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# The relationship between external rotator strength to size of rotator cuff tear

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# THE RELATIONSHIP BETWEEN EXTERNAL ROTATOR STRENGTH TO SIZE OF ROTATOR CUFF TEAR.

Joanne Sklaar

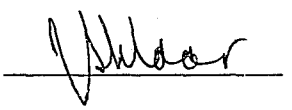
A research report submitted to the Faculty of Medicine, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Physiotherapy.

Johannesburg

2000

# DECLARATION

I declare that this research report is my own unaided work, except to the extent indicated in the reference citations and acknowledgements. It is being submitted in partial fulfilment of the requirements for the degree of MSc (Physiotherapy) at the University of the Witwatersrand. It has not been submitted before for any other degree or examination in any other University.

Signature: 

Date: 30|10|00

# DEDICATION

To my husband Barnett and children Lara and Daniel with thanks for not minding too much about all the hours spent away from them.

# PUBLICATIONS AND PRESENTATIONS

Sklaar J. 1992. Clinical evaluation to determine the Potential Success of Conservative Treatment of Rotator Cuff Impingement. In: Proceedings of 5th International Conference of Manipulative Therapists. Vail, Colorado, June 1-4, pp 241-243.

Sklaar J. 1995. Test to Predict Treatment Outcome. *South African Journal Physiotherapy*, vol 51, no 1, pp 13-15.

# ABSTRACT

Clinically it was observed that patients with decreased *static resisted external rotation strength of the arm (tested in neutral)* often had rotator cuff tears. In addition, it was observed that the size of the rotator cuff tear seemed to be correlated with the amount of loss of muscle strength.

The purpose of this study of the shoulder was to ascertain:

1. If *static resisted external rotation strength of the arm (tested in neutral)* can be used as a diagnostic test to ascertain if a tear of the rotator cuff is present.

2. If a relationship exists between the decrease of strength of the arm when testing *static resisted external rotation (in neutral)* and the size of the cuff tear.

Thirty- two subjects who had been selected by an orthopaedic surgeon to have their rotator cuff arthroscopically examined, were used for the study. Certain exclusion criteria were applied and twelve subjects were excluded from the study. The pre-operative testing consisted of a routine shoulder examination, which was expanded to include the Constant score method. Isometric muscle testing of the rotator cuff muscles was undertaken using a Nicholas hand held dynamometer. The opposite unaffected arm was used as a control. The force production of the affected arm was then calculated as a percentage of the control arm, thus resulting in a dimensionless relative measurement of the strength of the affected arm.

The intra-operative results of the arthroscopic examinations were obtained and if a tear was present, the size was calculated by multiplying the length and breadth of the tear. The pre-operative findings and intra-operative results were analysed using the Pearson's correlation coefficient test.

The results show that an inverse relationship exists between the size of the tear and the strength of *static resisted external rotation force of the arm ( r = 0.62 )* i.e. the larger the tear, the less the strength of the arm when testing *static resisted external rotation in neutral.*

The results also show that if the relative strength (%) of the affected arm is known, then in 62 % of the cases the tear size can be accurately calculated. The statistical tests were unable to demonstrate any relationships between the other parameters tested (i.e. pain, function, abduction strength, internal rotator strength) and tear size. In addition it was found that when using *static resisted external rotation strength of the arm (tested in neutral)* as a diagnostic test in isolation, it is difficult to differentiate accurately between no tear and a small tear of the cuff. A large or massive tear is easier to diagnose.

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The patients for agreeing to be part of this study.

# ABBREVIATIONS

| | |
|---|---|
| scaption | plane of the scapula |
| cuff | rotator cuff |
| SS | supraspinatus |
| IS | infraspinatus |
| TM | teres minor |
| SSc | subscapularis |
| ER | *static resisted external rotation in neutral* |
| MMT | manual muscle testing |
| HHD | hand- held dynamometer |
| NMMT | Nicholas manual muscle tester |
| ERS | static resisted external rotation tested in neutral in a standing position |
| IRS | static resisted internal rotation tested in neutral in a standing position |
| ABD S | static resisted abduction in standing |
| ERL | static resisted external rotation tested in neutral in a lying position |
| IRL | static resisted internal rotation tested in neutral in a lying position |
| ABD L | static resisted abduction in lying |
| ABD 90° | static resisted abduction in 90° scaption |
| (S%) | affected arm strength ratio |
| ERS (S%) | affected arm strength ratio for static resisted external rotation in standing |
| IRS (S%) | affected arm strength ratio for static resisted internal rotation in standing |
| ABD S (S%) | affected arm strength ratio for static resisted abduction in standing |
| ERL (S%) | affected arm strength ratio for static resisted external rotation in lying |
| IRL (S%) | affected arm strength ratio for static resisted internal rotation in lying |
| ABD L (S%) | affected arm strength ratio for static resisted abduction in lying |
| ABD 90° (S%) | affected arm strength ratio for static resisted abduction in 90° scaption |

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# 1.0 Introduction

The management of patients with rotator cuff pathology in South Africa is frequently initiated by the physiotherapist. The exact nature and degree of cuff pathology is often difficult to quantify and thus treatment outcomes cannot always be accurately predicted. Signs and symptoms of a rotator cuff tendinosis often overlap those of a rotator cuff tear (Neer, 1972). Clinicians may therefore erroneously think that a tear has resolved, when in fact it was a misdiagnosis of a severe tendinosis and vice versa (Neer, 1983). Sophisticated investigations (radiography, computed tomography, magnetic resonance imagery and ultrasound) are also often inaccurate in determining the extent of the pathology (Alchek and Carson, 1997; Breazeale and Craig, 1997).

Unnecessary physiotherapy is costly and time consuming. A reliable and inexpensive test that could accurately differentiate between a tendinosis or a tear of the rotator cuff, would be very valuable. This may lead to a more accurate prognosis. Thus making the decision of whether to pursue conservative treatment (i.e. physiotherapy) or to refer for further investigations easier.

This study is based on an assessment of rotator cuff function as a diagnostic tool. It is specifically an assessment of static resisted external rotation strength of the arm tested in neutral as a test of rotator cuff function. Initial clinical observations reveal that static resisted external rotation strength of the arm tested in neutral (Cyriax, 1978) may be a reliable prognosticator of rotator cuff pathology and subsequently an evaluation of conservative treatment (Sklaar, 1992, 1995).

Clinically, patients presenting with rotator cuff pathology often respond well to conservative treatment. It was observed however, that there were some patients, who initially responding well to conservative treatment later relapsed, and had to finally resort to surgery (Sklaar, 1992, 1995). These patients were all noted to have less strength of static resisted external rotation of the affected arm when tested in neutral. This decrease in strength was observed to persist, despite comprehensive strengthening programmes. Routine manual muscle testing

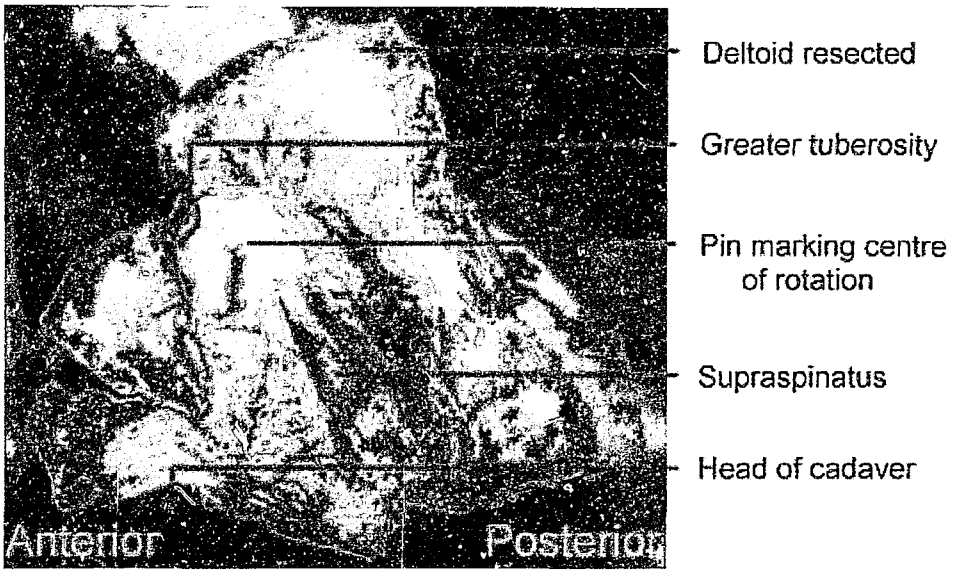



**Figure 1.1** A superior view of a dissection of the right arm of a cadaver.
The arm is in internal rotation. The deltoid has been resected and folded away. A pin is positioned at the vertical axis of rotation of the head of humerus. The greater tuberosity is marked in black . The supraspinatus muscle appears to run into the capsule posterior to the axis.

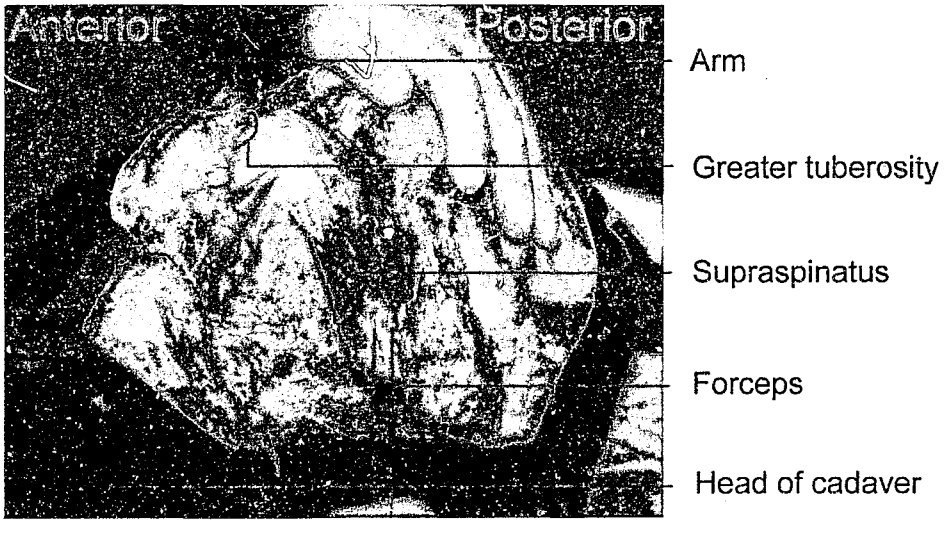



**Figure 1.2** A superior view of a dissection of the right arm of a cadaver.
Note the right arm externally rotates as the forceps pulls on the belly of supraspinatus.

(Daniels and Worthingham, 1972; Cyriax, 1978; Kendall et al, 1993) was used to assess the muscle strength. The operative notes of the patients who underwent the surgery consistently reported that a tear of the supraspinatus was present (Sklaar, 1992). This was puzzling, as static resisted external rotation strength of the arm tested in neutral is a muscle test for infraspinatus and teres minor and should therefore not be affected by a supraspinatus tear (Cyriax, 1978).

A possible explanation may be found, if supraspinatus, besides functioning as an abductor and stabiliser of the arm, can also assist in external rotation of the neutral arm. A more appropriate name for testing static resisted external rotation of the neutral arm may be a "posterior rotator cuff test" (Keating, 1993). In other words implying that, static resisted external rotation strength of the neutral arm tests supraspinatus, infraspinatus and teres minor as a unit.

It was observed, in a cadaver study (Sklaar, 1992), that there was no apparent visible division between the insertions of supraspinatus and infraspinatus to the head of the humerus (Figure 1.1 and Figure 1.2). This observation has been confirmed and documented in histological studies by Soslowsky, et al (1997). In this same cadaver study (Sklaar, 1992), pulling on the supraspinatus muscle of the cadaver to simulate a muscle contraction caused external rotation of the arm (Figure 1.2). This is explained by Calliet (1988), who postulated that if the head of the humerus is viewed from a superior view, the axis of rotation is anterior to the line of pull of the supraspinatus (Figure 1.1). Therefore with the arm in neutral, this muscle may be able to function as an external rotator. Many other studies have also postulated that supraspinatus assists in external rotation of the arm (Jenp et al, 1996; Kelly et al, 1996; Itoi et al, 1997; Hintermeister et al, 1998), and this may be an explanation for the decreased static resisted external rotation strength observed in patients with isolated supraspinatus tears. In addition, recent research has revealed microscopic observations of interdigitations of the rotator cuff muscles at their insertions (Clark and Harryman, 1992; Blevins et al, 1997). This may lead one to speculate that even if an isolated supraspinatus tear is observed, the unobserved interdigitating fibres of infraspinatus may be affected (Codman, 1990; Blevins et al, 1997). Therefore static resisted external rotation strength of the affected arm could be decreased as a result of the loss of infraspinatus function. Finally, if the rotator cuff tear disrupts the

attachment between the supraspinatus and the infraspinatus, it could be speculated that the infraspinatus may be rendered weaker, due to the loss of muscle alignment and muscle tension. (Itoi et al, 1997).

In summary, in subjects with an apparently unaffected infraspinatus and teres minor, static resisted external rotation strength could be decreased for the following reasons:

- A tear of supraspinatus results in a loss of the external rotator strength.
- A tear disrupting the attachment between the supraspinatus and infraspinatus causes a decrease of external rotator strength.
- The torn interdigitating fibres of an apparently intact infraspinatus (macroscopically not visible) may impede muscle function.

The assumption is that the less the static resisted external rotation strength of the affected arm tests, the greater the involvement of supraspinatus, infraspinatus and finally teres minor may be, in the pathology.

**The objective of this study was to determine the value of using static resisted external rotation strength of the neutral arm as a clinical test.**

The following was addressed:

Is static resisted external rotation strength of the arm (when tested in neutral):

A. Related to the size of the rotator cuff tear?

B. A test that may be used to ascertain if a tear of the rotator cuff is present?

# 2.0 Literature Review

In the literature review, the gross anatomy of the rotator cuff is briefly discussed (2.1). This is followed by the pathogenesis of the rotator cuff pathology (2.2). The examination section is a short overview of the inconsistencies in the clinical examination of the shoulder joint (2.3). The Constant Scoring method is discussed (2.3.1) and the role of special investigations of the rotator cuff is briefly commented on (2.3.2.3). Muscle testing (2.4) and rotator cuff muscle function and testing (2.4.2) are finally discussed in separate sections.

## 2.1 ANATOMY

The rotator cuff consists of the supraspinatus, infraspinatus, teres minor and subscapularis. The supraspinatus, infraspinatus and teres minor have their origin on the posterior surface of the scapula and are called the posterior rotator cuff muscles (Keating et al, 1993). The subscapularis has its origin on the anterior surface of the scapula and is called the anterior rotator cuff muscle (Keating et al, 1993). The supraspinatus originates from the supraspinous fossa of the scapula and the infraspinatus (the medial two-thirds) and teres minor (the upper two-thirds of the lateral margin) originate from the infraspinous fossa of the scapula. (Jobe, 1990). These three muscles all converge on the greater tubercle of the humerus and are described as attaching as separate tendons to the superior, middle and inferior impressions of the tubercle in the following order: supraspinatus; infraspinatus; teres minor (Williams et al, 1989; Tobias and Arnold, 1967). The subscapularis muscle originates from the medial two-thirds of the subscapular fossa and has also been described as inserting via its tendon into the lesser tubercle of the humerus (Williams et al, 1989; Tobias and Arnold, 1967). The individual muscles are described as blending with the capsule to form the rotator cuff (Williams et al, 1989). This description is perhaps misleading because it creates the impression that each muscle could be tested as a separate entity, and that the only continuous structure is the capsule.

Recently research has shown that the insertions of the rotator cuff overlap and interdigitate extensively, especially between supraspinatus and infraspinatus (Clark and Harryman, 1992;

Soslowsky et al, 1997). The subscapularis and supraspinatus similarly interdigitate and form a sheath around the long head of the biceps tendon as it penetrates the rotator cuff at a point which is called the rotator interval (Soslowsky et al, 1997). A tendon slip from the supraspinatus forms the roof of this sheath and fibres from both tendons join together to form the floor of the sheath (figure 2.1). In addition this area is reinforced by the coracohumeral ligament which is a fibrous structure extending between the coracoid process to the interval between the subscapularis and supraspinatus. (Matsen and Arnst, 1990) When individual tendon fibres are followed, rather than inserting as individual tendons they intersect with and blend with fibres from adjacent tendons.

This interconnected arrangement may have importance in the pathogenesis of rotator cuff tears (Clark and Harryman, 1992; Soslowsky et al, 1997). The long head of the biceps tendon must also be directly related to the rotator cuff function due to the sheath around it formed by the supraspinatus and subscapularis (figure 2.1). In addition to the arrangement of blended muscle fibres, the capsule and coracohumeral ligament are also intimately related to the rotator cuff and this may be a factor in distribution of forces between the tendon insertions (Burkhart, 1992, 1993, 1997).

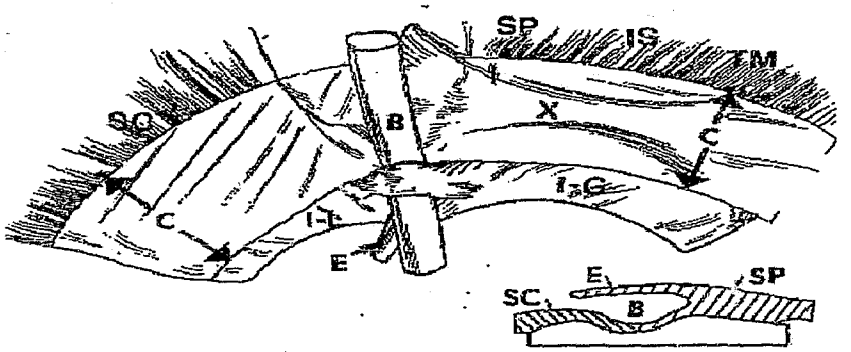



**Figure 2.1** Deep surface of the rotator cuff-capsule complex.

Note the confluence of the supraspinatus and subscapularis tendons proximal to their insertions of lesser (I-L) and greater (I-G) tuberosities. The inset is a cross-section of the bicipital groove and related structures. Note the sheath surrounding the biceps tendon (B). The deep portion of this sheath is formed by the subscapularis tendon, and a slip (E) from the supraspinatus tendon is formed *over* the biceps tendon. Also shown is the pericapsular band (X). C = capsule, SC = subscapularis, SP = supraspinatus, IS = infraspinatus, TM = teres minor. *(From* Clark JM, Harryman II DT. 1992. Tendons, Ligaments, and Capsule of the Rotator Cuff. *Journal of Bone and Joint Surgery, vol 74 A, pp 713-725,* with permission.)

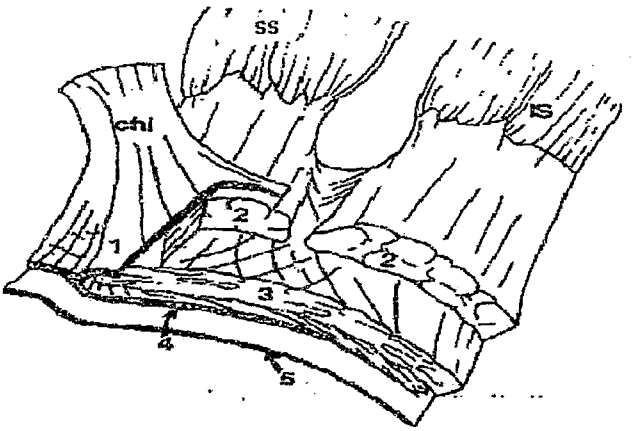



**Figure 2.2** Dissection sectioned transversely at various sites

Dissection sectioned transversely at various sites in the supraspinatus (SS) and infraspinatus (IS) tendons, coracohumeral ligament (chl), and capsule of the shoulder, which demonstrates the five layers. (From Clarke JM, Harryman II DT. 1992. Tendons, Ligaments and Capsule of the Rotator Cuff. *Journal of Bone and Joint Surgery vol, 74 A, pp, 713-715, with permission.)*

A five-layer structure (figure 2.2) of the rotator cuff and capsule (near the insertions of supraspinatus and infraspinatus), has been described by Clark and Harryman (1992), as follows;

**Layer 1** is composed of the superficial fibres of the coracohumeral ligament.

**Layer 2** which is the main portion of the rotator cuff tendons, is seen as closely packed parallel tendon fibres grouped in large bundles extending directly from the muscle bellies to the insertion on the humerus.

**Layer 3** is also a thick tendinous structure but with smaller fascicles than in layer 2 and a less uniform orientation. The third layer is where most of the muscle interdigitation is said to take place (Blevins et al, 1997).

**Layer 4** is composed of loose connective tissue with thick bands of collagen fibres running *perpendicular* to the primary fibre orientation of the rotator cuff tendons.

It contains the deep extension of the coracohumeral ligament and has been variously described as a transverse band, a pericapsular band, or a rotator cable. This layer may have a

role in the distribution of forces between tendinous insertions which explains why some rotator cuff tears are clinically asymptomatic and why a tear in supraspinatus may still result in acceptable rotator cuff function (Burkhart, 1993). This extention on the other hand, may also explain why a torn supraspinatus can render an intact infraspinatus /teres minor complex weaker (Itoi et al, 1997).

**Layer 5** is the true capsular layer and forms a continuous cylinder from glenoid to humerus.

These recent histological findings seem to indicate that the rotator cuff becomes a continuous structure near its insertion. With this arrangement of blended fibres, the force from the contraction of one muscle is not isolated to that muscle's attachment, but in addition affects the attachment of adjacent tendons. This interdigitation may affect the results of attempts to isolate the affected muscles by manual muscle testing. Contraction of any one of the rotator cuff muscles will directly impact on all the others as a direct result of this close interrelationship.

The anatomy is also unique in that supraspinatus (and to a lesser extent biceps and infraspinatus) is "sandwiched" in a space between two "bony" structures. Inferiorly the head of the humerus and superiorly the coracoacromial arch, which comprises the acromion and coracoid, linked by the thick, "bony" coracoacromial ligament. This space is also known as the acromiohumeral joint (Maitland, 1991) or supraspinatus outlet (Soslowsky et al, 1997). This anatomical relationship predisposes the muscle to impingement (Neer, 1983; Flatow et al, 1994). Impingement occurs when the smooth gliding of the tendons, which are overlaid by the subacromial bursa, are impeded and therefore subject to injury (Unthoff and Sarkar, 1991).

## 2.2 PATHOGENESIS OF ROTATOR CUFF PATHOLOGY

In the shoulder, pathogenesis of the rotator cuff is a complicated issue for a number of reasons:

- Rotator cuff pathology encompasses a spectrum of pathologies which includes oedema or swelling, tendinosis and/or fibrosis, and tears (Neer, 1972, 1983; Unthoff and Sano, 1997).

- Neer (1983) described a continuum of pathology, with which some authors agree (Ellman, 1990). This theory, has however been refuted by other authors, who say that a progression of pathology does not occur in all patients and that not all tendinopathies lead to tears. (Ianotti, 1992; Blevins et al, 1977; Unthoff and Sano, 1997).

- The signs and symptoms of the different pathologies overlap considerably i.e. a full thickness tear can be painless and the patient may be fully functional (Burkhart, 1992, 1993; Burkhart et al, 1994), whereas a tendinopathy can cause severe pain and loss of function (Matsen and Arnst, 1990).

The causes of rotator cuff pathology are multifactorial (Blevins et al, 1997; Soslowsky et al, 1997; Unthoff and Sano, 1997). This makes classification difficult and controversial. Unthoff and Sarkar, (1991) have formulated a classification based on where the lesion originates and this seems to lead to the least confusion. If the lesion starts in the tendon it is classified as *intrinsic or primary.* If the lesion starts in an adjacent or remote structure, or is related to some disease then it is called a *secondary or extrinsic* cause.

### 2.2.1 Primary (intrinsic ) causes of Rotator cuff pathology

Intrinsic causes of rotator cuff pathology are traditionally accepted as due to *degenerative* age changes and patterns of *microvascularity* (Blevins et al, 1977; Soslowsky et al, 1997; Unthoff and Sano, 1997). This however ignores two factors that can cause primary rotator cuff

damage and that is *trauma* (macro- and micro-) and primary reactive tendinopathy or *calcific tendinitis* (Unthoff and Sarkar, 1993, Unthoff and Sano, 1997).

### 2.2.1.1 Degenerative Changes

Normal healthy rotator cuff muscle-tendon units subjected to tensile loads do not normally fail. The tendon must usually first be weakened by degeneration (Macnab, 1973; Cofield, 1985; Blevins et al, 1997; Breazeale and Craig, 1997; Unthoff and Sano, 1997). Brewer, (1979) among others (Benjamin and Ralphs, 1996; Blevins et al, 1997; Soslowsky et al, 1997; Unthoff and Sano, 1997) has demonstrated age related changes in the rotator cuff. These are said to occur as acute self-limiting episodes of fibre failure. These changes are usually painless and thus the patient is unaware of the damage occurring. The precise manner in which this degeneration occurs is poorly understood. However, it most likely involves the biological response of the tendon to loading, impingement, as well as to age related alterations in tendon metabolism, vascularity, and structure (Unthoff and Sarkar, 1991; Benjamin and Ralphs, 1996; Blevins et al, 1997).

Rotator cuff tears are usually age related. Pettersen (1942) performed arthrography on 71 symptom free, healthy shoulders that had no previous history of trauma. These were the shoulders of people presenting after some traumatic episode to their *opposite* shoulder. Thirteen of these shoulders had partial or full thickness tears, (these were mostly in the 70-75 year age group). It was concluded from these findings that the tears were age related degenerative tears and that these occurred painlessly.

This age related degeneration theory has been strengthened by many cadaver studies, that have shown conclusively that the incidence of partial thickness tears increases dramatically with age and that full thickness tears are almost exclusive to older patients (Matsen and Arnst, 1990; Breazeale and Craig, 1997; Unthoff and Sano, 1997). These degenerative tears may heal with scar tissue, or they may not heal at all, or they may progress to larger tears. All of these weaken the rotator cuff and places more stress on the remaining healthy fibrils (Unthoff and Sarkar, 1991; Benjamin and Ralphs, 1996; Unthoff and Sano, 1997). These healthy fibrils

may now wear at a faster rate due to this abnormal increase in load. As these areas of fibre failure increase, it must at some stage result in weakening the function of the rotator cuff. This at some point may result in loss of stability of the head of the humerus. Unthoff and Sano (1997) believe that the rotator cuff can fail in its *"physiologic function "* long before it tears, and in fact, may never tear. Therefore, in view of the fact that failure might be a temporary condition, they have adopted the following definition; *" failure of the rotator cuff is a condition in which interference with its function prevents the rotator cuff from fulfilling its physiologic role."*

Any of these scenarios can result in a loss of centralisation of the head of humerus, which then migrates superiorly and anteriorly and increases the chance of impingement against the acromion and coracoacromial ligament. The rotator cuff is therefore not only subjected to age related changes and massive tensile stresses which accelerate wear, but is also subjected to impingement because of the failure of the function of the rotator cuff. A vicious cycle may then ensue. When pain does occur with a tear, it is usually as a result of an extension of an existing small tear.

### 2.2.1.2 Trauma

Macro - trauma

One incident of severe trauma, which causes major rotator cuff damage or rotator cuff tears is rare. As has been said previously, tendons in general are extremely strong and are unlikely to rupture in healthy young individuals (Benjamin and Ralphs, 1966; Unthoff and Sano, 1997). The incidence of acute rotator cuff tears due to trauma has been shown to be only 8% in a study of 510 patients presenting for rotator cuff repair in a Mayo Clinic series (Cofield, 1985).

Micro-trauma

The rotator cuff is constantly subjected to micro-trauma which may result in tendinopathy and/or tears of the rotator cuff. The causes of tendinopathies are poorly understood (Unthoff

and Sarkar, 1991; Benjamin and Ralphs, 1996). It is commonly thought that mechanical overload is a factor and this is a very reasonable clinical assumption in rotator cuff pathology (Unthoff and Sarkar, 1991; Benjamin and Ralphs, 1996) because the shoulder is the most mobile joint in the body.

Excessive stress is placed on the rotator cuff which must compensate for the lack of stability by acting as a dynamic stabiliser. The force closure or muscle action is high due to inadequate form closure or static stabilisers (Vleeming et al, 1990). The rotator cuff is therefore subjected to more day-to-day tensile stress than most other tendons in the upper limb. The forces can be excessive i.e. a throwing athlete can produce humeral angular velocities of up to 7,000 degrees per second (Fleisig et al, 1993; Arroyo et al, 1997). Therefore it is not unreasonable to assume that these tensile stresses, if repetitive or excessive, may result in microtrauma to the rotator cuff. This may result in or accelerate the normal age related degenerative changes. This process takes place at a microscopic level and these micro-tears may initially go undetected as they are painless, or at least cause only minimal pain (Pettersen, 1942; Matsen and Arnst, 1990). Damage occurs if the loading is either too great, or if the recovery time is too short. If the action e.g. throwing is at a sub-maximal level but of a repetitive nature, it may overwhelm the adaptive healing process of the tendon and result in chronic injuries of the tendon (Benjamin and Ralphs, 1996).

Swelling of the tendon may result from these micro-tears and as this occurs in a confined space (supraspinatus outlet), the incidence of impingement will increase and this may compound the injury. The impingement may also cause pain inhibition with resultant rotator cuff weakness, which can lead to loss of stabilisation of the head of the humerus and further impingement ensues (biomechanical).

The problem is, that this is a clinical diagnosis, as biopsies are rare. In addition, this is also difficult to prove by laboratory examination (Unthoff and Sarkar, 1991; Benjamin and Ralphs, 1996; Unthoff and Sano, 1997).

### 2.2.1.3 Microvascularity of the Rotator cuff

The microvascular pattern of the rotator cuff has been well described (Moseley and Goldie, 1963; Rathburn et al, 1970; Ianotti, 1992). Codman, (1990) defined a hypovascular area (Critical Zone) as the area just proximal to the supraspinatus insertion (Breazeale and Craig, 1997). This is the area where rotator cuff tears are found to most commonly initiate from and this hypovascularity has been linked to the tears (Ianotti, 1992). It has however been shown that this area is in fact highly vascularised by an anastamoses between the tendinous and osseous blood vessels (Moseley and Goldie, 1963; Matsen and Arnst, 1990). Filling of the blood vessels, seems to be dependent on the position of the arm. Rathburn et al (1970) noticed that with abduction almost total filling of the blood vessels occurred. With adduction a "wringing out" or hypovascular effect, (similar to bending a garden hosepipe to stop the flow of water) was noted.

Lohr and Unthoff (1991) observed the blood flow throughout the entire thickness of the muscle in the Critical Zone. Histologically the vessels were found to be more abundant on the bursal (superficial) side of the rotator cuff than on the joint (undersurface) side. This may result in more efficient healing on the bursal surface. The undersurface of the tendon in the Critical Zone had a uniformly hypovascular pattern, which in turn may predispose the tendon on the joint side to poor healing and subsequent tears (Lohr and Unthoff, 1991; Breazeale and Craig, 1997).

Laser doppler studies have also shown evidence of hypervascularization in areas of impingement i.e. the bursal side (Ianotti, 1992). This again would contradict the theory that hypovascularity due to impingement is the cause of tears in the Critical Zone. A hyperemic response to injury, which results in swelling, may instead play a role in the pathogenisis of the bursal side tears. The hypovascular areas of the joint surface area of the muscle may also be the area where the degenerative painless tears occur (Ianotti, 1992). The contradictions in microvascular patterns may be the explanation for different pathological changes occurring on the bursal versus the joint side of the muscle (Ianotti, 1992).

It cannot however be conclusively said, that hypovascularity is the cause of degenerative tears, because it has been shown that the major source of nutrition for some tendons is from tissue perfusion rather than vascular origins (Ianotti, 1992).

#### 2.2.1.4 Reactive Rotator Cuff Failure

The most well known cause of reactive rotator cuff failure in the shoulder is calcifying tendinitis. Calcification of the tendon usually occurs in the supraspinatus tendon approximately 1cm medial to the greater tuberosity (Critical Zone)(Unthoff and Sarkar, 1991). It is a primary reactive tendinopathy which results in the formation of hydroxyapatite and calcium deposits in the tendon. It is self healing and not progressive. Symptoms usually either arise from impingement, or increased intratendinous pressure. Occasionally rupture of the deposit into the bursa may temporarily increase the symptoms (Unthoff and Sarkar, 1991, 1993; Unthoff and Sano, 1997). Rotator cuff damage due to impingement is usually seen in the formative phase. Failure may also be caused by pain, either due to impingement or during the resorptive phase, when intratendinous swelling can render the patient immobile (Unthoff and Sano, 1997). Diagnosis can be confirmed on X-ray.

### 2.2.2 Extrinsic (secondary) causes of Rotator Cuff Pathology

Extrinsic factors refer to rotator cuff pathology that is not primarily caused by the rotator cuff itself, but by the surrounding structures, or secondarily to kinetic abnormalities, or diseases. Kinetic abnormalities and diseases are not directly related to this research project and therefore are not fully discussed. It is however acknowledged that they are important causes of rotator cuff pathology.

Extrinsic factors can be summarised under the headings of *primary* and *secondary* impingement.

#### 2.2.2.1 Primary Impingement

Primary impingement refers to any local changes related to the supraspinatus outlet tunnel that causes a decrease in its size and therefore promotes impingement. Impingement is unique to the shoulder. For normal unimpeded movement of the rotator cuff, and particularly the supraspinatus, the biceps tendon and the upper portion of infraspinatus, good function and biomechanics of the entire shoulder complex (acromioclavicular, sternoclavicular, scapulathoracic, glenohumeral and acromiohumeral joints) is required (Maitland, 1991).

Neer (1972) postulated that 95% of rotator cuff tears were due to impingement and he popularised the term "impingement syndrome". He pointed out that in the normal use of the arm, movement at the shoulder joint, occurred in the plane of the scapula, otherwise known as scaption (Poppen and Walker, 1976). The supraspinatus insertion along with the subjacent biceps tendon and the upper infraspinatus therefore pass beneath the coracoacromial arch and the opportunity for impingement is high. A continuum of pathology from an oedema to tears of the rotator cuff was proposed (Neer, 1983) and finally in 4% of cases with large or massive tears, the total disruption of the glenohumeral joint or rotator cuff arthropathy was described (Neer et al, 1983). Neer (1972,1983) classified rotator cuff pathologies into three stages as follows:

***Stage 1*** - reversible oedema and haemorrhage in patients under 25 years of age;

***Stage 2***- tendinosis and/or fibrosis, that affect patients in the 25- 40-year age group;

***Stage 3***- bone spurs and tendon ruptures, which present in the over 40-year-old group.

The supraspinatus outlet can be compromised by the following conditions that may then result in primary impingement of the rotator cuff:

- Acromioclavicular joint separation.
- Acromioclavicular degenerative osteophytes.
- Acromial and/or coracoid malunion or non-union.
- Greater tuberosity malunion.

- Developmental abnormalities e.g. os acromiale (unfused epiphysis) and coracoid malformation.
- Shape and slope of the acromion.
- Spurs or osteophytes on the anterior edge of the acromion and the insertion of the corocoacromial ligament.

(Ianotti, 1992; Arroyc et al, 1997; Soslowsky et al, 1997).

There is controversy in the literature as to whether the various shapes and slopes of the acromions are anatomical variations or acquired conditions. (Bigliani et al, 1986 and 1991; Edelson, 1995) In other words, is the primary lesion due to anatomical variations of the acromion, or are these changes degenerative or prolific changes of the undersurface of the acromion. These degenerative changes would then be similar to acromial spurs and osteophyte formation, which are due to chronic rotator cuff pathology.

Osteophytes that form on the anterior third of the acromion as well as spur formation at the attachment of the coracoacromial ligament may also compromise the space, but must not be confused with the architecture of the acromions (Bigliani et al, 1986 and 1991). Spurs/osteophytes are most likely acquired by subacromial pressure which stretches or tractions the coracoacromial ligament in a similar manner to formation of osteophytes in the spine, which form due to excessive movement of the vertebra in spinal instability (Kirkaldy-Willis, 1984).

Bigliani et al (1986) studied the shape of the acromion in 140 shoulders in 71 cadavers, to establish a possible relationship between the shape of the acromion and full thickness tears. The overall incidence of tears in this elderly population (average age was 74.4 years) was 34%. This seemed to link the more curved and hooked acromions with tears.

They identified three types of acromion shapes:

***Type I:*** flat (17%) ***3%*** were associated with rotator cuff tears.

***Type II:*** curved (43%) ***24%*** were associated with rotator cuff tears.

***Type III:*** hooked (39%) ***70%*** were associated with rotator cuff tears.

Stereophotogrammetry studies which look at the acromiohumeral relationship in a three dimensional manner have also shown that acromial undersurface and rotator cuff tendons are closest between 60-120 degrees of elevation. This contact was much more pronounced in type III acromions, thus subjecting the rotator cuff to increased microtrauma. (Flatow et al, 1994).

There is a strong association between "hooked" acromions and rotator cuff tears. Is it however, the increased impingement due to intrinsic rotator cuff pathology that has caused secondary degenerative change in shape of the acromion, or are the Type III acromions anatomical variations which therefore predisposed the rotator cuff to impingement and tearing? The answer to this remains unclear (Ianotti, 1992).

Edelson (1995) examined 750 dry scapulae, 211 from subjects who had died when they were younger than 30 years old, and hooking of the acromion was not found in any of these subjects. It was observed that the hooked acromions developed in an increasing number at later ages. The hooks were examined from below and it was postulated that they were formed by new growth that had ossified at the site of insertion of the coracohumeral ligament and were not anatomical variations. This is not conclusive, but it seems unlikely to be coincidental that none of the scapulae of individuals under thirty years of age had increased slopes of their acromions. Tears under the age of 30 years are rare, so perhaps this strengthens the hypothesis that it is an acquired condition (Edelson, 1995;Unthoff and Sano, 1997). If these changes are considered as secondary to a primary intrinsic tendinopathy, then the shape of the acromion and/or spur and/or osteophyte formation, should theoretically be classified as intrinsic causes of rotator cuff pathology (Ogata and Unthoff, 1990).

#### 2.2.2.2 Secondary Impingement

Secondary impingement refers to kinematic disorders that increase the chance of impingement. These varied and often unrelated conditions are listed below:

- Instability-atraumatic multidirectional.

- Acquired subtle anterior instability.
- Capsule contracture.
- Scapulohumeral neuromuscular dysfunction.
- Kyphotic and/or stiff thoracic spine.
- Cervical spine dysfunction and/or radiculopathy.
- Neuropraxia e.g. suprascapular nerve.

(Matsen and Arnst, 1990; Jobe and Pink, 1993; Arroyo et al, 1997; Cordasco and Bigliani, 1997)

### 2.2.3 Tears of the Rotator cuff

Rotator cuff tears can be full thickness i.e. with communication between the subacromial bursa and glenohumeral joint occurring, or partial thickness, with no communication occurring (Breazeale and Craig, 1997). Partial thickness tears can occur on the joint side, bursal side or a midsubstance or interstitial tear (Ellman, 1990).

Neer (1972, 1983) classified tears of the rotator cuff as stage III. There is some confusion as to whether a partial tear should be considered an advanced stage II lesion or a stage III lesion. The logical conclusion is that a partial tear and should also be classified as a stage III (Ellman, 1990). This however does not accurately describe the severity of the tear.

Ellman (1990) drew up a sub-classification of stage III (partial or full thickness tears), as follows,

Partial tears were classified as:

- articular
- bursal
- interstitial

The size of the partial tears were graded as,

Grade I < 3mm deep
Grade II 3-6mm deep
Grade III > 6mm deep

The area of defect caused by the tear (partial or full thickness) was measured as *base of tear x maximum retraction.*

Full thickness tears were classified as

- supraspinatus
- infraspinatus
- teres minor
- subscapularis

This grading based on the above method of sizing can lead to confusion. This is especially true when grading partial tears. A tear, 5cm in diameter and almost full thickness, will be classified as a grade III, as will a much smaller 1cm diameter tear that is only 6mm deep. These two tears are obviously not similar and therefore the grading is inadequate. However there does not however seem to be consensus as to which grading system is best or any logical reason for these divisions of grades. Tears seem to have been arbitrarily divided into sizes and graded (Post et al, 1983).

Another grading system (Post et al, 1983) suggests using the longest diameter of the tear as a reference. In this system a small tear is less than 1cm. A medium- sized tear is greater than 1cm and less than 3cm. A large tear is greater than 3cm and less than 5cm and a massive tear is greater than 5cm.

The severity of the tear will also be affected by the orientation of the tear (Leffert and Rowe, 1988) and the muscles involved in the tear (Burkhart et al, 1994). However, classifying the tears by the number of muscles involved is also inaccurate because of the tendons becoming confluent near their insertions (Gartsman et al, 1998). The area of the tear (*base of tear x*

*maximum retraction)* as described by Ellman, (1990) has often been used as a measure of tear size (Itoi et al, 1997; Gartsman et al, 1998) and is used to describe the tear size here.

### 2.2.4 Summary

Rotator cuff pathology encompasses a wide spectrum of pathologies ranging from a mild oedema to a large tear. It is therefore not unreasonable to speculate that a tear of the rotator cuff would be the most debilitating pathology to the individual. It has been shown however, that a person can have a full thickness rotator cuff tear with full pain-free function of the arm. In contrast, an individual may be rendered unable to use the arm due to a severe oedema or tendinosis of the rotator cuff. Diagnosis of the stage of pathology is therefore complex as the severity of pain and loss of active movements can be misleading.

A number of extrinsic and intrinsic factors contribute to rotator cuff pathology and these overlap considerably. Impingement can occur due to intrinsic weakness of the rotator cuff which could be age related or due to an extrinsic factor when the function of the rotator cuff as a stabiliser is lost. The impingement damages the rotator cuff by repetitive compression and may cause a proliferation of cells and blood vessels in the body's attempt to heal. This swelling of the rotator cuff is due to intrinsic fibre damage and causes further subacromial crowding and therefore more impingement which at this stage may be painful (Unthoff and Sano, 1997). This repetitive impingement may stimulate spurs or osteophyte growth in the long term or even, as some authors propose, changes in the shape of the acromion. This will also increase the chance of impingement. A tear is usually the result of a combination of attrition, hypovascularity, trauma and impingement (Blevins et al, 1997; Soslowsky et al, 1997; Unthoff and Sano, 1997).

## 2.3 EXAMINATION

In this section the topics covered will be the Constant Score (2.3.1), as this scoring method was used. A brief overview will be given of the general inconsistencies of clinical examination (2.3.2) and special investigations (2.3.3). Muscle testing, which is an integral part of the examination, is discussed separately (2.4)

### 2.3.1 Constant Score

Shoulder scoring systems are proposed as a simple method to describe, evaluate and/or compare the management of shoulder conditions (Gerber, 1993; Romeo et al, 1996; Kuhn and Blasier, 1998).

Various different scoring systems have been proposed (Gerber, 1993; Romeo et al, 1996). However validity of these systems and interrater reliability between these systems is lacking (Kuhn and Blasier, 1998). Without substantial scientific validation studies or a concensus on a selected scoring system, a standard scoring system cannot and does not exist (Gerber, 1993; Romeo et al, 1996; Kuhn and Blasier, 1998)

The Constant Scoring System is a widely used scoring system in Europe and is increasingly being used in America. It is a numerical description of the quality of shoulder function. It attempts to use subjective and objective tests in order to assess shoulder function. The use of this system was prompted by the 1992 International Shoulder Surgeons Congress, in which all authors were required to present data using the Constant and Murley scoring system (Gerber, 1993; Romeo et al, 1996; Kuhn and Blasier, 1998). This system has been the subject of psychometric validation and age specific values have been established. It has been used worldwide since 1987 (Romeo et al, 1996). The Constant Score, although widely used, is still not totally acceptable, primarily because the reliability of the method of strength testing has not been properly established (Romeo et al, 1996; Bankes et al, 1998; Kuhn and Blasier, 1998).

Table 2.3.1 shows the point allocation for the subjective assessment according to the Constant and Murley (1987) method.

**Table 2.3.1 Point Allocation for the Subjective Assessment**

| | **Number of Points** |
|---|---|
| **Pain Scale** | **0 ( severe) -15 ( no pain)** |
| **Activities of daily living** | **0-10** |
| Ability to Work | 0- 4 (full work) |
| Recreational/ Sport Activities | 0- 4 (unaffected) |
| Sleep | 0 - 2 (unaffected) |
| **Ability to position arm** | **0-10** |
| Up to Waist | 2 |
| Xiphoid | 4 |
| Neck | 6 |
| Head | 8 |
| Above head | 10 |
| **Total points possible** | **35** |

In table 2.3.1 the subjective parameters used in the Constant Score to assess the level of pain that the patient experiences, as well as their ability to perform certain activities of daily living are shown (Appendix B) (Constant and Murley, 1987).

In this score 35 points are allocated for subjective assessment. Pain (15), activities of daily living (10) and ability to position arm (10). The maximum pain that the patient experiences is marked on a visual analogue scale and accounts for 15 points for no pain (Appendix B).

Table 2.3.2 shows the point allocation for the objective assessment according to the Constant and Murley (1987) method.

**Table 2.3.2 Point Allocation for the Objective Assessment**

| | **Number of Points** |
|---|---|
| Active Range of Pain Free Flexion | 0 ($0$-$30^0$)- 10 ($151$-$180^0$) |
| Active Range of Pain Free Abduction | 0 ($0$-$30^0$) - 10 ($151$-$180^0$) |
| Combined Active External Rotation | 0 – 10 |
| Combined Active Internal Rotation | 0 – 10 |
| Power of Abduction | 0 - 25 (1 point per pound or 0.45 kg) |
| **Total points possible** | **65** |

In table 2.3.2 the objective parameters measure the composite movements of functionally relevant positions as well as flexion and abduction. Power of abduction is also included in this score (Appendix B). Passive movements are excluded from this method (Constant and Murley, 1987).

Sixty-five (65) points are available for objective measurement of range of movement and strength. Flexion and abduction are measured using a goniometer. The combined movements of external and internal rotation are measured by testing the hand behind head and hand behind back position respectively (Appendix B). An unaffected shoulder will score one hundred (100) points consisting of thirty five (35) points for subjective (Table 2.3.1) and sixty five (65) for objective (Table 2.3.2).

Passive movement is not considered important as this scoring is directed at the quality of function, rather than the diagnosis. It can be used independently of the diagnosis of the condition (Constant and Murley, 1987; Gerber, 1993). A large proportion of points are allocated to strength. Twenty-five points are allocated to the patient if they are able to hold 25 pounds (11.25kg) or more in "lateral elevation" (Constant and Murley, 1987). The strength

can be measured using a Cybex Dynamometer (Lumex Corporation, Bayshore, NY), however this is often not appropriate as it is both costly and is not easily transportable (Constant and Murley, 1987). In the original study Constant and Murley (1987) used a tensiometer (unsecured spring balance). The method as described by Moseley (1972) was used to measure shoulder power. However the method of testing is not clear and leads to confusion (Gerber, 1993; Kuhn and Blasier, 1998; Marcus et al, 1998). Gerber (1993), in an attempt to standardise the measuring method and eliminate this confusion, assessed muscle strength using an Isobex dynamometer (Curser AG, Berne, Switzerland). This measurement was compared to the Constant and Murley Score. The results using the Isobex dynamometer were much lower than those of Constant and Murley(1987). Gerber (1993) felt that a comparison between the two methods was not possible unless the testing was standardised. This result was confirmed by Bankes et al (1998), who compared strength values obtained by an Isobex dynamometer, a secured spring balance and an unsecured spring balance. This testing was conducted on both pathological and normal shoulders. Bankes et al (1998) concluded that the unsecured spring balance was not an acceptable means of measurement, as it was not possible to standardise. It was rather suggested that the secured spring balance be used, as an inexpensive alternative or the Isobex, as a more expensive alternative.

The Constant score has been found to be relatively independent of the observer. If the same device is used, an intra-observer error of 3% (0%-8%) has been shown (Romeo et al, 1996). The Constant Score, although widely used, is still not totally acceptable, primarily because the reliability and validity of the methods of strength testing have not been properly established (Romeo et al, 1996; Bankes et al, 1998; Kuhn and Blasier, 1998).

### 2.3.2 General Clinical Assessment

A full examination of the entire shoulder complex is necessary to make an accurate diagnosis when rotator cuff pathology is suspected. However, the glenohumeral and acromiohumeral joints must be specifically examined (Maitland, 1991). The shoulder complex forms the attachment between the trunk and arm and therefore the trunk and most especially the cervical spine must also be examined as a potential source of rotator cuff pathology (Magary, 1997).

The examination of the shoulder complex has been well described (Cyriax, 1978; Hawkins and Bokor, 1990; Maitland, 1991) and is not discussed here in its entirety. General inconsistencies in the examination are highlighted.

#### 2.3.2.1 Subjective Examination

Many shoulder clinicians would agree that a diagnosis could often be suggested by taking an accurate and relevant history (Richards, 1992). This diagnosis must then be confirmed by the objective/physical examination.

The history cannot stand alone because of the following inconsistencies:

- 50% of patients cannot relate their pain to any specific injury, but have an insidious onset (Matsen and Arnst, 1990)
- Women are affected almost as much as men, therefore there is no gender difference (Matsen and Arnst, 1990)
- Many manual labourers never develop rotator cuff pathology, leading one to suspect that the injury is not always related to heavy work (Neer, 1983; Matsen and Arnst, 1990)
- The non-dominant arm is affected as frequently as the dominant arm. This leads one to suspect that the frequency of use of the arm is often unrelated to the frequency of the pathology (Neer, 1983; Matsen and Arnst, 1990; Payne et al, 1997)
- A patient with a large or massive tear often presents with severe, constant pain and/or has disturbing night pain. A tendinosis can similarly present with these symptoms (Neer, 1983; Matsen and Arnst, 1990; Richards, 1992; Cordasco and Bigliani, 1997; Payne et al, 1997). Alternatively a full thickness tear can be painless and the only presenting symptom might be weakness (Neer, 1983; Matsen and Arnst, 1990; Cordasco and Bigliani, 1997; Payne et al, 1997)
- Tears of the rotator cuff are related to age, and unlikely to occur in the younger than 40-year age group (Neer, 1983). However, tears have often been confirmed intra-operatively

in overhead sportsman in their twenties (Neer, 1983; Jobe and Bradley, 1989; Hawkins and Bokor, 1990; Matsen and Arnst, 1990)

#### 2.3.2.2 Physical/Objective Examination

There is also considerable variation in the value of any component of the physical examination, including special testing. This is partly due to the wide variety of dissimilar signs and symptoms that occur in each separate diagnostic category. In addition, the components of the physical examination have not been thoroughly assessed for validity (Cofield, 1993; Kuhn and Blasier, 1998).

#### 2.3.2.3 Special Tests

Special tests are often recommended for assessing rotator cuff pathology. They are however not accurate in isolation:

- Impingement signs (Hawkins and Kennedy, 1980; Neer, 1983), which if positive, indicate that the structures in the subacromial space are being impinged. They do not differentiate between the stages of pathology or the structures being impinged.

- Lift off sign (Gerber and Krushell, 1990), which if positive indicates a subscapularis tear. The hand behind back position needed for this test is not always possible with rotator cuff pathology.

- A drop arm test, which if present is said to indicate a rotator cuff tear (Daniels and Worthingham, 1972). However it has been shown to be negative in patients with confirmed rotator cuff tears (Neviaser, 1971; Burkhart, 1997)

- A shoulder shrug sign (Cofield, 1993) i.e. excessive elevation and rotation of the scapula, is usually present in large tears of the rotator cuff. However. Cases of full thickness supraspinatus tears have been described, that present with strong elevation and no evidence of a shrug. These tears have been termed "functional" tears (Burkhart, 1997). Patients with full thickness tears and a positive shrug sign, often have full range passive elevation of the arm, or have passive elevation of the arm which is usually much greater than the very limited active movement. A frozen shoulder syndrome can similarly result in a shoulder shrug sign. This is due to glenohumeral joint stiffness. In these cases, passive and active movement of the arm will be very limited.

- Maitland (1991) differentiates between supraspinatus muscle pathology and acromiohumeral joint pathology. He monitors the pain response, while alternatively compressing the humerus up against the acromion and then distracting the humerus away from the acromion during execution of the problem movement. These tests have however been shown to be unreliable (Magary, 1993)

**2.3.2.4 Differential Diagnosis**

The differential diagnosis of rotator cuff pathology includes all other causes of shoulder pain. (Hawkins and Bokor, 1990). Cervical spine pathology in particular can often mimic rotator cuff pathology (Hawkins and Bokor, 1990; Matsen and Arnst, 1990; Karas and Ionetti, 1997) as follows:

- The area of pain referral of the C5 dermatome overlaps pain referral from the rotator cuff.

- Nerve root pathology of particularly C5 (C4 and C6) can also cause rotator cuff muscle weakness, that may result in impingement, leading secondarily to rotator cuff pathology.

- A pathological C5/6 nerve root which is stretched via the brachial plexus as it is caught under a slow moving coracoid process (due to muscle spasm and/or weakness of scapula musculature) may mimic an arc of pain, which is a classic sign of rotator cuff impingement. The brachial plexus is impinged at approximately 60 degrees of arm abduction and then released at approximately 120 degrees of arm abduction as the scapula rotation continues (Elvey, 1986).

There are also many other shoulder conditions that either mimic or occur simultaneously with rotator cuff pathology or that can be the primary cause of secondary rotator cuff pathology. Some of these conditions are frozen shoulders, acute and chronic calcific tendonitis, acromioclavicular arthritis, bicipital tendinitis, glenohumeral instabilities and abnormalities of the joint surfaces (Jobe and Bradley, 1989; Matsen and Arnst, 1990; Payne et al, 1997)

#### 2.3.2.5 Summary

In the examination of patients presenting with rotator cuff pathology the major problems confounding an accurate diagnosis are:

- There are many other conditions that can mimic and/or co-exist with rotator cuff pathology.
- The signs and symptoms of the various stages of rotator cuff pathology can overlap considerably.
- The validity of the various aspects of the examination procedure has not been thoroughly investigated.

### 2.3.3 Investigations

Conventional radiograph (X-rays) are said to be essential and a matter of routine in patients presenting with shoulder pathology (Richards, 1992). They demonstrate the bony anatomy of the shoulder joint (King and Healy, 1999). Abnormalities however, often lag the clinical course of impingement and the information obtained in most cases is non-specific. (Neer, 1972; Breazeale and Craig, 1997; King and Healy, 1999).

A number of other imaging techniques are available. These are usually only used if the diagnosis is unclear (Alchek and Carson, 1997). Each modality has certain strengths and weaknesses in evaluating rotator cuff pathology.

Routine arthrography in rotator cuff pathology is said to be invasive and non-specific (Ellman et al, 1986; Breazeale and Craig, 1997).

MRI provides multi-planar images that are reported to have excellent soft tissue contrast, allowing a detailed evaluation of the rotator cuff (King and Healy, 1999). However, 26% of normal shoulders are said to have abnormal findings, making interpretation of findings difficult (Sher et al, 1995). Rockwood et al (1990) have made the following comment concerning MRI, " It is experimental, costly, and probably not indicated for patients with a routine rotator cuff problem."

Computed Tomography (CT) is said to provide an excellent depiction of bony anatomy in the axial plain. It however has the disadvantage of using ionising radiation and having poor soft tissue contrast compared with MRI (King and Healy, 1999).

Ultrasound (U/S) is said to be one of the best predictors of the state of the rotator cuff muscle. It is non-invasive, relatively inexpensive and can be performed dynamically (Alchek and Carson, 1997; King and Healy, 1999). The accuracy of the results of U/S is highly dependent on the skill of the examiner. Technical failure may also occur in patients with excess

subcutaneous fat. In addition there are certain blind areas that can compromise the findings (Sartoris, 1992; Breazeale and Craig, 1997; King and Healy, 1999).

In South Africa, the additional problem is that there is a huge section of the population who do not have access or finance for normal X-rays. This emphasises the need for a more accurate clinical diagnosis that does not rely on expensive investigations.

## 2.4 MUSCLE TESTING

Once a diagnosis of rotator cuff pathology is made, the stage of pathology must be determined in order to establish a prognosis. This is extremely difficult because of the overlap and inconsistencies in the signs and symptoms of each diagnostic category.

It seems logical that tears of the rotator cuff will result in a loss of force transmission to the humerus (Itoi et al, 1997), which in turn will lead to a decrease in shoulder strength. It is not therefore unreasonable to suspect that the larger the tear the greater the loss of muscle strength. Testing muscle force may therefore be the key factor in the examination that may lead to a more accurate diagnosis of the stage of pathology. Muscle testing, perhaps more importantly, if done repeatedly as a reassessment, may result in a more accurate way of detecting if the rotator cuff is improving or deteriorating.

### 2.4.1 Methods of Muscle Testing

In the nineteenth century, muscle performance was assessed using crude manual muscle testing such as observing posture, gait and active range of movement. In the beginning of the twentieth century, the poliomyelitis virus epidemic necessitated a better method of testing muscle strength and manual muscle testing (MMT) as initially described by Lovett and Martin (1916) was used extensively (Sapega, 1990).

The grading system currently most commonly used is a scale of 0-5;

0 – no muscle contraction;
1 – trace or flicker of contraction, no movement;
2 – poor full range movement with gravity eliminated;
3 – fair full range movement against gravity;
4 – good, full range movement with resistance and gravity;
5 - normal

These 6 basic categories are also sometimes described slightly differently and can be expanded with a plus or minus sign (Daniels and Worthingham, 1972; Florence et al, 1992; Kendall et al, 1993).

Manual muscle testing is however not reliable enough (Backman et al, 1989; Ploeg and Oosterhuis, 1991; Kuhlman et al, 1992). Most errors in manual muscle testing are made when estimating minor weaknesses and/or normal muscle strength. (Bohannon and Andrews, 1987; Sapega, 1990). A manual muscle testing grade of 4 or 5 can be very inaccurate. Experienced physiotherapists have rated patients with strength deficits of up to 50% as having normal strength (Beasley, 1956; Wadsworth et al, 1987; Krebs, 1989; Florence et al, 1992).

Sapega (1990) has compared manual muscle testing to "auscultation of the heart without a stethoscope". It must be kept in mind, that the original manual muscle testing as described by Lovett and Martin (1916) was only devised to measure the integrity of the function of the anterior horn cell in poliomyelitis victims and not an assessment of normal muscle function.

The realisation of the importance of a more objective, accurate and specific assessment resulted in more sophisticated computerised muscle dynamometry (Backman et al, 1989). However, despite these modern methods, manual muscle testing as used in the days of poliomyelitis, is still probably the most commonly used form of muscle testing today (Marina et al, 1982; Bohannon and Andrews, 1987; Sapega, 1990).

Since the introduction of hand-held dynamometers (HHD), e.g. the Nicholas Manual Muscle Tester (NMMT), the accuracy of manual muscle testing has improved, with reports of good intra-rater reliability and fair inter-rater reliability (Bohannon, 1986; Bohannon and Andrews, 1987; Backman et al, 1989; Magnusson et al, 1990; Sapega, 1990; Ploeg and Oosterhuis, 1991; Deones et al, 1994; Brinkman, 1994; Stratford et al, 1994). More specifically, in the shoulder complex, hand-held dynamometers have been shown to have good intra-rater reliability when testing external rotator performance (Sullivan et al, 1988). Strain gauges have also been described as a more accurate means of measurement than manual muscle testing

(Oldham and Howe, 1995). Isokinetic dynamometers, although very costly, have also proved to be reliable methods of measuring muscle function and can also be set up to measure isometric force (Malerba et al, 1993; Oldham and Howe, 1995).

Isotonic, isokinetic and isometric muscle testing are the most common modes of testing. Isometric muscle testing (used in this study) can be defined as "the measurement of static external forces that are produced by isometric muscle contractions " (Sapega, 1990). Work and power, however, cannot be measured with isometric testing, as the measurements do not involve movement through distance. Isometric testing using a variety of devices has been shown to have good or excellent test and retest reliability on both normal subjects and patients (Sapega, 1990; Malherbe et al, 1993). Ideally, data should be collected at multiple points in the arc of the range of movement to create a strength curve, which has been shown to be comparable with curves generated by dynamic testing on computerised systems (Sapega, 1990).

There is however, no single testing mode that has been found conclusively to be the best or most valid method for testing muscle strength (Kuhlman et al, 1992). It is said that all modes of strength testing bear some relationship to each other (Sapego, 1990; Kramer and Ng, 1996). Initially isometric testing was thought to be less effective in its correlation to function as compared to isokinetic testing. It has however been suggested that isokinetic muscle testing is not as accurate as previously thought, especially if care is not taken with calibrating the machine's axis alignment, overshoot and ramping (Rothstein et al, 1987; Malherbe et al, 1993).

Simple isometric testing may in fact, be as reliable a test of function as isokinetic testing (Sapega, 1990; Malherbe et al, 1993; Wilson et al, 1996). Studies comparing the reliability of testing with isokinetic devices such as Cybex (Lumex Corporation, Bayshore, NY) and the reliability of testing with a hand-held dynamometer e.g. Nicholas Manual Muscle Testers have been shown to have no statistical differences (Bohannon, 1990; Stratford and Balsor, 1994; Trudelle - Jackson et al, 1994). Recent studies have also shown a high correlation between isokinetic and isometric testing especially if end range of motion is excluded

(Sapega, 1990). It must be noted that many of these studies use eccentric isometric muscle contraction i.e. a "break test" (Bohannon and Andrews, 1987) and compare it to concentric isokinetic muscle testing (Deones, 1994; Trudelle–Jackson, 1994), and therefore the results of the studies must be questioned. Subjects can also often not tolerate isokinetic testing of the injured shoulder (Rabin and Post, 1990; Malherbe et al, 1993). Some disadvantages of isometric muscle testing are that it only measures force production. It also produces higher absolute muscle and joint forces than dynamic testing, which in some conditions may be undesirable (Sapega, 1990).

Isometric testing using a hand-held dynamometer may either be done as a "make-test" or "break-test" (Bohannon and Andrews, 1987; Bohannon, 1988; Ploeg and Oosterhuis, 1991; Stratford and Balsor, 1994). The "make test" is done by the subject exerting a maximum force against a stationary dynamometer. In a "break test", the examiner pushes the dynamometer against the subject's limb until the subject's maximum effort is overcome and the joint gives way (Wadsworth et al, 1987; Stratford and Balsor, 1994). The latter test is said to include eccentric muscle work and produces higher force values than the "make test" (Stratford and Balsor, 1994; Bohannon et al, 1998). There seems to be some controversy in the literature as to which of the two tests is more accurate. A "break test" is said by some to be a better test, because it is easier to obtain a maximal contraction and the patients co-operation (Backman et al, 1985). If a "break test" as opposed to a "make test" is being used, then the tester knows that the subject's peak force and not their own is being recorded. Stratford and Balsor (1994) compared the reliability of a "make test" versus a "break test" using a Nicholas Manual Muscle Tester. In this study it was found that the "make test" was more reliable. This was said to be due to the additional skills required of the tester. Ideally the tester should prove their intrarater reliability with whichever test is being used (Riddle et al, 1989).

Hand-held dynamometers are easily transportable, relatively inexpensive and at least as accurate as any other testing device (Wadsworth et al, 1987). They are however limited in measuring muscle strength less than a 2 (poor). Manual muscle testing principles are said to be fairly adequate to measure this (Wadsworth et al, 1987). For the purposes of this research

report a Nicholas Manual Muscle Tester was used to test the isometric break force of the rotator cuff muscles.

### 2.4.1.1 Factors that will affect the Reliability of Testing

Muscle testing in a non-laboratory setting poses considerable difficulties and obtaining valid reliable results is often difficult (Backman et al, 1989; Stratford and Balsor, 1994; Oldham and Howe, 1995). The following discussion, outlines some of the areas that must be addressed if reliable results are desired:

***Testing Protocol***

Standardisation of the test situation is important (Backman et al, 1989; Oldham and Howe, 1995). The machinery must be calibrated regularly, unless as in the Nicholas Manual Muscle Tester it is calibrated in the factory (Trudelle-Jackson et al, 1994). If more than one machine is being used, interdevice reliability must be proven. Trudelle-Jackson et al (1994) investigated the interdevice reliability of two separate Nicholas Manual Muscle Testers. They tested the hamstring force of 30 subjects. The testing was conducted over 2 days and three trials were performed with each Nicholas Manual Muscle Tester. The study was well controlled and executed. The Nicholas Manual Muscle Tester was shown to be valid and highly reliable for testing between trials (HHD A: r = 0.98, 95% confidence interval; 0.99-0.98: HHD B: r = 0.97, 95% confidence level; 0.98-0.92) and between days (HHD A: r = 0.87, 95% confidence interval; 0.94-0.74: HHD B: r = 0.85; 95% confidence level; 0.92-0.71). These results are consistent with the findings of previous intrarater reliability studies of hand-held dynamometers (Bohannon, 1986; Nies Byl et al 1988; Bohannon and Andrews 1989; Riddle et al 1989). Interdevice reliability between the two machines was shown to be poor (r = 0.59: 95% confidence interval 0.77-0.32). The authors were very clear that this might not apply to other hand-held dynamometers, as no other studies could be found to compare or confirm their findings. It is however recommend that because of these adverse results, the same testing device should be used for research purposes or for re-testing a patient's clinical progress. There were however a number of potential problems in this study.

The zero value was reset before each test, which ensures that the force gauges are set back to zero each time. However, it may have been advisable to check the accuracy of the device by applying weights to the force plate. One of the devices used may have been calibrated incorrectly in the factory. No mention is made of the individual devices being checked for factory errors.

The application of the apparatus, limb position and joint angle, must be consistent. As small changes can affect the muscle function, making comparisons invalid. (Bohannon and Andrews, 1987; Wadsworth et al, 1987; Backman et al, 1989; Kuhlman et al, 1992).

When testing rotator cuff muscles, if the apparatus is applied proximal to the wrist, this will eliminate errors from any wrist dysfunction. Ideally the elbow joint should also be excluded. This is not possible if rotation of the shoulder joint is to be tested.

Stabilisation is essential if any testing is to be reliable. In the case of the glenohumeral joint, it is important to eliminate substitution especially from the trunk. (Bohannon and Andrews, 1987; Sapega, 1990, Deones, 1994). It is easier to stabilise the testing if the patient is supine, with straps at mid-thoracic and pelvic levels. However, no systematic study on the effect of stabilisation could be found (Dvir, 1995).

The same time of day and same place of testing should be used to eliminate as many variables as possible (Wadsworth et al, 1987). The noise level should be controlled and no interruption should be allowed to distract the subject (Backman et al, 1985).

***Patient/Subject Compliance***

Full maximum voluntary contraction is essential if the isometric testing is to be considered valid (Sapega, 1990). A number of factors will affect the efficacy of testing:

Subject co-operation is an essential factor. This necessitates that the patient totally understands what he is expected to do. The manner in which the test procedure is explained

must be as simple and concise as possible (Wadsworth et al, 1987). A trial run may improve the patient's understanding of the test. It has been shown however, that familiarity of the test may result in an initial increase in strength. This apparent increase in strength has been ascribed to "neural factors" i motor learning (Ploeg and Oosterhuis, 1991). It is therefore preferable to have a rehearsal before the actual test is done. This is however not always clinically possible.

The presence of pain makes measurements uncertain and therefore, the intensity of the pain should be recorded as it may affect the results (Backman et al, 1985; Brox, 1997). The rotator cuff is particularly prone to pain inhibition due to the "sandwiching" effect of the impingement position. Ben-Yishay et al (1994) has shown that the muscle strength in patients with rotator cuff pathology increased after administering a subacromial anaesthetic injection. This suggests that pain inhibition masked the muscle strength. In this study, they took baseline isokinetic strength values as well as baseline manual muscle test values (a scale of 0-5). An increase in strength occurred on re-testing after the administration of subacromial anaesthetic injections. This increase of strength occurred despite the presence or absence of rotator cuff tears. There is no doubt that pain can inhibit maximal muscle contraction. However, in this study, no reference is made to how the pain was measured. The method of manual muscle testing is also not clear and therefore one must doubt the reliability of this testing.

Itoi et al (1997) in a similar study, measured the isokinetic strength of abduction/adduction and external/internal rotation, in patients with full thickness and partial thickness rotator cuff tears. The subjects were tested before and after a local subacromial anaesthetic injection. The strength increased in both abduction and external rotation after the injection. The testing regime was however very vigorous, consisting of a preliminary session of four repetitions at 60°/second and 180°/second as a warm up, followed by three maximum repetitions at each speed. This testing was then repeated for all directions before a subacromial anaesthetic injection was administered. Patients with full thickness tears often cannot tolerate any isokinetic testing (Walker at al, 1987; Rabin and Post, 1990; Malherbe et al, 1993) and therefore it may be possible that this vigorous testing may have increased the pain and

decreased the baseline muscle force. There is no reference as to whether or not pain was present and/or had increased during the testing. Higher force values may have been obtained pre-injection if a less vigorous mode of testing had been used e.g. isometric testing. The testing may have caused the pain which inhibited the force

The verbal commands given must be consistent as this can change the performance and change the reliability of the results. If the verbal commands are encouraging, it may improve the patient performance e.g. " hold, hold, don't let me move you " in a loud encouraging voice (Wadsworth et al, 1987; Mc Nair, 1995).

***Intrarater/Interater Reliability***

Inconsistent results occur when the tester is unable to generate higher forces than the muscle being tested (Marina et al, 1982). This is especially true in the large muscle groups e.g. quadriceps in the lower limb (Oldham and Howe, 1995). Large differences of strength in injured versus non-injured legs that have been detected by isokinetic dynamometry, have similarly not been detected when using a hand-held dynamometer (Agre et al, 1987; Deones et al, 1994). These errors have been ascribed to the lack of the tester's strength. The accuracy of muscle testing with hand-held dynamometers seems to be directly related to the experience of the examiner (Kendall et al, 1993; Bohannon, 1986; Bohannon and Andrews, 1987). However, of equal importance, is the strength of the examiner. If the muscle force being tested cannot be sufficiently " held" in a hold test or "broken" in a "break test", then errors will be made (May et al, 1997). Research has shown that the reliability in testing the upper limb is higher than the lower limb. One of the reasons is the difficulty in matching or overcoming the stronger lower limb muscles (Agre et al, 1987). Discrepancies can also be avoided if the tester pre-tests their own strength (against an immovable object) in the relevant positions and therefore knows their own peak force production (NMMT instruction manual). The subject should not be able to reproduce this, if the test is to be accurate. With reference to testing the rotator cuff, the muscle group that poses the most problems as far as tester strength is concerned, is testing internal rotation with the arm in neutral and the subject standing. This is not only due to the tester's strength but also due to the difficulty of stabilising the trunk and

the difficulty of eliminating the strong synergistic shoulder adductors and internal rotators (pectoralis mayor, latissimus dorsi and teres major)(Wadsworth et al, 1987).

***Other Criteria***

Normative data collection is extremely difficult as it relies on many variables, weight and age being most significant (Backman et al, 1989; Sapega, 1990). Some easier point of reference for normal is needed. The opposite limb is commonly used if it is not affected or injured. The assumption that the two limbs are symmetrical is a reasonable assumption in the lower limb, but may be more variable in the upper limb (Sapega, 1990). This is especially true in overhead sportsmen that predominantly use the dominant arm e.g. tennis.

Backman et al (1985) using a hand-held dynamometer, tested the isometric strength in 128 randomly selected subjects, in an attempt to obtain normative data. It was found that in most muscle groups there was no significant difference in strength between sides and this included testing shoulder abductors in 90 degrees. Murray et al (1985) using 40 normal adults reported similar results. In this study, a strength gauge assessed the maximum isometric forces of various shoulder muscles.

Many studies of sportsmen, using one dominant arm e.g. baseball pitchers, have quantified external and internal rotator forces. The testing, using concentric and/or eccentric isokinetic modes of testing, found that arm dominance did not significantly affect force values (Hinton, 1988; Sirota et al, 1997). Surprisingly there was no statistical difference in either external or internal rotator mean torque production in the dominant versus the non- dominant arm (Sirota et al, 1997). In some studies, a decrease in the production of external rotation torque values of the dominant arm has been shown (Wilk et al, 1993). It may be reasonable to make a clinical assumption that these changes may be due to early rotator cuff pathology (Sirota et al, 1997). Pitchers who trained vigorously off-season were found to produce greater internal rotation torque values of the dominant arm. No similar increase of the external rotator torque values was found (Wilk et al, 1993). It is difficult to compare results from the various studies, as different speeds of testing are often used, as well as different types of muscle contractions.

Many studies concur that there is no statistical difference between dominant versus non-dominant arms, even in sportsmen involved in one arm dominated overhead sport (Hinton, 1988; Wilk et al, 1993; Sirota et al, 1997).

When testing muscle force using a hand-held dynamometer, the mean value of three scores measured is preferable to the highest score (Ploeg and Oosterhuis, 1991). Magnussen et al (1990) using a Nicholas Manual Muscle Tester to test abduction force, showed that the most reliable results were obtained using the mean of the last three repetitions. If there is a huge difference in the values of the three tests, then patient compliance is suspect (Backman et al, 1985).

### 2.4.2 Rotator Cuff Muscle Function and Testing

Muscle testing of the shoulder is an important part of a shoulder examination (Cyriax, 1978; Bohannon and Andrews, 1987; Maitland, 1991). It is however, particularly difficult to accurately assess the individual muscle function of the rotator cuff, because of: confounding factors such as:

- The complex interaction of synergists of the shoulder and the rotator cuff muscles (Kuhlman et al, 1992; Jenp et al, 1996; Kelly et al, 1996).

- The interdigitating nature of the rotator cuff muscles, especially supraspinatus and infraspinatus (Soslowsky et al, 1997).

- Pain inhibition due to impingement, which may cause apparent muscle weakness (Ben-Yishay, 1994).

The glenohumeral joint has minimal static stabilisation and this places an increased demand on the shoulder muscles (Matsen and Arnst, 1990) and more specifically, the rotator cuff muscles. These muscles hold the head of the humerus in a centralised position on the glenoid so as to allow the mobilising muscles (i.e. the deltoid) to function efficiently throughout

movement (Arroyo et al, 1997). This prevents excessive gliding of the head of the humerus during movement and should prevent undue impingement and injury. Normally with elevation of the arm the head of humerus is said to initially glide superiorly 3 mm on the glenoid and then to remain centralised within 1 mm of the centre of rotation (Poppen and Walker, 1976; Howell et al, 1986). The rotator cuff muscles therefore function as a unit to stabilise the humeral head (Kronberg and Bronstrom, 1995).

Inman et al (1944) emphasized the importance of muscle force couples as an essential principle in the mechanism of elevation of the arm. A force couple is two equal but oppositely directed forces, which allows rotation around a centre point. In the glenohumeral joint two important force couples are described. The first couple is in the coronal plane and comprises the deltoid muscle and the rotator cuff. The directional force of the deltoid is upward and outward if the arm is at the side, whereas the force of the rotators is downward and inward. If these forces are resolved into their respective vectors, then their forces will be equal and opposite allowing elevation to occur efficiently (Inman, 1944; Speer and Garrett, 1993). The second important force couple of the shoulder is in the transverse plane (Burkhart, 1992, 1993, 1997). In this plane, the anterior force is the subscapularis and the posterior force is the combined action of supraspinatus, infraspinatus and teres minor. If the anterior and posterior force couples are in balance, this will hold the head of the humerus centrally in the glenoid, allowing efficient movement of the arm (Burkhart, 1992, 1997). It has also been shown that even if there is a full thickness tear of supraspinatus, if subscapularis anteriorly and infraspinatus and teres minor posteriorly are in balance, they will effectively hold the head of humerus centralised and allow efficient elevation (Burkhart, 1992). A cadaver study, in which each individual rotator cuff muscle was measured and the force it was capable of generating was estimated, has shown that the strength ratio between the anterior rotator cuff and the posterior rotator cuff muscles are more or less constant. In other words, the force generating capacity of subscapularis is estimated as equal to the combined force generating capacity of supraspinatus, infraspinatus and teres minor (Keating et al, 1993).

Shoulder movement is therefore achieved by the complex interaction of the mobilising and stabilising muscles, the most important for the glenohumeral joint being the interaction of the

deltoid and the rotator cuff muscles. The role of the scapula muscles have not been discussed as they are not the subject of this dissertation, they are however, also essential to shoulder function.

Th rotator cuff therefore functions as a combined unit to stabilise the head of the humerus as well as each muscle functioning as an individual unit (Keating et al, 1993; Jenp et al, 1996). However, there is some controversy surrounding the function of the individual rotator cuff muscles (Walsh et al, 1998). Supraspinatus has been tested using abduction as it is said to initiate and assist this movement (Inman et al, 1944; Post et al, 1983; Howell and Kraft, 1991). Infraspinatus and teres minor were said to externally rotate the shoulder and similarly were tested using external rotation (Cyriax, 1978). Subscapularis was tested by using internal rotation, as it is one of the internal rotators of the shoulder (Cyriax, 1978). The above methods of testing may however result in misinterpretation.

**Supraspinatus**

The contribution of the supraspinatus muscle to the power and motion of the shoulder has not always been clear (Howell et al, 1986). Testing elevation in any plane of movement to assess the function of supraspinatus has been shown to be an invalid test (Colachis et al, 1969; Colachis and Strohm, 1971; Howell et al, 1986; Kuhlman et al, 1992). This is because supraspinatus and deltoid both function throughout abduction. Both have individually been shown to be able to initiate and fully abduct the arm. Studies have shown that when one of the two muscles have been rendered incapable by either an axillary or suprascapular nerve block, the subjects were still able to fully abduct their arms. In these studies, the strength of abduction has been shown to be +\- 50 % of the total strength (Colachis et al, 1969; Colachis and Strohm, 1971; Howell et al, 1986; Kuhlman et al, 1992). Electromyographic (EMG) analysis has also shown that the two muscles act together throughout the range of abduction (Inman et al, 1944).

Furthermore, sportsmen have been reported to return to the same high level of sport with either an isolated suprascapular nerve lesion (Holzgraefe et al, 1994) or an isolated axillary

nerve lesion (Perlmutter et al, 1977). These findings seem to strengthen the laboratory findings. It therefore seems extremely difficult, if not impossible, to isolate a supraspinatus weakness as the deltoid functions synergistically in all planes of elevation.

Jobe and Moynes (1982) refute the above suppositions. They propose that the rotator cuff muscles and particularly supraspinatus must be assessed and strengthened individually. They have specifically studied supraspinatus, and have said that the "empty can" position, i.e. 90 degrees elevation in the plane of the scapula (scaption), with full humeral internal rotation (thumb down), results in the best EMG activity of supraspinatus. The study has suggested that this position isolates supraspinatus from the other rotator cuff muscles. The "empty can" position (thumb down) is said to anatomically align the supraspinatus in an optimal neutral position. However, this is a potentially dangerous position for impingement and it is therefore not clinically advisable as a test or exercise in the pathological shoulder. The "full can" (thumb up) position (Kelly et al, 1996) is a modification of the "empty can" (thumb down) position and has similarly been shown to be an optimal position for supraspinatus muscle contraction. The external rotation or thumb up position of the "full can" test creates less of a chance of an impingement and therefore may minimally be a better position. Neither of these tests isolates supraspinatus function from deltoid function and can therefore not be used as an accurate test for supraspinatus. In addition to deltoid being very active in the "empty can" position, Rowlands et al (1995) have shown that infraspinatus is similarly very active.

Blackburn et al (1990) also observed EMG values produced by the rotator cuff in various positions, including the "empty can" position. It was concluded from these observations that the greatest EMG activity produced by supraspinatus was actually in the prone position with the humerus abducted 100 degrees and externally rotated to the thumb up position (Blackburn's test). Worrel et al (1992) in a subsequent study, compared Jobe's test ("empty can") with Blackburn's test. In this study, the maximum voluntary isometric contraction in each position was recorded using a Nicholas Manual Muscle Testing device. In addition, the EMG activity produced by the supraspinatus in each of the positions was recorded. The "empty can" position produced a higher muscle force value than Blackburn's test, but the EMG activity of supraspinatus was much higher in the prone (Blackburn's test) position. This

*difference may be due to deltoid substitution being more active in the "empty can" position* and therefore supraspinatus is recruited less and vice versa.

Malanga et al (1996) conducted a similar study to Worrel et al (1992). However they in addition, measured the EMG values of the deltoid muscle and found that the middle deltoid was significantly active in both Blackburn's and Jobe's test. The anterior deltoid was more active in the Jobe's test and the posterior deltoid was more active in the Blackburn's test. It was reported that both positions produced significant supraspinatus muscle activity. The difference in supraspinatus activity between the two positions was not found to be statistically significant.

It view of the above findings, it therefore seems impossible to eliminate deltoid muscle function in either of the testing positions. This seems to confirm that neither position will accurately isolate the supraspinatus muscle force. These tests must perhaps only be used as gross screening tests.

The supraspinatus, as suggested above acts as a stabiliser of the head of the humerus throughout all shoulder movement, it also functions with deltoid as a strong abductor of the arm. However, it is also part of the posterior rotator cuff and therefore is anatomically positioned to be able to assist external rotation of the arm in the neutral (Caillet, 1988; Keating et al, 1993; Hughes and An, 1996; Jenp et al, 1996; Kelly et al, 1996; Itoi et al, 1997). No one single position has been identified as the optimal position for testing shoulder muscles and especially the rotator cuff muscles (Kuhlman et al, 1992; Malherbe et al, 1993). However, EMG studies have confirmed supraspinatus to be very active during isometric testing of external rotation in the neutral arm position at zero degrees rotation (Kronberg et al, 1990; Kelly et al, 1996; Jenp et al, 1996). In addition, testing in this position decreases the chance of pain inhibition (due to impingement) interfering with the test. Isometric testing of external rotation in the neutral position may therefore be a valuable test of supraspinatus as well as infraspinatus and teres minor.

In the pathological shoulder, Brems (1987) using a hand held-dynamometer found, that the weaker external rotation was, the larger the rotator cuff tear. Most tears are said to start as a supraspinatus tear (Burkhart et al, 1991; Burkhart, 1996), thus possibly linking external rotation with a lack of supraspinatus integrity.

Goutallier et al (1994) in a study using CT scans showed that patients with tears of supraspinatus (and/or subscapularis) might present with marked fatty degeneration of an (apparently) intact infraspinatus muscle. This degeneration was thought to cause the decreased muscle force of external rotation. However, the interdigitating anatomy of the rotator cuff has not been taken into account in this study and therefore it cannot conclusively be said that infraspinatus is intact, unless it is examined microscopically. Itoi et al (1997) in their study reported that supraspinatus contributed 19%–33% to the strength of abduction and 22%-33% to the strength of external rotation. Rotator cuff tears usually start in supraspinatus and then extend posteriorly to infraspinatus (Burkhart, 1993,1997). Thus possibly linking decreased external rotation strength with supraspinatus and not only infraspinatus tears. This strengthens the theory that external rotation tests the entire posterior rotator cuff (supraspinatus, infraspinatus and teres minor), and not only infraspinatus and teres minor.

It has also been shown that some patients with full thickness supraspinatus tears can fully elevate (Burkhart, 1994). In addition, recent in vitro studies have demonstrated that the infraspinatus/teres minor complex and subscapularis act as a force couple in the transverse plane and therefore can stabilise the head of the humerus adequately to allow good abduction of the arm, even in the presence of a supraspinatus tear (Otis et al, 1994; Itoi et al, 1997).
If the deltoid force is strong enough, then manual muscle testing of abduction will often ***not*** reveal any weakness, as the deltoid substitution masks any loss of force due to the tear of the supraspinatus (Otis et al, 1994; Itoi et al, 1997).

The literature therefore seems to indicate that testing external rotation in neutral could possibly be an indicator of the size of a tear of the posterior rotator cuff. Studies in which only a supraspinatus tear has been identified have reported that manual muscle testing of external rotation has revealed decreased muscle force (Burkhart, 1993,1996; Burkhart et al, 1994). It

may be deduced from this, that the slight loss of force detected could be due to the loss of supraspinatus function or alternatively that the torn supraspinatus renders the infraspinatus weak, due to the loss of the anatomical connections. It has been shown conclusively that tears can be painless (Pettersson, 1942; Sher et al, 1995) and that weak but painless static resisted external rotation of the neutral arm can indicate a supraspinatus and/or infraspinatus tear (Brems, 1989; Burkhart, 1989; Itoi et al, 1997).

In the light of these studies, static resisted external rotation of the neutral arm may therefore be a better indicator of supraspinatus tears than abduction (Kronberg et al, 1990).

**Infraspinatus/teres minor**

The major external rotators of the humerus are infraspinatus and teres minor. The posterior deltoid is also a weak external rotator especially in the prone abducted position (Kendall et al, 1993). In addition, supraspinatus assists external rotation in the neutral arm (Calliet, 1988; Hughes and An, 1996; Jenp et al, 1996; Kelly et al, 1996; Hintermeister et al, 1998). The infraspinatus is said to account for as much as 60% of the external rotator strength (Colachis and Strohm, 1971). Teres minor is said to be responsible for up to 45% of the external rotator strength (Colachis and Strohm, 1971). Teres minor and infraspinatus are considered to function in a similar manner and it is difficult to isolate one from the other (Inman, 1944; Jobe and Moynes, 1982; Ballentyne et al, 1993; Jenp et al, 1996). Anatomically however, they are very different. Infraspinatus has a horizontal orientation, whereas teres minor is obliquely oriented (Ruwe et al, 1994). Teres minor is also a morphological component of the deltoid and is supplied by the same nerve as deltoid i.e. the axillary nerve.
Infraspinatus, teres minor and subscapularis due to the morphological caudal extension of the scapula, form a functional unit and can function as depressors of the head of humerus as well as rotators (Inman et al, 1944). It is reasonable to speculate on the basis of this anatomy that teres minor and subscapularis may in fact be the key to function in the presence of a large full thickness tear that encompasses supraspinatus and infraspinatus. Most tears are posterior rotator cuff i.e. supraspinatus extending into infraspinatus (Burkhart, 1991). Therefore, if subscapularis and teres minor are intact and in balance in the transverse plane, they may be

able to stabilise the head of the humerus allowing reasonable function. The individual nerve supply of teres minor and subscapularis may also allow function on the same basis in the presence of a suprascapular nerve compression or even a C5 nerve root compression. This is however pure speculation, but may be worthwhile for research in the future. For purposes of this research paper the infraspinatus and teres minor will be considered as a functional unit.

The optimal position for testing infraspinatus/ teres minor is controversial (Walch et al, 1998). For example, Kelly et al (1996) suggests 45 degrees of internal rotation with the arm in the neutral position. Jenp et al, (1996) in their study recommend 90° of abduction in the sagittal plane with the arm in half maximal external rotation, this is similar to the "hornblower" sign (Walch et al, 1998). The hornblower sign tests resisted external rotation in 90° of elevation in the scapular plane. If this tests weak, it is said to indicate an irreparable infraspinatus and teres minor tear. The 'dropping' arm sign is a test that tests the ability of the patient to maintain the arm in zero degrees of abduction and 45° external rotation. It is said to indicate an irreparable infraspinatus tear if the arm 'drops' back into internal rotation (Walch et al, 1998). It must also be kept in mind that the confusion may be as a result of the fact, that many of the studies use EMG as a measure of force production and it has been shown that there is a non-linear relationship between EMG values and force production (Zuniga and Simons, 1969).

Jenp et al (1996) analysed positions of maximum EMG values and maximum isometric muscle force production of the rotator cuff and found them to be different (Worrel et al, 1992). Maximum EMG activity of the rotator cuff muscles was found to be highest in the neutral rotation or mid range position and they concluded that the positions used to test isolated muscle function is not the same position as maximum force. In their study, however, they tested muscle force using apparatus that included the wrist muscles and this would adversely affect the accuracy of the results.

EMG studies have shown that the infraspinatus is very active in neutral position with zero degrees humeral rotation (Jenp et al, 1996; Kelly et al, 1996). This position also shows high activation of supraspinatus and isolates supraspinatus and infraspinatus from posterior deltoid

(Kronberg et al, 1990; Kelly et al, 1996). Testing external rotation in this position is also not expected to compromise the subacromial space (Ballentyne et al, 1993).

**Subscapularis**

The muscles that internally rotate the humerus are subscapularis, pectoralis major, teres major and latissimus dorsi. Cyriax (1978) has recommended that adduction be used as a test to exclude subscapularis pathology. For example, if adduction tests strong/painless and internal rotation tests weak/painful then the problem must be subscapularis as this is the only muscle of the four that does not adduct the arm. In theory, this may be possible, however the researcher has not been able to find any studies to corroborate these findings. Resisted internal rotation in the neutral position with the forearm at 90 degrees, which is traditionally used to test subscapularis appears to be inaccurate (Gerber, 1991; Greis et al, 1996; Jenp et al, 1996; Kelly et al, 1996).

Gerber and Krushell (1991) noted that patients with subscapularis tears could not "lift off" from the hand behind back position and has shown this to be an accurate test of subscapularis tears. He has called this the "lift-off test". However, patients with rotator cuff pathology often cannot achieve the hand behind back position. If they can achieve the position, severe pain may in turn inhibit the movement and not weakness, thus making the test invalid (Greis et al, 1996). Therefore this test can only be interpreted properly if the subject has full range of passive internal rotation in the hand behind back position and if active internal rotation is painfree (Gerber and Krushell, 1991). EMG studies have also shown that subscapularis can best be activated with the arm in the 90 degree abducted position (Jenp et al, 1996; Kelly et al, 1996). This position however, is prone to pain inhibition from impingement. In this position the strength of subscapularis can also be masked by deltoid function.

Muscle testing, perhaps should therefore be directed at the whole rotator cuff in general, or more specifically the anterior and posterior rotator cuff muscles. The anterior rotator cuff muscle or subscapularis, is not commonly injured (Ticker and Warner, 1997) and testing using the "lift–off" test if internal rotation is full range has been shown to be clinically

accurate (Gerber and Krushell, 1991). The posterior rotator cuff muscles, supraspinatus, infraspinatus and teres minor are all external rotators and the former two are commonly injured, whereas teres minor is rarely injured (Burkhart, 1993; Keating et al, 1993). Testing external rotation to assess the posterior rotator cuff would therefore be essential. A test position is needed that maximises the activation of the desired rotator cuff muscles and at the same time minimises the synergists that assist this movement (Jenp et al, 1996; Kelly et al, 1996). The position must also avoid impingement, as pain will inhibit muscle force (Ben-Yishay et al, 1994). Testing external rotation in neutral seems to fulfil all these criteria.

Summary

- The best position for muscle testing of the arm in order to avoid pain inhibition due to impingement in the pathological rotator cuff is the neutral arm.

- Deltoid and supraspinatus have both been shown to be capable of initiating and abducting the arm equally. Therefore testing supraspinatus in abduction in neutral can be misleading.

- The positions said to isolate the supraspinatus i.e. "empty can" (Jobe's test), "full can" test and Blackburn's test are still subject to deltoid, infraspinatus and subscapularis substitution. These positions are also all at risk for impingement and therefore pain may inhibit accurate findings.

- The major internal rotators of the humerus are subscapularis, pectoralis major, teres major and latissimus dorsi. Substitution can mask a subscapularis weakness or tear.

- The lift-off test, although proving to be a reliable test of a subscapularis tear, is often unachievable due to stiffness and / or pain inhibition.

- Static resisted external rotation of the neutral arm tests the integrity of the entire posterior rotator cuff and accounts for the muscles most commonly affected. Substitution from the posterior deltoid is minimal. Positional pain in neutral is also minimal, therefore static resisted external rotation of the neutral arm may be an accurate test of posterior rotator cuff function.

# 3.0 Materials and Methods

## 3.1 SUBJECTS

Patients, who were selected by the attending orthopaedic surgeon for elective arthroscopic surgery of the shoulder, were asked if they would participate in this study. The subjects were all admitted into hospital on the morning of the surgery. If they were agreeable, they were asked to read the information form and sign the consent section (Appendix A).

### 3.1.1 Exclusion Criteria

1. Any history or signs and symptoms of significant cervical spine pathology, ascertained by a routine cervical spine examination (Appendix B).
2. A history of any recent (3 weeks) trauma or previous major trauma e.g. a dislocation or fracture.
3. Any pain or shoulder pathology in the control arm that could inhibit or cause a decrease in force production in the control arm e.g. osteo-arthritis
4. Any general pathology that could affect the power of either of the arms e.g. a frozen shoulder, rheumatoid arthritis or neuro-muscular disorders.
5. If the participant's shoulder was too painful to co-operate adequately.
6. Refusal to participate.
7. Subjects who had already been given the pre-medication.
8. Subjects who could match or exceed the force production of the researcher. This was determined by pre-testing the force production of the researcher so that unreliable impressions of force could be avoided
9. Any intra-articular pathology such as loose bodies.
10. Incomplete data.
11. Subjects who had undergone previous shoulder surgery.

## 3.2 MATERIALS

The Nicholas Manual Muscle Tester Model 01160 (NMMT) (Lafayette Instrument. 3700 Sagamore Parkway North, Lafayette Indiana 47903 USA) was used to measure the isometric muscle force produced by the rotator cuff muscles (Figure 3.1 and 3.2). The Nicholas Manual Muscle Tester is a hand-held manual muscle testing device, which provides an objective measurement of the force production of a muscle. The peak force (kilograms) required to break an isometric contraction is measured as the researcher applies a force against the subject's limb. The Nicholas Manual Muscle Tester is placed between the researcher's hand and the patient's limb via the rotating stirrup (figure 3.2). The force is transmitted through the unit from the researcher to the subject. The unit is small enough to be held in one hand and is easy to read. The unit is easily transportable and therefore subjects can be screened "on site" wherever that may be, unlike the larger and more expensive systems such as Cybex. There are other similar sized manual muscle testers on the market, however this one has been proven to be reliable (Bohannon, 1986; Nies Byl et al, 1988; Worrell et al, 1992). It is also affordable for the average practitioner.

It has a load cell, which is designed to eliminate errors due to non-perpendicular loading. It can record measurements from 0.0 - 199.9 kilograms. The calibration of the machine can only be done in the factory. However there is an easy to use test button, which is a built-in self-check of the electronic mechanism (Figure 3.2). There is also a reset button to check if the machine is set at zero before the start of each test (Figure 3.2). This is necessary due to fluctuations in temperature, which affect the electronic strain gauge. If necessary, this is easily adjusted using the screwdriver provided with the machine. This adjusts the potentiometer via an access hole on the back of the Nicholas Manual Muscle Tester.

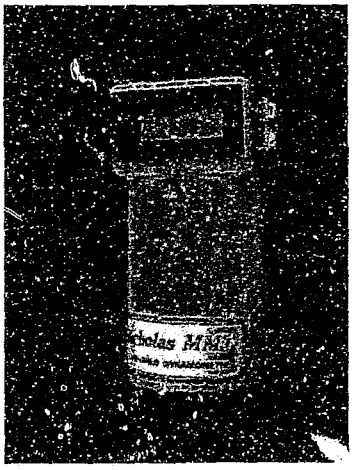


**Figure 3.1** Front of the NMMT. Displaying the dial from which measures are read.

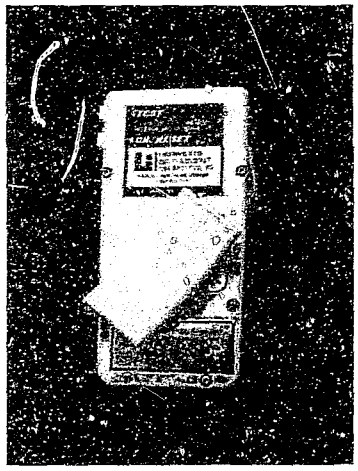


**Figure 3.2** Back of the NMMT. The set and reset buttons can be seen, as well as the stirrup, which is placed against the subject's limb.

## 3.3 METHOD

### 3.3.1 Intrarater Reliability

In an attempt to test the intrarater or intratester reliability (Rothstein and Echternach et al, 1992), eight replicates of external rotator strength were tested on eight shoulders using a Nicholas Manual Muscle Tester. The subjects were all physiotherapists who had no previous history of shoulder problems. The mean age was 27 years, with a range of 22 to 33 years. The position tested was external rotator strength in lying. The method of testing is described in 3.3.2. The testing was repeated at the same time of day, on two consecutive days i.e. 24 hours apart. A comparison was made between results of the two testing sessions using the Student's paired t-test, Wilcoxon matched pairs, signed ranks- test, as well as a test described by Bland and Altman (1986).

### 3.3.2 Procedure

The patients were admitted to the ward on the morning of the operation. They were routinely given a pre-medication after the anaesthetist had examined them. This pre-medication was delayed for subjects in this study. It was only administered once the testing was completed.

The same testing room, which was quiet and private, was always used. The operating days were always Tuesdays and Thursdays.

A routine shoulder examination (Cyriax, 1978; Constant and Murley, 1987; Maitland, 1991) (Appendix B), which was modified to incorporate the Constant Scoring method (Constant and Murley, 1987), was completed. Pain was recorded on the visual analogue scale (Appendix B) and this was the maximum pain they had experienced pre-operatively. A value of 15 points is allocated for no pain experienced and zero points are allocated for the most severe pain the subject could possibly experience.

A modification was made to the Constant Score, for the power measurement. The method described by Constant and Murley (1985), to measure force, uses a scoring based on the number of pounds, using a pulley system (Moseley, 1963), which the subject can resist in abduction up to a maximum of 90°. Twenty-five pounds was used as the reference weight. A person with an unaffected shoulder should be able to abduct to 90°. The score given for being able to lift 25 pounds is 25 points and proportionally less for less weight being lifted (Table 2.3.2).

The researcher modified this test, by testing abduction in 90° scaption (Figure 3.13). Force measurements were measured with the Nicholas Manual Muscle Tester and a score was calculated by using the force value of the affected arm divided by the force value of the control arm multiplied by 25 points i.e. if the control arm is considered "normal" strength for that subject, then the score would be 25. The score for the affected arm would be worked

out in proportion to the control arm e.g. if the value for the control is 4kg and the value for the affected arm is 3kg then the points scored would be ¾ x 25 = 18.75 points.

The isometric muscle force produced by the rotator cuff of both the subject's arms was tested. The Nicholas Manual Muscle Tester was used to measure the force. There is no recorded statistical difference in muscle force between dominant versus non-dominant arm (Backman et al, 1985; Hinton, 1988; Sirota et al, 1997).

In the event of the subject being stronger than the researcher in the position being tested, unreliable impressions of force would occur (NMMT instruction manual). Therefore the researcher, prior to testing, established her maximum force measurement capability for each test by pushing the Nicholas Manual Muscle Tester against the force test support plate (Figure 3.3). The test was firstly done with the researcher pushing against a wall (Figure 3.4) and secondly by pushing down on a table positioned below her (Figure 3.5). These positions simulated the actual testing positions needed to test the subjects.

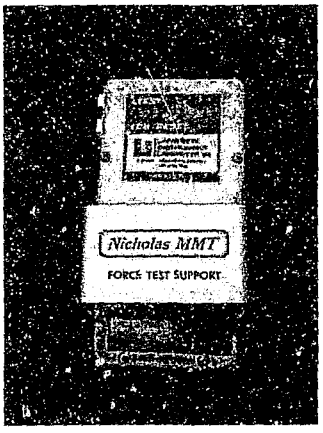



**Figure 3.3** NMMT force test support plate.

This is seen placed over the stirrup.



**Figure 3.4** Position for testing external rotator force.

Maximum force is applied against an immovable object (wall).



**Figure 3.5** Position for testing ABD 90°.

Maximum force is applied downwards against an object.

The researcher had no prior contact or knowledge of the subject's diagnosis or doctor's notes. Similarly, the surgeon was blinded to the researcher's testing results.

### 3.3.3 General Principles

The Nicholas Manual Muscle Tester was placed just proximal to the styloid process (to avoid any force generated by the wrist or fingers) and the isometric "break test" was applied in the direction required.

The subjects were given the instruction that they must statically resist the pressure applied by the researcher and try to prevent the researcher breaking the hold. The subject was instructed to make a fist for conformity.

They were told:

1. That the pressure was going to be built up slowly (over three seconds) while the researcher encouraged them by saying "HOLD " three times slowly in a loud, encouraging voice (Mc Nair et al, 1996), before actually breaking the hold on the fourth time. This allowed time for the subject to recruit as many muscle fibres as possible. The contraction was held for a maximum of four seconds (Kelly et al, 1996) This was timed using a second hand on a wrist- watch.

2. That the subjects must resist the force as much as possible, but not produce pain. If pain was experienced then the intensity was graded on a scale of zero to five (0 to 5). Zero (0) being no pain and five (5) being the most severe pain that could be imagined.

3. The researcher would apply force until the isometric hold of the subject was broken. This moment would mark the end of the test.

4. Each test would be repeated three times in each position.

5. The test was not to compare the researcher's force against the subject's force.

6. Their affected arm would be compared to their unaffected arm.

7. Prior to each new test position a trial run of the test would be done on each arm using minimal pressure to familiarise the subject with the procedure.

The testing was started on the unaffected side to decrease any anxiety on the subject's part as well as to encourage an attempt at maximum force. The testing was done in the following order: external rotation, internal rotation and then abduction.

Each test was repeated three times and each time the peak force in kilograms as well as the pain response was recorded.

### 3.3.4 Testing Positions

Three different starting positions were chosen, as these are the positions routinely used in examination of the shoulder (Daniels and Worthingham, 1972; Cyriax, 1978, Jobe and Moynes, 1982; Kendall et al, 1993). The order of testing was:

Position 1: Standing arm by the side.
Position 2: Lying arm by the side.
Position 3: Sitting arm abducted to 90° in the plane of the scapula (scaption).

This order was chosen for the following reasons: standing with the arm by the side is not considered as stable a position as lying with the arm by the side. It is easier to stabilise the testing in a lying position. It was thought that the most accurate test position would be the latter. Therefore, the former test although valuable, was almost considered as a training run. Standing is also less threatening for the subject and therefore less stressful to start with. Standing with the arm in 90° elevation is a potentially painful position and therefore this was

the final position tested, so that if this provoked any lasting pain, it would not compromise any prior testing.

### 3.3.4.1 Position 1 - Standing arm by the side

The subjects stood (stride) with their one side against the doorframe in the doorway so that their forearm on that side was at 90 ° to their arm and was free to rotate. The frame was used to prevent using body strength as a substitution strategy. For testing static resisted external rotation in standing (ERS) and static resisted internal rotation in standing (IRS) the arm being tested was against the frame. For testing static resisted abduction in standing (ABD S) the opposite arm was against the frame. The instruction to the patient was that they must not lose contact with, or apply undue pressure onto the frame at any stage.

1. For testing external and internal rotation the subjects elbow was flexed to 90 ° and the forearm was midway between supination and pronation (Figure 3.6 and 3.7)



**Figure 3.6** Testing position for ERS. Note the position of the NMMT is proximal to the styloid process.

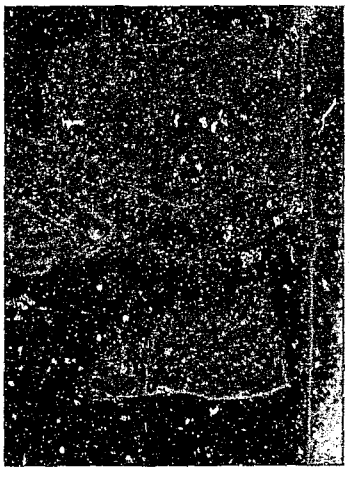


**Figure 3.7** Testing position for IRS.

2. For testing abduction the arm was held at the side with elbow straight. To facilitate the test, the wrist was moved one handbreadth away from the subject's thigh. The researcher using her hand as the measurement measured this position. The measurement was between the subject's ischial tuberosity and just proximal to styloid process. The subject was shown how to keep the elbow locked.

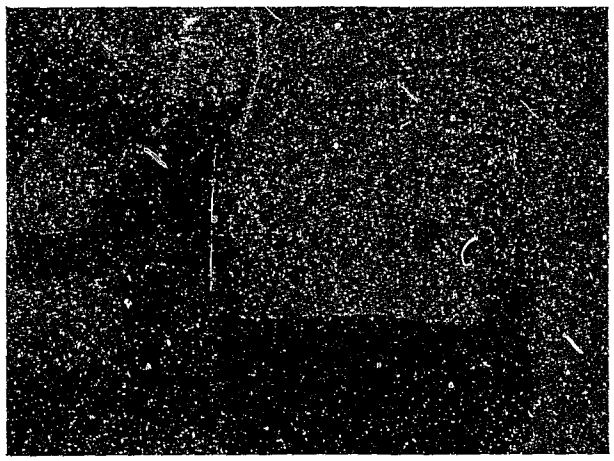


**Figure 3.8** Testing position for ABD S.
Note arm is one hand's breadth away from ischial tuberosity.

### 3.3.4.2 Position 2 - Lying arm by the side

The subject lay supine on the examination couch, arms resting next to his sides. A strap was placed around the pelvis in order to stabilise the trunk. The humerus was aligned in the horizontal position by placing towels under the elbow. The subject did not have a pillow for his head.

1. For testing static resisted internal and external rotation in lying (IRL and ERL) the elbow was flexed to 90° and the forearm was midway between supination and pronation (Figure 3.9 and 3.10 respectively).



**Figure 3.9** Testing position for ERL



**Figure 3.10** The position for testing IRL

2. For testing static resisted abduction in lying (ABD L) the arm was held at the side with the elbow straight. To facilitate the test, the wrist was moved one handbreadth away from the thigh as described above for standing (Figure 3.11).



**Figure 3.11** The testing position for ABD L

### 3.3.4.3 Position 3 - Sitting with arm abducted to 90° in scaption

The patient sat on a chair with his back supported.

1. For testing static resisted abduction (ABD 90°) the modified Jobe's test or "full can" (Kelly et al, 1996) was used i.e. the arm was held in 90° elevation in the plane of the scapula. This is approximately 30° of horizontal flexion, but varies slightly from patient to patient. A ruler was used to align the arm and scapula (Figure 3.12). The subject's hand was held in a "full can" i.e. thumb up position instead of in the "empty can" or thumb down (pronated hand and internally rotated) position as described in the original test (Jobe et al, 1982). This was to avoid impingement and possible pain inhibition (Figure 3.13).

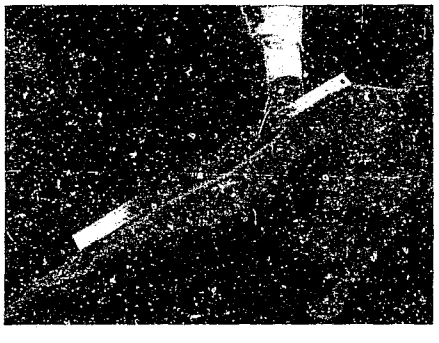


**Figure 3.12 The** arm is lined up with plane of scapula.



**Figure 3.13** Testing of ABD 90 °

## 3.3.5 Arthroscopy

During the arthroscopy the orthopaedic surgeon recorded:

1. If a tear was present.
2. The width and length of the tear was measured as follows: the length from the tuberosities and the width from the biceps tendon. The measurements were made using the normal arthroscopy instruments, which were of a known size.
3. Whether the tear was a full or partial thickness.

4. If the tear was joint side, bursal side or interstitial.
5. The orientation of the tear i.e. longitudinal, transverse etc.
6. The position of the tear i.e. which muscle was involved. This was recorded as a *supraspinatus* (SS), *infraspinatus* (IS), teres minor (TM) and/or subscapularis (SSc) tear.

This was recorded on the enclosed physiotherapy form (Appendix C). The measurements of the width and length of the tear was used for the purposes of this research

### 3.3.6 Measurements

The force generated by the control arm was considered as the maximum (100%) that each individual subject could generate. A percentage value was calculated to describe the relative strength of the affected arm (the affected arm strength ratio (S%)) This measurement was therefore no longer a force measurement, but rather a dimensionless relative measure of the strength of the affected arm i.e. a "clinical" index, which measures relative strength.

This was calculated as follows:

- The mean force (kg), in each position tested, was calculated.
- The mean force production of the affected arm over the mean force production of the control arm as a percentage.

$$\text{Affected Arm Strength Ratios (\%)} = \frac{\text{Mean force of affected arm (kg)}}{\text{Mean force of control arm (kg)}} \times \frac{100}{1}$$

The above is illustrated by the following example:

| ERL | Test number | Affected arm | Control arm |
|---|---|---|---|
| | 1 | 8kg | 10kg |
| | 2 | 7.8kg | 10.2kg |
| | 3 | 8.2kg | 9.8kg |
| **Mean score:** | | **8kg** | **10kg** |

ERL (S%) = 8/10 * 100/1 = 80%

This was interpreted as the affected arm being only able to generate 80% of its maximum strength.

(S%) was recorded for each position tested as follows

**Postion 1:**

ERS (S%) - affected arm strength ratio for static resisted external rotation strength in standing.

IRS (S%) - affected arm strength ratio for static resisted internal rotation strength in standing.

ABD S (S%) - affected arm strength ratio for static resisted. abduction in standing.

**Position 2:**

ERL (S%) - affected arm strength ratio for static resisted external rotation strength in lying.

IRL (S%) - affected arm strength ratio for static resisted internal rotation force in lying.

ABD L (S%) - affected arm strength ratio for static resisted abduction force in lying.

**Position 3:**

ABD 90° (S%) - affected arm strength ratio for static resisted abduction in 90° scaption.

The size of the tear was calculated by multiplying the width of the tear by the length of the tear (Ellmann, 1989, 1990) i.e. width x length = tear size ($cm^2$).

A modified Constant Score was also calculated by the addition of the individual score values obtained from the clinical examination (Addendum C)(Constant and Murley, 1987).

### 3.3.7 Statistical Analysis

The intratester reliability was analysed, using the Student's paired t-test, the Wilcoxon matched pairs, signed-ranks test, as well as the procedure described by Bland and Altman (1986).

Pearson's correlation coefficients were calculated to determine the relationship between the tear size ($cm^2$) of the rotator cuff and the affected arm strength ratio obtained from each position tested. External rotation, internal rotation and abduction (S%) were measured in the following two positions: standing arm by the side and lying arm by the side. In sitting, only ABD 90° (S%) was tested.
Pearson's correlation coefficients were similarly calculated to determine the relationship between the tear size ($cm^2$) of the rotator cuff and the Constant Score of the affected arm, as well as to determine the relationship between ERL (S%) and ERS (S%).

Finally, Pearson's correlation coefficients were calculated to determine the relationship between the pain the subject's were complaining of pre-operatively and:

- the size of the tear ($cm^2$) of the rotator cuff measured intra-operatively,
- the (S%) calculated for each of the above positions,
- the Constant Score.

# 4.0 Results

Thirty-two subjects were initially tested for this study. They were all patients who were scheduled for arthroscopic examination of their shoulder joints. Twelve subjects were excluded for the following reasons:

- Five of the subjects had significant cervical spine pathology. One having an absent biceps reflex. Four of the five also had significant pain in the control arm as well as cervical spine pathology.
- One subject had more pain in the control arm than the affected arm.
- Two subjects had recent severe trauma, in addition one of the two subjects had also been pre-medicated (dormicum 7.5mg).
- One subject was an insulin dependent diabetic and had a frozen shoulder.
- One subject was too painful to co-operate.
- One subject had a loose body in his glenohumeral joint.
- In one subject the data collection was incomplete.

The remaining twenty subjects were between the ages of 18 and 70 years old.
Ten females (Age range 18 - 63 years)
Ten males (Age range 18 - 70 years)
Fourteen subjects were right handed, five were left-handed and one was ambidextrous.
Eleven of the subject's right shoulders were affected and nine had left shoulders affected.

***Intratester Reliability Study:***

Based on Student's paired t-test, tests 1 and 2 were found not to differ significantly ($p = 0.8153$). As this test was done for a small sample ($n = 8$), the latter result was confirmed with the Wilcoxon matched pairs, signed ranks-test ($p = 0.8658$), which is the non-parametric equivalent of Students t-test.

According to the Bland and Altman (1986) analysis, the mean difference between test 1 and 2 was 0.025 kg with a 95% confidence interval (-0.545 kg; 0.0.595 kg). The 95% confidence level is narrow (0.57 kg), therefore showing very little difference between the results of the two tests.

As a result of the analysis of the above two statistical tests, the intratester/intrarater reliability was acceptable.

***Tear Size versus Muscle Testing Studies***

Table 4.1 (overleaf) shows the intra-operative measurements of the width and length of the rotator cuff tears and the corresponding calculations of the affected arm strength ratio (S%) of ERL, ABD L, and ABD 90°. It also lists which muscles are torn in each case.

**Table 4.1 Table of tear sizes ($cm^2$) and the affected arm strength ratios (%) of ERL, ABD L, and ABD 90° and the affected muscles.**

| SUBJECT | TEAR SIZE | ERL | ABD L | ABD 90° | AFFECTED MUSCLES |
|---|---|---|---|---|---|
| 1 | No Tear | 88% | 79% | 106% | No Tear |
| 2 | No Tear | 101% | 94% | 101% | No Tear |
| 3 | No Tear | 94% | 96% | 84% | No Tear |
| 4 | No Tear | 82% | 94% | 106% | No Tear |
| 5 | No Tear | 80% | 71% | 57% | No Tear |
| 6 | No Tear | 87% | 102% | 83% | No Tear |
| 7 | No Tear | 86% | 82% | 90% | No Tear |
| | **Average** | **88%** | **88%** | **90%** | |
| 8 | 2 x 1 $cm^2$ | 82% | 90% | 76% | SS |
| 9 | 2 x 1 $cm^2$ | 85% | 76% | 105% | SS |
| 10 | 2 x 1 $cm^2$ | 90% | 33% | 31% | SS |
| 11 | 2 x 1 $cm^2$ | 64% | 97% | 68% | SS |
| | **Average** | **80%** | **74%** | **70%** | |
| 12 | 3 x 1 $cm^2$ | 98% | 138% | 136% | SS & IS |
| 13 | 3 x 1 $cm^2$ | 96% | 118% | 99% | SS & IS |
| 14 | 3 x1 $cm^2$ | 91% | 88% | 51% | SS & IS |
| | Average | 95% | 115% | 95% | |
| 15 | 4 x 2 $cm^2$ | 76% | 57% | 55% | SS & IS |
| 16 | 4 x 5 $cm^2$ | 69% | 25% | 0% | SS, IS & SSc |
| 17 | 4 x 3 $cm^2$ | 72% | 71% | 85% | SS & IS |
| 18 | 5 x 4 $cm^2$ | 53% | 60% | 53% | SS & IS |
| 19 | 6 x 3 $cm^2$ | 47% | 76% | 80% | SS, IS & TM |
| 20 | 8 x 6 $cm^2$ | 46% | 58% | 0 % | SS, IS & TM |
| | **Average** | **61%** | **58%** | **46%** | |

Table 4.1 shows:

1. Seven of the subjects (1-7) had no rotator cuff tears and the ERL (S%) was over 80 % in all cases and over 85% in five cases. This averages as 88%.

2. The subjects with no tears (1-7) all had ABD 90° (S%) values of 83% and higher except subject (5), who had ABD 90° (S%) values of 57%. The values for ABD L (S%) were all greater than 71% .The average (S%) for ERL and ABD L is 88% and 90% for ABD 90°.

3. Four subjects (8-11) had 2x1cm tears and three (8-10) of these subjects had an ERL (S%) of 82% or greater. The average is 80%.

4. Three subjects (12-14) had 3x1cm$^2$ tears, and they all had ERL (S%) values greater than 91% and ABD L (S%) values greater than 88%. In addition, two values of ABD 90° (S%) were greater than or equal to 99%.

5. Six subjects (15-20) had large or massive tears. ERL (S%) and ABD L (S%) in all cases was less than 76%. ERL (S%) averages as 61% and ABD L (S%)averages as 58%. ABD 90° (S%) was less than 55% in all subjects except subjects (17) and (19) where ABD 90° (S%) is 85% and 80% respectively. ABD 90° (S%) averages as 46%.

6. All the subjects with tears had supraspinatus (SS) tears, nine (12-20) had supraspinatus (SS) and infraspinatus (IF) tears. Subjects 19 and 20 had supraspinatus (SS), infraspinatus (IF) and teres minor (TM) tears and only one subject (16) had supraspinatus (SS), infraspinatus (IF) and subscapularis (SSc) tears.

Table 4.2 shows the correlations between tear size and the affected arm strength ratio in each position tested, as well as the correlations between tear size and the Constant Score values.

**TABLE 4.2 Correlations between the tear variable and the affected arm strength ratios (%) as well as the Constant Score variable**

| | CORRELATION COEFFICIENT (R) | $R^2$ |
|---|---|---|
| **ERL (S%)** | **- 0.79** | **0.62** |
| IRL (S%) | 0.21 | 0.42 |
| ABD L (S%) | 0.46 | 0.21 |
| ABD 90° (S%) | 0.19 | 0.03 |
| **ERS (S%)** | **-0.69** | **0.48** |
| IRS (S%) | 0.43 | 0.19 |
| ABD S (S%) | 0.40 | 0.16 |
| Constant Score | 0.28 | 0.08 |

Table 4.2 shows:

- There is a negative correlation between tear size ($cm^2$) and the affected arm external rotator strength ratios (%) in both lying and standing (ERL (S%) and ERS (S%)). ($R^2 = 0.62$, $R^2 = 0.48$)
- There is not a good relationship between tear size and the affected arm abduction and internal rotator strength ratios in any of the positions tested (IRL (S%), ABD L (S%), ABD 90° (S%), IRS (S%) and ABD S (S%)).
- There is not a good relationship between the Constant Score and the tear size.

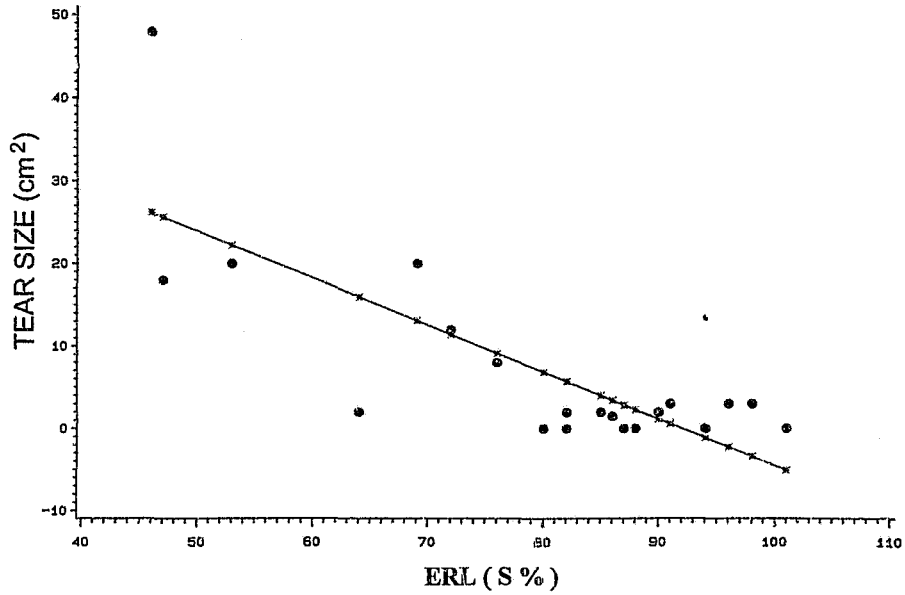



**Figure 4.1** External Rotator Affected Arm Strength Ratio (%) in Lying vs. Tear Size ($cm^2$)

The scatter plot (Figure 4.1) of external rotator affected arm strength ratios in lying (%) vs. tear size ($cm^2$) illustrates the negative linear relationship between the two. This is confirmed by the Pearson's correlation coefficient of (- 0.79). This means that as the tear size increases the (S%) of external rotation decreases.

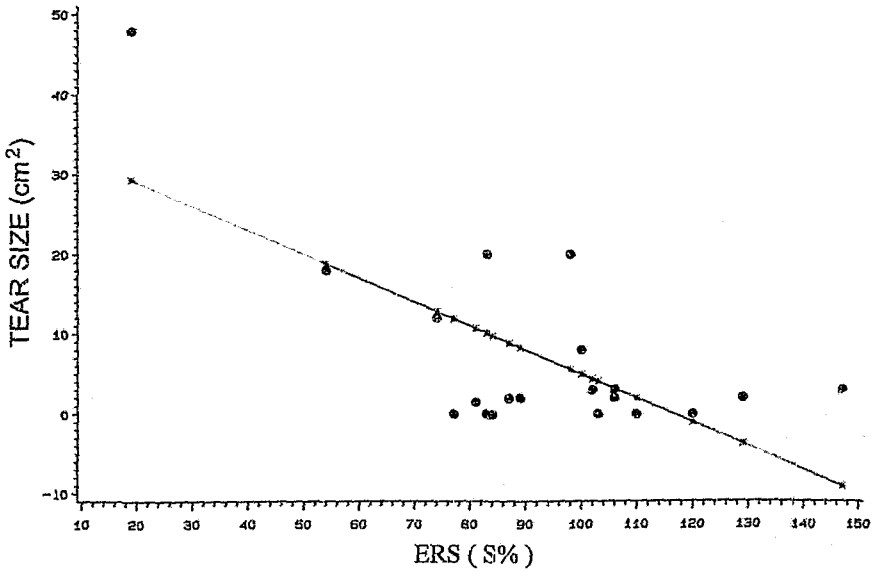



**Figure 4.2** External Rotator Strength Ratio (%) in Standing vs. Tear Size ($cm^2$)

The scatter plot (Figure 4.2) of external rotator strength in standing (%) vs. tear size ($cm^2$) illustrates a negative linear relationship between the two. This is confirmed by the Pearson's correlation coefficient of (***-0.69***), indicating that as the tear size increases the force production of external rotation decreases

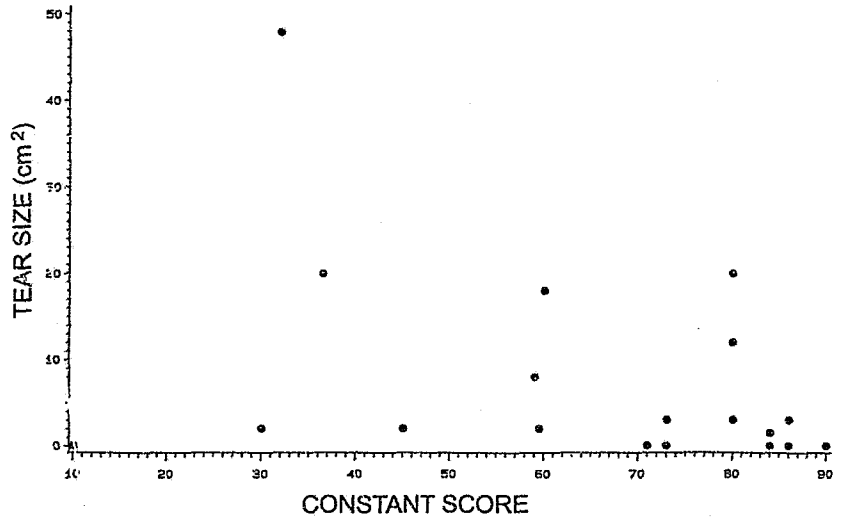



**Figure 4.3** Constant Score vs. Tear Size ($cm^2$)

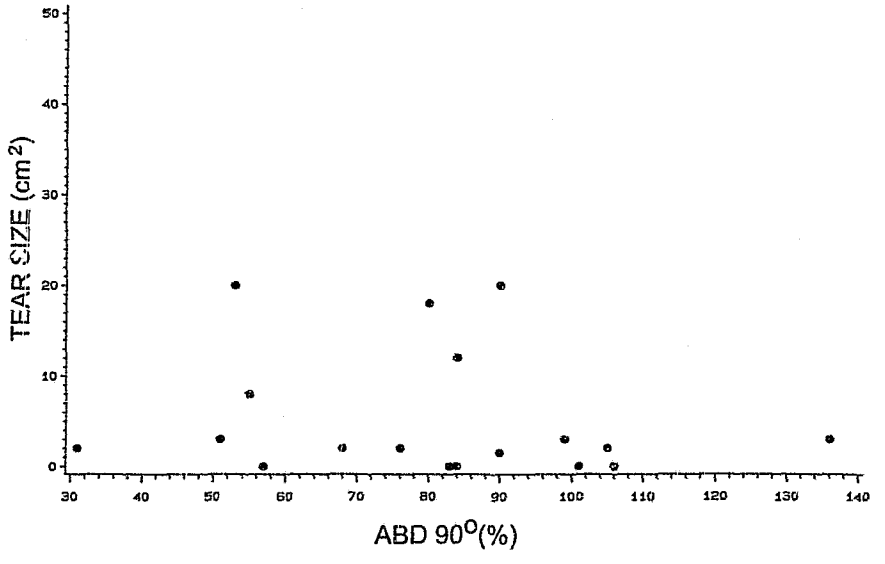



**Figure 4.4** Abductor Affected Arm Strength Ratios (%) in 90° Scaption vs. Tear Size ($cm^2$)

The scatter plot of Constant Score vs. Tear Size (Figure 4.3) as well as the scatter plot of Abductor (S%) measured in 90° scaption vs. Tear Size (Figure 4.4) reflect a random scatter pattern which indicates that there was no linear relationship between the parameters measured. The Pearson's correlation coefficients are 0.28 and 0.19 respectively

Similarly no linear relationship was demonstrated in any of the other test positions vs. tear size and they have therefore not been represented graphically.

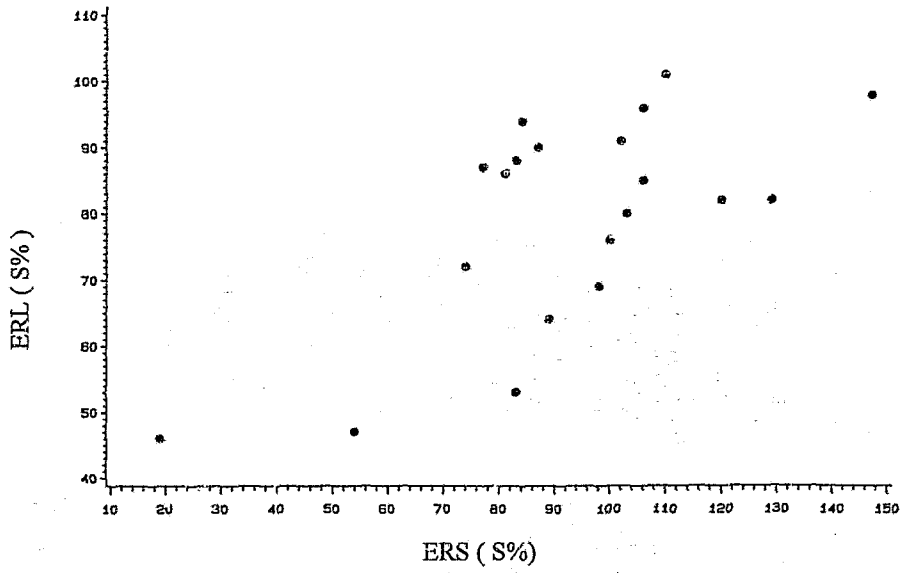



**Figure 4.5** External Rotator Strength Ratios in Lying (%) vs. External Rotator Strength in Standing (%)

The scatter plot of the ERL (S%) and the ERS (S%) (Figure 4.5) gives an indication of a positive linear relationship. (R = 0.67)
It would seem that as the ERL (S%) increases the ERS (S%) also increases.

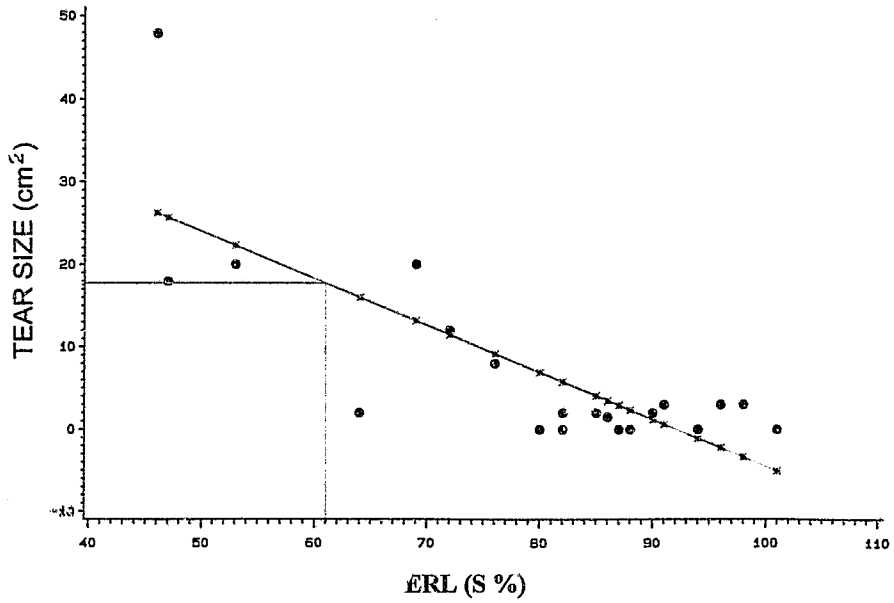



**FIGURE 4.6** External Rotator Strength Difference In Lying (%) vs. Tear Size ($cm^2$)

*Predicting tear size*

There was a negative correlation between the Tear Size and ERL (S%)(Figure 4.1 and 4.6). A best fit linear regression line: $\hat{y} = 52.45 - (0.57)(ERL\ (S\%))$ [**where** $\hat{y}$ = predicted tear size and ERL (S%) = External Rotator Affected arm strength ratio in Lying] was drawn on the scatter plot to indicate this relationship (Figure 4.1 and 4.6). The regression line can be used as a predictor of tear size if ERL (S%) is known. For example if **ERL (S%)** was measured as **61%,** (Figure 4.6) then the predicted tear size in this case would be **17.68cm²** (Figure 4.6).

The same answer would have been found if the regression formula was used i.e.

$\hat{y} = 52.45 - (0.57)(61)$ (Where ERL (S%) is known to be **61%**)

$= 17.68\ cm^2$

The square of the correlation coefficient ($R^2$) between tear size and ERL (S%) is 0.62 (Table 4.2). Therefore on the above basis, tear size can be correctly predicted in 62% of cases where ERL (S%) is known.

Similarly there was a negative correlation observed between tear size and ERS (S%). A best-fit linear regression line was also plotted on this scatter plot to indicate the derived relationship. (Figure 4.2)

This regression line and/or formula $\hat{y} = 35.05 - (0.3005)(\text{ERS (S\%)})$ [where ERS (S%)= External Rotator Strength Ratio in Standing (%)] can similarly be used as a predictor of tear size if the ERS (S%) is known.

The square of the correlation coefficient ($R^2$) between tear size and ERS (S%) is 0.48 (Table 4.2) Therefore on the above basis tear size can be correctly predicted in 48% of cases where ERS (S%) is known.

*Pain versus Muscle Testing, Constant Score and Tear Size Study*

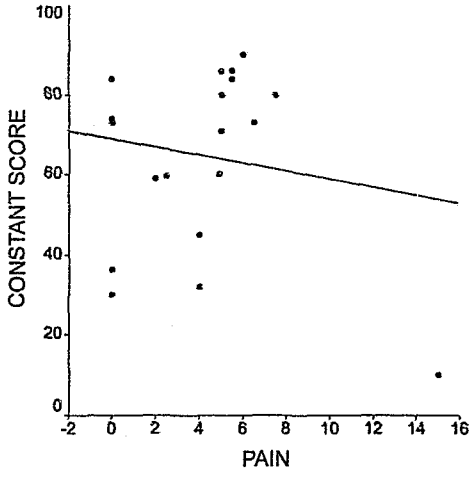



**Figure 4.7** Pain vs. Constant Score

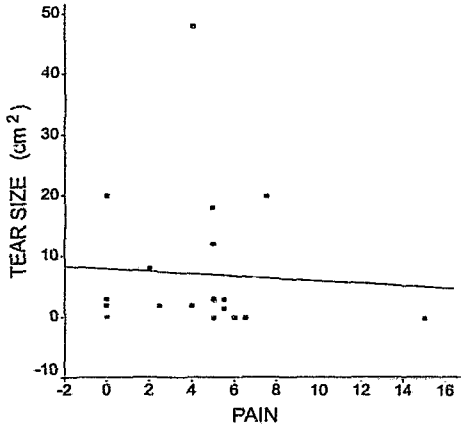



**Figure 4.8** Pain vs. Tear Size ($cm^2$)

The scatter plot of Pain vs. Tear Size (Figure 4.7) as well as the scatter plot of Pain vs. Constant Score (Figure 4.8) reflect a random scatter pattern which indicates that there was no linear relationship between the parameters measured. The Pearson's correlation coefficients are 0.06 and 0.16 respectively.

Similarly no linear relationship was demonstrated in any of the other test positions versus pain and they have therefore not been represented graphically.

Table 4.3 shows the correlation between the levels of pain (recorded on a visual analogue pain scale) that the patient complained of pre-operatively and the other parameters measured i.e. the tear size, the affected arm strength ratio in all the positions tested as well and the Constant Score.

**TABLE 4.3 Correlations between the pain variable and tear size variables, the affected arm strength ratios variables as well as the Constant Score variable**

| | Correlation coefficient (R) | $R^2$ |
|---|---|---|
| Tear Size | 0.05 | 0.003 |
| ERL | 0.19 | 0.034 |
| IRL | 0.48 | 0.232 |
| ABD L | 0.33 | 0.110 |
| ERS | 0.07 | 0.005 |
| IRS | 0.17 | 0.310 |
| ABD S | 0.06 | 0.004 |
| ABD 90° | 0.39 | 0.153 |
| Constant Score | -0.16 | 0.024 |

Table 4.3 shows:

There is no relationship between:

- Pain and tear size
- Pain and any of the strength deficits measured
- Pain and the Constant Score variable

# 5.0 Discussion and Conclusion

The accuracy of testing muscle force with a hand-held dynamometer such as the Nicholas Manual Muscle Tester is said to be affected by many factors e.g. errors of the testing procedure, an inaccurate testing device, the compliance or lability of the subjects or the condition being tested, as well as the reliability of the tester (Riddle et al, 1987).

In an attempt to assess the tester and/or device error an intrarater/intratester reliability test using the Nicholas Manual Muscle Tester was performed on 8 shoulders as described in 4.1. According to Bland and Altman (1986) the mean difference in a method that has perfect reproducibility will be zero. The mean difference between these two trials was –0.025 kg, which is not significantly different from zero (t-test: p=0.8153; Wilcoxon matched pairs, signed-ranks test: p=0.8658). The 95% confidence interval for this difference is (-0.545; 0.595), and hence with 95% confidence, the error in measurement will be no more than 0.57kg (1.96*sd). In clinical terms this means that the tester is reliable within a 0.57kg error when testing physiotherapy subjects with no previous or current shoulder problems.

Ideally the intrarater reliability should have been tested on the population being tested i.e. on patients scheduled for arthroscopy surgery (Riddle et al, 1989). The patients were however unwilling to be admitted a day early as this would have been inconvenient, as well as extra hospital costs would have been incurred.

According to the results of the two statistical tests, the intrarater/-tester reliability (in the group of subjects tested) was high. In addition the tester was an experienced clinician (Kendall et al, 1993; Bohannon, 1986; Bohannon and Andrews, 1987). It is therefore not unreasonable to consider that the tester was reliable. One Nicholas Manual Muscle Tester was used in this trial, thus eliminating any chance of inter-device errors (Trudelle - Jackson et al, 1994).

The population studied was a heterogeneous group. Subjects were of different ages and had variable pathologies. The consulting orthopaedic surgeon had selected the subjects for an

arthroscopic examination of their rotator cuff muscles. The researcher was blind to the diagnosis and reasons for the operations. Previous authors have shown that strength varies by age and gender (Murray et al, 1985; Constant and Murley, 1987), therefore the subject's unaffected contralateral shoulders was used as the control. It has been shown that there is no statistically significant difference between testing dominant versus non-dominant arms (Hinton, 1988; Wilk et al, 1993; Sirota et al, 1997). The dominant arm is however generally stronger (even if not statistically relevant) and therefore a small percentage difference may in fact be normal (Kuhlman et al, 1992). The above does not take into account that the contra-lateral side may have a tear of the rotator cuff without any presenting clinical symptoms (Kuhlman et al, 1992; Itoi et al, 1997). This has been suggested as an explanation for decreased external rotator strength being reported in the dominant arm in symptom free overhead sportsmen (Wilk et al, 1993). The subjects in this study were excluded if they had any obvious pathology that could affect the force production of the control arm (see 3.1.1). It is however possible that a non-symptomatic small tear of the control arm could be missed. This may explain the fact that the three subjects, 12,13 and 14 (Table 4.1) with $3cm^2$ tears had such small strength differences between the control arm and the affected arm. It would be a valuable research project to investigate this. However, the major obstacles would be that it would be very invasive and/or expensive to investigate.

A Nicholas Manual Muscle Tester was chosen to test the isometric muscle function, as this is a reliable, transportable and fairly inexpensive method of testing (Malerba et al, 1993). It is also less painful, in this group of subjects, to use isometric testing as apposed to a more vigorous form of testing such as isokinetic testing (Brown and Friedman, 1998). Patients with tears are often not able to tolerate isokinetic testing (Rabin and Post, 1990). The optimum position for muscle testing the rotator cuff still remains controversial (Kuhlman et al, 1992). External rotation (in neutral) in lying has been shown to be a reliable position for testing the posterior rotator cuff (Jenp et al, 1996; Kelly et al, 1996). It is a position of minimal risk for impingement. In addition, it tests the rotator cuff most accurately with minimal synergistic muscle action (Jenp et al, 1996; Kelly et al, 1996). Internal rotation cannot be tested in isolation, as the other internal rotators (pectoralis major, latissimus dorsi and teres major) are impossible to eliminate. Gerber's "lift-off" test is the most accurate test for assessing a

subscapularis tear, but many patients with rotator cuff pathology will not be able to achieve this hand behind back position (Greis et al, 1996).

Stabilisation of the trunk was extremely difficult to achieve in standing, despite the precautionary measures taken of using the doorframe. Testing internal rotation in neutral was the most difficult test to execute, even in the more stable lying position. It was found that even if the tester had every mechanical advantage, the internal rotator group was extremely difficult to break in the larger, stronger male subjects. Every care had to be taken in order to eliminate any errors due to this. The reliability of testing internal rotation in normal subjects in these positions could be an interesting future study.

In this study, the results show (Pearson's correlation coefficient of (- *0.79*)) that there is an inverse relationship between tear size and ERL (S%) (Table 4.2). This seems to confirm the original clinical observation i.e. if ERL (S%) is low then there is usually a tear of the rotator cuff (Sklaar, 1992, 1995). The square of the correlation coefficient ($R^2$) between tear size and ERL (S%) is 0.62 (Table 4.2). Therefore on the above basis, tear size can be correctly predicted in 62% of cases where ERL (S%) is known (Figure 4.6). In addition, an inverse relationship was also demonstrated between ERS (S%) and tear size (Table 4.2). In this case the results show that if ERS (S%) ($R^2 = 0.48$) is known then in 48% of the cases the size of the tear can accurately be predicted (Table 4.2).

The 14% discrepancy between ERL (S%) and ERS (S%) ($R^2 = 0.62$; $R^2 = 0.48$; Table 4.2) may have been due to the increased difficulty in stabilisation of the body and arm in standing compared with lying. The substitution from trunk movement and other shoulder synergists is much easier to control in lying and therefore, this may be interpreted as static resisted external rotation (neutral arm) tested in lying to being a more accurate test than in standing. The results do show however that ERL (S%) and ERS (S%) are associated ($R = 0.67$) (figure 4.5), and that as the one increases/decreases so does the other. This strengthens the hypothesis that the strength production of static resisted external rotation is linked to tear size. It is however clear that testing in the lying position is a much better test than in standing (Table 4.2).

*No correlation was found between tear size and function* (Constant Score) or tear size and testing abduction or internal rotation in any of the test positions (Table 4.2). This strengthens the inverse relationship found between the strength production of static resisted external rotation and tear size, in lying and standing (Table 4.2).

In all the subjects tested if a tear was present, there was always at least a tear of supraspinatus. The results show that no correlation could be found, between tear size and muscle strength production when testing abduction in any of the positions (Table 4.2). This confirms the inaccuracy of using abduction as a measure of isolating a supraspinatus weakness and/or tear (Itoi et al, 1997). These tests using abduction cannot eliminate deltoid function and therefore deltoid strength confounds any strength findings when testing abduction or elevation. This also strengthens the case for rather using static resisted external rotation as a major muscle test for posterior rotator cuff dysfunction. As discussed previously this tests supraspinatus, infraspinatus and teres minor.

Clinically it would be useful to be able to have a standardised scale of affected arm strength ratios and their clinical interpretations. The trend looking at these results (Figure 4.1) seem to indicate that if ERL (S%) is 61% or less i.e. the affected arm is only able to produce 61% or less of it's estimated possible strength production. Then the tear is likely to be large. If ERL (S%) is equal to or greater than 88%, then there is likely to be no tear.

Six subjects (15 to 20) had large tears and average ERL (S%) of 61% (Table 4.1). The ABD L (S%) and ABD 90° (S%) averages in these subjects were also low, (58% and 46%). However, in subjects 17 and 19 who both had massive tears, the ABD 90°(S%) values tested surprisingly high, 85% and 80% respectively (Table 4.1). This may be due to the small sample size, or may confirm the inaccuracy of using abduction to test supraspinatus strength.

Seven of the subjects (1-7) had no tears recorded, and the average ERL (S%) was 88% (range of 80%- 101%)(Figure 4.1). This would seem to indicate that if the strength difference is over 88% then there is unlikely to be a tear. This is also confirmed by the high (S%) values of ABD L (88%) and ABD 90° (90%).

Four subjects (8-11) had 2x1cm$^2$ tears and the average ERL (S%) was 80%, therefore it could possibly be said that if ERL (S%) is <=80% a small tear could be suspected. This suspicion may be strengthened by lower values of ABD L (74%)and ABD 90° (70%)(Figure 4.1).

If the average ERL (S%) are looked at in conjunction with ABD L (S%) and ABD 90°(S%), there also seems to be a trend emerging. The subjects with no tears had high ERL (S%) as well as high ABD L (S%) and ABD 90°(S%). The subjects with small tears had a lower ERL (S%) of 80% as well as much lower (S%) of ABD L (74%) and ABD 90° (70%)(Table 4.1). Subjects with large tears averaged 61% and also had low ABD L and ABD 90° (58% and 46%). From this, there seems to be a grey area for (S%) that fall between 80% and 88%. This grey area could represent either a small tear or no tear at all.

In summary the trend seems to show that:

ERL (S%) greater than or equal to 88% represent no tear,
ERL (S%) 80% to 88% represent no tear or a small tear,
ERL (S%) 62% to 80% represent a small tear and
ERL (S%) 0 to 61% represent a large tear.

A similar trend also seems to be emerging for the ABD L (S%) and ABD 90° (S%) and the accuracy of the diagnosis may improve dramatically if the other (S%) values besides ERL (S%) are analysed. This may be worthwhile as a future research project.

Three subjects (12-14) with 3x1cm$^2$ tears seem to confound this theory. They all had ERL (S%) values greater than 91% (average (S%) 95%) and ABD 90°(S%) averaging at 95%. ABD L (S%) values were all greater than 88% (Average (S%) 115%). Two of the values of ABD L (S%) show that the affected arm is in fact able to produce greater strength values than the control (subjects 12 and 13). This leads one to suspect that the control arm in these subjects may have had some undiagnosed pathology. These three values may however, with greater numbers, prove to be the exception to the rule. Or perhaps, anatomically a 3x1cm$^2$ tear has

less effect on strength transmission than a 2x1cm$^2$ tear. More subjects in each tear size category are needed to confirm these theories.

In the subjective examination, pain was assessed, using a visual analogue scale as described by Constant and Murley (1987). The most severe pain that the subject experienced pre-operatively was recorded on the visual analogue scale. No correlation between tear size and pain could be found (table 4.3) (Post et al, 1983). There was no correlation between pain and ERL (S%), ERS (S%) or any of the other parameters measured (Table 4.3). Clinically therefore, this could be interpreted as there being no correlation between pain and function (Constant Score) or pain and muscle strength.

Pain was also assessed verbally with each individual muscle force test and recorded. If pain was present then the subject was also questioned as to whether this pain had affected their strength. One subject felt the pain was much too severe to attempt testing even with the arm in the neutral position. This case was withdrawn (3.1.1) from the study. The arthroscopy result reported that the patient had a large intratendinous tear. Intratendinous tears are said to cause severe pain and this may be worthwhile to look at as future research.

ABD 90° is considered to be a position of pain. However most subjects in this study were able to achieve this position easily. Only two subjects were exceptions. Thus they were given a value of zero and both were subsequently found to have massive tears.

In the first few subjects, external and internal rotations were tested in the ABD 90° position. These tests were excluded from the study as they caused severe 5/5 pain, and this affected the subject's muscle force. These tests were the final tests performed and therefore the earlier values measured were still included in the study.

In retrospect, the pain should have been measured on a visual analogue scale, as this would have provided more meaningful results, which could have been analysed statistically. However, verbal reports were used as a screening method of the intensity of pain, and subjectively, pain did not appear to affect the results. Ben-Yishay et al (1994) showed that

muscle strength production increased after administering local anaesthetic injections into the shoulder joint, even in the normal population. Therefore it is questionable if use of a local anaesthetic is a better test of strength production than if the pain is left as a constant factor. Pain may have an inhibitory affect on muscle strength. Therefore if the pain is present, the strength values may not be accurate in terms of what that muscle can produce (Brox et al, 1997). It is however accurate in terms of what it can produce at that given moment, with that particular pathology.

If testing is to be done after a subacromial lidnocaine or similar anaesthetic injection has been administered, then the control arm, theoretically, would also have to be injected. This is invasive and beyond the scope of physiotherapy in South Africa. This could be used in conjunction with a doctor as a further research study, i.e. to assess the affect of pain inhibition on muscle strength production in this patient population.

There is a strong relationship between ERL (S%) and tear size in the population group tested. Pain and function have not been found to be directly related to tear size, but are parameters that are related to rotator cuff pathology. Pain primarily and then disability, are the major reasons for operative procedure (Neer et al, 1983; Ellman et al, 1986; Grana et al, 1994; Cordosa and Bigliani, 1997; Gartsman et al, 1998). If the status of pain and function is known from the general examination and tear size is estimated from ERL (S%), then a clearer picture of severity of the pathology may be estimated. For example if pain and function are severely impaired and the ERL (S%) is low e.g. 61% (Table 4.1), suggesting the tear is large, then conservative treatment may not be indicated. However, if ERL (S%) is high e.g. 88% (Table 4.1), then conservative treatment may be pursued as this indicates that the pathology may not be severe.

ERL (S%) was found to be an indicator of tear size, and in 62% of subjects, if ERL (S%) is known, the tear size (S%) can be accurately estimated. If ERL is 61% or less, it is reasonable to assume that the subject may have a large or massive tear. The less the ERL (S%), the higher the chance of a large or massive tear. If ERL (S%) is 88% or more, there is likely to be no tear or a small tear. The accuracy of the diagnosis may improve dramatically if the other (S%)

values besides ERL (S%), as well as the function (Constant Score) and pain levels of the subjects are analysed. This may be worthwhile as a future research project.

Similar studies to this one could not be found in the literature, so a comparison of the results could not be made. However, many studies show that decreased strength of external rotation and abduction suggest a large rotator cuff tear (Post et al, 1983; Matsen and Arnst, 1990; Arroyo et al, 1997; Cordosa and Bigliani, 1997). Brems (1987,1988) measured muscle force (using a digital HHD) in rotator cuff tears and reported that any disruption in rotator cuff function often first manifests in external rotation. It was reported in this study that the size of the tears are directly related to external rotator strength (neutral). Ballentyne et al (1993) also noted an association between decreased external rotator strength and shoulder pathology. However, manual muscle testing was used without any hand-held dynamometers, this has not been found to be accurate enough. Warner et al (1990) also noted an association between external rotation force and tear size. Itoi et al (1997) report that shoulders with full thickness supraspinatus tears have weak abduction and external rotation. The external rotator strength according to their isokinetic study decreased by 22%-33% in the cases with supraspinatus tears. No correlation was reported between isokinetic muscle force and tear size. It was felt that factors other than force transmission may be involved in the strength loss. Their study cannot however be compared to this one, as they did not test isometric force at all. In addition, as discussed previously, although the muscle force increased after a pain block was administered, the force baseline measurements may have been initially decreased by the vigorous method of isokinetic testing, making the pre-block values invalid.

It also may be a valuable research project to assess patients presenting for conservative treatment of rotator cuff pathology by calculating ERL (S%). If patients have ERL (S%) that are low e.g. less than 61%, and have to resort to surgery, the tear size could be predicted and then this calculation could be checked for accuracy. Similarly patients with ERL (S%) that are high, and (according to these results) have a good chance of responding to conservative treatment, could be followed over a period of time to see if the predictors are accurate clinically.

In conclusion:

- It is extremely difficult to differentiate between no tears and a minor tear of the rotator cuff.
- A large tear is easier to diagnose.
- Abduction, as used traditionally as a diagnostic test for supraspinatus is not specific enough.
- The individual rotator cuff muscles cannot be tested in isolation.
- The pain experienced pre-operatively is not related to tear size.
- Shoulder function is not related to tear size.
- ERL (S%) has been shown to be inversely related to tear size.
- The tear size can be calculated using the ERL (S%) and this calculation has been shown to be correct in 62% of cases.
- This percentage accuracy may increase if ERL (S%) is looked at in the entire context of the examination.

# APPENDICES

## APPENDIX A

### SUBJECT INFORMATION SHEET

**Dear patient,**

In order to complete my Masters degree in Physiotherapy, I am conducting a study on patients with shoulder problems and I would appreciate your assistance.

For the study I am measuring the strength of certain muscles in your problem arm and comparing this to your normal arm.

In order to obtain an accurate measure I will test your arms on a computerized exercise machine as well as doing a shoulder examination similar to the doctor's examination.

I will then compare these test results with the actual findings at the operation.

The testing is completely pain free and will take approximately 15 minutes.

There will be no charge at all.

All information will be confidential and you will remain anonymous.

Participation in this research project is voluntary.

You may withdraw at any stage without prejudice.

If you would like to volunteer for the above research project and agree to participate in this study and allow your previous and future medical records to be used, please sign below.

Thanking you in anticipation,

Joanne Sklaar BSc. Physiotherapist

**CONSENT**

I have read the information sheet & understand the procedures detailed.

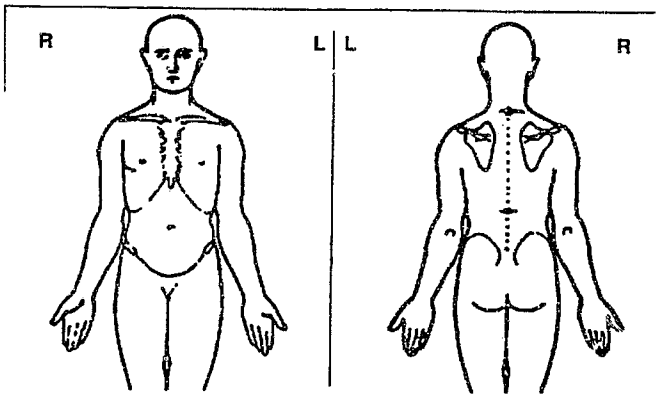
I agree to act as a subject in the above research project & I agree to allow my medical records pertaining to my shoulder problem to be used for the purposes of the research.

**PARTICIPANT** **RESEARCHER**

DATE

**APPENDIX B**

**SHOULDER** **EXAMINATION**




**MAIN COMPLAINT** PAIN, STIFFNESS, WEAKNESS, INSTABILITY, CREPS.

AGE LEFT OR RIGHT HANDED

**PERIODICITY** constant intermittant

**QUALITY** DEEP SUPERFICIAL SHARP DULL ACHE BURN LAME

| | None | mild | moderate | severe |
|---|---|---|---|---|
| **INTENSITY** | I----------/----------/----------I | | | |
| INCR / DECR | 15 | 10 | 5 | 0 |

**AGGRAVATING FACTORS** **TOTAL /15**

Positioning waist (2) , xiphoid (4), neck (6) , top of head (8), above head (10)

SLEEPING (2) WORK(4) SPORT / RECR (4) **TOTAL** **/20**

**RELIEVING FACTORS**

POSITIONS MEDICATION

OTHER

**HISTORY**

PRESENT

PAST

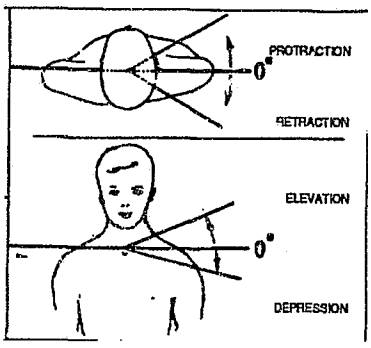
PREVIOUS TREATMENT

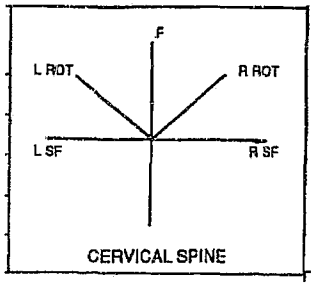
HCl INJECTIONS

PHYSIOTHERAPY

GENERAL HEALTH INVESTIGATIONS

**OBJECTIVE EXAMINATION**




OBSERVATION ANTERIOR REFLEXES

LATERAL

POSTERIOR

GENERAL POSTURE

**ACTIVE MOVEMENT**

| | FLEXION | ABDUCTION |
|---|---|---|
| 0 - 30 ( 0) | | |
| 31 - 60 (2) | | |
| 61 - 90 (4) | | |
| 91 - 120 (6 ) | | |
| 121 - 150 (8 ) | | |
| 151 - 180 ( 10 ) | | |

**TOTAL /20**

**EXTERNAL ROTATION**

NEUTRAL

**HBH** ELBOW FORWARD / BACK 2 POINTS EACH

**HOH** ELBOW FORWARD / BACK

**FULL ELEVATION** FROM HOH **TOTAL /10**

**INTERNAL ROTATION** - hand behind back

DORSUM OF HAND - LATERAL THIGH (0 ), BUTTOCK ( 2), L/S JUNCTION (4 ), WAIST L3 (6 ), T12 ( 8), INTERSCAPULAR T 7 (10 ) **TOTAL /10**

**HAND ON SHOULDER**

**PASSIVE MOVEMENT**

| FLEXION | ABDUCTION |
|---|---|
| EXTERNAL ROT. | INTERNAL ROTATION |
| O | |
| 45 | |
| 90 | |
| >90 | |

IMPINGEMENT TEST

STABILITY

## PALPATION

SUPRASPINATUS

INFRASPINATUS/TERES MINOR

BICEPS

SUBSCAPULARIS

STERNOCOSTAL JOINT

ACROMIOCLACICULAR JOINT

GLENOHUMERAL JOINT

P/A'S A/P'S LONGITUDINAL.

## APPENDIX C

**Patient Physiotherapy Sheet**

Patient Physiotherapy Sheet

Date:

Dear Physiotherapist,

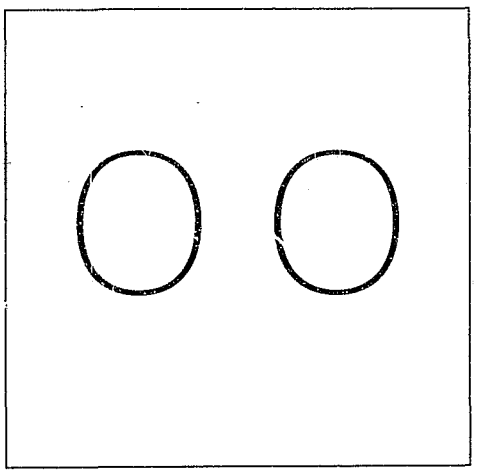
Re: Mr./ Mrs./ Miss

The above patient underwent surgery today. The following procedure/s were done;

(L Rt ) Shoulder

| | | | | | |
|---|---|---|---|---|---|
| ☐ | Arthroscopy | ☐ | Acromioplasty | | |
| ☐ | Rotator Cuff Repair | ☐ | Tear | | |
| ☐ | Stabilisation | | | Gr. 1 | ☐ |
| ☐ | Excision Clavicle | | | Gr. 2 | ☐ |
| ☐ | Ant. Labrum | | | Gr. 3 | ☐ |
| ☐ | Slap | | | | |
| ☐ | Other | | | | |

Arthroscopy View of Tear:



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