view the estimates of sensitivity or specificity as single numbers in isolation to quantify a clinical test result finding (Hegedus & Stern, 2009).

2.4.2 Likelihood ratios

Likelihood ratios (LR) summarize and incorporate the information contained in both sensitivity and specificity results and this helps to overcome the short comings and improves the clinical utility of both specificity and sensitivity. A LR tells the clinician how likely a given clinical test result is, in patients with the disorder compared with how likely it is in patients without the disorder. LRs modify the probability of the specific disorder given a specific clinical test result, and allow the clinician to be more certain if the disorder is present or not (Davidson, 2002; Hegedus & Stern, 2009).

LRs are calculated using the formulae:

- Positive LR (LR of a positive test): Sensitivity / (1-Specificity)
- Negative LR (LR of a negative test): (1-Sensitivity) / Specificity

The higher the positive LR, the more certain the clinician can be that a positive clinical test result will indicate the patient has the disorder. A LR close to 1.0 will provide little change in probability that a person has or does not have the disorder. A positive LR greater than 1.0 will increase the clinician's confidence that the patient has the disorder in question. A positive LR of >10 increases the probability of the

patient having the disorder by approximately +45%. A negative LR decreases the clinician's confidence that the patient has the disorder in question. A negative LR of <0.1 decreases the probability of the patient having the disorder by approximately -45% (Davidson, 2002; Hegedus & Stern, 2009).

High quality studies of diagnostic accuracy are required for clinicians to calculate and apply LRs to individual cases. Key features of high quality of a study are the selection of a sufficient sample of consecutive patients suspected of having the target condition to ensure that the study is adequately powered and the use of blinded assessors. (Davidson, 2002; Hegedus & Stern, 2009; Lewis, 2009). Diagnostic accuracy studies should be assessed using a validated tool such as the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) tool (Appendix 1). The QUADAS tool consists of 14 questions that address both the internal and external validity of diagnostic accuracy studies. Diagnostic studies require that all patients receive both the clinical test (index test) and the criterion reference standard test (Hegedus et al., 2007; Hegedus & Stern, 2009; Whiting et al., 2004).

2.5 Diagnostic accuracy of clinical tests for subacromial impingement syndrome

2.5.1 Literature review search strategy

A search to identify diagnostic accuracy studies for the clinical examination of the shoulder was conducted in January 2008. The following electronic databases were searched: MEDLINE via PubMed, MEDLINE via OVID, CINAHL, SPORT-Discus, AMED Allied and Complimentary Medicine, Cochrane Library, PEDro, ProQuest 5000 International, ProQuest Health and Medical Complete, EBSCO Megafile Premier, Science Direct and the World Wide Web via Google.

The search strategy of these databases included terms and keywords related to diagnostic accuracy studies of clinical examination of the shoulder: shoulder, shoulder pain, glenohumeral joint, rotator cuff tendons, impingement, subacromial impingement syndrome, rotator cuff tears, subacromial bursitis, clinical examination,

tests, clinical tests, physical tests, orthopaedic special tests, sensitivity, specificity and likelihood ratios. The titles and/or abstracts of these citations were reviewed to identify papers specifically detailing diagnostic accuracy studies of clinical examination of the shoulder. The search was limited to studies written in or translated to English and using human subjects. The reference lists of each paper were searched to identify other relevant papers.

Two existing systematic reviews with meta-analyses evaluating the accuracy of diagnostic tests for the investigation of shoulder pain were identified (Dinnes et al., 2003; Hegedus et al., 2007). A systematic review without meta-analysis, investigating rotator cuff test accuracy was also identified (Hughes et al., 2008).

2.5.2 Systematic reviews from the literature

2.5.2.1 The effectiveness of diagnostic tests for the assessment of shoulder pain due to soft tissue disorders: a systematic review

This review identified 10 cohort studies using a clear literature search strategy (Dinnes et al., 2003). The authors used clear study inclusion and exclusion criteria and a modified/early form of the QUADAS tool to assess the studies. The authors described their meta-analysis technique in detail. A clear strength of the review was the calculation of sensitivity, specificity, positive LR, negative LR and 95% confidence intervals for all the clinical tests and the use of a standardised data extraction tool by all the reviewers. Seven of the 10 studies examined the accuracy of individual clinical tests and six studies estimated the accuracy of a specific clinical examination or the combination of two or more positive clinical test signs. Seven of the 10 cohort studies used arthroscopy or surgery as the criterion reference standard. Three of the studies used MRI or the subacromial injection test (SIT) as the criterion reference standard. Four clinical shoulder examination tests were examined in more than one study: Empty Can Test, Neer Sign, Hawkins-Kennedy Test and Painful Arc Test. All studies took place in specialist settings using medical practitioners as examiners.

Dinnes et al. (2003) concluded that for individual clinical shoulder examination tests, the tests evaluated tended to be either highly sensitive or highly specific, and very few demonstrated both high sensitivity and specificity. Few tests provided convincing evidence of the presence or absence of the pathology being tested in the settings in which they were applied (Dinnes et al., 2003).

Individual tests did perform well in the study by Hertel et al. (1996) with positive LRs of >10. These tests were the External Rotation Lag Sign (ERLS), the Drop-Arm Test, the Lift Off Test and Internal Rotation Lag Sign (Dinnes et al., 2003; Hertel et al., 1996).

Other individual clinical shoulder examination tests that have both a high positive LR and a low negative LR from the review of Dinnes et al. (2003) were the Rent Test (Wolf & Agrawal, 2001) and the Internal Rotation Resistance Strength Test (Zaslav, 2001). Dinnes et al. (2003) concluded that there was insufficient evidence to recommend any one clinical examination test or set of tests to provide an indication of the accuracy of clinical examination at differentiating SIS from other causes of shoulder pain (Dinnes et al., 2003).

For studies that estimated the accuracy of a specific clinical examination or the combination of two or more positive clinical test signs, positive LRs were all <5.0, indicating that a positive diagnosis on the basis of a clinical examination as a whole is not a convincing result (Dinnes et al., 2003). In four of the reviewed studies the combination of two or more tests were found to have sufficiently low negative LRs to confirm that pathology is absent in those patients with a negative diagnosis (Itoi, Kido, Sano, Urayama, & Sato, 1999; Litaker, Pioro, Bilbeisi, & Brems, 2000; Lyons & Tomlinson, 1992; MacDonald, Clark, & Sutherland, 2000). The pooled results of the meta-analysis from these four studies indicated overall sensitivity of 0.90 and specificity of 0.54 for the diagnosis of full thickness rotator cuff tears (Dinnes et al., 2003). Dinnes et al. (2003) concluded that due to the high sensitivity for these studies, a clinical examination carried out by a specialist may be able to rule out a full thickness rotator cuff tear, but is less accurate in detecting a full thickness rotator cuff tear.

2.5.2.2 Physical examination tests of the shoulder: a systematic review with meta-analysis of individual tests

In the systematic review by Hegedus et al. (2007), 21 cohort studies were identified by the authors with many studies published since 2001 and included studies which used surgery, computed tomography, MRI or double contrast arthrography results as the criterion reference standards. Only studies published in English were included in the review and also only if either the sensitivity or specificity value was reported. Studies were excluded if clinical tests were performed under anaesthesia, used cadavers or were part of a "clinical examination". All studies were assessed by two reviewers and the reviewers were not blinded to title of author of the study. If there was any disagreement between the reviewers a third reviewer made the conclusive decision (Hegedus et al., 2007). The authors used the current QUADAS criterion critique tool to evaluate the quality of each study. The QUADAS tool assesses fourteen components and scored with either a "yes" when the component is satisfied, or else "no" or "unclear". Studies with scores of 10 satisfied components, were deemed of high methodological quality (Hegedus et al., 2007; Whiting et al., 2004). This review differed from the earlier review by Dinnes et al. (2003) who focused on the accuracy of diagnostic imaging and only included 10 studies on clinical tests in their review. This review by Hegedus et al. (2007) investigated all clinical tests of the shoulder and identified a total of 45 studies with 21 specifically investigating SIS and rotator cuff tears. All studies took place in specialist settings using medical practitioners as examiners.

The review identified six studies evaluating individual clinical tests for SIS and 15 studies evaluating individual clinical tests for rotator cuff tears. Studies investigating the accuracy of a specific clinical examination or the combination of two or more positive clinical tests were not evaluated.

A meta-analysis from the pooled data of four studies with similar outcomes was performed for the Neer Sign and Hawkins-Kennedy Test for SIS. A meta-regression of the diagnostic odds ratio technique was used for the meta-analysis. The pooled sensitivity and specificity for the Neer Sign was 0.79 and 0.53 respectively. For the

Hawkins-Kennedy Test the pooled sensitivity and specificity was 0.79 and 0.59 respectively, with the authors concluding that the test may serve as a screen for SIS (Table 4) (Hegedus et al., 2007).

Table 4: Pooled sensitivity and specificity data for subacromial impingement syndrome

Clinical test for SIS	Pooled Sensitivity	Pooled Specificity
Neer Sign	0.79	0.53
Hawkins-Kennedy Test	0.79	0.59

Of the fifteen studies in the review that investigated clinical tests to assess rotator cuff integrity, nine examined the ability of the individual tests to detect any rotator cuff tear and five examined the ability to assess the tear of a specific rotator cuff tendon (Hegedus et al., 2007). Three tests: the ERLS (Hertel et al., 1996), the Supine Impingement test (Litaker et al., 2000) and the Drop Arm test (Murrell & Walton, 2001) demonstrated high specificity (>0.90) for a tear of any rotator cuff tendon (Hegedus et al., 2007). The ERLS may also be diagnostic of an infraspinatus tendon tear with a specificity of 0.98 and negative LR ratio of 0.02 (Hegedus et al., 2007; Walch, Boulahia, Calderone, & Robinson, 1998).

For specific clinical tests for a subscapularis tendon tear, the Bear Hug and Belly Press Tests demonstrated specificity of 0.92 and 0.98 respectively (Barth, Burkhart, & De Beer, 2006). These two tests appear to be valuable at ruling in a subscapularis muscle tendon tear when the clinical test is positive (Hegedus et al., 2007). The Hornblower's Sign may be diagnostic of severe degeneration of teres minor or absence of the infraspinatus tendon with sensitivity and specificity of 0.95 and 0.92 respectively (Table 5) (Walch et al., 1998).

2.5.2.3 Most clinical tests cannot accurately diagnose rotator cuff pathology: a systematic review

In the third and most recent systematic review by Hughes et al. (2008) identified 13 studies evaluating 14 clinical tests. The authors used strict inclusion criteria of studies only published in English, human participants with shoulder pain and for clinical diagnostic testing for rotator cuff pathology. Studies were only included if reported sensitivity and specificity values (or enough data to calculate sensitivity and specificity values) which allowed calculation of LR values were included. A clinical test was deemed diagnostically useful if it possessed a positive LR ratio of >10 or a negative LR ratio of <0.1. Three additional studies investigating diagnostic accuracy of SIS or rotator cuff tears not included in the previous systematic reviews were also identified (Itoi et al., 1999; Itoi, Minagawa, Yamamoto, Seki, & Abe, 2006; Kim, Jeong, Lee, & Song, 2006). All studies reviewed took place in specialist settings using medical practitioners as examiners.

This most recent review differed from the earlier review by Hegedus et al. (2007) in that it focused solely on rotator cuff pathology and impingement tests for SIS. The authors also required both sensitivity and specificity values from the diagnostic studies so to complete both positive and negative LRs calculations. This review only used studies that used arthroscopy, open surgery report and MRI as criterion reference standards. This differed from Hegedus et al. (2007) who included studies that used computed tomography (Walch et al., 1998) or double contrast arthrography (Litaker et al., 2000) as criterion reference standards.

The two studies in the review investigating palpation of supraspinatus tendon for signs of possible defect/rupture both reported high sensitivity values (Lyons & Tomlinson, 1992; Wolf & Agrawal, 2001). Wolf and Agrawal (2001) also found high specificity, a positive LR of 29.91 and a negative LR of 0.04.

Two evaluations of the Drop Arm Test for supraspinatus pathology produced a positive LR ratio above 10 or a negative LR ratio below 0.1 (Çalis et al., 2000). These results were not found in five other evaluations across three studies (Hughes et al., 2008; Murrell, 2004; Murrell & Walton, 2001; Park et al., 2005).

Results of the review indicated that the Empty Can Test demonstrated high diagnostic accuracy only once in 21 evaluations across six studies (Holtby & Razmjou, 2004; Itoi et al., 1999; Itoi et al., 2006; Kim et al., 2006; Leroux, Thomas, Bonnel, & Blotman, 1995; Park et al., 2005). Kim et al. (2006) reported a negative LR ratio of 0.03, using pain or weakness as a criterion during clinical testing for rotator cuff tears (Table 5) (Hughes et al., 2008).

The only impingement test to produce a positive LR ratio >10 *or* a negative LR ratio <0.1 was the Hawkins-Kennedy Test (Çalis et al., 2000; Hughes et al., 2008). However, this result was not found in six other evaluations across three studies (Table 5) (Çalis et al., 2000; MacDonald et al., 2000; Park et al., 2005).

Table 4: The accuracy of clinical tests from the literature

Study	Clinical test	Pathology	QUADAS score	Sensitivity/ Specificity	-ve LR/+ve LR
(Barth et al., 2006)	Bear Hug Sign Belly Press Sign Napoleon Sign	Subscapularis tear	11/14	0.60/0.92 0.40/0.98 0.25/0.98	0.32/7.5 0.61/20 0.77/11.9
(Çalis et al., 2000)	Hawkins-Kennedy Drop Arm Test	SIS-stage three tears Supraspinatus tears	8/14	1.00/0.36 0.15/1.00	0.00/1.56 0.85/infinity
(Hertel et al., 1996)	ERLS	Any rotator cuff tear	7/14	0.97/0.96	0.03/24
(Itoi et al., 1999)	Empty Can Test Full Can Test	Full thickness rotator cuff tears	8/14	0.89/0.50 0.86/0.57	0.23/1.77 0.25/2.01
(Itoi et al., 2006)	Empty Can Test Full Can Test	Any rotator cuff tear	11/14	0.87/0.43 0.83/0.53	0.30/1.53 0.32/1.78
(Kim et al., 2006)	Empty Can Test Full Can Test	Any rotator cuff tear	10/14	0.99/0.43 0.89/0.54	0.03/1.74 0.20/1.93
(Litaker et al., 2000)	Supine Impingement Test	Any rotator cuff tear	10/14	0.97/0.09	0.33/1.07
(Park et al., 2005)	Empty Can Test Infraspinatus Test	SIS SIS	10/14	0.44/0.99 0.42/0.90	0.62/4.4 0.64/4.2
(Walch et al., 1998)	Hornblower's Sign ERLS	Teres minor/ infraspinatus tear	7/14	0.95/0.72 0.98/0.98	0.70/3.4 0.02/49
(Wolf & Agrawal, 2001)	Palpation of supraspinatus (Rent's Test)	Supraspinatus tears	10/14	0.96/0.97	0.04/29.91

2.5.3 Clinical examination or combination of two or more tests for subacromial impingement syndrome

To date, researchers have focused much of their attention on individual clinical tests to diagnose SIS pathology. Few researchers have investigated combinations of clinical features such as age, signs and symptoms as clinical predictors of the different stages of SIS pathology.

In a large retrospective study Litaker et al. (2000) used a linear regression analysis model to establish potential associations between signs, symptoms and clinical test results, with the presence of a rotator cuff tear. Double contrast arthography was used as the criterion reference standard. Three factors were found to have significant ($P<0.05$) association with a rotator cuff tear: weakness on external rotation strength testing (two points assigned), aged 65 years old or greater (two points assigned) and reporting night pain (one point assigned) (Litaker et al., 2000). The study was of high quality with a QUADAS score of 10/14 as reviewed by Hegedus et al. (2007). The presence of the three factors or a combined score of four or more created an associated positive LR ratio of 9.84 compared with only 1.93 for an expert diagnosis by a specialist (Table 6). The presence of the three factors or a combined score of four or more was associated with a strong specificity (0.95) and high positive predictive value (0.93) (Litaker et al., 2000). This is the only known study to date to use subjective clinical features in the form of age and the presence of night pain as predictors of rotator cuff tears or SIS. This study suggests specific signs and symptoms in combination may be more accurate at diagnosing rotator cuff tears than a diagnosis drawn from a more general examination or from individual shoulder clinical tests (Dinnes et al., 2003; Litaker et al., 2000).

Murrell and Walton (2001) carried out a large prospective trial comparing 23 clinical tests on patients with and without rotator cuff tears. Surgery was used as the criterion reference standard. The study had a QUADAS score of 5/14 as assessed by Hegedus et al. (2007) and the reviewer commented that the methodology lacked sufficient detail and description (Hegedus et al., 2007). The results revealed that three tests were predictive of a rotator cuff tear: supraspinatus weakness, weakness in external rotation and positive impingement signs (Table 6). When all three tests

were positive or if any two tests were positive and the patient was 60 years of age or older, the post test probability (PTP) was 0.98. If none of the tests were positive the post test probability dropped to 0.05 (Murrell & Walton, 2001).

Few studies have been published since the systematic review by Dinnes et al. (2003) that investigate the accuracy of particular clinical features, signs and symptoms (a clinical examination *per se*) in patients with SIS pathology.

Park et al. (2005) carried out a large prospective trial and used a stepwise logistic regression analysis comparing eight common clinical tests with patients with and SIS pathology (Table 6). The researcher's aim was to determine which tests or combination of the eight tests were the best diagnostic tools for subacromial bursitis, partial thickness and full thickness rotator cuff tears. Surgery was used as the criterion reference standard. The results showed that for the diagnosis of impingement syndrome (results of all three stages of SIS combined) the Hawkins-Kennedy Test, a positive Painful Arc Sign and weakness with the Infraspinatus Test were the best combination of tests. If all three tests were positive the positive LR was 10.56 with a PTP of 0.95 (Park et al, 2005).

The study also found for the diagnosis of full thickness rotator cuff tear the Drop Arm Sign, a positive Painful Arc Sign and weakness with the Infraspinatus Test was the best combination of tests. If all three tests were positive the positive LR was 15.57 and a post-test probability (PTP) of 0.91 (Park et al., 2005). If the patient was aged 60 years of age or older and had all three positive tests the positive LR increased to 28.00 and the PTP to 0.95 (Park et al., 2005). The study was of good quality as scored by Hegedus et al. (2007) with a QUADAS score of 10/14 and was deemed to be the only adequately powered study in the recent systematic review (Hegedus et al., 2007).

Table 5: Summary of the diagnostic accuracy of a clinical examination in diagnosing rotator cuff tears and subacromial impingement syndrome

Study	Pathology	Signs/Symptoms	Score	+ve LR	PTP
(Litaker et al., 2000) 448 subjects Reference Standard- Double contrast arthography QUADAS score 10/14 Specialist shoulder orthopaedic practice	Full and partial rotator cuff tears	Weakness on external rotation (2 points assigned) Aged 65 years or older (2 points assigned) Night pain (1 point assigned)	-Score of 4 points or more -Score of 2 or 3 points -Score of 0-1 point	9.84 1.36 0.23	0.93
(Murrell & Walton, 2001) 400 subjects Reference Standard - Surgery QUADAS score 5/14 Specialist shoulder orthopaedic practice	Full and partial rotator cuff tears	Supraspinatus weakness Weakness with external rotation testing Impingement sign (Neer Sign)	-Three tests are positive -2/3 tests positive & <60yrs -2/3 tests positive & >60yrs -1/3 tests positive & <40yrs -1/3 tests positive & 40-69yrs -1/3 tests positive & >70yrs -None of the tests are positive	Not tested	0.98 0.64 0.98 0.12 0.45 0.76 0.05
(Park et al., 2005) 552 subjects Reference Standard - Surgery QUADAS score 10/14 Specialist shoulder orthopaedic practice	Overall impingement syndrome (SIS) --- Full Thickness Rotator Cuff Tear --- Full Thickness Rotator Cuff Tear	Hawkins-Kennedy Painful Arc Sign Infraspinatus Test --- Drop Arm Sign Painful Arc Sign Infraspinatus Test --- Drop Arm Sign Painful Arc Sign Infraspinatus Test	-If all three tests are positive -If 2/3 tests are positive -If 1/3 tests are positive - None of the tests are positive --- -If all three tests are positive -If 2/3 tests are positive -If 1/3 tests are positive -None of the tests are positive --- If all three tests are positive + patient 60 years or older -If all three tests are positive + patient <60 years	10.56 5.03 0.90 0.17 --- 15.57 3.57 0.79 0.16 --- 28.00 0.09	0.95 0.90 0.63 0.24 --- 0.91 0.69 0.33 0.09 --- 0.95 0.06

In a recent prospective cohort study rotator cuff tear size was investigated to determine the effect on shoulder strength and range of motion (McCabe, Nicholas, Montgomery, Finneran, & McHugh, 2005). Sixty one patients with a confirmed diagnosis of a rotator cuff tear +/- SIS and scheduled for surgery, were randomly assigned for a clinical examination by one of either two experienced orthopaedic physical therapists. There were strict inclusion and exclusion criteria for the study, the physical therapist used a standardized examination to assess shoulder pain, function, range of motion and strength and these clinical findings were compared to the extent of the rotator cuff pathology. The reliability of the strength and movement tests was not determined. The extent of the rotator cuff pathology (presence of tear, tear size and thickness) was documented during arthroscopy by one of either two treating orthopaedic surgeons in the study. The physical therapists were not blinded to the diagnosis of a rotator cuff tear, although the surgeons were blinded to the results of the clinical examination.

The results of the study indicated that tear size was significantly affected by patient age with the mean age for large thickness tears 57$\pm$15 years and the mean for massive tears 62 $\pm$ 9 years. The patient sample as a whole had significant strength deficits compared to the asymptomatic side in all of the tests: abduction strength at 90 degrees, Full Can Test and external rotation strength at 90 degrees of abduction. Marked range of motion losses in shoulder flexion, external rotation at 0 degrees and in abduction at 90 degrees were also observed. Abduction strength deficit at 10° was significantly affected by rotator cuff tear size ($P<0.0001$). Twenty of the 25 patients with large or massive full thickness rotator cuff tears had strength deficits of more than 50% relative to the asymptomatic side with resisted abduction testing at 10 degrees (McCabe et al., 2005).

2.5.4 Summary of the diagnostic accuracy of individual clinical tests and clinical examinations for subacromial impingement syndrome

There were some differences in the methodology of the three systematic reviews that were identified. Both Hughes et al. (2008) and Dinnes et al. (2003) presented sensitivity, specificity, positive and negative LR values, while Hegedus et al. (2007)

only presented either sensitivity or specificity values. Dinnes et al. (2003) also presented 95% confidence intervals on its data which the other two reviews did not present. Hegedus et al. (2007) highlighted a number of clinical tests that only had either a very high specificity or sensitivity. There is the potential for inappropriate diagnostic conclusions if sensitivity or specificity values have wide confidence intervals or if clinician's view the estimates of sensitivity or specificity as single numbers in isolation to quantify a clinical test result finding (Davidson, 2002; Hegedus & Stern, 2009). Using positive and negative LRs to determine the diagnostic accuracy of a clinical test improves the clinical utility and any short comings of both the specificity and sensitivity values (Davidson, 2002; Hegedus & Stern, 2009). Hughes et al. (2008) also had similar strict inclusion criteria by excluding studies that did not used MRI or surgery as the criterion reference standard. All three studies had a clear search strategy, inclusion/exclusion criteria and study evaluation tool.

With respect to individual studies within the review a positive LR ratio >10 was found in the evaluations of the Napoleon, Lift-Off, Belly-Press (Barth et al., 2006) and Drop Arm Tests (Çalis et al., 2000). This suggests that a positive result increases the likelihood that a rotator cuff tear is present. The clinician then has a greater confidence that before doing the test that the rotator cuff tear is present. A negative LR ratio below 0.1 was found in evaluations of the Hawkins-Kennedy (Çalis et al., 2000) and Empty Can Tests (Kim et al., 2006) suggesting that a negative test may reduce the likelihood that a rotator cuff tear is present. None of the results from the study of the clinical tests demonstrating a positive LR ratio >10 or a negative LR ratio <0.1, were found in a second study (Hegedus et al., 2007). A study by Wolf and Agrawal (2001) found a positive LR ratio >10 and a negative LR ratio <0.1 when they investigated the palpation of a supraspinatus deficit (Rent's test). There is a clear consensus from the three systematic reviews of the literature that individual clinical tests for SIS/rotator cuff tears have poor diagnostic accuracy (Dinnes et al., 2003; Hegedus et al., 2007; Hughes et al., 2008). The three systematic reviews also unanimously found that the vast majority of diagnostic accuracy studies for SIS/rotator cuff tears had poor methodological design and were underpowered. The clinical tests in the studies were all completed by medical practitioners (orthopaedic

surgeons or rheumatologists) and almost all were conducted in tertiary or specialist outpatient or hospital settings. No studies currently exist examining the diagnostic accuracy of clinical tests for SIS pathology, including rotator cuff tears in the primary care setting or by non medical specialist clinicians such as physiotherapists.

From the systematic review by Dinnes et al. (2003), the meta-analysis of the literature confirmed that a combination of clinical tests or a clinical examination *per se* may be useful at ruling out a rotator cuff tear (high sensitivity and low negative LR) but is less accurate at detecting a rotator cuff tear when it is present (low specificity and high positive LR).

There is some consensus in the literature that a cluster of subjective and objective features from a clinical examination may be useful in diagnosing SIS and rotator cuff tears. A single high quality and adequately powered study by Park et al. (2005) published since the review by Dinnes et al. (2003) indicates that particular signs and clinical features are accurate in predicting SIS and rotator cuff tears. For the detection of SIS, a patient with a positive Hawkins-Kennedy Test, Painful Arc Sign and Infraspinatus Test had a positive LR of 10.56 (Park et al., 2005). Litaker et al. (2000) also demonstrated positive a LR of 9.84 for weakness on external rotation testing (Infraspinatus Test), night pain and being aged 65 or older for rotator cuff tears. Both studies were of high quality with a QUADAS score of 10/14 as assessed by Hegedus et al. (2007) and a sample size of over 400 patients each. A single study used night pain (Litaker et al., 2000) however, no other studies used subjective clinical features as predictors of SIS or rotator cuff tears.

The results of the reviews also indicated that the presence of a full thickness rotator cuff tear was also significantly affected by the patient's age (Litaker et al., 2000; McCabe et al., 2005; Murrell & Walton, 2001; Park et al., 2005). In the study by Park et al. (2005) when the patient is aged 60 or older and had all three positive clinical tests, the positive LR increased from 15.57 to 28.00 (Park et al., 2005).

Overall, a specialist medical practitioner can use a clinical examination to rule out the presence of a rotator cuff tear using test and combination of clinical signs that have been researched. Recent evidence suggests particular combinations of signs and

clinical features have high positive LRs and may be useful in diagnosing full thickness rotator cuff tears, but further research is needed to the demonstrate these combinations in large, adequately powered studies with clearer methodologies.

2.5.5 Criterion reference standard

A criterion reference standard should identify and rule out the target condition correctly. The most common reference standard diagnostic test against which clinical examination tests of the shoulder are compared, is direct intra-operative arthroscopy or observation during surgery (Hegedus et al., 2007; Hughes et al., 2008). Indirect imaging methods including magnetic resonance imaging (MRI) and diagnostic ultrasound (DUS) have also been used as criterion reference standards in diagnostic accuracy studies; however these methods have varying degrees of accuracy for evaluating shoulder pathology (ACC, 2004; Dinnes et al., 2003; Lewis, 2009).

2.5.5.1 Criterion reference standard for subacromial impingement syndrome

The subacromial injection test (SIT) is the injection of local anaesthetic into the subacromial space and has been advocated as a criterion reference standard for SIS (Çalis et al., 2000; Neer, 1983; Silva et al., 2008; Tennent et al., 2003). Abolition of a patient's impingement symptoms following SIT or ultrasound guided SIT is believed to confirm that the contents of the subacromial space including the SAB is the source of the patient's shoulder pain.

DUS allows a dynamic assessment of the contents of the subacromial space and can visualize the impingement of the SAB during active shoulder movements in SIS patients (Gilbert, 2007; Read & Perko, 1998; van Holsbeeck & Strouse, 1993). In New Zealand, DUS is the imaging technique most commonly used to assess shoulders and rotator cuff tendons and is a valid diagnostic test for diagnosing full thickness rotator cuff tears (ACC, 2004; Dinnes et al., 2003). DUS has been used previously as a criterion reference standard test in diagnostic accuracy studies of the shoulder (Naredo et al., 2002; Read & Perko, 1998).

In a study investigating the use and efficacy of logistic regression analysis in the diagnosis of SIS, DUS was found to have high sensitivity, specificity and overall

accuracy approaching 90% for diagnosing SIS (Stieler, 2002). DUS may be used as a criterion reference standard to assess the diagnostic accuracy of clinical tests for SIS including rotator cuff tears.

2.6 Diagnostic ultrasound

The identification of painful and disabling disorders such as SIS and rotator cuff tears is important in the management of shoulder pain patients. Although many patients with SIS improve with non-surgical treatment such as physiotherapy, those patients that do require surgical management do best if the management plan is implemented as quickly and efficiently as possible (ACC, 2004; Dinnes et al., 2003; Yen et al., 2004; Ziegler, 2004). The findings of the ACC guidelines indicate that along with considering the functional demands of the patient, the detection of a full thickness rotator cuff tear via diagnostic imaging is regarded as a key factor in the decision making process when surgical repair is contemplated (ACC, 2004; Fotiadou et al., 2008; Matava et al., 2005; Williams, Rockwood, Bigliani, & Ianno, 2004; Wu, Dubinsky, & Richardson, 2003).

In a study by Wu et al. (2003) the only statistically significant predictor for requiring surgical intervention was the finding of full-thickness rotator cuff tear (with or without tendon retraction) on DUS. Patients with full thickness rotator cuff tear were 4.3 times more likely to undergo surgery than those with no tears (Wu et al., 2003). There is consensus in New Zealand that early surgical management for a massive rotator cuff tear has the most to offer people with otherwise healthy tissue and who are deemed physiologically young and active (ACC, 2004; Dinnes et al., 2003; Yen et al., 2004). The use of diagnostic imaging in the form of DUS can provide non-medical practitioners with a tool for detecting SIS pathology.

Currently in New Zealand, X-rays and DUS are the imaging techniques available to primary health care providers such as General Practitioners and physiotherapists (ACC, 2004). The plain X-ray is sensitive and specific at detecting fractures in patients with shoulder pain and is recommended for anyone with a clinical suspicion of fracture or dislocation (ACC, 2004; Gilbert, 2007).

DUS is purported to be an excellent tool at imaging soft tissue around the shoulder joint. It has been reported to be able to diagnose a number of soft tissue disorders including: impingement, subacromial bursitis, shoulder joint infections/effusions, bicep tear/subluxation, partial/full thickness and massive rotator cuff tears (Awerbuch, 2008; Dinnes et al., 2003; Gilbert, 2007; Lew, Chen, Wang, & Chew, 2007; Shahabpour, Kichouh, Laridon, Gielen, & De Mey, 2008). Due to the superficial scanning ability, small imaging window and limiting expertise of the practitioner, DUS is often seen only as a screening tool. Diagnostic ultrasound is considered a safe, speedy, portable, non-invasive, low-cost and easily accessible diagnostic tool (Ardic et al., 2006; Awerbuch, 2008; Fotiadou et al., 2008; Gilbert, 2007; Lew et al., 2007).

2.7 Diagnostic accuracy of diagnostic ultrasound in diagnosing subacromial impingement syndrome

2.7.1 Literature review search strategy

A search to identify the diagnostic accuracy of DUS in shoulder pathology was conducted in January 2008. The following electronic databases were searched: MEDLINE via PubMed, MEDLINE via OVID, CINAHL, SPORT-Discus, AMED Allied and Complimentary Medicine, Cochrane Library, PEDro, ProQuest 5000 International, ProQuest Health and Medical Complete, EBSCO Megafile Premier, Science Direct and the World Wide Web via Google.

The search strategy of these databases included terms and keywords related to DUS of the shoulder and diagnostic accuracy studies: shoulder, glenohumeral joint, rotator cuff tendons, impingement, rotator cuff tears, bursitis, diagnostic ultrasound, imaging, diagnostic accuracy, sensitivity, specificity and LRs. The titles and/or abstracts of these citations were reviewed to identify papers specifically detailing diagnostic accuracy of DUS of the shoulder. The search was limited to studies written in or translated to English and using human subjects. The reference lists of each paper were searched to identify other relevant papers.

2.7.1.1 Description and quality of included studies

The results of the search identified a total of 14 cohort studies investigating the diagnostic accuracy of DUS have been published since the end period (October 2001) of the systematic review by (Dinnes et al., 2003) until January 2008 (Table 7).

2.7.1.2 Interventions

There was variability in the frequencies of the transducers used in the studies. All studies used a variable or fixed frequency of 7.5 MHz or more. Nine studies used transducers that exceeded 9 MHz. Only one study exclusively used a transducer with a fixed frequency of 10 MHz or more (Milosavljevic, Elvin, & Rahme, 2005) while another study used a fixed frequency of 10 MHz in comparison to a 7.5 MHz transducer (Changa et al., 2002) and a third study used both a 7 MHz and 10 MHz linear transducer (Yen et al., 2004). All studies except one used a standardized scanning technique and diagnostic criteria (Goldberg, Bruce, Walsh, & Sonnabend, 2003).

2.7.1.3 Outcomes

Studies generally concentrated on the detection of full thickness rotator cuff tears (11/13 studies). Six studies also attempted to differentiate between full or partial thickness rotator cuff tears while seven of the studies presented results on the presence of any rotator cuff tears.

2.7.1.4 Sample details

The 14 studies included a total of 1766 patients with an average sample size of 126. Most sample sizes were generally small with only four studies including at least 100 participants (Goldberg et al., 2003; Milosavljevic et al., 2005; Zehetgruber, Lang, & Wurnig, 2002; Ziegler, 2004).

The majority of studies (9/14) were prospective in design and five were retrospective. The majority of the studies took place in hospital or radiological department settings. The study setting was not reported in one study (Cullen, Breidahl, & Janes, 2007). Only three studies were conducted in office based clinics (Iannotti et al., 2005; Moosmayer & Smith, 2005; Ziegler, 2004) while only one was conducted in a

community setting (Goldberg et al., 2003). Only eight studies gave more than a general indication of the inclusion and exclusion criteria of the study. Most studies (11/14) gave details of the gender distribution and the mean age of the included participants. The mean age of included participants across the studies was 57 years of age. Where it was reported, most studies included a majority of male patients (63% overall).

2.7.1.5 Reference standards

Twelve of the studies employed surgery as the criterion reference standard test. One study used MRI (Ardic et al., 2006) and another study used arthrography (Goldberg et al., 2003). Both were judged in the review by Hegedus et al. (2007) to have an unsuitable criterion reference standard test. Sufficient details to allow replication of the criterion reference standard tests were provided in only six studies (Ardic et al., 2006; Changa et al., 2002; Frei, Chladek, Trc, Kopecny, & Kautzner, 2008; Milosavljevic et al., 2005; Moosmayer & Smith, 2005; Teefey et al., 2004).

The period between the criterion reference standard and the index test (DUS) was judged to be short enough to correctly identify the target condition in eight of the studies. Partial verification bias was present in three of the studies (Changa et al., 2002; Moosmayer, Heir, & Smith, 2007; Moosmayer & Smith, 2005) where only a subset of those undergoing the DUS index test actually underwent the criterion reference standard test. Differential verification bias, where more than one criterion reference standard test was used was not present in any of the studies.

2.7.1.6 Test interpretations

Eight studies explicitly reported that the diagnosis from the index DUS test was blinded from the reference standard test result. Diagnostic review bias (knowledge of the ultrasound result) was present in all of the studies except for two (Milosavljevic et al., 2005; Moosmayer et al., 2007). Three studies did not describe uninterpretable/intermediate results or participant withdrawals (Ardic et al., 2006; Cullen et al., 2007; Moosmayer et al., 2007; Moosmayer & Smith, 2005).

2.7.1.7 QUADAS score

Seven of the studies had a QUADAS score of 10 or more out of 14 and were judged from this review to be of high quality (Hegedus et al., 2007; Whiting et al., 2004).

Table 6: Diagnostic accuracy of diagnostic ultrasound for diagnosing subacromial impingement syndrome pathology: Methodology & Quality

Study	QUADAS score	Type	Subjects	Location of US scan	Reference Standard	Examiners	Ultrasound transducer frequency
(Frei et al., 2008)	8/14	Retrospective	N=20 M=14 F=6 Mean age= 56y	Hospital	Surgery	DUS: two experienced physicians SR: one of four experienced surgeons	Linear transducer 9-13 MHz
(Fotiadou et al., 2008)	8/14	Prospective	N=88 M=47 F=41 Mean age=57y	Hospital	Surgery	DUS: one experienced radiologist SR: one of four experienced surgeons	Linear transducer 8-13 MHz
(Cullen et al., 2007)	9/14	Prospective	N=68 M=46 F=12 Mean age=56y	Not stated	Surgery	DUS: one experienced radiologist SR: not stated	Linear transducer 5-12 MHz
(Moosmayer et al., 2007)	12/14	Prospective	N=58 M=31 F=27 Mean age=52y	Medical centre and hospital	Surgery	DUS: one orthopaedic surgeon SR: one orthopaedic surgeon	Linear transducer 5.5-9.4 MHz
(Iannotti et al., 2005)	11/14	Prospective	N=99 M/F=NS Mean age=NS	Office-Based	Surgery	DUS: physician assistant and nurse-clinician SR: one experienced surgeon	Linear transducer 7.5 MHz
(Milosavljevic et al., 2005)	13/14	Prospective	N=190 M=114 F=71 Mean age=57	University Hospital	Surgery	DUS: one experienced radiologist SR: one of three experienced surgeons	Linear transducer 10 MHz
(Ardic et al., 2006)	10/14	Prospective cross sectional study	N=58 M=31 F=27 Mean age=55.5yr	Research hospital	MRI	DUS: one experienced radiologist	Linear transducer 7.5 MHz and 5 MHz curved array

Study	QUADAS score	Type	Subjects	Location of US scan	Reference Standard	Examiners	Ultrasound transducer frequency
(Moosmayer & Smith, 2005)	8/14	Prospective	N=79 M/F=NS Mean age=54y	Office-based	Surgery	DUS: inexperienced orthopaedic surgeon SR: experienced surgeons	Linear transducer 5.5-9.4 MHz
(Ziegler, 2004)	10/14	Retrospective	N=262 M=173 F=109 Mean age=63y	Office-based	Surgery	DUS & SR: one orthopaedic surgeon	Portable linear transducer 7.5 MHz
(Yen et al., 2004)	11/14	Prospective	N=50 M=26 F=24 Mean age= 63y	Hospital	Surgery	US: one sonographer (consensus by 2 or 3) SR: NS	Linear transducer 7 MHz and 10 MHz
(Teefey et al., 2004)	12/14	Prospective	N=71 No other details	Hospital	Surgery	DUS: one of two radiologists with 10 years experience SR: NS	Linear transducer 7.5 MHz and 9 MHz
(Goldberg et al., 2003)	9/14	Retrospective	N=336 M=194 F=142 Mean age=57y	Community based clinics	Arthrogram	DUS: 109 different radiologists ATG: one of three radiology clinics	Linear transducer 7.5 MHz
(Changa et al., 2002)	9/14	Retrospective	Group 1 N=43 Group 2 N=32 No other details	Hospital	Surgery	DUS: Group1 technician had 5yrs experience. Group 2 radiologist had 10yrsexperience SR:NS	Group 1= Linear transducer 7 MHz Group 2= Linear transducer 10 MHz
(Zehetgruber et al., 2002)	10/14	Retrospective	N=332 M=189 F=143 Mean age=53y	Hospital	Surgery	US: three orthopaedic surgeons SR: two orthopaedic surgeons	Linear transducer 7.5 MHz

NS=not stated SR=who completed the surgery ATG=Arthrogram DUS=who completed diagnostic ultrasound examination M=male F=female N=total number

2.7.2 Results

2.7.2.1 Sensitivity, Specificity, Likelihood ratios for DUS in SIS

For any type of rotator cuff tear, sensitivity ranged from 0.66 to 0.99 and specificity from 0.60 to 0.98. Only two studies out of the total of seven reported sensitivities and specificities of 0.90 or more (Milosavljevic et al., 2005; Yen et al., 2004). Both prospective studies were of high quality scoring 11 or more out of a possible score of 14 on the QUADAS scale. Both studies used a single experienced radiologist operating a modern ultrasound machine with a 10 MHz linear transducer. For any rotator cuff tears, positive LRs ranged from 2.45 to 33.5 and negative LRs from 0.35 to 0.01. Only one study out of the total of seven had a combined positive LR of >10 (15.8) and a negative LR of <0.1 (0.05) (Milosavljevic et al., 2005) (Table 8 and 9).

For full thickness rotator cuff tears, sensitivity ranged from 0.24 to 1.00 and specificity from 0.61 to 1.00. Pooled sensitivity and specificity for the twelve studies was 0.86 and 0.91 respectively. Seven of the studies had a sensitivity and specificity of 0.90 or greater (Changa et al., 2002; Fotiadou et al., 2008; Frei et al., 2008; Milosavljevic et al., 2005; Moosmayer et al., 2007; Zehetgruber et al., 2002; Ziegler, 2004). Three of the studies utilised trained orthopaedic surgeons with limited experience operating the ultrasound machines (Moosmayer et al., 2007; Zehetgruber et al., 2002; Ziegler, 2004). All of the studies except three (office based) were set in a specialised hospital department (Iannotti et al., 2005; Moosmayer & Smith, 2005; Ziegler, 2004). Three of the studies utilised single trained and experienced (5 years plus) radiologists operating a modern ultrasound machine with a 10 MHz linear transducer) (Changa et al., 2002; Fotiadou et al., 2008; Milosavljevic et al., 2005).

For full thickness rotator cuff tears positive LRs ranged from 0.61 to >98 and negative LRs from 1.25 to 0.00. Seven of the studies had a combined positive LR of >10 and a negative LR of < 0.1 (Changa et al., 2002; Fotiadou et al., 2008; Frei et al., 2008; Milosavljevic et al., 2005; Moosmayer et al., 2007; Zehetgruber et al., 2002; Ziegler, 2004). From recent evidence a positive DUS result is very good at ruling in a full thickness rotator cuff tear while a negative DUS result is very good at ruling out a full thickness rotator cuff tear. With the high sensitivity and specificity and excellent LR

results, a positive US scan would be highly confirmatory and diagnostic of a full thickness rotator cuff tear.

For detection of partial thickness rotator cuff tears, sensitivity ranged from 0.70 to 0.94 and specificity from 0.83 to 0.98. The pooled sensitivity and specificity for the five studies was 0.82 and 0.92 respectively. Only one study had both sensitivity and specificity greater than 0.90 (Ziegler, 2004). This study scored 10/14 on the QUADAS scale and had a large sample size of 262 participants. One single trained orthopaedic surgeon carried out both the ultrasound and surgery using a portable linear 7.5 MHz transducer. Because the same individual performed the physical examination, ultrasound, and surgery, there is the potential of interpretation bias.

For detection of partial thickness rotator cuff tears, LRs ranged from 4.1 to 40 and negative LRs from 0.06 to 0.36. The single study had a combined positive LR of over 10 (23.5) and a negative LR of 0.1 (0.06) or less (Ziegler, 2004). The low negative LR ratio also indicates that a negative US result will be very good at ruling out a partial thickness rotator cuff tear (Ziegler, 2004). Recent evidence suggests that DUS has strong sensitivity and specificity for the detection of partial thickness rotator cuff tear. With a strong clinical suspicion of a partial thickness rotator cuff tear, a positive DUS scan will assist the clinician in diagnosing the injury. A DUS scan is not as effective in screening for partial thickness rotator cuff tears compared with full thickness rotator cuff tears.

Table 7: Diagnostic accuracy of diagnostic ultrasound for rotator cuff (RC) tears: Sensitivity and specificity

Study	Any RC tears Sensitivity	Specificity	Full RC tears Sensitivity	Specificity	Partial RC tears Sensitivity	Specificity
(Frei et al., 2008)	-	-	1.00	0.9	-	-
(Fotiadou et al., 2008)	-	-	0.98	1.00	0.87	0.90
(Cullen et al., 2007)	-	-	0.89	1.00	0.79	0.94
(Moosmayer et al., 2007)	0.66	0.95	1.00	0.97	-	-
(Iannotti et al., 2005)	-	-	0.88	0.82	0.70	0.83
(Milosavljevic et al., 2005)	0.95	0.94	1.00	0.91	0.80	0.98
(Ardic et al., 2006)	0.98	0.60	-	-	-	-
(Moosmayer & Smith, 2005)	0.67	0.98	0.77	0.98	-	-
(Ziegler, 2004)	0.99	0.86	0.96	0.94	0.94	0.96
(Yen et al., 2004)	0.95	0.90	-	-	-	-
(Teefey et al., 2004)	0.97	0.67	0.98	0.80	-	-
(Goldberg et al., 2003)	-	-	0.24	0.61	-	-
(Changa et al., 2002) Group 1= Group 2=	 - -	 - -	 0.52 0.92	 0.92 1.00	 - -	 - -
(Zehetgruber et al., 2002)	-	-	0.98	0.93	-	-
(Dinnes et al., 2003) meta-analysis Current review pooled data	- 0.88	- 0.84	0.87 0.86	0.96 0.91	0.67 0.82	0.94 0.92

Table 8: Diagnostic accuracy of diagnostic ultrasound: Likelihood ratios (LR) for detection of full thickness rotator cuff tears

Study	QUADAS score	Positive LR	Negative LR
(Changa et al., 2002)	9/14	>92	0.08
(Fotiadou et al., 2008)	8/14	>98	0.02
(Frei et al., 2008)	8/14	10	0.00
(Moosmayer et al., 2007)	12/14	33.3	0.00
(Milosavljevic et al., 2005)	13/14	11.1	0.00
(Zehetgruber et al., 2002)	10/14	14	0.02
(Ziegler, 2004)	10/14	16	0.04

2.7.2.2 Summary of results

In summary the results demonstrated some evidence for the use of DUS to detect any rotator cuff tears (Milosavljevic et al., 2005; Yen et al., 2004). Very good evidence currently exists to recommend the use of DUS for the detection of full thickness rotator cuff tears. With its strong sensitivity, specificity and LRs, DUS can be recommended as both an initial screen to rule out full thickness rotator cuff tears with a negative DUS result, and as a confirmatory test to rule in the diagnosis with a positive DUS result. Six of the recent DUS studies also demonstrated a combined positive LR of 10 or more and a negative LR of 0.1 or less for the detection of full thickness rotator cuff tears (Changa et al., 2002; Fotiadou et al., 2008; Frei et al., 2008; Milosavljevic et al., 2005; Moosmayer et al., 2007; Zehetgruber et al., 2002; Ziegler, 2004). The evidence for the use of DUS to accurately detect partial thickness rotator cuff tears is not as conclusive compared to full thickness rotator cuff tears. Only one DUS study demonstrated a combined positive LR of >10 and a negative LR of <0.1 for the detection of partial thickness rotator cuff tears (Ziegler, 2004).

2.7.3 Diagnostic ultrasound compared to magnetic resonance imaging

Five of the studies also compared DUS with MRI (Changa et al., 2002; Fotiadou et al., 2008; Frei et al., 2008; Iannotti et al., 2005; Teefey et al., 2004) (Table 10).

Table 9: Diagnostic accuracy: Diagnostic Ultrasound versus Magnetic Resonance Imaging

Study	Any RC tear Sensitivity	Specificity	Full RC tear Sensitivity	Specificity	Partial RC tear Sensitivity	Specificity
(Changa et al., 2002) Group 1= Group 2=	-	-	0.52 DUS 0.87 MRI *0.92 DUS *0.96 MRI	0.92 DUS 1.00 MRI 1.00 DUS 0.86 MRI	-	-
(Fotiadou et al., 2008)	-	-	*0.98 DUS *0.98 MRI	*1.00 DUS *1.00 MRI	*0.87 DUS *0.87 MRI	*0.90 DUS *0.90 MRI
(Frei et al., 2008)			1.00 DUS 0.92 MRI	0.90 DUS 1.00 MRI	-	-
(Iannotti et al., 2005)	-	-	*0.88 DUS *0.95 MRI	*0.83 DUS *0.87 MRI	*0.70 DUS *0.73 MRI	*0.83 DUS *0.85 MRI
(Teefey et al., 2004)	*0.97 DUS *1.00 MRI	*0.67 DUS *0.67 MRI	*0.98 DUS *1.00 MRI	*0.80 DUS *0.68 MRI	-	-

* No significant difference between DUS and MRI found -denotes not researched

2.7.4 Results

2.7.4.1 Sensitivity and specificity of DUS versus MRI

One study demonstrated comparable findings between DUS and MRI for the detection of any rotator cuff tear with strong sensitivity and specificity (Teefey et al., 2004). Arthroscopy was used as the criterion reference standard.

Ultrasound sensitivity was 0.97 and specificity 0.67. MRI sensitivity was 1.00 and specificity 0.67. There was no significant difference between DUS and MRI for the detection of any rotator cuff tear. The prospective study by Teefey et al. (2004) was of high quality (12/14 QUADAS) and the 7.5 and 9.0 MHz ultrasound linear transducer was operated by one of two radiologists with over 10 years US experience.

All five studies demonstrated comparable findings between DUS and MRI for the detection of full thickness rotator cuff tears (Changa et al., 2002; Fotiadou et al., 2008; Frei et al., 2008; Iannotti et al., 2005; Teefey et al., 2004). Surgery or arthroscopy was used as the criterion reference standard in each of the studies. Ultrasound sensitivity ranged from 0.88 to 1.00 and specificity from 0.80 to 1.00. MRI sensitivity ranged from 0.90 to 1.00 and specificity from 0.68 to 1.00. There was no significant difference for the sensitivity values of DUS and MRI for the detection of full thickness rotator cuff tears in four of the studies. A significant difference was found between DUS and MRI values in one group where the US was operated by a technician with only five years experience (Changa et al., 2002).

There was no significant difference for the specificity values of US and MRI for the detection of full thickness rotator cuff tears in four of the five studies. A perfect specificity of 1.00 for both US and MRI was reported with in one study indicating both imaging modalities are accurate at ruling in full thickness rotator cuff tears (Fotiadou et al., 2008). Generally, for the detection of full-thickness rotator cuff tears, DUS and MRI both had a very high sensitivity and a moderately high specificity.

Two studies demonstrated comparable findings between DUS and MRI for the detection of partial rotator cuff tears (Fotiadou et al., 2008; Iannotti et al., 2005).

Ultrasound sensitivity ranged from 0.70 to 0.87 and specificity from 0.83 to 0.90. MRI sensitivity ranged from 0.73 to 0.87 and specificity from 0.85 to 0.90. There was no significant difference for the sensitivity and specificity values of DUS and MRI for the detection of partial thickness rotator cuff tears in both studies (Fotiadou et al., 2008; Iannotti et al., 2005). Generally, for the detection of partial-thickness rotator cuff tears, DUS and MRI both had a strong sensitivity and specificity.

2.7.4.2 Summary of diagnostic ultrasound compared to magnetic resonance imaging

In summary the results demonstrated similar or comparable accuracy for the use of DUS and MRI to diagnose rotator cuff tears. Good evidence exists to recommend the use of DUS for the diagnosis of full thickness rotator cuff tears. With its strong sensitivity and specificity DUS can be recommended as both an initial screen to rule

out full thickness rotator cuff tears with a negative DUS result and as a confirmatory test to rule the diagnosis in with a positive DUS result.

2.7.4.3 Diagnostic ultrasound for subacromial bursitis

While the diagnostic accuracy and clinical utility for the use of DUS for diagnosing rotator cuff tears is well established, there are very few studies assessing the reliability, validity or diagnostic accuracy of DUS for diagnosing subacromial bursitis and SIS (Awerbuch, 2008).

Some authors believe fluid imaged on DUS or MRI in the SAB is an important feature in the diagnosis of subacromial bursitis (Bureau, Beauchamp, Cardinal, & Brassard, 2006; Farin, Jaroma, Harju, & Soimakallio, 1990; van Holsbeeck & Strouse, 1993) while other authors dispute the importance of this feature (O'Connor, Rankine, & Gibbon, 2005; Schmidt, Schmidt, Schicke, & Gromnica-Ihle, 2004). The DUS observation of bunching of the SAB during movement of the shoulder has been used as a criterion reference standard to diagnose SIS. It is thought that bunching is indicative of mechanical compression of the SAB by the overlying coracoacromial arch (Awerbuch, 2008; Read & Perko, 1998; Shahabpour et al., 2008).

In a study by Bureau et al. (2006), SIS patients were examined dynamically using DUS. The results showed that the SAB can be visualized being impinged and the humeral head migrating superiorly during abduction and flexion shoulder movement.

The term 'subacromial bursitis' has become a descriptor for the SAB being judged by the sonographer/radiologist to contain excessive fluid or thickened and being the source of patient's shoulder pain (Awerbuch, 2008; Gilbert, 2007). There are reports of high incidence of fluid being present in the SAB in asymptomatic shoulders and asymptomatic individuals (Awerbuch, 2008; Naranjo et al., 2002). In a recent study the thickness of the SAB was measured using DUS in patients with painful shoulders and in the same patient's asymptomatic shoulder. The SAB was measured from the superficial peribursal fat to the upper margin of the supraspinatus and a statistically significant association ($p<0.0001$) between the symptomatic shoulder (1.27mm mean SAB thickness) and the asymptomatic side (0.75 mean SAB thickness) was reported (Tsai et al., 2007). The authors argued that even though 2mm is thought to be the

normal SAB thickness, the key finding should be the increased SAB thickness in the symptomatic versus the asymptomatic shoulder as an indicator of SIS (Tsai et al., 2007).

Further research is needed to determine the correct assessment method and definition of SIS and subacromial bursitis, as well as higher quality studies to assess the validity and diagnostic accuracy of DUS in diagnosing subacromial bursitis and SIS in shoulder pain patients. The use of an ultrasound guided SIT should also be considered to determine if a thickened or fluid filled SAB is the actual source of the patient's shoulder pain.

3 Aim of the study

This exploratory study focuses on the diagnostic accuracy of a clinical examination carried out by physiotherapists in a primary care setting to diagnose the particular pathological stages of SIS. The overall aim of the study was to:

> measure the diagnostic accuracy of a variety of components of a clinical examination (age, history, symptoms, clinical tests) in respect to the presence of SAB fluid/bunching (subacromial bursitis), partial thickness rotator cuff tears and full thickness rotator cuff tears in the primary care setting (private practice physiotherapy clinics).

4 Methods

4.1 Patient selection and study design

Fifteen physiotherapists in private practice in Auckland, New Zealand who regularly refer patients for shoulder DUS scans were recruited (Appendix two). These physiotherapists have or are undergoing post graduate qualifications in musculoskeletal physiotherapy or manual therapy. All fifteen of the physiotherapists participated in a one hour pre-study instruction and training tutorial, to train them in the study's standardized clinical examination. Consecutive, self-referred, adult (>18 years) subjects, presenting for the first time with new-onset shoulder pain at private practice physiotherapy clinics were prospectively included into the study. The spectrum of subjects was representative of patients who would receive the clinical examination in the primary care setting. All subjects were funded by the Accident Compensation Corporation insurance scheme.

The study began in July 2008 and ran until March 2009. There were clear inclusion and exclusion criteria and all subjects read information sheets and signed informed consent forms (Appendix three). The assessing physiotherapist completed the standardized clinical examination for each subject. This included subjective history questions, active and passive shoulder movement tests and eleven SIS tests (Appendix four). Demographic characteristics with respect to age, gender, date on onset of shoulder pain and dominant hand for all subjects were recorded on the data collection form. The study was approved by the Northern Y Health and Research Committee (Reference: NTY/07/11/123) and the Auckland University of Technology Ethics Committee. Results from the clinical examination were posted to the lead researcher on the completion of the clinical examination. Subjects were referred to have a DUS immediately following the clinical examination at one of two Horizon Radiology clinics in Auckland (Figure 8).

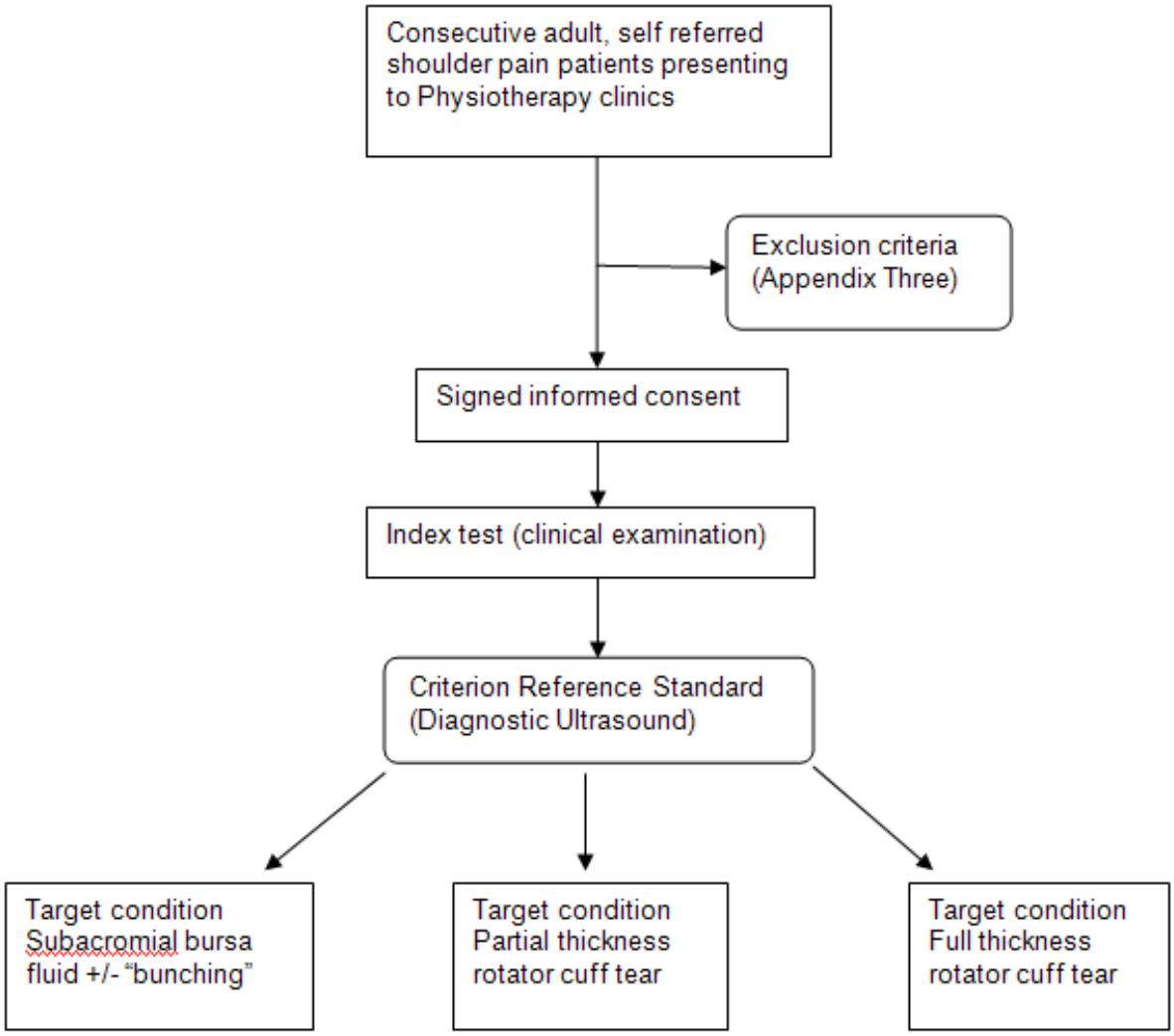

Figure 8: Flow chart of the study, n=38

4.2 Clinical examination

After reviewing the literature (section 2.5), the decision as to which specific subjective and objective signs, symptoms and tests were chosen for this research was based on proven diagnostic accuracy and the test's actual use within the New Zealand clinical setting. Efforts were also made to use clinical tests which have research supporting the various combinations of these tests. Subjective phenomena were also included on the recommendation of two orthopaedic surgeons.

The sequence for the physiotherapist in the clinical examination was as follows:

1. Seven dichotomous subjective questions were asked and were marked present or absent on the clinical examination form. These subjective features were: The presence of night pain where the patient cannot stay asleep because of shoulder pain, the presence of subacromial crepitus since the current shoulder pain developed, the presence of shoulder pain with overhead activities, the inability to lift a weight above shoulder level, if the presence of shoulder pain was due to a specific episode of trauma, if the presence of shoulder pain was from no history of trauma but instead a gradual onset.

2. Two active movement tests, the Drop Arm Sign and Painful Arc Sign were evaluated and were recorded as positive or negative (Appendix 5).

3. Active and passive ranges of motion tests were tested for all movements of the shoulder. The movements were evaluated and recorded as normal, restricted, painful or both restricted and painful. Internal rotation was measured with hand up the back and external rotation in neutral with the hand at the side of the patient.

4. Six individual rotator cuff integrity tests were evaluated: the Empty Can Test, Infraspinatus Test, External Rotation Lag Sign, Bear-Hug Test, Hornblower's Sign, and Speed's Test (Appendix 5).

5. The three impingement tests, Neer Sign, Hawkins-Kennedy Test and Horizontal Adduction Test were evaluated. All clinical examination tests were performed with the patient standing, and test results were recorded as either positive or negative (Appendix five).

4.3 Diagnostic ultrasound evaluation

All subjects received a DUS scan by one of two experienced sonographers with more than 30 years combined experience in musculoskeletal sonography and who

routinely scanned shoulders. A standardized DUS scan was completed on both shoulders using a Philips HD11 ultrasound machine using a 5-12 MHz, 50mm broadband linear array (Appendix six) (Lew et al., 2007; Papatheodorou et al., 2006). The DUS scan took place within three weeks of the clinical examination and all results were verified by a Radiologist. The results from the DUS scan stood as the criterion reference standard. The sonographers were blinded to the results of the clinical examination and the study subjects were instructed by the physiotherapist not to communicate any information regarding the clinical examination or the side of the symptomatic shoulder to the sonographers during the DUS scan.

A standardized diagnostic criterion for pathology from the DUS scan was used (Teefey et al., 2004; Tsai et al., 2007; van Holsbeeck & Strouse, 1993). The presence of SAB fluid/bunching was diagnosed if any fluid was seen within the SAB or the bursa was seen as thickened with parallel echogenic interfaces with a readily hypoechoic space centrally. The SAB was visualized during the dynamic examination to check for bunching of the SAB during flexion and abduction active movement and the results were recorded (Figure 9). Because a subacromial injection test (SIT) was not utilized to evaluate if the fluid in the SAB was the source of the subject's pain, the diagnosis of "subacromial bursitis" could not be given by the sonographers.

A partial thickness rotator cuff tendon tear was diagnosed if a hypoechoic area or a mixed hypoechoic or echogenic defect incompletely traversing the tendon was observed. The defect may be visualized extending to the articular or bursal surface or as a contour defect of the sub deltoid fat plane, but not extending medial to the junction of the humeral head and greater tuberosity (Figure 10).

A full thickness rotator cuff tendon tear was diagnosed if there was complete absence of the tendon, or an anechoic or hypoechoic defect of non-fibrillar tissue extending from the articular to the bursal surface or a contour defect of the sub deltoid fat pad extending medial to the junction of the humeral head and greater tuberosity was visualized (Teefey et al., 2004).

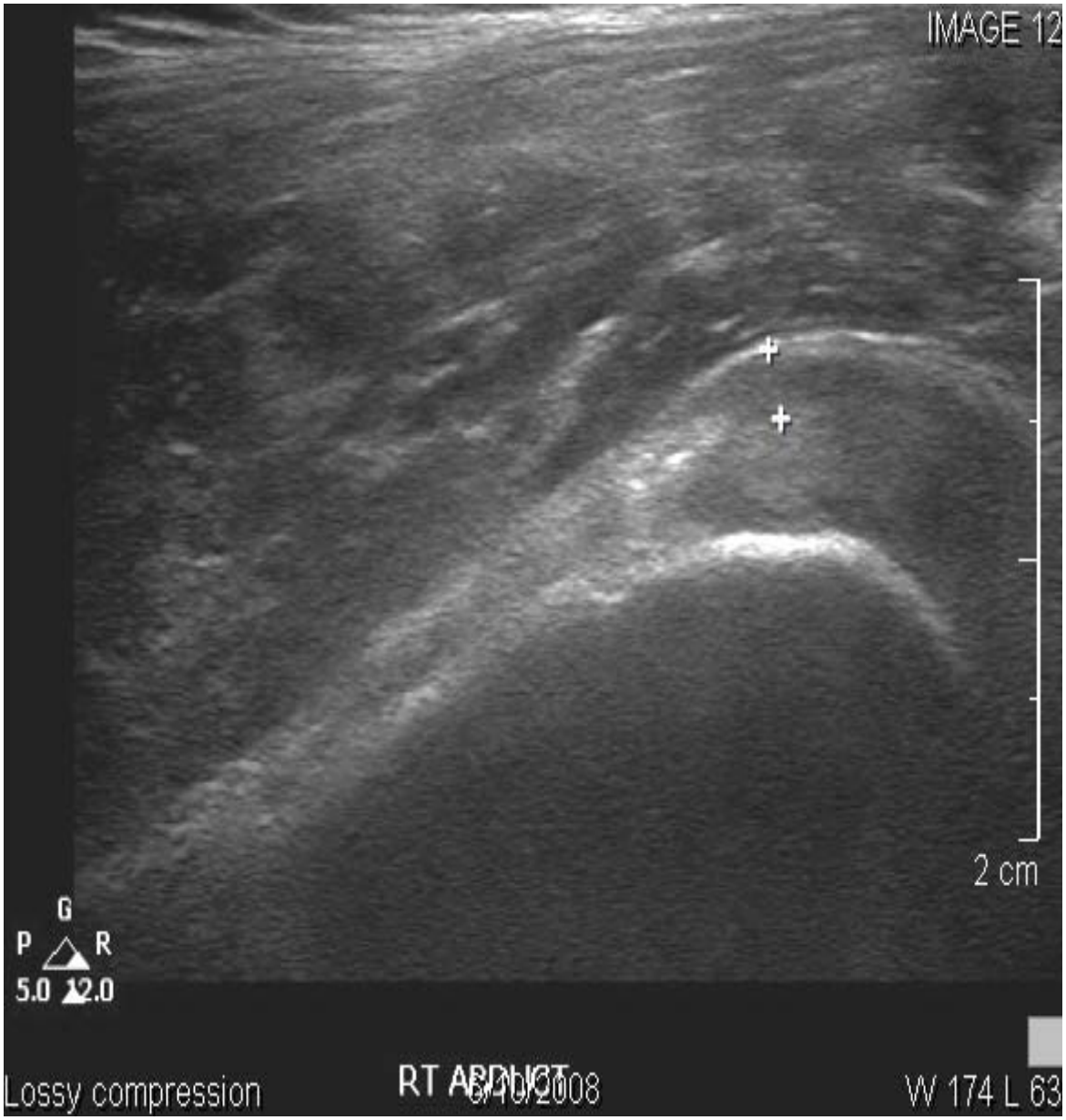

Figure 9: Fluid filled SAB with bunching causing impingement during abduction
(From a patient in the current study, Horizon Radiology, Auckland, New Zealand).

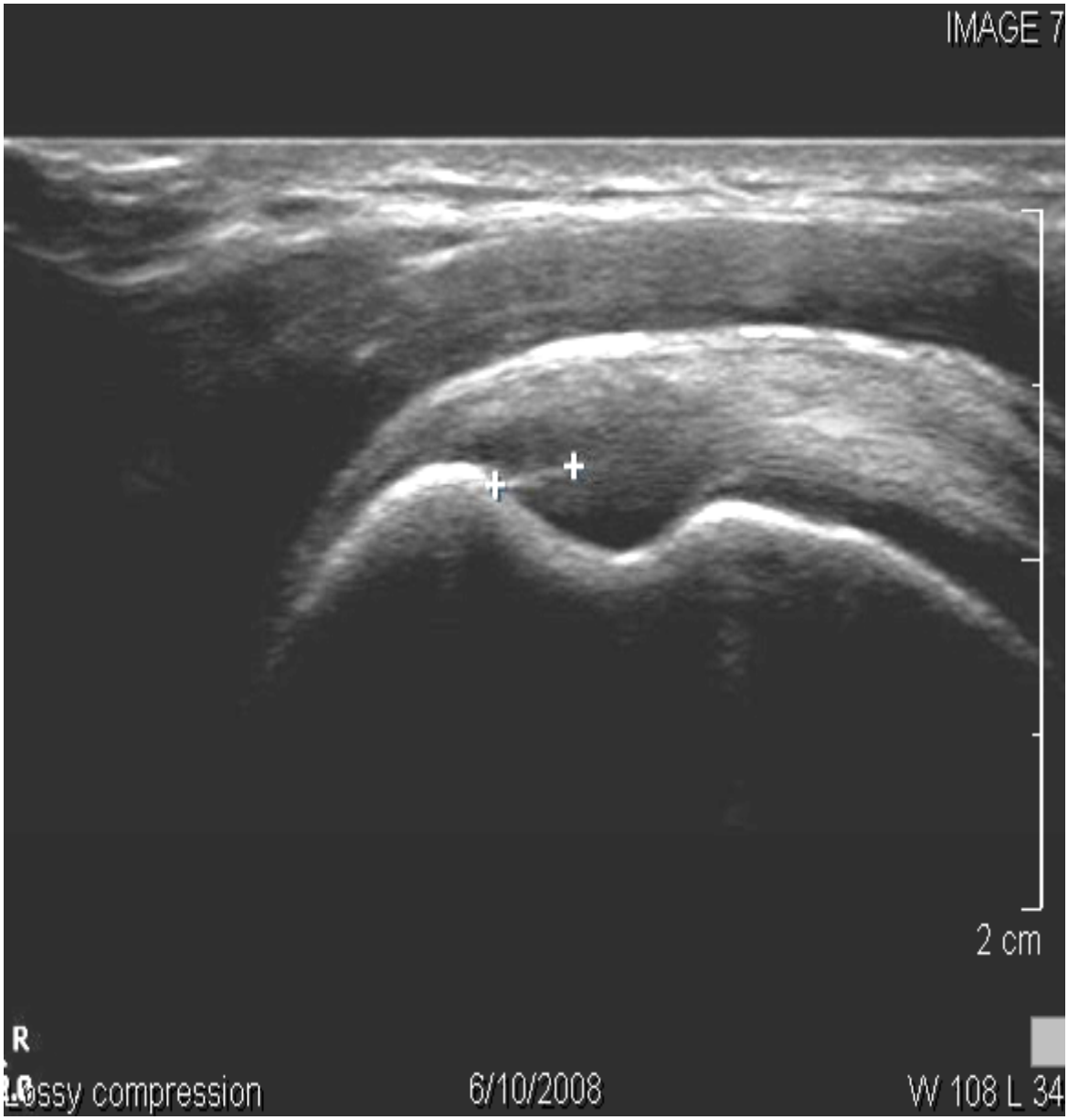

Figure 10: Partial thickness tear of the supraspinatus tendon
(From a patient in the current study, Horizon Radiology, Auckland, New Zealand)

4.4 Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 16.0 statistical software (Chicago, IL). Sensitivity, specificity, positive LR and negative LR were calculated using a DAG-stat Excel worksheet (Mackinnon, 2000). The respective 95% confidence intervals were also calculated.

Individual variables from the clinical examination were tested for their association with the DUS criterion reference standard using Pearson Chi-Squared Exact test. The alpha level was set at $P \leq 0.05$. A number of variables were retained as potential predictors for use in the logistic regression analysis to determine the most accurate set of clinical examination items for diagnosing SIS and the individual pathological stages of SIS. Because many of the independent variables examined in the univariate analyses are associated with one another, a stepwise multiple regression analysis (*P* to enter set at 0.15, *P* to remove set at 0.20) was undertaken to enable estimation of the odds ratios at each level of the predictor variable when adjusted for other variables in the model. A more liberal *P* value was utilized to avoid eliminating potentially meaningful variables during the initial screening process. The classification cut-off value was set at 0.5. The Nagelkerke R Square was calculated and this shows the percentage of variation in the outcome variable explained by the model (Park et al., 2005; Sutlive et al., 2008).

5 Results

5.1 Patients

Of the 38 subjects recruited into the study 23 (60.53%) were male and 15 (39.47%) females. The average age of the sample was 45 ± 12.5 years of age (range 21-80). There were no patient drop outs, withdrawals or uninterpretable results.

5.2 Clinical examination results

The clinical examination findings were compared with the DUS reference standard results. Clinical examination findings are listed in Tables 11, 12, and 13.

Table 10: Subjective clinical examination question results for all subjects of subacromial impingement syndrome n=38

Subjective clinical examination variable	% positive	n
Night pain-cannot stay asleep because of shoulder pain	78.9%	30
Presence of subacromial crepitus since shoulder pain developed	55.3%	21
Shoulder pain with overhead activities	94.7%	36
Unable to lift a weight above shoulder level	65.8%	25
A specific episode of trauma causing the current episode of shoulder pain	81.6%	31
Shoulder pain with no history of trauma but instead a gradual onset of pain	18.4%	7

Table 11: Results for clinical tests for all subjects of subacromial impingement syndrome n=38

SIS test	% positive	n
Drop Arm Sign	15.8%	6
Painful Arc Sign	76.3%	29
Empty Can Test	81.6%	31
Infraspinatus Test	31.6%	12
External Rotation Lag Sign	10.5%	4
Bear Hug Sign	28.9%	11
Hornblower's Sign	23.7%	9
Speed's Test	13.2%	5
Neer Sign	59.0%	23
Hawkins-Kennedy Test	73.7%	28
Horizontal Adduction Test	28.9%	11

Table 12: Results for active and passive range of motion tests for all subjects of subacromial impingement syndrome n=38

Movement	Active		Passive	
	pain	restricted	pain	restricted
Abduction	100%, (38/38)	60.5%, (23/38)	78.9%, (30/38)	47.4%, (18/38)
Flexion	78.9%, (30/38)	78.9% (30/38)	71.1%, (27/38)	34.2%, (13/38)
External rotation	31.6%, (12/38)	13.2% (5/38)	38.5%, (15/38)	15.8%, (6/38)
Internal rotation	60.5%, (23/38)	42.1% (16/38)	55.3%, (21/38)	15.8%, (6/38)
Extension	10.5%, (4/38)	5.3% (2/38)	5.3%, (2/38)	0%, (0/38)
Horizontal adduction	50%, (19/38)	13.2% (5/38)	26.3%, (10/38)	2.6%,(1/38)

5.3 Diagnostic ultrasound scan findings

All 38 patients underwent a DUS scan of the painful shoulder. The majority of patients (63.16%) had the presence of fluid/bunching of the SAB (Table 14).

Table 13: Diagnostic Ultrasound findings of subjects n=38

DUS findings	% positive	n
No detectable abnormal findings	10.52	4
Isolated full thickness supraspinatus tendon tear	10.52	4
Isolated partial thickness supraspinatus tendon tear	13.16	5
Presence of fluid/bunching of the SAB	44.72	17
Presence of fluid/bunching of the SAB + partial thickness supraspinatus tendon tear	13.16	5
Presence of fluid/bunching of the SAB + full thickness supraspinatus tendon tear	2.64	1
Presence of fluid/bunching of the SAB + partial thickness supraspinatus tendon tear + partial thickness bicep tendon tear	2.64	1
Full thickness biceps tendon tear + full thickness supraspinatus tendon tear	2.64	1

5.4 Correlation between clinical examination and diagnostic ultrasound findings

5.4.1 Diagnostic values for all the three pathological stages of subacromial impingement syndrome

A number of significant correlations were present between the clinical examination and DUS for all three pathological stages of SIS. Painful active abduction shoulder range of motion (ROM) was positive in all cases of SIS, while having shoulder pain with overhead activities was positive in nearly 95% of cases of SIS (Table 12, 13, 14). The Drop Arm Sign (P<0.02), Painful Arc Sign (P<0.02) and External Rotation Lag Sign (P<0.01) were all significantly associated with any stage of SIS (Table 15). Night pain and pain with overhead activities both had sensitivity of 0.9167 (95% CI: 0.730-0.990). A history of shoulder pain without trauma and pain of gradual onset had a specificity of 0.9286 (95% CI: 0.661-0.998) and a positive LR of 3.5 (95% CI: 0.47-26.17).

5.4.2 Diagnostic values for the presence of subacromial bursa fluid/bunching

There were strong correlations present between the clinical examination and DUS for the presence of SAB fluid/bunching (Table 16). Night pain (P<0.02) and the External Rotation Lag Sign (P<0.02) were all significantly associated with the presence of fluid/bunching in the SAB. Night pain and pain with overhead activities both had sensitivity of 0.9167 (95% CI: 0.73-0.99). A history of shoulder pain with no history of trauma (gradual onset of pain) both had specificity of 0.929 (95% CI: 0.661-0.998) and a positive LR of 3.5 (95% CI: 0.47-26.17).

Table 14: Overall diagnostic values of the clinical examination of subacromial impingement syndrome regardless of the stage or severity of the subacromial impingement syndrome.

Clinical examination variable/test	*P* Value	Sensitivity	Specificity	+ve LR	-ve LR
Night pain	.175	0.917	0.429	1.60	5.14
Subacromial crepitus	.175	0.583	0.500	1.17	1.20
Pain with overhead activities	.522	0.917	-	0.92	-
Unable to lift weight above shoulder	.522	0.708	0.429	1.24	1.47
Trauma causing shoulder pain	1.00	0.750	0.071	0.81	0.29
No history of trauma	1.00	0.250	0.929	3.50	1.24
Drop Arm Sign	.019*****	0.120	0.786	0.58	0.90
Painful Arc Sign	.019*****	0.833	0.357	1.30	2.14
AROM-Restricted Flexion	.740	0.417	0.500	0.83	0.86
AROM-Painful Flexion	.740	0.708	0.071	0.76	0.24
AROM-Restricted Abduction	.522	0.625	0.429	1.09	1.14
AROM-Painful Abduction	.522	0.368	0.632	1.00	1.00
AROM-Restricted External Rotation	.486	0.125	0.857	0.88	0.98
AROM-Painful External Rotation	.486	0.29	0.643	0.82	0.91
AROM-Restricted Internal Rotation	.227	0.333	0.429	0.58	0.64
AROM-Painful Internal Rotation	.227	0.625	0.429	1.09	1.14
AROM-Restricted Extension	.227	-	0.857	-	0.86
AROM-Painful Extension	.227	0.083	0.857	0.58	0.94
AROM-Restricted Horizontal Adduction	.650	0.083	0.786	0.39	0.86
AROM-Painful Horizontal Adduction	.650	0.500	0.500	1.00	1.00
PROM-Restricted Flexion	.245	0.375	0.714	1.31	1.14
PROM-Painful Flexion	.245	0.708	0.286	0.99	0.98
PROM-Restricted Abduction	1.00	0.417	0.429	0.73	0.73
PROM-Painful Abduction	1.00	0.875	0.357	1.36	2.86
PROM-Restricted External Rotation	-	0.125	0.786	0.58	0.90
PROM-Painful External Rotation	-	0.375	0.571	0.88	0.91
PROM-Restricted Internal Rotation	.740	0.250	0.714	0.88	0.95
PROM-Painful Internal Rotation	.740	0.583	0.500	1.17	1.20
PROM-Restricted Extension	.216	0.368	0.368	0.58	0.58
PROM-Painful Extension	.216	0.083	-	-	1.09
PROM-Restricted Horizontal Adduct	1.00	0.042	-	-	1.04
PROM-Painful Horizontal Adduction	1.00	0.333	0.857	2.33	1.29
Empty Can Test	.728	0.750	0.071	0.81	0.29
Infraspinatus Muscle Test	.728	0.333	0.714	-	0.71
External Rotation Lag Sign	.007*	0.006	0.500	0.12	0.53
Bear Hug Test	.187	0.250	0.643	0.70	0.86
Hornblower's Sign	1.00	0.208	0.714	0.73	0.90
Speed's Test	1.00	0.083	0.786	0.39	0.86
Neer Sign	.129	0.708	0.571	1.65	1.96
Hawkins-Kennedy Test	.129	0.792	0.357	1.23	1.71
Horizontal Adduction Test	.616	0.250	0.643	0.70	0.86

*****denotes significance *P value* ≤ 0.05 - denotes no result found

Table 15: Diagnostic values of the clinical examination for the presence of SAB fluid

Clinical examination variable/test	*P* Value	Sensitivity	Specificity	+ve LR	-ve LR
Night pain	.019*****	0.917	0.427	1.6042	5.143
Subacromial crepitus	.740	0.583	0.500	1.1667	1.200
Pain with overhead activities	.522	0.917	-	0.9167	-
Unable to lift weight above shoulder	.486	0.708	0.429	1.2396	1.469
Trauma causing shoulder pain	.227	0.250	0.929	3.5000	1.238
No history of trauma	.227	0.750	0.071	0.8077	0.286
Drop Arm Sign	.650	0.125	0.786	0.5833	0.898
Painful Arc Sign	.245	0.833	0.357	1.2963	2.143
AROM-Restricted Flexion	.740	0.417	0.500	0.8333	0.857
AROM-Painful Flexion	.216	0.708	0.071	0.7628	0.245
AROM-Restricted Abduction	1.00	0.625	0.429	1.0938	1.143
AROM-Painful Abduction	-	0.368	0.632	1.0000	1.000
AROM-Restricted External Rotation	1.00	0.125	0.857	0.8750	0.980
AROM-Painful External Rotation	.728	0.292	0.643	0.8167	0.908
AROM-Restricted Internal Rotation	.187	0.333	0.429	0.5833	0.643
AROM-Painful Internal Rotation	1.00	0.625	0.429	1.0938	1.143
AROM-Restricted Extension	.129	-	0.857	-	0.857
AROM-Painful Extension	.616	0.083	0.857	0.5833	0.935
AROM-Restricted Horizontal Adduction	.337	0.083	0.786	0.3889	0.857
AROM-Painful Horizontal Adduction	1.00	0.500	0.500	1.0000	1.000
PROM-Restricted Flexion	.503	0.375	0.714	1.3125	1.143
PROM-Painful Flexion	.117	0.708	0.286	0.9917	0.980
PROM-Restricted Abduction	.728	0.417	0.429	0.7292	0.735
PROM-Painful Abduction	1.00	0.875	0.357	1.3611	2.857
PROM-Restricted External Rotation	.650	0.125	0.786	0.5833	0.898
PROM-Painful External Rotation	1.00	0.375	0.571	0.8750	0.914
PROM-Restricted Internal Rotation	1.00	0.250	0.714	0.8750	0.952
PROM-Painful Internal Rotation	.740	0.583	0.500	1.1667	1.200
PROM-Restricted Extension	-	0.368	0.368	0.5833	0.583
PROM-Painful Extension	.522	0.083	-	-	1.090
PROM-Restricted Horizontal Adduct	1.00	0.042	-	-	1.044
PROM-Painful Horizontal Adduction	.268	0.333	0.857	2.3333	1.286
Empty Can Test	.277	0.750	0.071	0.8077	0.286
Infraspinatus Muscle Test	1.00	0.333	0.714	-	0.714
External Rotation Lag Sign	.014*****	-	0.714	1.4762	1.054
Bear Hug Test	.712	0.250	0.643	0.7000	0.857
Hornblower's Sign	.699	0.208	0.714	0.7292	0.902
Speed's Test	.337	0.083	0.786	0.3889	0.857
Neer Sign	.168	0.708	0.571	1.6521	1.959
Hawkins-Kennedy Test	.449	0.792	0.357	1.2315	1.714
Horizontal Adduction Test	.712	0.250	0.643	0.7000	0.857

*****denotes significance *P value* ≤ 0.05 - denotes no result found

5.4.3 Diagnostic values for partial thickness rotator cuff tears

There were weaker correlations present between the clinical examination and DUS for the partial thickness rotator cuff tears that did not reach significance (Table 17). Gender (male) of patient (*P*<0.077), painful active external rotation ROM (*P*<0.06) and painful passive external rotation (*P*<0.077) were all approaching significance. For

partial thickness tears; no history of trauma and the Empty Can Test both had sensitivity of 0.917 (95% C.I: 0.615-0.998). Restricted extension active ROM had specificity of 0.923 (95% C.I: 0.749-0.991), while both restricted horizontal and painful extension passive ROM both had specificity of 0.962 (95% C.I: 0.804-0.99).

Table 16: Diagnostic values of the clinical examination for partial thickness rotator cuff tears

Clinical examination variable/test	*P* Value	Sensitivity	Specificity	+ve LR	-ve LR
Gender of patient (male)	.077	-	-	-	-
Night pain	.704	0.833	0.231	1.08	1.38
Subacromial crepitus	1.00	0.583	0.462	1.08	1.11
Pain with overhead activities	.556	-	0.077	1.08	-
Unable to lift weight above shoulder	.714	0.583	0.308	0.84	0.74
Trauma causing shoulder pain	.395	0.083	0.769	0.36	0.84
No history of trauma	.395	0.917	0.231	1.19	2.77
Drop Arm Sign	.643	0.083	0.808	0.43	0.88
Painful Arc Sign	.689	0.833	0.269	1.14	1.62
AROM-Restricted Flexion	.734	0.500	0.577	1.18	1.15
AROM-Painful Flexion	.704	0.833	0.231	1.08	1.38
AROM-Restricted Abduction	.728	0.667	0.423	1.16	1.27
AROM-Painful Abduction	-	0.684	0.684	2.17	2.17
AROM-Restricted External Rotation	.158	-	0.808	-	0.81
AROM-Painful External Rotation	.060	0.083	0.577	0.19	0.63
AROM-Restricted Internal Rotation	.504	0.333	0.539	0.72	0.81
AROM-Painful Internal Rotation	.481	0.500	0.346	0.76	0.69
AROM-Restricted Extension	.556	-	0.923	-	0.92
AROM-Painful Extension	.287	-	0.846	-	0.85
AROM-Restricted Horizontal Adduction	.158	-	0.808	-	0.81
AROM-Painful Horizontal Adduction	1.00	0.500	0.500	1.00	1.00
PROM-Restricted Flexion	.714	0.417	0.692	1.35	1.19
PROM-Painful Flexion	1.00	0.750	0.308	1.08	1.23
PROM-Restricted Abduction	.489	0.583	0.577	1.38	1.38
PROM-Painful Abduction	.393	0.667	0.154	0.79	0.46
PROM-Restricted External Rotation	.643	0.083	0.808	0.43	0.88
PROM-Painful External Rotation	.077	0.167	0.500	0.33	0.60
PROM-Restricted Internal Rotation	.694	0.333	0.770	1.44	1.15
PROM-Painful Internal Rotation	1.00	0.583	0.462	1.08	1.11
PROM-Restricted Extension	-	0.684	0.684	2.17	2.17
PROM-Painful Extension	1.00	0.083	0.962	2.17	1.05
PROM-Restricted Horizontal Adduct	1.00	-	0.962	-	0.96
PROM-Painful Horizontal Adduction	.453	0.167	0.692	0.54	0.83
Empty Can Test	.395	0.917	0.231	1.19	2.77
Infraspinatus Muscle Test	.268	0.167	0.615	0.43	0.74
External Rotation Lag Sign	1.00	0.083	0.885	0.72	0.97
Bear Hug Test	1.00	0.250	0.692	0.81	0.92
Hornblower's Sign	.233	0.083	0.692	0.27	0.76
Speed's Test	.658	0.083	0.846	0.54	0.92
Neer Sign	.728	0.667	0.423	1.16	1.27
Hawkins-Kennedy Test	.453	0.833	0.308	1.20	1.84
Horizontal Adduction Test	1.00	0.250	0.692	0.81	0.92

*****denotes significance *P value* ≤ 0.05 - denotes no result found

5.4.4 Diagnostic values for full thickness rotator cuff tears

There were strong correlations present between the clinical examination and DUS for the presence of full thickness rotator cuff tears (Table 18). Age > 60 years (P<0.01), Drop Arm Sign (P<0.01) and painful passive internal rotation (P<0.04) were all significantly associated with full thickness rotator cuff tears. The Drop Arm Sign had sensitivity of 0.917 (95% CI: 0.730-0.980). Restricted external rotation active ROM had specificity of 0.903 (95% CI: 0.743-0.980) and a positive LR of 2.95 (95% CI: 0.60-14.48). Both restricted and painful extension active ROM had a respective specificity of 0.968 (95% CI: 0.833-0.999) (positive LR of 4.43, 95% C.I: 0.31-62.54) and 0.903 (95% CI: 0.743-0.980). For painful extension and restricted horizontal adduction passive ROM both had high specificity of 0.936 and 0.968 respectively. Both the ERLS and Speed's (positive LR of 2.95, 95% CI: 0.60-14.48) Test had specificity of 0.903 (95% CI: 0.743-0.980).

5.4.5 Clinical predictors of the different stages of subacromial impingement syndrome

The clinical predictors of the three discrete pathological stages of SIS (subacromial bursitis, partial thickness rotator cuff tear, full thickness rotator tear) were explored to determine if a combination of clinical examination items could improve the diagnostic value of the clinical examination. Potential predictor variables were entered into a multiple logistic regression model to determine the most accurate set of clinical examination items for all the subjects of SIS and for the three discrete pathological stages. The results of the logistic regression analysis are shown in Table 19. Night pain was the only clinical examination feature to predict the presence of SAB fluid/bunching in shoulder pain patients. Male gender was the only clinical examination item to predict a partial thickness rotator cuff tear. No predictors were found for full thickness tears or for all subjects of SIS.

Table 17: Diagnostic values of the clinical examination for full thickness rotator cuff tears

Clinical examination variable/test	*P* Value	Sensitivity	Specificity	+ve LR	-ve LR
Age groups (<35, 36-59, >60)	.008*****	-	-	-	-
Age groups (<59, 60>)	.008*****	-	-	-	-
Night pain	1.00	0.857	0.226	1.11	1.58
Subacromial crepitus	.207	0.286	0.387	0.45	0.54
Pain with overhead activities	1.00	-	0.064	1.07	-
Unable to lift weight above shoulder	.072	-	0.419	1.72	-
Trauma causing shoulder pain	.309	-	0.774	-	0.77
No history of trauma	.309	-	0.226	1.29	-
Drop Arm Sign	.006*****	0.903	0.429	1.60	5.14
Painful Arc Sign	.322	0.571	0.194	0.71	0.45
AROM-Restricted Flexion	.207	0.714	0.613	1.85	2.15
AROM-Painful Flexion	.307	-	0.258	1.33	-
AROM-Restricted Abduction	.401	0.429	0.355	0.66	0.62
AROM-Painful Abduction	-	0.184	0.184	0.23	0.23
AROM-Restricted External Rotation	.223	0.286	0.903	2.95	1.26
AROM-Painful External Rotation	1.00	0.286	0.677	0.89	0.95
AROM-Restricted Internal Rotation	.675	0.286	0.548	0.63	0.77
AROM-Painful Internal Rotation	.401	0.429	0.355	0.66	0.62
AROM-Restricted Extension	.339	0.143	0.968	4.43	1.13
AROM-Painful Extension	1.00	0.143	0.903	1.48	1.05
AROM-Restricted Horizontal Adduction	1.00	0.143	0.871	1.11	1.01
AROM-Painful Horizontal Adduction	.405	0.286	0.452	0.52	0.63
PROM-Restricted Flexion	1.00	-	0.258	1.35	-
PROM-Painful Flexion	1.00	0.714	0.290	1.01	1.02
PROM-Restricted Abduction	.410	0.286	0.484	0.55	0.68
PROM-Painful Abduction	.624	0.714	0.194	0.89	0.68
PROM-Restricted External Rotation	.569	0.286	0.871	2.21	1.22
PROM-Painful External Rotation	.681	0.286	0.581	0.68	0.81
PROM-Restricted Internal Rotation	.650	0.143	0.710	0.49	0.83
PROM-Painful Internal Rotation	.031	0.143	0.355	0.22	0.41
PROM-Restricted Extension	-	0.184	0.184	0.23	0.23
PROM-Painful Extension	1.00	-	0.936	-	0.94
PROM-Restricted Horizontal Adduct	1.00	-	0.968	-	0.97
PROM-Painful Horizontal Adduction	.650	-	0.226	1.29	-
Empty Can Test	.309	-	0.226	1.29	-
Infraspinatus Muscle Test	1.00	0.286	0.677	0.89	0.95
External Rotation Lag Sign	1.00	0.143	0.903	1.48	1.05
Bear Hug Test	1.00	0.286	0.710	0.98	0.99
Hornblower's Sign	1.00	0.286	0.774	1.27	1.08
Speed's Test	.223	0.286	0.903	2.95	1.26
Neer Sign	1.00	0.571	0.387	0.93	0.90
Hawkins-Kennedy Test	.063	0.429	0.193	0.53	0.34
Horizontal Adduction Test	.419	0.143	0.677	0.44	0.79

*****denotes significance *P value* ≤ 0.05 - denotes no result found

Table 18: Logistic regression model analysis of the clinical examination according to the different pathological stages of subacromial impingement syndrome

SIS stage	Final model variables	Final *P* value	Nagelkerke R Square
SAB fluid/bunching	Night pain	0.012	0.300
Partial thickness RC tear	Gender (male)	0.034	0.405
Full thickness RC tear	-	-	-
All subjects of SIS	-	-	-

5.4.6 Results compared to other studies in the literature

No diagnostic accuracy studies for SIS/rotator cuff tears have take place previously in the primary care setting. We were interested to compare our research findings for SIS and rotator cuff tears with other previous studies from tertiary/specialist care settings. Our best sensitivity and specificity values for the impingement and rotator cuff integrity clinical tests had equivalent or greater diagnostic accuracy than previously published studies (Table 20).

Table 19: Results for clinical tests for SIS compared to other studies

Test: Sensitivity & Specificity	Previous Literature Findings: Sensitivity & Specificity
Neer Sign Sensitivity-0.70 Specificity-0.57	0.79 Meta-analysis pooled data (Hegedus et al., 2007) 0.68 (Park et al., 2005) 0.68 (Silva et al., 2008) 0.39 (Bak & Faunø, 1997) 0.53 Meta-analysis pooled data (Hegedus et al., 2007) 0.51 (MacDonald et al., 2000) 0.31 (Çalis et al., 2000) 0.30 (Silva et al., 2008)
Hawkins-Kennedy Test Sensitivity-0.79	0.79 Meta-analysis pooled data (Hegedus et al., 2007) 0.74 (Silva et al., 2008) 0.72 (Park et al., 2005)
Empty Can Test Sensitivity-0.75	0.44 (Park et al., 2005)
Pain Arc Sign Sensitivity-0.83	0.74 (Park et al., 2005) 0.33 (Çalis et al., 2000)
Speed's Test Specificity-0.78	0.56 (Çalis et al., 2000)

Table 20: Results for clinical tests for rotator cuff tears compared to other studies

Test: Sensitivity & Specificity	Previous Literature Findings: Sensitivity & Specificity
Empty Can Test Sensitivity-0.92	0.98 (Kim et al., 2006) 0.89 (Itoi et al., 1999) 0.86 (Leroux et al., 1995) 0.84 (Hertel et al., 1996) 0.81 (Boileau, Ahrens, & Hatzidakis, 2004) 0.78 (Itoi et al., 2006) 0.64 (Litaker et al., 2000) 0.53 (Park et al., 2005) 0.41 (Holtby & Razmjou, 2004)
Painful Arc Test Sensitivity-0.83	0.78 (Park et al., 2005)
Drop Arm Sign Sensitivity-0.92	0.10 (Murrell & Walton, 2001) 0.35 (Park et al., 2005)
Speed's Test Specificity-0.90	0.35 (Leroux et al., 1995) 0.75 (Park et al., 2005)
External Rotation Lag Sign Specificity-0.90	0.98 (Hertel et al., 1996) 0.98 (Walch et al., 1998)

6 Discussion

6.1 Primary care setting

Patients with shoulder pain are a very common presentation to private practice physiotherapy clinics. No studies in the literature have investigated the diagnostic accuracy of clinical tests in a primary care setting. All studies in the literature to date investigating the diagnostic accuracy of SIS and rotator cuff integrity tests have used specialist clinicians (medical physicians, rheumatologists, surgeons) as the examiners of the shoulder pain patients (Dinnes et al, 2003; Hegedus et al, 2007, Hughes et al, 2008). Physiotherapists routinely assess and diagnose shoulder pain patients using a clinical examination. This study is the first to directly investigate correlations between specific symptoms and the diagnostic accuracy of a clinical examination performed by physiotherapists for SIS and rotator cuff tears in the primary care setting.

6.2 Subjective and historical features of the clinical examination

The diagnosis of patients with shoulder pain by clinicians has historically begun with a subjective history that enables the clinician to consider the most likely diagnosis based on a familiar history and set of symptoms. This is followed by a detailed physical examination that includes clinical tests and manoeuvres that are proposed to confirm or reject these initial diagnoses. Subacromial impingement syndrome patients often present with very similar signs and symptoms that can confound the process of making an accurate clinical diagnosis (Awerbuch, 2008; Lewis, 2009; Neer, 1972; Shahabpour et al, 2008; Silva et al, 2008; Williams et al, 2004).

In the current study we examined the most commonly employed subjective and objective signs and symptoms of a clinical examination and their accuracy as diagnostic tools for the three discrete pathological stages of SIS. Night pain, crepitus, and pain and weakness with overhead movement are commonly reported symptoms of SIS patients (ACC, 2004; Litaker et al, 2000). Very few studies have investigated the usefulness of historical and subjective features from a clinical examination for SIS and rotator cuff tears, although some have evaluated the effect of age on rotator cuff

tears (ACC, 2004; Litaker et al, 2000; McCabe et al, 2005; Murrell and Walton, 2001; Neer, 1972; Park et al, 2005).

A number of significant correlations were found for the subjective and historical features of the clinical examination. Night pain (P<0.02) was significantly correlated with the presence of SAB fluid/bunching while being of male gender (P<0.077) while not significant, did approach levels of significance for partial thickness rotator cuff tears. Age has been found to be an important clinical feature in the diagnosis of rotator cuff tears. With increasing age and stages of SIS the rotator cuff tendons degenerate and begin to develop macroscopic tears (Bigliani & Levine, 1997; Matava et al., 2005). In previous studies being aged 60 years of age or older, was significantly associated with full thickness rotator cuff tears (Litaker et al 2000; McCabe et al, 2005; Park et al, 2005). This finding was also found in our study with being aged 60 years or older significantly (P<0.01) associated with full thickness rotator cuff tears.

Our results showed that subjective and historical phenomena from the initial subjective interview were not found to be accurate predictors in diagnosing SIS. No subjective or historical clinical features had either a positive LR of 10 or greater or a negative LR of 0.1 or less.

A history of shoulder pain without trauma demonstrated a high specificity (0.93) and a positive LR of 3.5 for diagnosing SIS as a result of the presence of SAB fluid/bunching. Patients in primary care presenting for assessment with a gradual onset of shoulder pain have a fair likelihood of having SIS and the presence of fluid/bunching in the SAB. One possible explanation for this result is the postural induced overload of the contents of the subacromial space by altered humeral head and scapular kinematics. Superior translation of the humeral head in the glenoid fossa has been hypothesized (Lewis, 2009; Mulligan, 2001; Saharmann, 2001) and recently observed in patients with SIS (Cholewinski et al, 2008). What is apparent is that the cause of SIS is multi-factorial and may not be caused by a single traumatic event. Patients presenting with non-traumatic, gradual onset of shoulder pain should be assessed thoroughly for SIS.

The presence of night pain and pain with overhead movements are common symptoms of SIS (Litaker et al, 2000; Neer, 1972; 1983). The high sensitivity values (>0.90) for these two subjective features found in our study indicate that if these features are not present then the diagnosis SIS may be ruled out (Table 15 & 16). Pain with overhead movement may be explained by impingement of the SAB or pressure ischemia of the rotator cuff tendons during arm movements (Hyvonen, 2003). Although pain levels were not directly measured in this study, it appears from our results that in patients with fluid/bunching in the SAB, pain was a common symptom. Indeed results from the linear regression indicated that night pain (P<0.012) was the single most significant clinical predictor for the presence of fluid/bunching in the SAB. The SAB has been identified as being a major source of shoulder pain in SIS patients due to the presence of inflammatory cells and histological markers (Hyvonen, 2003). Additionally, it has been shown that arm position can cause pressure increases in the subacromial space (Hyvonen, 2003; Lewis, 2009). Subacromial impingement syndrome patients sleeping directly on the affected shoulder or having a large heavy arm hanging against gravity may cause compression or irritation of the inflamed SAB causing night pain. Another possible reason for the night pain is that patients with pain caused by inflammation will tend to be more aware of their pain while at rest or sleeping (Cyriax & Cyriax, 1983).

Being male (P<0.034) was also a significant clinical predictor for having a partial thickness rotator cuff tear. This finding may be explained by the fact that males tend to carry out heavier and more overhead work than females, therefore putting the rotator cuff tendons under larger loads. Indeed it has been shown that male blue-collar workers have a higher incidence of shoulder pain (Anderson-Ingemar et al., 1993; Green et al., 1999).

We believe that further research should be directed toward investigating other historical and subjective features and combining this with objective clinical tests in SIS patients. The subjective phenomena of night pain, pain with overhead movement, shoulder pain with insidious onset (no history of a traumatic episode), being aged over 60 years and being of male gender appears to be strongly associated with SIS.

6.3 Objective signs of the clinical examination

There were a number of significant correlations with respect to objective signs of the clinical examination. The Drop Arm Sign ($P<0.02$), Painful Arc Sign ($P<0.02$) and External Rotation Lag Sign ($P<0.01$) were significantly correlated with all subjects of SIS. The External Rotation Lag Sign ($P<0.02$) was also significantly correlated with the presence of SAB fluid/bunching, while the Drop Arm Sign ($P<0.01$) and pain with passive internal rotation range of motion (ROM) ($P<0.04$) was correlated with full thickness rotator cuff tears. The Drop Arm Sign and External Rotation Lag Sign have previously demonstrated extremely high sensitivity and specificity values in SIS and rotator cuff tear diagnostic accuracy studies (Çalis et al., 2000; Hertel et al, 1996; Walch et al, 1998).

Physiotherapists assess active and passive ROM of the shoulder joint to not only objectively gain ROM measurements but also to examine movement patterns, functional ability and tissue irritability (Bruckner & Kahn, 2001; Magee, 1997; Sahrmann, 2001). The pattern of a capsular loss of movement for adhesive capsulitis has been well documented (ACC, 2004; Cyriax & Cyriax 1983; Kelley, McClure & Leggin, 2009). Few studies have previously evaluated the active and passive ROM tests of the shoulder for SIS and rotator cuff pathology.

The present study included active and passive ROM testing of the shoulder joint as part of the clinical examination to see whether movements were painful or restricted or both. Our findings showed that 100% of patients had painful active abduction ROM. These results correspond well with other studies which demonstrate pain and restriction with abduction range in SIS and rotator cuff tear patients. Pain during abduction movement is thought to be caused by the compression of the subacromial contents (Ardic et al, 2006; McCabe et al, 2005; Naredo et al, 2002; Silva et al, 2008). It is commonly hypothesized that patients with a fluid filled, thickened or inflamed SAB will have pain with compression of the SAB against the coracoacromial arch during overhead arm movements. Patients with rotator cuff tears in the supraspinatus tendon may also experience pain with abduction ROM as this is a prime movement of the supraspinatus musculotendinous unit (Hyvonoen, 2003; Hertel et al., 1996).

Our results also demonstrated restricted passive horizontal adduction and painful passive extension both had high specificity values (>0.95) and a fair-to-moderate positive LR for partial thickness and full thickness rotator cuff tears (Table 17 & 18). The LR values did however have very wide confidence intervals affecting the exact accuracy of the respective LRs. The exact mechanical mechanism behind these results for these movement tests is unknown however passive extension ROM could possibly stretch or elongate painful or damaged anterior structures of the humerus such as the biceps or supraspinatus tendon.

Passive horizontal adduction ROM is exactly the same movement as the Horizontal Adduction Impingement Test, however the passive ROM specificity levels were significantly higher than the impingement test results in other studies (McLaughlin, 1951; Park et al, 2005). The greater specificity value may be explained by the earlier positioning of the passive ROM test in the examination. The passive horizontal adduction movement also stretches the posterior capsule of the shoulder joint and restriction of the posterior capsule has been previously associated with SIS (Laudner, Stanek & Meister, 2006). Our results indicate that certain painful or restricted active and passive abduction, extension and horizontal adduction are clearly more common with SIS and rotator cuff pathology patients.

Recent studies have demonstrated that a clinical examination or combination of signs and clinical features (i.e. age) appear to be able to accurately diagnose full thickness rotator cuff tears. We were particularly interested to see in the current study if a group or cluster of features from a clinical examination is of greater diagnostic value than individual clinical tests alone in accurately diagnosing the discrete stages of SIS (Hegedus et al, 2007, Hughes et al, 2008; Park et al, 2005). We carried out a similar linear logistic regression analysis to Park et al. (2005) to determine the best cluster of clinical predictors. Due to the small sample size in the current study, the only clinical predictor found was night pain for the presence of SAB fluid/bunching and being of male gender for partial thickness rotator cuff tears.

The literature suggests that individual clinical tests for SIS and rotator cuff tears have poor diagnostic accuracy and are not useful in differentially diagnosing specific soft tissue pathologies of the shoulder. The poor specificities and inadequate LR ratios

reflect the inability of these tests be useful in making an accurate diagnosis. Our results support this evidence with no clinical tests in our study displaying a positive LR >10 or a negative LR <0.1. Many of these clinical tests used in practice can be positive in the presence of other shoulder conditions and it is evident that specific clinical tests are unable to accurately assess individual soft tissue structures without influencing other surrounding shoulder tissue structures such as the SAB (Dinnes et al, 2003; Hegedus et al, 2007; Hughes et al, 2008; Itoi et al, 1999; Lewis, 2009, Park et al, 2005; Silva et al, 2008).

6.3.1 Impingement tests

In our study we used the three most common impingement tests: Neer Sign, Hawkins-Kennedy Test and Horizontal Adduction Test to assess for SIS (Hegedus et al, 2007; Park et al, 2005). For all of the three pathological stages of SIS, the overall sensitivity and specificity for the Neer Sign was 0.70 and 0.57 in other studies, while the current study demonstrated a sensitivity value for the Hawkins-Kennedy Test of 0.79 (Table 20). Our results compared very well to the pooled data for sensitivity from the recent meta-analysis of the current literature by Hegedus et al. (2007) and were better than many other studies (Bak & Fauno, 1997; Calis et al, 2000; Hegedus et al, 2007; McDonald et al, 2000; Park et al, 2005; Silva et al, 2008). Impingement tests for all three stages of pathology of SIS in this study had sensitivity and specificity values equivalent to or better than existing studies in the literature. This is a surprising result as the prevalence of SIS is reported to be much higher in the tertiary care setting than in the primary care setting (ACC, 2004; Lewis, 2009). The prevalence is the proportion of people in the sample who have the disorder. If there are more people in the sample with the target condition (as in the tertiary/specialist setting) then the number of true positive clinical test results would be greater and the number of true negative clinical test results lower. This has the effect of increasing the proportion of people who have the disorder who test positive (sensitivity) and increasing the proportion that do not have the disorder that test negative (specificity) (Davidson, 2002).

One possible explanation is the high incidence of mild stage SIS (SAB fluid/bunching or subacromial bursitis) patients in this study compared to patients with partial and

full thickness rotator cuff tears. The results from our study highlight that pain provoking impingement signs can also be used by non-medical practitioners such as physiotherapists in the primary care setting to help screen for all three stages of pathology of SIS and in particular painful SAB fluid/bunching or subacromial bursitis.

Our results also indicate that the severity of the subacromial impingement syndrome may affect the diagnostic accuracy of the individual clinical tests. Park et al. (2005), appears to be the only other study to investigate clinical tests for all three stages of pathology of SIS from subacromial bursitis through to full thickness rotator cuff tears. Our results were similar to those of Park et al., in that, as the severity of SIS increased so did the diagnostic accuracy of the rotator cuff integrity test. For early stage SIS (subacromial bursitis) the pain provocation impingement tests had higher sensitivity (0.70, 0.79) and specificity (0.57, 0.36) values.

6.3.2 Rotator cuff integrity tests

The current study demonstrated that individual rotator cuff integrity tests performed by physiotherapists had either high sensitivity or specificity values for patients with rotator cuff tears. Many of the clinical tests had greater diagnostic values than those demonstrated by other studies previously published. In our study, rotator cuff integrity tests appeared to be more sensitive than specific with the Empty Can Test for partial thickness rotator cuff tears and Drop Arm Sign for full thickness tears demonstrating high sensitivity levels. When sensitivity of a clinical test is high, a negative test rules out the diagnosis (SnNout) (Davidson, 2002). One possible reason for high sensitivity for the Empty Can Test and Drop Arm Sign is that the vast majority of the partial and full rotator cuff tears in our study affected the supraspinatus tendon. The Empty Can Test and Drop Arm Sign are both tests whose anatomical bases were originally designed to stress the integrity of the supraspinatus tendon in isolation from the other rotator cuff tendons (Calis et al, 2000; Leroux, 1995). These results from the current study suggest that a negative Empty Can Test and a negative Drop Arm Sign can rule out supraspinatus tendon tears. In the primary care setting, physiotherapists should routinely perform the Empty Can Test and Drop Arm Sign to help screen for rotator cuff tears specifically to the supraspinatus in SIS patients.

A number of factors could explain these results including pain inhibition and different definitions of a positive clinical test. Weakness caused by pain inhibition rather than true structural weakness of the rotator cuff tendon can complicate a diagnosis of SIS for non-medical practitioners or inexperienced clinicians (ACC, 2004; Lewis, 2009). There is variation in the literature of the definition of a positive test for rotator cuff integrity tests. For the Empty Can Test some authors stated that a positive test is regarded as any weakness less than normal (Murrell and Walton, 2001), or painful on testing (Leroux et al, 1995) while others considered the test positive if the patient gives way because of weakness and/or pain (Park et al, 2005). In our study the Empty Can Test was considered positive if pain and/or weakness caused the patient's arm to give way. Kim et al. (2006) investigated both pain and weakness as signs for a positive test during this test. In the study by Kim et al. strength was determined by manual muscle tests and pain was determined as being present or absent during the test. These authors demonstrated that the presence of both pain and weakness in both full and partial thickness rotator cuff tears produced a strong negative LR ratio indicating a negative Empty Can Test is very good at ruling out a rotator cuff tear (Kim et al, 2006). With rotator cuff integrity tests such as the Empty Can Test, clinicians should routinely compare the strength of the unaffected shoulder as well as recognize that a positive test is one in which both pain and weakness cause the arm to give way (Kim et al, 2006). Future research should investigate differentiating between painful shoulder structures, like the subacromial bursa, that may cause pain inhibition weakness and the true structural damage from a torn rotator cuff. Introducing an ultrasound guided subacromial injection into the subacromial space, as a secondary criterion reference standard, may assist in identifying the true source of pain and cause of the weakness and thus the true diagnostic accuracy of clinical tests (Calis et al, 2000; Kim et al, 2006).

The ability to isolate an individual rotator cuff tendon using specific clinical tests has yet to be verified by any study. In our study the rotator cuff integrity tests, which included Infraspinatus Muscle Test, Hornblower's Sign and Bear-Hug Test all demonstrated poor sensitivity and specificity which was expected as we did not have any of these specific tears in our cohort of patients. It appears that clinical tests for the integrity of the rotator cuff are unable to isolate individual tendon tears and many

lack a valid anatomical basis (Green et al, 2008; Hughes et al, 2008). Physiotherapists should recognise the inability to accurately diagnose individual rotator cuff tears using a positive result from a clinical test. Clinical tests are not specific enough to accurately detect a specific rotator cuff tear without influencing other surrounding shoulder soft tissue structures including the SAB (Frei et al, 2008, Itoi et al, 1999; Lewis, 2009; Silva et al, 2008).

6.4 Diagnostic ultrasound

In our study we chose to use DUS as our criterion reference standard. Dines et al. (2003) conducted a systematic review of the studies investigating the diagnostic accuracy of DUS in detecting rotator cuff pathology. They concluded that DUS is a valid diagnostic test for full thickness rotator cuff pathology. Since then, there have been 14 further studies that have examined the diagnostic accuracy of DUS in detecting rotator cuff pathology. There is general consensus in the literature that there is high diagnostic accuracy of DUS for detecting rotator cuff pathology especially for the diagnosis of a full thickness rotator cuff tear (Changa et al, 2003; Fotiadou et al, 2007; Moosymer et al 2007; Milosevljevic, 2005; Zehetgruber et al, 2002). The evidence for partial thickness tears is less convincing with only one large quality study being published since the review by Dinnes et al. in 2003 (Zeigler, 2004).

The literature review carried out as part of this thesis suggest that there is comparable accuracy between DUS and MRI for the detection of full thickness rotator cuff tears (Changa et al, 2002; Fotiadou et al, 2007; Iannotti et al, 2005; Teefey et al 2007). DUS can be recommended as a diagnostic imaging tool of equal diagnostic accuracy to MRI in diagnosing full thickness rotator cuff tears. DUS is up to 10 times cheaper than MRI in some settings (Dinnes et al, 2003). In New Zealand the average cost for an ACC funded MRI shoulder scan is $1000 and for an ACC funded shoulder DUS $180 (ACC, 2008). DUS also has the advantage of being able to scan patients with metal implants, patients who are claustrophobic and does not expose the patient to ionizing radiation (Ardic et al, 2005; Fotiadou et al, 2007; Gilbert, 2007; Lew et al, 2007). DUS can also compare shoulder disorders to the patient's non-affected side as well as permit dynamic imaging especially in the diagnosis of impingement of the

contents of the subacromial space including SAB bunching (Bureau et al, 2006; Gilbert, 2007; Lew et al, 2007). DUS does have limitations, when compared to MRI, with its poor ability to image the glenoid labrum, shoulder capsule, rotator cuff muscle atrophy, articular cartilage and bone morphological changes (Ardic et al, 2006; Dinnes et al, 2003; Gilbert 2007).

The high diagnostic accuracy of DUS found in this study's review of literature can be attributed to a number of factors, these include improved study design (as demonstrated by high QUADAS scores), improved ultrasound machine technology, operator experience and study setting. It is evident that recent researchers investigating the diagnostic accuracy of DUS for rotator cuff pathology have improved individual study design and have reduced biases and common methodological flaws such as not using a standardized assessment procedure. Other reasons for the improved results are the use of higher resolution (8-12 MHz) linear transducers which have resulted in improved spatial resolution (Cullen et al, 2007; Fotiadou et al, 2007). Along with improved equipment, studies had improved results when utilising experienced radiologists. It was demonstrated that radiologists with at least 10 years of shoulder DUS experience or fellowship trained radiologists improved the diagnostic accuracy of DUS (Changa et al, 2002; Cullen et al, 2007; Fotiadou et al, 2004; Teefey et al, 2004). DUS is very dependent upon the operator, the greater the experience and expertise, the greater the diagnostic accuracy in detecting rotator cuff pathology.

In the current study we used a standardized DUS assessment and diagnosis procedure and scans were completed by one of two sonographers with more than 30 years combined experience. The sonographers were blinded to the results of the clinical examination and the study participants were instructed by the physiotherapist not to communicate any information regarding the clinical examination or the side of the symptomatic shoulder to the sonographers during the DUS scan.

Ultrasonography was performed with a high resolution (5-12 MHz) linear probe. One limitation to our study design was the use of DUS as the criterion reference standard in diagnosing SAB fluid/bunching as opposed to a subacromial injection. The subacromial injection test has the ability to assess if the fluid filled/thickened SAB is

indeed the source of the patient's pain. We only classified patients as having the presence of SAB fluid/bunching rather than a diagnosis of subacromial bursitis.

Most of the recent DUS studies were set in hospitals or radiology clinics. Only one study was set in a community/primary care setting. However this study had a number of design flaws such as not including standardised diagnostic criteria or assessment protocol (Goldberg et al, 2003). Our study is only the second to investigate the diagnostic accuracy of clinical tests of the shoulder using DUS as the criterion reference standard for rotator cuff tears in the primary care setting. It is also the first study to directly use DUS as a criterion reference standard for SAB fluid/bunching being present in SIS. Further studies are needed to validate the use of DUS as a criterion reference standard for subacromial bursitis, rotator cuff tears (partial and full thickness) and SIS in the primary care setting. DUS is the most commonly utilized imaging tool used in New Zealand to assess shoulders for SIS pathology. Currently there is a paucity of evidence demonstrating the diagnostic accuracy of DUS for the SIS pathology of subacromial bursitis and partial thickness rotator cuff by sonographers. The vast majority of DUS shoulder scans in New Zealand are funded by ACC and take place in the primary care setting (ACC, 2008; Gilbert 2007). Validation of DUS in the primary care setting for SIS is urgently needed.

6.5 Limitations and future research

There were several limitations to our study. Firstly we did not investigate the reliability and reproducibility of the clinical examination. There were 15 physiotherapists in different locations who acted as examiners of participants in the study. A one hour long pre-study instruction and training tutorial took place to explain the clinical examination and teach the clinicians the physical tests. Future research investigating the intra- and inter tester reliability of the clinical examination is required. Future research could also assess the diagnostic accuracy of both specialist (medical practitioners, as defined by the ACC Shoulder Guidelines (2004) and non-specialist (physiotherapists) clinicians in diagnosing SIS using a clinical examination with a single cohort of clinical patients. The current ACC guidelines state that a specialist clinician may be able to rule out rotator cuff pathology using a clinical examination

(ACC, 2004). Recent studies have demonstrated that physiotherapists are very capable of undertaking tasks that medical practitioners have traditionally performed in musculoskeletal practice. These roles include the assessing of patients on orthopaedic surgical waiting lists and triaging musculoskeletal patients in the emergency department setting (McClellan, Greenwood & Benger, 2006; Oldmeadow et al, 2007). By assessing the diagnostic accuracy of a clinical examination for SIS and rotator cuff tear patients, and directly comparing a physiotherapist to a medical practitioner, the ability of physiotherapists to be potential specialist clinicians in musculoskeletal practice may be recognised in the future.

The main limitation of our study was the small sample size. Pre-study power calculations estimated a required sample size of 200 patients was needed for the study to be adequately powered (Hegedus and Stern, 2009). Due to time constraints and low patient recruitment, our study was modified to a pilot study with a final sample size of 38. Clearly the small sample size affected the power of this study and reduced the ability to detect statistically significant relationships or correlations. The lack of power affected the specificity, sensitivity, negative LR and positive LR values associated with wide confidence intervals. This gave the respective accuracy values a less precise measure of accuracy than the estimates. Also, the small sample size did not allow the completion of the linear regression analysis to determine the best subjective and objective clinical predictors for the three different pathological stages of SIS. The Nagelkerke R Square values shown in Table 19 also showed a wide percentage of variation in the outcome variables of night pain and male gender. The small sample size of our study limited the value of any predictive logistic modelling however the modelling was completed to help identify potentially valuable variables that could be used in any future clinical prediction rule SIS research. Future studies should use power calculations to determine the exact number of subjects who are needed to prove the accuracy of clinical tests.

Another limitation to our study was the use of DUS as our criterion reference standard. Future research should be directed at investigating the diagnostic accuracy of both subjective features and physical tests for the different stages of SIS in the primary care setting. Consideration should be given to comparing the accuracy of arthroscopy or surgery to the DUS criterion reference standard for SIS and

subacromial bursitis. The use of a SIT should also be considered to investigate if the presence of fluid in the SAB is in fact the source of the patient's shoulder pain.
One limitation of this study was the exclusive use of the Accident Compensation Corporation insurance scheme to fund patients in the study. By having only patients who were included in the study if they had suffered an accident or trauma may have biased our results.

Despite its small sample size and limitations this study is an important addition to the current literature surrounding the diagnostic accuracy of clinical tests for SIS and rotator cuff pathology. This is the first study to use physiotherapists as examiners and to be set in a primary care setting. This study appears to be only the second to use DUS as a criterion reference standard for SIS in the primary care setting. The study is also the first to examine the diagnostic accuracy of historical and subjective clinical features (other than night pain and age) from the clinical examination. The results demonstrated in the current study could be used by future studies as a starting point in the development of a clinical decision or prediction rule to assist clinicians in the diagnosis of SIS.

7 Conclusions

This exploratory study set out to measure the diagnostic accuracy of a variety of subjective and objective features of a clinical examination performed by physiotherapists with respect to subacromial bursitis, partial thickness tears and full thickness tears in the primary care setting. Our results indicate that no historical, subjective or objective phenomena from the clinical examination can be relied upon in their own right to make a definitive diagnosis of a subacromial bursitis, partial or full thickness tear of the rotator cuff tendons.

Despite the aforementioned, the current study does provide some evidence that the presence of night pain is strongly correlated with the presence of SAB fluid/bunching. It also shows that night pain and pain with overhead activity have a high sensitivity for SAB fluid/bunching presence. Similarly, the absence of night pain and pain with overhead activity are two subjective features from a clinical examination that are useful in ruling out the presence SAB fluid/bunching. Male gender ($P<0.034$) was the best predictor of partial thickness rotator cuff tears while being 60 years of age or older ($P<0.01$) significantly correlated with full thickness rotator cuff tears.

The Drop Arm Sign ($P<0.01$) and ERLS ($P<0.01$) were significantly correlated with SIS and full thickness rotator cuff tears. Clinical tests for the three pathological stages of SIS and also mild stage SIS (presence of SAB fluid/bunching) had equivalent or if not greater diagnostic accuracy than previous report studies in the literature. The results suggest that the Hawkins-Kennedy Test and Neer Sign can be used by physiotherapists in the primary care setting to rule out the presence of SAB fluid/bunching and SIS if the tests are negative. For mid to end stage SIS (rotator cuff tears) the Empty Can Test and Drop Arm Sign, with their high sensitivity, can be used to rule out rotator cuff tears, especially specific to the supraspinatus tendon, when the tests are negative.

The current study adds to the body of evidence for the assessment, clinical examination and diagnostic accuracy of clinical tests for the pathological stages of SIS. Individual clinical tests did display high sensitivity values which may be used by a physiotherapist to SNout (rule out) a rotator cuff tear. Physiotherapists should

interpret these results with care as all of the clinical tests displayed at best, only modestly fair LR values with wide confidence intervals. Despite this, strong and significant correlations were found in the current study for subjective features of the clinical examination such as night pain, pain with overhead activities, age and male gender.

Following on from the literature reviews and the results from the current study, physiotherapists are recommended to take away several key practice points. Firstly no clinical predictors for full thickness rotator cuff tears could be found. Secondly, any patient with a strong clinical suspicion of a rotator cuff tear should be referred for a DUS scan since they have been shown to be a valid tool for diagnosing full thickness rotator cuff tears. Thirdly, physiotherapists should recognise that night pain is significantly correlated with early stage SIS (presence of fluid/bunching in the SAB or subacromial bursitis). Finally, all individual clinical tests have failed to demonstrate diagnostic utility and high specificity and positive LR values for diagnosing SIS and rotator cuff tears. Until future research improves the clinical utility of these tests physiotherapists should concentrate on using proven clinical tests with strong negative LRs and high sensitivity values such as the Empty Can Test to help screen and rule out a rotator cuff tear. As the current study took place in the private practice physiotherapy clinics, these findings can be extrapolated easily and used during routine musculoskeletal practice in the primary care setting.

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9 Appendices

Appendix 1: Quality Assessment of Diagnostic Accuracy Studies (QUADAS) tool (Whiting et al., 2004)

1. Was the spectrum of patients, representative of the patients who will receive the test in practice?
2. Were selection criteria clearly described?
3. Is the reference standard likely to classify the target condition correctly?
4. Is the period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests?
5. Did the whole sample or a random selection of the sample receive verification using a reference standard of diagnosis?
6. Did patients receive the same reference standard regardless of the index test result?
7. Was the reference standard independent of the index test (i.e. the index test did not form part of the reference standard)?
8. Was the execution of the index test described in sufficient detail to permit replication of the test?
9. Was the execution of the reference standard described in sufficient detail to permit its replication?
10. Were the index test results interpreted without knowledge of the results of the reference standard?
11. Were the reference standard results interpreted without knowledge of the results of the index test?
12. Were the same clinical data available when test results were interpreted as would be available as when the test is used in practice?
13. Were uninterpretable/intermediate test results reported?
14. Were withdrawals from the study explained?

Appendix 2: Recruitment letter

Private Bag 92006
Auckland 1142, NZ
T: +64 9 921 9999
www.aut.ac.nz

Dear colleague

You have been identified as a recent referrer of patients for diagnostic ultrasound. Associate Professor Wayne Hing and I are undertaking research investigating the accuracy of a physiotherapy clinical examination of the shoulder in diagnosing subacromial impingement syndrome (SIS).

This research involves the collection of information related to the signs, symptoms and the associated clinical tests of the shoulder specific to the diagnosis of SIS with respect to the reference standard of diagnostic ultrasound.

We are asking physiotherapists to use a standardized clinical examination developed from best current evidence based practice.

The study will involve multiple private practice clinics Auckland wide in partnership with Horizon ultrasound scanning clinics.

The study aims to develop a cluster a signs and symptoms as clinical predictors of SIS.

Your participation in the study will be greatly appreciated and your participation will be acknowledged in the final publication of the study.

If you interested in participating please contact myself or Dr Wayne Hing.

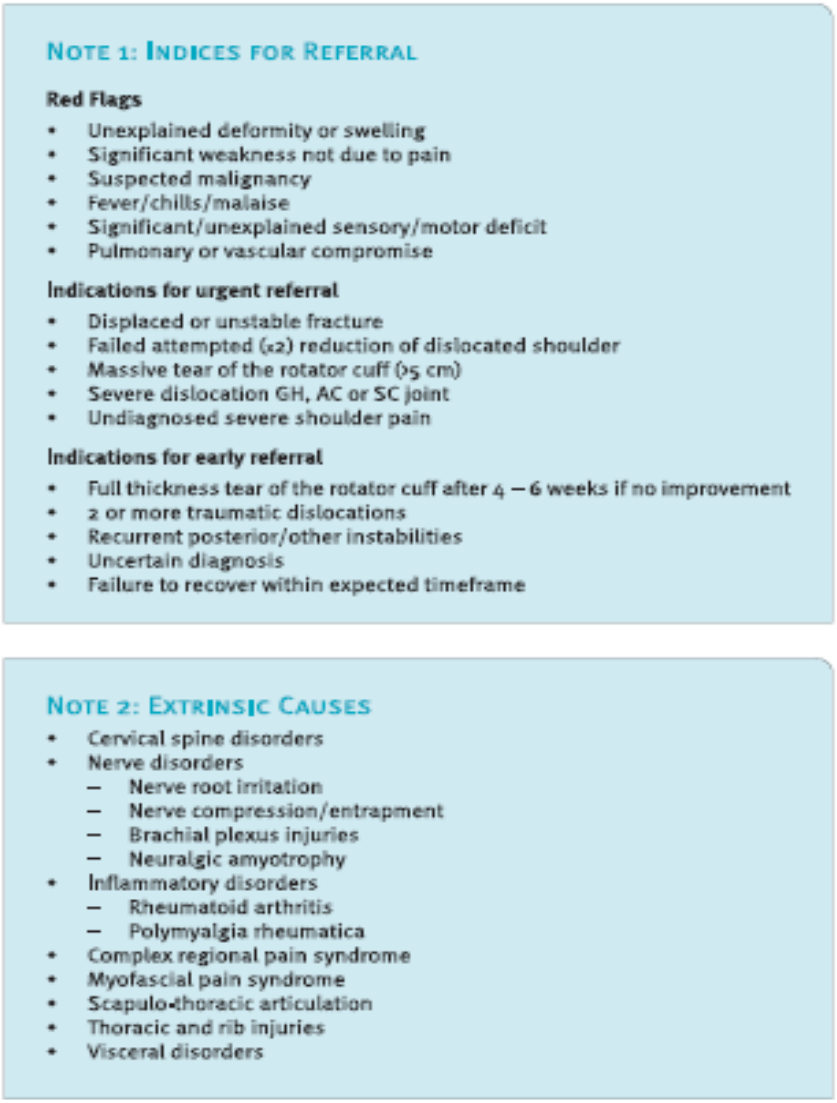
Many thanks

Daniel Harvey

Appendix 3: Inclusion/Exclusion criteria

Inclusion Criteria: Self-referred adult (>18y) ACC patients, presenting for the first time with new-onset shoulder pain for assessment and treatment at private practice physiotherapy clinics

Exclusion Criteria: Patients with Red Flags (Note 1) and patients with shoulder pain from suspected extrinsic causes (Note 2).



NOTE 1: INDICES FOR REFERRAL

Red Flags

- Unexplained deformity or swelling
- Significant weakness not due to pain
- Suspected malignancy
- Fever/chills/malaise
- Significant/unexplained sensory/motor deficit
- Pulmonary or vascular compromise

Indications for urgent referral

- Displaced or unstable fracture
- Failed attempted (x2) reduction of dislocated shoulder
- Massive tear of the rotator cuff (>5 cm)
- Severe dislocation GH, AC or SC joint
- Undiagnosed severe shoulder pain

Indications for early referral

- Full thickness tear of the rotator cuff after 4 – 6 weeks if no improvement
- 2 or more traumatic dislocations
- Recurrent posterior/other instabilities
- Uncertain diagnosis
- Failure to recover within expected timeframe

NOTE 2: EXTRINSIC CAUSES

- Cervical spine disorders
- Nerve disorders
  - Nerve root irritation
  - Nerve compression/entrapment
  - Brachial plexus injuries
  - Neuralgic amyotrophy
- Inflammatory disorders
  - Rheumatoid arthritis
  - Polymyalgia rheumatica
- Complex regional pain syndrome
- Myofascial pain syndrome
- Scapulo-thoracic articulation
- Thoracic and rib injuries
- Visceral disorders

Accident Compensation Corporation (2004). The diagnosis and management of soft tissue shoulder injuries and related disorders. Best practice evidence based guideline.

Patient Information Sheet

Dated 01/01/2008

Principal Researchers: Associate Professor Dr Wayne Hing, AUT University, Ph: 09 921 9999 extension 7800.

Daniel Harvey, AUT University Masters of Health Science candidate, Ph: 0800 427 497, Postal Address: 51 Swanson Road, Henderson, Auckland 0610.

Project title: The diagnosis of subacromial impingement syndrome and associated pathology in the primary care setting

Introduction: You are invited to take part in a research study investigating how accurate the clinical examination skills of a Physiotherapist are in diagnosing particular shoulder injuries. Please feel free to take as much time as possible to consider taking part. You may wish to take home this information and read it in your own time before making a decision. Taking part in this study is voluntary and you have the right to decline taking part in the study and you may also withdraw from the study at any time and this will in no way affect your future treatment/care.

Aim of the study: The aim of the study is to find out what single clinical test or group of tests performed by a Physiotherapist is accurate in diagnosing a specific soft tissue injury to the shoulder joint.

Participant selection: Participants for the study will come from patients like you presenting to Physiotherapy clinics with shoulder pain. The Physiotherapist will determine that you don't have any exclusion criteria, for example that your pain is being referred from your neck or spine. Many Physiotherapy clinics around Auckland are involved in the study and as researchers we hope to have up to 200 participants.

Study: The study is based in two parts. Firstly the Physiotherapist will interview you and then assess your shoulder movement and strength in a clinical examination. This is what would normally take place. The Physiotherapist will record your examination findings onto a data collection sheet for the researchers. The next part of the study is that you will be referred to have your shoulder scanned using diagnostic ultrasound. This is the same machine that is used to check up on developing foetuses in expectant mothers. Ultrasound is also very good at identifying soft tissue injuries in parts of the body including the shoulder.

Cost: If you are an ACC patient the cost of assessment with the physiotherapist and the diagnostic ultrasound will be free and covered by ACC.

Timeframes: The initial assessment with the Physiotherapist will take around 30-45 minutes. You will be referred immediately for a diagnostic ultrasound scan to the closest Horizon Scanning clinic to you. We hope to have you booked in for a scan within the week. The

scan itself usually takes somewhere between 20-45 minutes to complete. Following the scan the study is completed and the researchers will analyse the scan results with the Physiotherapist's clinical examination. There is no therapeutic treatment arm to the study. You will then be free to return to the physiotherapist to resume normal treatment and management. Your physiotherapist will receive a copy of your scan results. No material which could personally identify you will be used in any reports of this study.

Benefits of the study: You are actively assisting in a study which will develop guidelines and clinical decision rules for Physiotherapists. Ultimately you are helping to improve the diagnostic accuracy of all Physiotherapists in treating shoulder pain patients. Enhanced diagnosis of shoulder pain will lead to better treatment and management options for patients.

Risk/inconveniences of the study: There are no known foreseen risks. There may be a small delay in treatment while you wait to have your shoulder scanned. This small wait is necessary so not to bias the findings of the study.

Interpreter: If you are in need of an interpreter one will be provided.

Note: If you have private medical insurance, please check with your insurance company before agreeing to take part in the trial. You should do this to ensure that your participation will not affect your medical insurance.

If you have any queries or concerns regarding your rights as a participant in this study you may wish to contact a Health & Disability Advocate- 0800 555 050.

Ethics: Approved by the ***Health and Disability Northern Y Regional Ethics Committee on 07/04/2008. Reference:*** **NTY/07/11/123.**

Compensation:

In the unlikely event of a physical injury as a result of your participation in this study, you may be covered by ACC under the Injury Prevention, Rehabilitation and Compensation Act. ACC cover is not automatic and your case will need to be assessed by ACC according to the provisions of the 2002 Injury Prevention Rehabilitation and Compensation Act. If your claim is accepted by ACC, you still might not get any compensation. This depends on a number of factors such as whether you are an earner or non-earner. ACC usually provides only partial reimbursement of costs and expenses and there may be no lump sum compensation payable. There is no cover for mental injury unless it is a result of physical injury. If you have ACC cover, generally this will affect your right to sue the investigators.

If you have any questions about ACC, contact your nearest ACC office or the investigator.

Consent Form

Dated 01/01/2008

Project title: **The diagnosis of subacromial impingement syndrome and associated pathology in the primary care setting**

Project Researchers: ***Associate Professor Dr Wayne Hing, AUT University***

Daniel Harvey, Masters of Health Science candidate

Tick

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 01/01/2008
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ I am not suffering from heart disease, high blood pressure, any respiratory condition (mild asthma excluded), any illness or injury that impairs my physical performance, or any infection
- ○ I agree to have a clinical examination and diagnostic ultrasound scan of my shoulder
- ○ I agree to take part in this research.
- ○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Participants signature:

……

Participants name:

.....……

Date :

……

Approved by the ***Health and Disability Northern Y Regional Ethics Committee on 07/04/2008.*** ***Reference:*** **NTY/07/11/123.**

Note: The Participant should retain a copy of this form.

Appendix 4: Shoulder clinical examination tool

Shoulder clinical examination

Date of examination: Examiner/Clinic:
Patient's name:
Date of birth/Age: Gender:
Injured shoulder: *circle one* Right / Left
Dominant side: *circle one* Right / Left
Date of the start of the current episode of shoulder pain:
Any chronic medical conditions/co-morbidities:

Subjective history:

- ☐ Night pain-cannot stay asleep because of shoulder pain
- ☐ Presence of subacromial crepitus since shoulder pain developed-clicking, clunking, grouching
- ☐ Pain with overhead activities
- ☐ Unable to lift a weight above shoulder level- such as removing an object from a high shelf
- ☐ Shoulder pain with no history of trauma but instead a gradual onset of pain
- ☐ A specific episode of trauma causing the current episode of shoulder pain
  Please specify mechanism ie. fall on outstretched arm, forced abduction: _____

Objective signs: Tick if any test is positive

Active movement tests:

- ☐ Drop Arm Sign-sudden drop or sharp pain during lowering of arm
- ☐ Painful Arc Sign-between 60-120 degrees in the scapular plane

Tick if any of the active range of motion tests is painful or restricted

Abduction:	☐	Restricted	☐	Painful
Flexion:	☐	Restricted	☐	Painful
External rotation:	☐	Restricted	☐	Painful
Internal rotation:	☐	Restricted	☐	Painful
Extension:	☐	Restricted	☐	Painful
Horizontal adduction:	☐	Restricted	☐	Painful

Passive movement tests

Tick if any of the passive range of motion tests is painful or restricted

Abduction:	☐	Restricted	☐	Painful
Flexion:	☐	Restricted	☐	Painful
External rotation:	☐	Restricted	☐	Painful
Internal rotation:	☐	Restricted	☐	Painful
Extension:	☐	Restricted	☐	Painful
Horizontal adduction:	☐	Restricted	☐	Painful

Rotator cuff tests- Tick if any tests are positive

- ☐ Empty Can Test
- ☐ Infraspinatus Test
- ☐ External Rotation Lag Sign
- ☐ Bear-Hug test
- ☐ Hornblower's sign
- ☐ Speed's Test

Impingement signs- Tick if any tests are positive

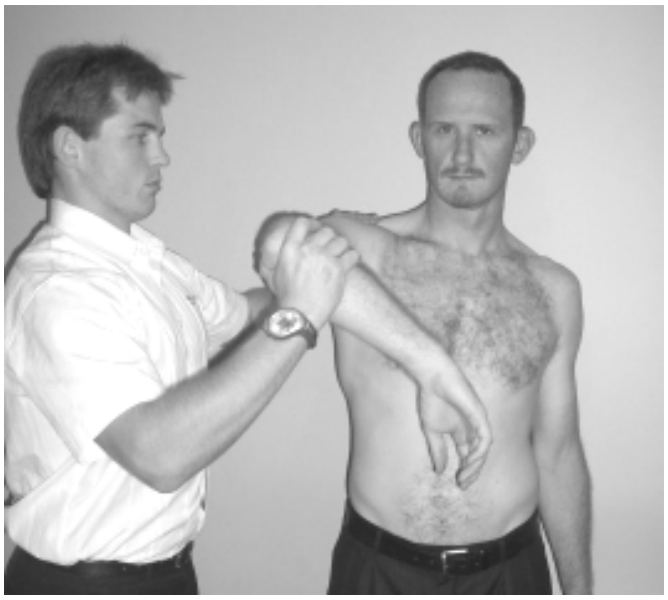
- ☐ Neer sign
- ☐ Hawkins-Kennedy Test
- ☐ Horizontal adduction Test

Appendix 5: Clinical tests

The first impingement test was the Neer Sign. For this manoeuvre the therapist stands behind the patient and fixates the scapula. The patients arm is internally rotated and the therapist passively moves the arm to end range flexion. A positive result is if pain is produced in the anterior or lateral part of the shoulder prior to end range flexion and usually in a range of 90 and 140 degrees flexion (Neer, 1972, 1983; Park et al., 2005; Silva et al., 2008).

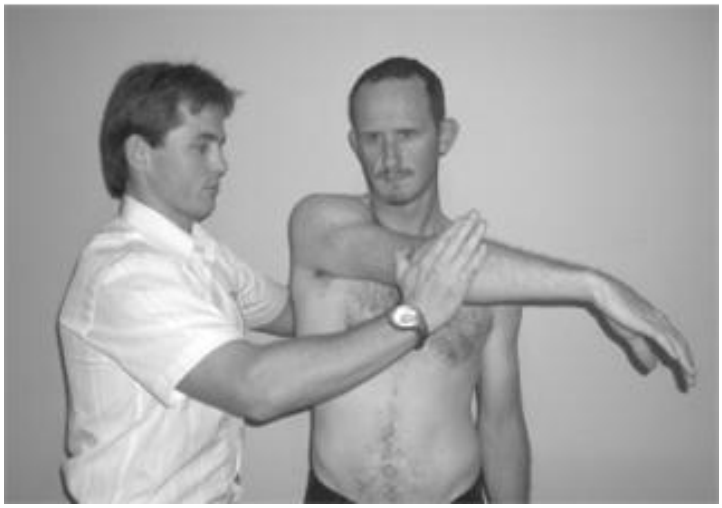
Neer Sign

The second impingement test is the Hawkins-Kennedy Test. The patient is positioned in standing with arm placed in 90 degrees of forward flexion and elbow bent to 90 degrees. The therapist applies internal rotation to the humerus through the distal arm while stabilizing the scapula. A positive result is if pain occurs in the shoulder during the manoeuvre (Leroux et al., 1995; Park et al., 2005).



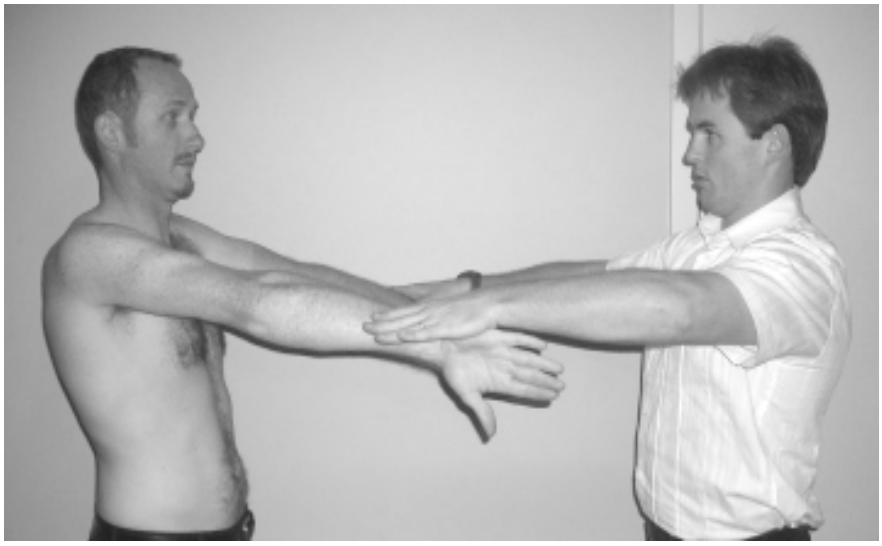
Hawkins-Kennedy Test

The final impingement test is the cross-body Horizontal Adduction Test. The therapist passively moves the arm into horizontal adduction across the patient's body. A positive result is if pain occurs in the shoulder during the maneuver (McLaughlin, 1951; Park et al., 2005).



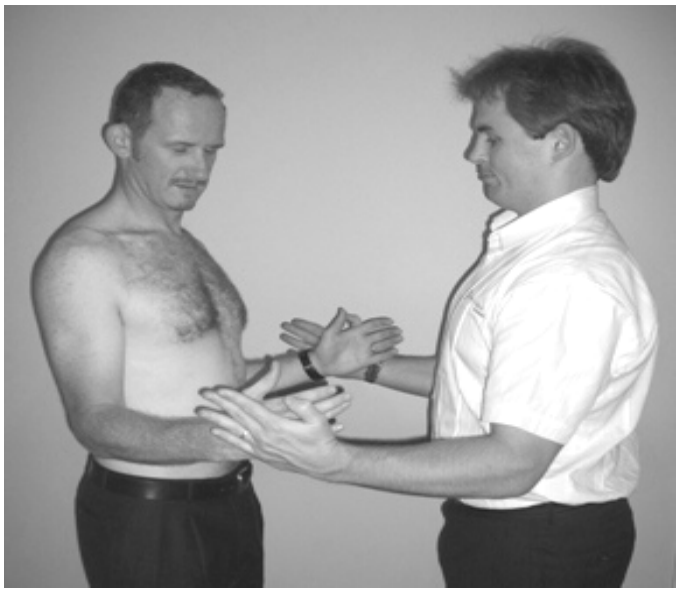
Horizontal Adduction Test

The first rotator cuff integrity test was the Empty Can Test. The Empty Can Test is designed to detect weakness of the supraspinatus. The patient is standing with arms in 90 degrees elevation in the scapular plane, elbows in extension and the shoulders are in full internal rotation. The therapist applies caudal force to the patient's distal arms. A positive result is if pain and/or weakness cause the patient's arm to give way (Jobe & Moyes, 1982; Malanga, Jenp, Growney, & An, 1996; Park et al., 2005).



Empty Can Test

The second test is the Infraspinatus test and is designed to detect weakness of the infraspinatus. The patient is positioned standing with arms adducted by side in neutral rotation and an elbow flexed to 90 degrees. The therapist applies an internal rotation force to the distal arms. A positive result is if pain and/or weakness cause the patient's arm to give way (Leroux et al., 1995; Park et al., 2005).

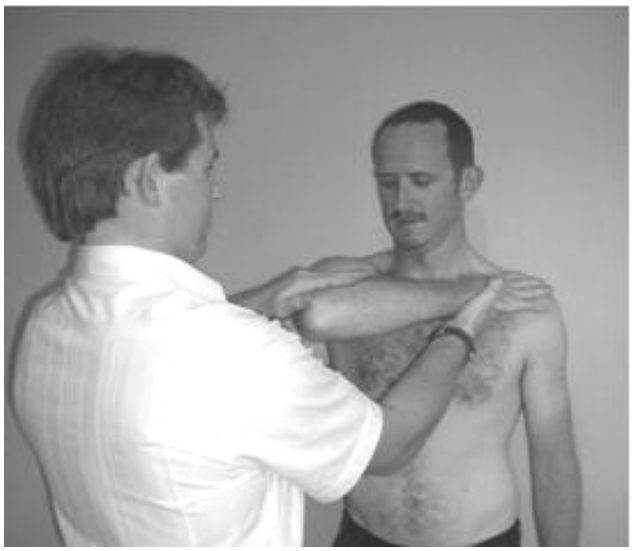


Infraspinatus test

The third test is the External Rotation Lag sign (ERLS) and is designed to detect weakness of the supraspinatus and infraspinatus force couple. The patient is positioned standing with arm adducted by side in neutral rotation and elbows flexed to 90 degrees. The therapist passively moves the arm into maximal external rotation and the patient is asked to hold the position. A positive result: if the patient is unable to hold the arm in the position and the arm falls into internal rotation by more than five degrees of rotation (Hertel et al., 1996; Park et al., 2005).

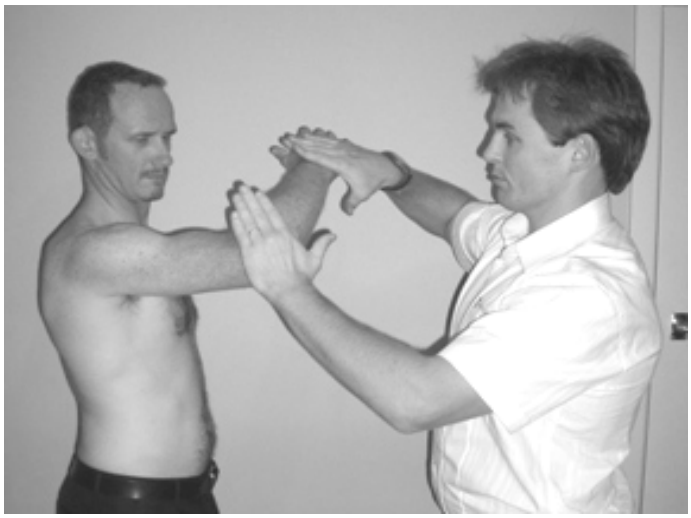
External Rotation Lag Sign

The fourth test is the Bear-Hug Test is designed to detect weakness of the subscapularis. The patient is positioned standing with the palm of the affected arm on the patient's opposite shoulder. The therapist tries to remove the patient's hand from the starting position using an external rotation force perpendicular to the forearm. A positive result is if the patient cannot hold the hand against the shoulder (Barth et al., 2006).



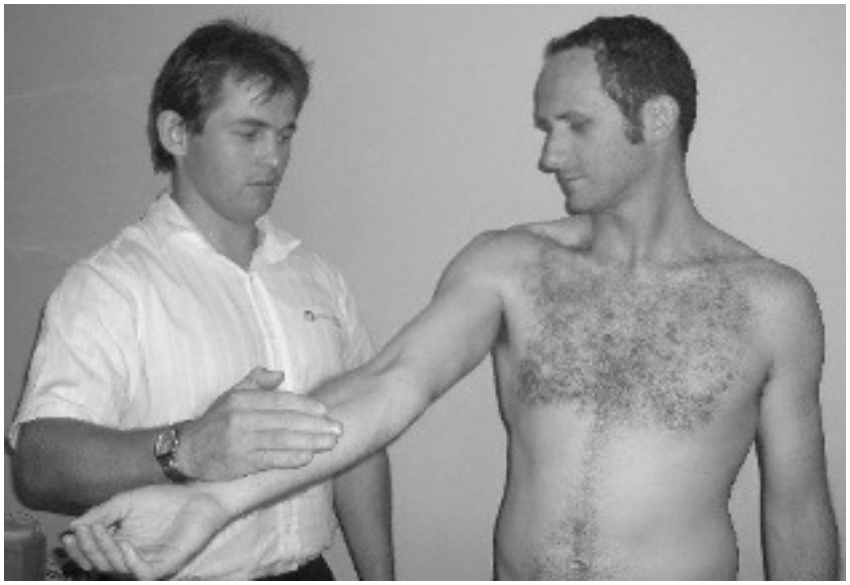
Bear-Hug Test

The fifth test is Hornblower's Sign and is designed to detect the absence of infraspinatus and sever degeneration and weakness of teres minor. The patient is positioned in standing with arm abducted to 90 degrees in the scapular plane and elbow flexed to 90 degrees. The therapist is positioned to the side of the patient with one hand supporting the elbow of the patient and the other in a position to resist the distal forearm. The patient rotates the forearm into external rotation against the graded resistance of the therapist's hand. A positive result is if the patient's arm cannot be externally rotated in this position (Walch et al., 1998).



Hornblower's Sign

The sixth test was Speed's Test and is designed to detect to detect biceps tendon lesions. The patient is positioned standing with the elbow extended, forearm supinated and the humerus elevated to 60°. The examiner resists humeral forward flexion. A positive result is if pain is located to the bicipital groove (Park et al., 2005).



Speed's Test

Appendix 6: Standardized diagnostic ultrasound procedure

Ultrasonography was performed with a Philips HD11 ultrasound machine using a 5-12 MHz, 50mm broadband linear array. The long head biceps tendon is examined with arm adducted and the patients forearm supinated resting on the thigh. The tendon is scanned from the bicipital groove distally to the long head biceps muscle belly in long and axial planes. The ossesous anatomy of the groove and its depth and the tendon's stability during external rotation of the patient's arm, which accentuates subluxation are assessed. The intra-articular portion of the tendon is examined with posterior extension of the patient's arm, with the elbow flexed and the palm of the hand placed over the posterior iliac crest.

The subscapularis tendon is examined in two orthogonal planes (long & axial) with the patient's arm in passive external rotation. The coracoid process is visualised in a medial position, and the superior subscapularis recess and the subdeltoid/subacromial bursa is assessed for the possibility of fluid collection or bursal wall thickening during internal and external rotation.

The supraspinatus tendon is examined in two orthogonal planes with the posterior extension of the patient's arm, with the elbow flexed and the palm of the hand placed over the posterior iliac crest (as described above for assessing the intra-articular LHB tendon). The supraspinatus tendon is examined in at least two arm positions, the second may be with the forearm supinated and the flexed to 90 degrees the arm is drawn posteriorly to achieve maximum elbow flexion. Once again the tendon is scanned in two orthogonal planes.

The infraspinatus tendon is examined in two orthogonal planes with the patients bent arm placed across their chest with the palm of the hand resting on the opposite shoulder.

The posterior glenohumeral joint, was assessed with the patients arm positioned as for infraspinatus above the posterior glenohumeral joint is examined. This is performed dynamically by external & internal rotation of the forearm and hand.

The patient's arm is adducted in a relaxed position and the coracoacromial ligament is examined at 90 degrees to its long axis. The dynamic assessment of the SAB is performed during abduction while maintaining this probe alignment. The probe is scanned from the acromion process to the coracoid process. The bursa is assess for whether there is fluid within the bursa, whether the bursal wall is thickened and a dynamic examination takes place to see if is there bursal bunching during active arm abduction and flexion (Lew et al., 2007; Papatheodorou et al., 2006).