# THE EFFECTS OF SCAPULOTHORACIC REHABILITATION ON SHOULDER PAIN IN COMPETITIVE SWIMMERS

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# DECLARATION

I, Megan Dutton, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor part of it has been, is being, or is to be submitted for another degree in this or any other university.





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* Please note: all photographs included in the dissertation were taken by the author. The model consented to all the photographs being included in this dissertation.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| AC | Acromioclavicular |
| AMSESS | American Shoulder and Elbow Surgery Score |
| cm | Centimetre |
| CSS | Constant Shoulder Score |
| EMG | Electromyography |
| GH | Glenohumeral |
| ICC | Intraclass correlation coefficient |
| Kg | Kilogram |
| km | Kilometre |
| m | Metre |
| mm | Millimetre |
| NRS | Numeric Rating Scale |
| ROM | Range of motion |
| s | Second |
| SA | Subacromial |
| SC | Sternoclavicular |
| ST | Scapulothoracic |
| PSS | Penn Shoulder Score |
| VAS | Visual Analogue Scale |
| VRS | Verbal Rating Scale |

# GLOSSARY OF TERMS

*Acromioclavicular (AC) Joint:* Plane synovial joint between the lateral end of the clavicle and acromion of the scapula[3,5-7].

*Biomechanical Coupling: "The rotation or translation of a joint about or along an axis which is consistently associated with rotation or translation of another joint about its respective axes[8]."*

*Body Roll:* The rotation of the trunk around the longitudinal axis of a swimmer's body when performing the freestyle stroke[9].

*Glenohumeral (GH) Joint:* Multi-axial ball and socket synovial joint between the head of the humerus and glenoid of the scapula[3,5-7].

*Shoulder Impingement:* The entrapment of the rotator cuff, subacromial bursa or biceps tendon between the anterior third of the coracoacromial arch and the humeral head, during arm elevation[2,10,11].

*Initial Catch:* First phase of swimming, characterised by hand entry into the water, in a *"fingers first"* fashion[12,13].

*Lateral Scapula Slide Test:* A quantitative measure of scapula stabiliser strength, measured in three positions namely *"arm by side"*; *"hands on hips"* and *"arms at or below 90°"*[3].

*Pain: A physical and emotional response to a noxious stimulus that is specific to each individual; influenced by an individual's social environment, behaviour, attitudes and beliefs[10,14].*

*Penn Shoulder Score (PSS):* A condition specific, self-report, 100-point questionnaire, which utilises a multi-level 10 point numeric rating scale for pain, a single level 10 point numeric rating scale for satisfaction and a Likert scale for shoulder function[15].

*Primary Impingement:* The structural narrowing of the sub-acromial space due to the development of osteophytes or os acromiale[2,16-19].

*Pull Through:* Second phase of swimming, characterised by a straight through pull (Figure 2.2), from full GH flexion to the hip, and requires adduction and internal rotation of the shoulder[12,20].

*Range of Motion (ROM):* Magnitude of movement occurring at a joint, expressed as degrees(˚)[7].

*Recovery:* The final phase of swimming, where the arm is brought forward, in a circular motion from the hip to full shoulder elevation outside the water, allowing hand entry to occur[12,20].

*Scapulothoracic Dyskinesis:* Abnormal or altered movement of the scapula in relation to the thorax, at the ST joint[10,12,20-22]

*Scapulothoracic (ST) Joint:* Physiologic joint between the scapula and thorax[3,5-7].

*Secondary Impingement:* The encroachment of the subacromial bursa and rotator cuff tendons between the humeral head and coracoacromial arch (external or subacromial impingement), due to altered biomechanics[16,17,19]

*Sternoclavicular (SC) Joint:* Plane synovial joint between the sternal end of the clavicle and manibrum of the sternum, attaching the upper limb to the axial skeleton[3,5-7].

*Subacromial(SA) Joint:* Physiologic joint between the coracoacromial arch and the head of the humerus[3,5-7].

*Tilt angle: "A measure of the effect of an elevation of one scapula and depression of the other, and the effect of side-bending the trunk[12]."*

*Visual Analogue Scale (VAS):* A 100 mm line anchored by *"no pain"* and *"worst imaginable pain"*, which can be used to determine pain intensity when marked by a participant[23].

## ABSTRACT

**Background:** Competitive swimmers have a high incidence of shoulder pain. Secondary shoulder impingement is thought to be primarily responsible for shoulder pain in competitive swimmers. The effective management of shoulder impingement has been widely investigated; however there is minimal consensus on the optimal method of treatment and rehabilitation of shoulder impingement. In addition, current research does not adequately consider the role of scapulothoracic rehabilitation in the management of shoulder impingement.

**Aim:** To determine the effects of a scapulothoracic rehabilitation programme on shoulder pain in competitive swimmers.

**Specific objectives:** (a) To determine whether there were significant differences in Penn shoulder *"pain", "satisfaction"* and *"function"* scores; GH flexion, external rotation, internal rotation and total rotation ROM; thoracic rotation ROM; scapula stability; pectoralis minor muscle length and 100 m freestyle swimming time trial; between an experimental group that performed a scapulothoracic rehabilitation programme, and a control that performed a standard rehabilitation programme, over a nine week study period. (b) To determine whether there were significant relationships between outcome measures (as stated above) (c) To determine the clinical effects of scapulothoracic and standard rehabilitation programmes on the above mentioned outcome measures

**Methods:** Fifty competitive swimmers with unilateral shoulder pain, between the ages of 18 and 30 years, who performed five swim training sessions per week, and three dry land training sessions per week, were recruited for this study which had a randomised experimental design. Familiarisation of the testing procedures was conducted one week prior to the commencement of the respective six week rehabilitation programmes. During familiarisation, participants gave written informed consent and completed the personal questionnaire; and body composition measurements and screening tests were performed. Thirty-two participants were eligible to participate in this study. Participants were randomly assigned to either the experimental or control group. The experimental group received a progressive six week scapulothoracic rehabilitation programme. The control group received a progressive six week standard rehabilitation programme. Standard testing was conducted before the rehabilitation programme, at weeks three and six during the programme, and at week nine after the commencement of the rehabilitation programmes.

Standard testing included the assessment of Penn shoulder scores for shoulder *"pain"*, *"satisfaction"* and *"function"*; measurement of GH elevation, external rotation, internal rotation and total rotation ROM and thoracic rotation ROM; scapula stability; pectoralis minor muscle length; and 100 m freestyle swimming time trial.

**Results:** A six week rehabilitation programme significantly reduced Penn shoulder *"total pain"* score (p =0.00001); and improved Penn shoulder *"function"* score (p = 0.003), range of GH flexion (p = 0.00001), GH internal rotation (p = 0.00001), thoracic rotation (p = 0.00001); and enhances scapula stability (Lateral scapula slide test: *"Arm by side"* p = 0.00002; *"Hands on hips"* p = 0.00001; *"Arms at 90° GH abduction"* p = 0.007). Significant interactions occurred between groups over time for Penn shoulder *"satisfaction"* scores (p = 0.02); GH external rotation ROM (p = 0.01) and 100 m freestyle swimming time trial (p = 0.00001). However, these results were due to significant differences in the experimental group, predominantly compared to baseline measures, but sometimes compared to week 3 measures. A range of clinical effects were reported for the respective outcome measures. There were also numerous significant correlations between outcome measures.

**Discussion and conclusion:** A six week rehabilitation programme was effective in the treatment of shoulder pain due to impingement in competitive swimmers. No significant differences were found between the scapulothoracic and standard rehabilitation programmes, which both included scapula musculature exercises. The dose effect of the additional exercises in the scapulothoracic rehabilitation programme may have been too small to detect significant differences between groups. Based on the findings in this study, modifications to the scapulothoracic rehabilitation programme have been recommended to further evaluate the effects of a combined scapula and thoracic rehabilitation programme on shoulder impingement in competitive swimmers.

**Key words:** Shoulder, pain, impingement, swimmers, scapulothoracic rehabilitation.

# CHAPTER 1: INTRODUCTION AND SCOPE OF THESIS

## 1.1 INTRODUCTION

Swimming is a complex skill that requires physical attributes to maximise propulsive force against the viscosity of water. Ninety percentage of injury complaints by swimmers pertain to the shoulder, although hand and elbow injuries do occur[12,24]. The incidence of shoulder pain in swimmers is reported to occur equally between males and females, during all parts of the stroke, at all distances and levels of training and predominantly affects the freestyle and butterfly strokes[24,25]. Furthermore the nature of shoulder pain may vary from a nagging pain when using hand paddles, to debilitating pain that inhibits further progress in training. The location of pain is also variable about the shoulder[25]. The primary cause of this high incidence of shoulder pain in swimmers is thought to be secondary shoulder impingement[10].

Shoulder impingement is the entrapment of the rotator cuff tendons, primarily the long head of the biceps and/or supraspinatus tendons, between the anterior third of the coracoacromial arch and humeral head[10]. Shoulder impingement may be further delineated into primary and secondary impingement. Primary impingement is defined as the reduction in subacromial space due to anatomical abnormalities, for example osteophytes and os acromiale. Secondary impingement occurs when structural or functional deficits result in pathological translation, hyperangulation or excessive rotation of the humeral head on the glenoid, thereby decreasing the subacromial space[18]. In addition, the excessive scapula protraction and internal rotation required for swimming may be associated with an increased thoracic kyphosis, which may result in muscular imbalances between the shoulder rotators and scapula stabilisers[10]. This may lead to anterior translation of the humeral head and secondary impingement[13].

A coupling relationship exists between the thoracic spine and the shoulder girdle, where shoulder elevation is associated with ipsilateral thoracic lateral flexion and rotation[26,27]. Improved thoracic position may be associated with beneficial effects on shoulder ROM, strength and scapular kinematics, including improvements in both scapula posterior tilt and the length-tension relationships within the shoulder girdle muscle complex[28,29]. An optimal thoracic posture may therefore provide a stable scapula position, which allows for optimal functioning of the GH joint[5,30].

Kinetic chain rehabilitation is a holistic approach which considers the body as a linked system of interdependent segments. The effective rehabilitation of shoulder elevation and function may therefore be dependent on regaining trunk and scapula control[4]. The inclusion of trunk control early in the rehabilitation of shoulder pain may facilitate and reinforce normal movement patterns. McMullen et al[4] demonstrated that kinetic chain rehabilitation of the shoulder was associated with a reduction in shoulder pain, which did not respond to conventional shoulder rehabilitation.

## 1.2 STATEMENT OF THE PROBLEM

Current evidence for the treatment and rehabilitation of shoulder impingement recommends trigger point and soft tissue therapy[10,19,31]; stretching of the posterior shoulder joint capsule, pectoralis major and minor muscles[10,19,24,31,32]; improving scapula stability and rotator cuff muscle strength[10,11,19,24,31-34] and functional strengthening[4,10,31]. There is a lack of consensus regarding the optimal method of treatment and rehabilitation of shoulder impingement. Further, existing research does not consider the role of posture or trunk control in shoulder rehabilitation.

Scapula stability and rotator cuff strength may be rehabilitated using a variety of closed and open kinetic chain exercises including scaption[11,31,33], rowing[11,19,31,33], push-up plus[11,19,31,33], press-up[11,19,31], dynamic hug[11] and resistance band shoulder retraction, external rotation and flexion[10,11,24,32]. However, of these exercises, only scaption, rowing and push-up plus incorporate trunk control simultaneously with scapula control[11,31,33]. The sternal-lift and shoulder dump exercises, as described by McMullen et al[4], emphasise thoracic extension and shoulder elevation with ipsilateral thoracic lateral flexion and rotation, respectively. A combined scapulothoracic rehabilitation protocol utilising these two exercises in conjunction with scaption, rowing and push-up plus may therefore provide more effective rehabilitation of trunk and scapula control.

## 1.3 AIMS AND OBJECTIVES

### 1.3.1 Aim

The aim of this study was to determine the effects of combined scapula and thoracic (scapulothoracic) rehabilitation, compared to isolated scapula (standard) rehabilitation on shoulder pain and dysfunction in competitive swimmers.

### 1.3.2 Specific objectives

Specific objectives of this study were:

- To determine whether there were significant differences in Penn shoulder *"pain", "satisfaction"* and *"function"* scores; GH flexion, external rotation, internal rotation and total rotation ROM; thoracic rotation ROM; scapula stability; pectoralis minor muscle length and 100 m freestyle swimming time trial; between an experimental group that performed a scapulothoracic rehabilitation programme, and a control that performed a standard rehabilitation programme, over a nine week study period.
- To determine whether there were significant relationships between Penn shoulder *"pain"*, *"satisfaction"* and *"function"* scores; GH flexion, external rotation, internal rotation and total rotation ROM; thoracic rotation ROM; scapula stability; pectoralis minor muscle length and 100 m freestyle swimming time trial.
- To determine the clinical effects of scapulothoracic and standard rehabilitation programmes on Penn shoulder *"pain"*, *"satisfaction"* and *"function"* scores; GH flexion, external rotation, internal rotation and total rotation ROM; thoracic rotation ROM; scapula stability; pectoralis minor muscle length and 100 m freestyle swimming time trial.



### 1.3.3 Significance of study

Physiotherapists working with swimmers are often challenged to accurately diagnose and effectively treat shoulder impingement. Holistic treatment of swimmers includes optimal management of shoulder impingement, to prevent re-injury and/or further injury from occurring. Rehabilitation is commonly used in the long term management of shoulder impingement. However, current literature has yet to reach a consensus on the optimal method of treatment and rehabilitation of shoulder impingement. In addition, the effect of posture or trunk control in shoulder rehabilitation has not been systematically investigated.

This study will provide new information regarding the effects of scapulothoracic rehabilitation on shoulder pain in swimmers. This is of practical relevance for physiotherapists working with swimmers. The findings of this study may assist in the development of a holistic management paradigm for the treatment of shoulder impingement in swimmers, including kinetic chain rehabilitation.

## 1.4 CONCLUSION

In preparation for the randomised, experimental study of the thesis, a review of the literature on the anatomy and biomechanics of the shoulder joint complex, swimming biomechanics, shoulder impingement in swimmers and the management and rehabilitation of shoulder impingement (with emphasis on scapulothoracic rehabilitation) will be presented in Chapter 2. This will be followed by a description of the study designed to examine the effects of scapulothoracic and standard rehabilitation on shoulder pain in competitive swimmers. The methods, study procedure, results and a discussion of the study findings will be presented in Chapter 3. The summary and conclusion section will complete this thesis in Chapter 4.

# CHAPTER 2: LITERATURE REVIEW

The prevalence of shoulder pain in swimmers varies from 3% to 80%[12,24,32,35], with 35% of elite level swimmers experiencing pain sufficient to interfere with, or inhibit participation in training[12]. It is estimated that an average university swimmer performs in excess of one million strokes per arm annually[24]. Further, the upper limb generates 90% of the forward propulsive force required during swimming, through shoulder adduction and internal rotation[32,36]. In addition, each stroke cycle subjects the swimmer to impingement for 25% of the stroke time[12]. Therefore, secondary shoulder impingement is thought to be the primary cause of this high incidence of shoulder pain in swimmers, and may be related to instability of the shoulder[10].

The purpose of this review is to outline the components that contribute to shoulder pathology in swimmers. The biomechanics of swimming and upper quadrant anatomy will be reviewed. Further, the relationship between swimming and possible causes of shoulder pain will be examined, with a focus on shoulder impingement. Lastly, the current trends in treatment and rehabilitation of shoulder impingement will be discussed.

The databases searched for literature included PubMed, Medline, Science Direct and EBSCOhost. The key words used included *"shoulder pain", "shoulder injury", "shoulder impingement", "swimmer's shoulder", "freestyle stroke", "shoulder biomechanics", "thoracic spine", "upper quarter biomechanics", "biomechanical coupling", "scapulothoracic rehabilitation", "identification and diagnosis of shoulder pain", "treatment"* and *"rehabilitation".*

## 2.1. EPIDEMIOLOGY OF SHOULDER PAIN IN SWIMMERS

Pink et al[37] reported that competitive swimmers perform a minimum of 2 500 shoulder rotations per day. Weldon et al[24] determined that collegiate swimmers performed an excess of one million strokes per arm annually. Further, Sein et al[22] demonstrated that elite level swimmers, train an average of 15 hours per week and cover approximately 35 kilometres (km) per week. In addition, shoulder adduction and internal rotation are primarily responsible for the forward propulsive force required when swimming[32,36]. Thus the shoulder is at high risk for injury when swimming due to repetitive overload.

Initially, the prevalence of shoulder pain in swimmers was reported as 3%[38]. However, more recent studies have reported prevalence rates of 15% to 80%[12,22,24,32,35,39]. McMaster et al[40] demonstrated the prevalence of shoulder pain sufficient to interfere with the training as 10% in age group swimmers (10 – 18 years), 13% in senior swimmers (18 – 35 years), and 26% in national team swimmers. Further, 47%, 66% and 73% of swimmers in these respective categories reported a history of shoulder pain. Similarly, Yanai et al[12] demonstrated that 35% of shoulder pain experienced by competitive swimmers may be sufficient to interfere with or inhibit training.

An American sport injury survey reported that recreational swimmers have a low injury potential due to the buoyancy of water (US Bureau of Labour Statistics (1990)[41]. Wolf et al[39] determined that the shoulder was the region most frequently injured in division I collegiate swimmers. The injury incidence varied between 31% for males and 36% for females. Approximately 60% of these injuries occurred primarily due to swimming, while 40% of injuries were associated with activities outside the pool. The freestyle stroke was the most common stroke speciality and thus had the greatest injury incidence. However, swimmers specialising in strokes other than freestyle exhibited a 33% greater risk for injury, compared to specialist freestyle swimmers. In addition, the injury risk for shoulder pain doubled if swim training exceeded 15 hours per week, and quadrupled if swimming distance exceeded 35 km per week[22].

In summary, the incidence of shoulder pain in swimmers occurs in both males and females of all ages; is more likely to develop in swimmers whom do not specialise in the freestyle stroke; and is dependent on a swimmer's level of participation in competition, and therefore quantity of training[12,22,24,32,35,39]. An overview of the anatomy, biomechanics and coupling of the upper quadrant is required, to better understand the incidence of shoulder pain in swimmers, and is discussed in the following section.

## 2.2. THE MECHANICS OF SHOULDER PAIN IN SWIMMERS

A comprehensive understanding of upper quadrant anatomy, biomechanics and coupling, as well as the biomechanics of swimming and freestyle stroke mechanics is required to appreciate the aetiology of shoulder pain in swimmers.

### 2.2.1 THE SHOULDER COMPLEX

#### a) Functional anatomy and biomechanics

The shoulder joint complex is a dynamic structure that comprises a series of articulations including the glenohumeral (GH), acromioclavicular (AC) and sternoclavicular (SC) joints; as well as the scapulothoracic (ST) and subacromion (SA) physiological joints. The multi-axial ball and socket GH joint is the centre of movement within the shoulder complex, and favours mobility over stability. The scapula and associated ST joint provide the necessary stability required for upper quarter function; form a base for muscular attachments; and are essential in the transfer of energy from proximal to distal allowing optimal shoulder function[3,5-7].

Panjabi[42] described a joint stabilising model specific to the spine which consists of three interdependent subsystems including passive (capsular and ligamentous), active or dynamic (muscular), and control (neural) subsystems. These subsystems interact within the shoulder complex to create joint stability. For the purposes of this review, emphasis will be placed on active or dynamic (muscular) and passive (capsular) stability of the shoulder complex.

Dynamic stability of the ST joint is provided through the synergistic co-contractions and resultant force couples of upper and lower fibres of the trapezius muscle in association with the serratus anterior muscle. The upper trapezius muscle is primarily utilised for clavicular elevation and retraction relative to the thorax[21,30]. However, each degree of clavicular elevation results in one third of ST upward rotation and two thirds of ST anterior tilting[21]. The excessive ST anterior tilting may be stabilised through the activation of the serratus anterior muscle, which contributes to scapular posterior tilting [21,30]. Further, the serratus anterior muscle, in association with the lower fibres of trapezius, produces upward rotation torque on the scapula[21]. The levator scapula muscle assists scapula stability under load[30]. Scapula downward rotation, elevation and retraction is produced by the contraction of the levator scapula, as well as the rhomboid muscles[30,43]. Thus, the levator scapula and rhomboid muscles are required to lengthen during dynamic movement, to ensure upward rotation of the scapula.

Further, the combined force couple of the upper and lower fibres of the trapezius muscle and the serratus anterior muscle counteract the downward scapula rotation produced by the deltoid muscle during GH flexion, optimising GH congruency[30]. In addition, the rotator cuff complex, deltoid and long head of biceps brachii act as dynamic stabilisers for the GH joint[5].

The rotator cuff is a musculotendinous complex formed by the supraspinatus, subscapularis, infraspinatus and teres minor muscles. The subscapularis provides GH internal rotation and humeral head depression[5]. In addition, Lippit et al[44] demonstrated the stabilising role of the subscapularis muscle during GH movement. The humeral head is *"centred"* on the glenoid fossa, preventing excessive anterior and superior translation during GH movement[44]. The infraspinatus muscle is a GH external rotator and humeral head depressor. It is assisted by the teres minor muscle, which produces 45% of the external rotation force. The supraspinatus muscle is responsible for the initial 45° of GH abduction and GH stability[5]. Ihashi et al[45] determined that the supraspinatus muscle may have both internal and external rotational actions on the GH joint, dependant on arm position. Low ranges of GH abduction with internal rotation resulted in the supraspinatus producing additional internal rotation. In contrast, a resting position of GH neutral or external rotation resulted in the supraspinatus producing external rotation. Further, as the range of GH abduction increased, supraspinatus stimulation resulted in GH external rotation. The primary role of the rotator cuff is to stabilise the head of the humerus within the glenoid during upper limb movement[3,5]. The subscapularis (anterior) and the infraspinatus and teres minor (posterior) force couple works to counteract the action of the deltoid, and has a primary role in stabilising the humeral head during movement[3,5,46].

Optimal GH flexion requires the initial activation of the GH (subscapularis, infraspinatus and teres minor) force couple in conjunction with the force couple responsible for scapula upward rotation. Hurov[43] examined the electromyographic (EMG) activity of muscles during shoulder movements and concluded that the deltoid is recruited in all movement. The subscapularis is also recruited during external rotation of the shoulder and provides anterior GH stability. Lastly, activity in the long head of biceps compresses the humeral head against the glenoid, limiting GH external rotation ROM. Thus, the long head of biceps provides multidirectional GH joint stability when activated[5]. The tendons of the rotator cuff blend into the joint capsule[5].

The GH joint capsule is lax, allowing for approximately two centimetres (cm) of humeral head translation in a resting position[47]. The capsule contributes to passive GH joint stability together with the GH ligaments and rotator cuff tendons[5,47]. The GH capsule may influence shoulder biomechanics and ROM[5]. Additional passive GH joint stability is provided by the GH ligaments[5]. The superior GH and coracohumeral ligaments, together with the supraspinatus muscle, prevent the downward displacement of the humerus and limit GH external rotation between 0° and 60° of GH flexion[5]. Anterior GH stability is provided by the middle GH ligament, which limits external rotation from neutral to 90° of GH abduction[5,48,49]. Lastly, the anterior aspect of the inferior GH ligament limits elevation and provides anterior GH stability, while the posterior aspect prevents GH posterior subluxation during elevation and internal rotation[5,49,50]. The resultant co-ordination of these three independent stabilising mechanisms ensures an efficient scapulohumeral rhythm [5,6].

### b) Biomechanical coupling

Biomechanical coupling may be defined as *"the rotation or translation of a joint about or along an axis that is consistently associated with rotation or translation of another joint about its respective axes[8]."* This may be illustrated by analysing scapulohumeral rhythm. Normal scapulohumeral rhythm involves a complex interaction between the ST and GH joints, which share a 1:2 ratio in the overall contribution to motion in overhead arm elevation[3,5,21]. Hurov[43] described scapular kinematics through overhead elevation of the arm. Initially scapula upward rotation occurs about the ST and AC joints, until 60˚ GH flexion. Secondly, SC rotation takes place, resulting in elevation of the lateral clavicle coupled with greater scapula upward rotation. During this phase the humerus externally rotates to prevent impingement of the greater tuberosity against the acromion. Thirdly, the clavicle rotates posteriorly about its longitudinal axis at the SC joint. This movement is coupled with posterior tilting of the scapula. Overhead arm elevation is completed by the GH joint. Ludewig et al[21,51] demonstrated that the overall ST motion during arm elevation occurred due to the coupled movement between the clavicle (SC joint) and scapula (AC joint). Normal overhead elevation required 30° of posterior rotation, approximately 15° retraction and less than 10° of elevation of the clavicle at the SC joint[21,51,52]. Simultaneous scapula upward rotation and posterior tilting occurred at the AC joint. Further, the AC joint exhibited a 1:1 coupling ratio with ST motion[21,51].

However, the ST joint is a physiologic joint and therefore highly unstable[3,5,6]. It may be possible that thoracic spine posture could influence scapula positioning due to the lack of bony articulations between the scapula and the thorax[3,6]. Poor scapula orientation may disrupt normal scapulohumeral rhythm and overhead arm elevation when movement is initiated. Numerous studies have investigated the potential kinematic link between the shoulder complex and the thoracic spine during overhead arm elevation[26,27,53,54]. Theodoris et al[27] found that arm elevation was predominantly associated with thoracic extension and ipsilateral lateral flexion and rotation. However, Stewart et al[53] observed that the thoracic coupling of lateral flexion and rotation during unilateral arm elevation could be either contra- or ipsilateral at the T1-6 level. These varied results may be related to the inconsistent coupling of movement within the thoracic spine[54]. Willems et al[55] demonstrated a 56% incidence of ipsilateral rotation with active thoracic lateral flexion, and a 22% incidence of ipsilateral lateral flexion with active thoracic rotation at the T1-4 level. There was an 83% ipsilateral coupling of thoracic rotation and lateral flexion at the T4-8 level. In more recent studies, Fayad et al[54] determined unilateral arm elevation to be coupled with thoracic extension and rotation. Further, ipsilateral thoracic lateral flexion was observed at the initiation of movement. In addition, Crosbie et al[26] observed coupled unilateral arm elevation with lower thoracic extension, ipsilateral upper thoracic lateral flexion and upper thoracic rotation. Furthermore, scapular upward (external) rotation was significantly correlated with upper thoracic rotation range.

In summary, a limitation in the range of thoracic motion may be associated with a functional restriction of upper limb movement [26,27,54]. Reduced thoracic rotation may result in restricted thoracic ipsilateral lateral flexion[26,27,53,55], thoracic extension[26,27,54], upward scapula rotation[26] and range of unilateral arm elevation[26,27,53,54]. This associated coupling between the thoracic spine and unilateral arm elevation may therefore influence the biomechanics of swimming. An over-view of the forces acting on a swimmer during the freestyle stroke is required to better understand the biomechanics of swimming, and is discussed in the following section.

### 2.2.2 BIOMECHANICS OF SWIMMING

Wolf et al[39] conducted an epidemiologic study on the injury patterns in division I collegiate swimming, over a 5 year period. The freestyle stroke was the most common stroke speciality, and was associated with the greatest total of overall injuries. This section will therefore provide an overview of the forces acting on a swimmer during the freestyle stroke, as well as an analysis of the freestyle stroke.

#### a) Propulsive forces

Historically, the mechanism of producing propulsive forces by swimmers has received minimal attention. It was believed that swimmers pulled in a linear fashion, until Councilman[56] disproved this theory in a two dimensional biomechanics analysis, finding that swimmers moved their hands in a curvilinear path, described as an *"s-shaped"* pull[20]. Thus, a theory based on Bernoulli's principle of hydrodynamic forces was proposed. Due to the curved linear pathway of the hand, the water flowing over the back of the hand and arm would travel faster than the water underneath the hand and arm, thus creating a differential pressure, termed lift [56]. Schleihauf[57,58] further supported the notion that both lift[56], which acts perpendicular to hand motion, and drag are essential for propulsion.

The theory of producing lift has received much criticism and several studies have disproved it[59-61]. Rushell et al[60] conducted a three dimensional biomechanical analysis of the freestyle stroke and found that freestyle propulsion was primarily due to drag forces based on Newton's Third Law of Motion. Further this study incorporated body roll, which Councilman[56] had failed to consider, and resulted in the development of a *"straight-through"* pull[60]. Blanch[10] argued that the curvilinear path of the hand is due to Newton's second law, which states that a body in motion will accelerate in proportion to the forces placed on it. Swimmers displace water, thereby decreasing the ability of the swimmer to use it as a stable base to produce propulsion. This results in the hand moving to find still water to pull on. It is important to obtain the greatest possible surface area perpendicular to the line of pull and this may be obtained by *"keeping a high elbow"* (the plane of the elbow is above that of the hand)[60].

Riewald[62] demonstrated that the propulsive drag forces produced by the hand stopped before the hand reached the hip. Further, the propulsive lift forces throughout the stroke were negligible. Thus an early catch, with an early exit has been implemented for the freestyle stroke.

### b) Drag forces

Swimming velocity may be determined by the ability of a swimmer to reduce the drag experienced, rather than increasing the propulsive forces during the freestyle stroke[10,63]. Toussaint et al[63] described the active drag experienced by a swimmer in relation to the square of swimming velocity, indicated by the following equations:

$$D=K.v^2$$

And:

$$K = \rho . C_{D.} A_p$$

Where D denotes drag force; K is a constant incorporating water density (ρ), a dimensionless drag co-efficient ($C_D$) accounting for form effects and cross-sectional area ($A_p$); and v is swimming velocity.

Therefore, skilled swimmers are able to synchronise propulsive peaks with the phases in which the body cross sectional area is at a maximum[63]. Further, elite level swimmers have refined techniques that result in a more stable body position and therefore a smaller K value. These swimmers are able to achieve greater swimming velocities through the production of maximal propulsive forces and the generation of minimal drag forces.

In summary, the modern freestyle stroke utilises the principles of equal body rotation and balance in water, an early catch with early exit, a high elbow and lastly a straight through pull, arm stroke[10,20,63]. These principles are explored in the mechanics of the freestyle stroke.

### 2.2.3 FREESTYLE STROKE MECHANICS

The freestyle stroke is a cyclic action characterised by the rotation of the trunk around the longitudinal axis of the body. This action is described as *"body roll"*, and is thought to facilitate breathing action, and may also contribute to hand velocity by influencing the hand displacement relative to water[9]. Swimmers should experience body roll of between 35° to 45° on each side when completing an arm cycle, thereby reducing their form drag[64]. Psycharakis et al[64] described four roll profiles based on the quantity of shoulder roll and hip roll displayed by swimmers, including shoulder and hip roll symmetry, shoulder or hip roll asymmetry only, shoulder and hip roll asymmetry on the same side and shoulder and hip roll asymmetry on opposite sides. Further, Yanai[65] showed that swimmers rolled their shoulders substantially more than their hips. However when swimming velocity was increased, shoulder roll decreased by up to 9°[66] and hip roll increased[12,67]. In addition, Sanders et al[67] demonstrated that as swimming velocity increased, the range of roll decreased from the shoulders to the hips, increased from the hips to the knees, and increased again from the knees to the ankles. Hip roll angles also increased as swimming distance increased[12,67].

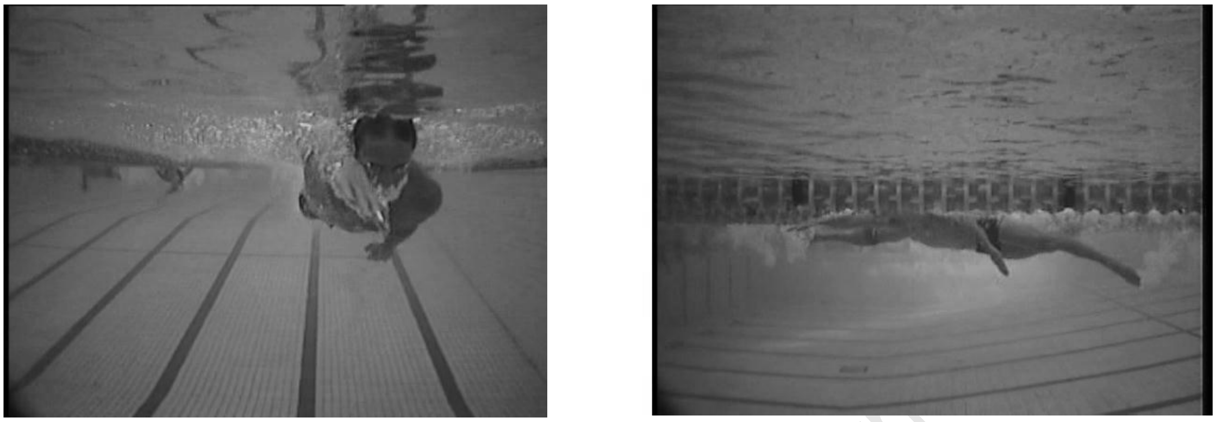
Body roll is also influenced by a swimmer's breathing pattern. Vezos et al[64] found that a swimmer's breath occurred during the first part of the recovery phase of their stroke, and head movement was co-ordinated with body roll to prevent excessive head lift. Breath-taking also resulted in an increased pull time. However, unilateral breathing created lateral asymmetry, with increased tilt and decreased elevation on the non-breathing side, and higher arm recovery on the breathing side[12].

The upper limb, predominantly the shoulder, is responsible for 90% of the forward propulsion required when swimming, with the legs producing the remaining 10%[32,36]. Therefore the description of freestyle stroke mechanics, which may be divided into three distinct phases, will focus on the upper limb.

#### a) Initial catch

The initial catch (Figure 2.1) is characterised by hand entry into the water, in a *"fingers first"* fashion, closely followed by wrist flexion. The swimmer's arm is fully extended, with the shoulder completely elevated and externally rotated to obtain maximum forward reach[12,13]. Yanai et al[12] determined that the end range of shoulder elevation required during this phase may be reduced by an increase in the tilt angle. Tilt angle is defined as *"a measure of the effect of an elevation of one scapula and depression of the other, and the effect of side-bending the trunk[12]."*

Scapula elevation and retraction are performed by the superior trapezius and rhomboid muscles respectively. The serratus anterior muscle is highly active from the initial catch through the pull through phase and protracts and upwardly rotates the scapula[20].



**Anterior** **Lateral**

**Figure 2.1:** *Initial catch of a freestyle swimmer demonstrated by the entry of the right hand into the water, as viewed from anterior and lateral.*

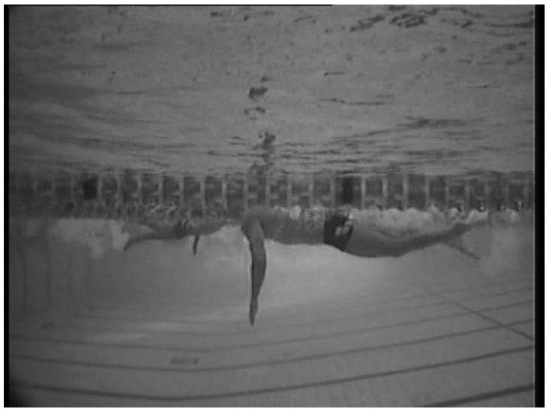
### b) Pull through

Johnson et al[20] recommended a straight through pull (Figure 2.2) from full GH flexion to the hip. Glenohumeral adduction and internal rotation is required to complete the straight through pull[12]. Humeral adduction and extension is achieved through the activation of the pectoralis major muscle, while GH internal rotation is balanced by the antagonistic external rotator, teres minor muscle [20]. The latissimus dorsi and subscapularis muscles fire simultaneously from mid pull through to the start of the recovery phase[20].

### c) Recovery

The arm is brought forward in a circular motion from the hip to full shoulder elevation outside the water, allowing hand entry to occur. The primary movers during the recovery phase are the deltoid and supraspinatus muscles, which abduct and externally rotate the shoulder[12,20].

In summary, the cyclical movement of swimming is predominately driven by the shoulder joint complex. Excessive loading on the shoulder joint complex and subsequently the rotator cuff musculotendinous complex may occur. The swimmer’s shoulder is thus at high risk for injury, due to overuse and fatigue[22]. Potential factors that may contribute to shoulder pain, specifically impingement, in swimmers include a variety of freestyle stroke flaws[20]. The pathomechanics of swimming are examined in freestyle stroke flaws.



**Anterior** **Lateral**

**Figure 2.2:** *A good straight through pull of a freestyle swimmer demonstrated by the right arm, as viewed from anterior and lateral.*



### 2.2.4 FREESTYLE STROKE FLAWS

Swimmers that are at risk of developing shoulder pain, primarily due to impingement, may exhibit one or more of the following characteristics: excessive GH flexion[12], excessive GH internal rotation[12,20,62,68], delayed initiation of GH external rotation[5,12,20] and unilateral breathing[12,20].

#### a) Excessive glenohumeral flexion

Yanai et al[12] determined that the shoulder could be subjected to impingement in 10% of the freestyle stroke time, particularly during the initial catch phase of the stroke. This may be largely due to fluid force generating a large moment about the shoulder, which forces the arm into elevation beyond the shoulder's maximum elevation angle. This leads to increased compressive forces on the subacromial structures, which may cause pain. The compressive forces may be reduced by increasing the shoulder girdle tilt angle, thus reducing the GH flexion angle at hand entry, or by strengthening the shoulder extensor muscles, including the latissimus dorsi, pectoralis major, teres major and triceps brachii muscles. A further reduction in the compressive forces on the subacromial structures may be obtained by performing a *"fingers first"* catch and avoiding full elbow extension at hand entry[12].

### b) Excessive glenohumeral internal rotation

The shoulder is adducted and internally rotated during the pull through phase of swimming[12]. Excessive GH internal rotation may occur due to a cross-over hand entry or thumb-first hand entry[20]. However, excessive rotation is also characteristic of a *"high-elbow pull through"* technique[62], which requires GH internal rotation and horizontal abduction. Although this technique places the muscles of forward propulsion at a mechanical advantage within the shoulder, it is a position of risk for impingement. Therefore a *"high elbow pull through"* technique is recommended, within the limitations of GH ROM, to improve swimming stroke efficacy[12,68].

### c) Delayed initiation of glenohumeral external rotation

Shoulder abduction and external rotation is required for optimal swimming recovery phase biomechanics[12,20]. Yanai et al[12] demonstrated that excessively large GH internal rotation angles and delayed initiation of GH external rotation occur during the recovery phase of swimming. Further, GH external rotation is required to prevent the impingement of the greater tuberosity against the acromion at 90° GH abduction[5]. Therefore, a delayed initiation of GH external rotation may increase the risk for shoulder impingement.

### d) Unilateral breathing

Unilateral breathing may create an asymmetric body roll due to a compensatory crossover pull through on the non-breathing side[20]. A lateral asymmetry may occur where the tilt angle is increased and elevation angle is decreased on the non-breathing side. Swimmers are more likely to develop shoulder impingement on the breathing side[12]. Therefore, a bilateral breathing technique is recommended to minimise the risk of impingement.

Freestyle stroke flaws addressed the pathomechanics of swimming. However a swimmer may have individual biomechanical abnormalities that influence the freestyle stroke[10,12,20,22]. These biomechanical abnormalities are discussed in the next section.

## 2.2.5 SCAPULOTHORACIC DYSKINESES

A swimmer may exhibit the swimming stroke pathomechanics due to individual biomechanical and physiological abnormalities. Scapulothoracic dyskineses may occur as a result of these abnormalities[10,12,20,22]. Scapulothoracic dyskinesis may be described as abnormal or altered movement of the scapula in relation to the thorax, at the ST joint[10,12,20-22].

The factors contributing to scapulothoracic dyskinesis include pain[10,69,70], muscular imbalances[3,6,17,21,24,51,71,72] and abnormal cervical and thoracic posture[28,29,43,73,74].

**a) Pain**

The biopsychosocial model of pain includes a nociceptive stimulus which is perceived to be painful and elicits an emotional response. The behaviour of an individual in response to pain is influenced by the social environment and beliefs regarding pain[10,14]. Kibler et al[69] reported that pain in the shoulder girdle may lead to scapula dyskinesis. Further, Falla et al[70], determined that pain induced through the injection of hypertonic saline into the upper, middle and lower fibres of trapezius resulted in decreased upper and increased lower fibre of trapezius muscle activation of the painful shoulder during bilateral GH flexion. However, the control shoulder exhibited increased trapezius activation[70]. Scapula dyskinesis may therefore occur due to excessive upper trapezius muscle activation, which produces increased clavicular elevation and ST anterior tilting[21,30]. Further investigation is required to determine the relationships between pain; scapular muscle flexibility, strength and activation; and GH joint proprioception.

**b) Muscular Imbalances**

Muscle inhibition due to weakness or fatigue is a non-specific response to a painful shoulder condition; and leads to scapular instability in 68% of rotator cuff injuries, and 100% of GH injuries[3,6]. The muscles most frequently inhibited in impingement syndrome include serratus anterior[6,21,24,51,71] and lower trapezius [3,6,72], resulting in decreased scapula upward rotation and posterior tilting (a reduction of approximately 10˚)[17,21,51,71]. There is a reduction in acromial elevation, which is associated with decreased GH joint abduction[6]. Further, the superior trapezius muscle is overactive in the majority of painful shoulders resulting in increased clavicular elevation and reduced scapula posterior tilt[21,51,72]. Excessive soft tissue tightness in the pectoralis minor and posterior shoulder joint capsule may lead to increased scapula anterior tilting. Pectoralis minor tightness may also contribute to increased scapula internal rotation[17,21,51]. Delayed activation of the rotator cuff results in increased humeral head superior translation and reduced external rotation[21,24]. These scapular and humeral kinematic deviations increase the proximity of the rotator cuff tendons to the coracoacromial arch. However, minimal evidence supports the possible reduction in subacromial space due to muscular imbalances[75]. The muscular imbalances in impingement syndrome and the associated biomechanical effects are summarised in Table 2.1.

**Table 2.1:** *Summary of muscular Imbalances and their associated effects within shoulder impingement syndrome*[6,17,21,24,51,71,72].

| Anatomical Structure | Imbalance | Associated Effects |
|---|---|---|
| Serratus anterior | Inhibition | Decreased scapula upward rotation[6,17,21,51,71]<br>Decreased scapula posterior tilt[17,21,51,71] |
| Lower trapezius | Inhibition | Decreased scapula upward rotation[6,17,21,51,71] |
| Upper trapezius | Activation | Increased clavicle elevation[21,51,72]<br>Decreased scapula posterior tilt[21,51,72] |
| Rotator cuff musculature | Inhibition | Increased humeral superior translation[21,24]<br>Decreased humeral external rotation[21,24] |
| Pectoralis minor | Tightness | Increased scapula anterior tilt[17,21,51]<br>Increased scapula internal rotation[17,21,51] |
| Posterior shoulder joint capsule | Tightness | Increased scapula anterior tilt[17,21,51]<br>Increased humeral head anterior or superior translation[21] |

### c) Cervical and Thoracic Posture

Scapula orientation is partially dependant on cervical and thoracic posture[43]. Lewis et al[74] found that an increase in cervical lordosis (forward head posture) contributed to an increased thoracic kyphosis angle and resulted in a forward shoulder posture. The scapula is therefore orientated in relatively more elevation, protraction, downward rotation and anterior tilt, with an increased thoracic kyphosis. Further, Kebaetse et al[29] determined that an erect thoracic spine posture significantly influences scapula upward rotation, posterior tilting, range of GH abduction and muscle force above 90˚ GH flexion, in relation to a slouched posture.

Bullock et al[28] observed the effects of sitting posture on shoulder ROM and pain in individuals suffering with shoulder impingement. A significance difference in the range of GH flexion was reported, with a mean GH flexion of 109.7˚ in a slouched posture, and 127.3˚ in an erect posture. However, there were no significant differences between postures and pain intensity. Lewis et al[73] reported similar findings where an erect thoracic posture significantly increased GH flexion, but had no effect on pain. Furthermore, a slouched posture may be associated with a reduction in thoracic extension ROM[74]. Biomechanical coupling of the upper quadrant (Section 2.2.1, page 9) indicates that reduced thoracic extension may result in restricted thoracic rotation[26,27,54], ipsilateral thoracic lateral flexion[26,27,53,55], upward scapula rotation[26] and range of unilateral arm elevation[26,27,53,54].

In summary, a slouched posture adversely affects thoracic range of motion[26,27,54] and scapula kinematics by inhibiting upward rotation and posterior tilting[29]. The length-tension relationships of the shoulder girdle are negatively influenced, resulting in a decrease within the sub-acromial space and mal-tracking of the humeral head[21,28,29,51,73]. Glenohumeral elevation, flexion and abduction ranges are reduced, and there may be an increased risk for the development of shoulder impingement. Therefore, an erect posture [28] may significantly reduce the risk for shoulder impingement.

### 2.2.6 SUMMARY OF THE LITERATURE: THE MECHANICS OF SHOULDER PAIN IN SWIMMERS

The freestyle stroke is a cyclical movement characterised by equal body roll[9,12,60,64-67] and an arm stroke incorporating an early catch[12,13,20]; a high elbow and straight-through pull[10,12,20,60]; and an early exit[10,12,13,20,63]. These characteristics of the freestyle stroke enable swimmers to reduce the drag and increase the propulsive forces required to move forward while swimming[56-63]. Further, freestyle is predominately driven by the shoulder joint complex[32,36], which is at risk of injury due to overuse and fatigue[22].

The biomechanical coupling between the joint of the upper quarter, indicates that shoulder pain in swimmers may occur due to scapulothoracic dyskineses[3,6,10,17,21,24,28,29,43,51,69-74] which may result in freestyle stroke flaws[5,12,20,62,68]. Unilateral arm elevation is coupled with scapula upward rotation and posterior tilt[26,29]; thoracic extension[26,27,54]; thoracic ipsilateral lateral flexion[26,27,53,55] and rotation[26,27,53,54]. Thus, a reduction in thoracic ROM may result in unequal *"body roll"* and a reduced *"tilt angle"* during the freestyle stroke[12,64]. A swimmer thus requires excessive GH flexion to perform an early catch[12]. Additionally, scapulothoracic dyskineses may lead to excessive GH internal rotation[12,20,62,68] and delayed initiation of GH external rotation[5,12,20] when swimming.

Scapulothoracic kinesis is adversely affected by pain[10,69,70], muscular imbalances[3,6,17,21,24,51,71,72] and abnormal cervical and thoracic posture[28,29,43,73,74]. This results in altered length-tension relationships of the shoulder girdle musculature. An associated decrease in the sub-acromial space occurs, with mal-tracking of the humeral head and a reduction in GH ROM[21,28,29,51,73]. Therefore shoulder pain in swimmers may occur due to shoulder impingement[2,10,11]. This theory is explored in the next section.

## 2.3. DEFINITION OF SHOULDER PAIN IN SWIMMERS

Kennedy et al[38] described swimmer's shoulder as the *"common, painful syndrome of repeated shoulder impingement in swimmers[38]."* Shoulder impingement is broadly defined as the entrapment of the rotator cuff, subacromial bursa or biceps tendon. The resultant mechanical irritation and compression of these structures during arm elevation occurs between the anterior third of the coracoacromial arch and the humeral head[2,10,11].

### 2.3.1 TYPES OF SHOULDER IMPINGEMENT

Currently, literature describes two types of shoulder impingement (primary or secondary) based on causative factors[1,2,16-19,22].

#### a) Primary shoulder impingement

Primary shoulder impingement is the structural narrowing of the sub-acromial space due to the development of osteophytes or os acromiale[2,16-19]. Pain occurs due to overuse and repetitive loading of the subacromial structures during overhead activity[2,17-19]. Neer[1] described three stages of primary shoulder impingement related to rotator cuff pathology. These stages of impingement, as well as common affected age groups, clinical presentations and recommended treatment, have been summarised in Table 2.2.

Primary shoulder impingement may contribute to the development of shoulder pain in swimmers[2,17-19]. However, Blanch[10] determined that the primary cause of shoulder pain in swimmers is usually related to the development of secondary shoulder impingement.



**Table 2.2:** *Neer's stages of primary shoulder impingement as related to rotator cuff pathology[1,2].*

| Stage | Age (years) | Presentation | Treatment |
|---|---|---|---|
| I | <25 | Acute inflammation, oedema and haemorrhage in rotator cuff tendons | Conservative |
| II | 25 – 40 | Fibrosis and tendonitis in rotator cuff tendons | Conservative and/or operative |
| III | >40 | Mechanical disruption of the rotator cuff tendon and formation of osteophytes along anterior acromion | Surgical anterior acromioplasty and rotator cuff repair |

### b) Secondary shoulder impingement

Secondary impingement describes the encroachment of the subacromial bursa and rotator cuff tendons between the humeral head and coracoacromial arch (external or subacromial impingement), due to altered biomechanics[16,17,19]. Glenohumeral instability or hypermobility associated with the delayed activation of the scapulothoracic stabilisers causes the pathological anterior and superior translation of the humerus, with subsequent impingement of the rotator cuff and biceps tendons[16-19].

Shoulder impingement was first described by Neer[1] as a pathology or diagnosis. Current literature now describes impingement as a cluster of symptoms associated with various pathologies, as opposed to a diagnosis. These pathological mechanisms include rotator cuff and biceps tendon pathologies, scapular dyskinesis, shoulder instability and GH internal rotation deficits[16,17,22]. The rotator cuff muscle complex, specifically the supraspinatus muscle, is responsible for caudal gliding of the humeral head away from the glenoid during shoulder elevation [76]. Dysfunction of this muscular complex may lead to the entrapment of the rotator cuff or biceps tendons and subsequently, shoulder impingement[16,17,22]. Scapular dyskinesis may contribute to the development of shoulder impingement in the absence of scapula upward rotation, posterior tilting or external rotation[17]. The resultant scapula kinematics allow pathological humeral head translation and thus the impingement of the rotator cuff and biceps tendons[16-19].



Jobe et al[77,78] hypothesised that repetitive and forced overhead activity may cause gradual stretching of the anteriorinferior capsuloligamentous structures, resulting in mild anterior shoulder instability and associated shoulder impingement. Although this hypothesis has been extensively utilised in literature as a potential underlying mechanism contributing to impingement, little empirical evidence exists to support this theory. In addition, GH internal rotation deficit is a sports specific adaptation of the posterior shoulder structures to chronic overload[16]. Morrison et al[79] demonstrated that GH internal rotation deficits may be due to hypertonic GH external rotators, which are subject to eccentric loading when throwing. However, Burkhart et al[80] hypothesised that contracture of the posterior shoulder capsule is responsible for the range of motion deficit. Increased tightness within the posterior shoulder capsule may cause increased scapula anterior tilting and thus may increase the risk for shoulder impingement[16,21,51]. Thus, the aetiology of pain experienced by swimmers with shoulder impingement will be considered in the next section.

### 2.3.2 AETIOLOGY OF SHOULDER PAIN IN SWIMMERS

Secondary shoulder impingement, associated with instability, is thought to be the primary cause of shoulder pain in swimmers[10]. Rupp et al[81] reported positive test results for anterio-inferior instability (50%), scapulothoracic dyskinesis (55%), shoulder impingement (50%) and significant muscular imbalances between the GH internal and external rotators in high level swimmers with shoulder problems. Bak et al[13] determined a 51% correlation between shoulder impingement and anterio-inferior instability. These results support the hypothesis described by Jobe et al[77,78] that mild anterior shoulder instability and associated shoulder impingement may occur with repetitive and forced overhead activity. However, Sein et al[22] found no significant correlation between GH joint laxity and repetitive forceful overhead activity in swimmers. However, there were significant correlations between GH joint laxity and extreme pain; and GH impingement and shoulder pain. Further, a significant correlation between a positive impingement sign and the presence of supraspinatous tendinopathy was determined. Therefore, Sein et al[22] disagreed with the hypothesis described by Jobe et al[77,78] and postulated that swimmer's shoulder pain may be due to a volume-induced supraspinatus tendinopathy. Pain therefore occurs as the supraspinatous tendon thickens due to repetitive movement and is impinged under the acromion during swimming. This form of impingement was first described by Walch et al[82] and is regarded as the primary cause of shoulder pain in athletes participating in overhead activities, including swimming[83].

The aetiology of shoulder pain in swimmers due to secondary impingement is unclear. A swimmer may develop shoulder impingement due to scapulothoracic dyskinesis[77,78,81] resulting in anterio-inferior instability[13,77,78,81]. The resultant shoulder pain occurs due to the mechanical irritation, inflammation and resultant microtrauma of the subacromial bursa and rotator cuff tendons as they encroach between the humeral head and coracoacromial arch during overhead motion[16,17,22]. There may be the development of an associated supraspinatus tendinopathy[22,81,82]. This may be exasperated by the number of shoulder rotations performed[24,37] and distance covered by a swimmer during training[22]. Additional risk factors associated with the development of shoulder impingement in swimmers, are discussed in the following section.

### 2.3.3 INTRINSIC AND EXTRINSIC FACTORS CONTRIBUTING TO THE DEVELOPMENT OF SHOULDER IMPINGEMENT IN SWIMMERS

The factors that contribute to an increased risk of shoulder injury in swimmers may be divided into intrinsic and extrinsic risk factors. Intrinsic factors relate to the inherent anatomy and biomechanics, or abnormalities thereof, for a specific swimmer.

Extrinsic factors are associated with the external environment, for example: training time, distance, use of equipment and weather conditions[84]. Several intrinsic risk factors have been discussed in depth in earlier sections of this chapter. Please refer to freestyle stroke flaws (Section 2.2.4, page 15) and scapulothoracic dyskineses (Section 2.2.5, page 16).

The intrinsic risk factors that may contribute to an increased risk of shoulder impingement in swimmers include a history of previous shoulder injury[40]; poor cervical and thoracic posture[10,21,28,29,43,51,73,74]; scapula dyskinesis with associated muscular imbalances and altered recruitment patterns[3,6,10,21,24,51,71,72]; pain[10,69,70,85]; and a lack of flexibility in the pectoralis minor muscle and the posterior GH capsule[10,21,51] . Further, the intrinsic risk factors associated with abnormal swimming biomechanics include a cross-over hand entry or thumb-first hand entry[20]; dropped elbow or excessively high elbow pull through[10,12,20,68]; unilateral breathing pattern; and concomitant lateral and body roll asymmetry[12,20]. In addition, swimmers that specialise in strokes other than freestyle are reported to have a 33% greater risk for shoulder injury compared to specialised freestyle stroke swimmers[39]. Extrinsic factors for shoulder impingement in swimmers include training distance and time[22,39]; the use of hands paddles[12]; and dry land (strength) training[39]. Sein et al[22] reported that elite swimmers were twice as susceptible to shoulder injury if training durations exceeded 15 hours per week; and were four times more likely to develop shoulder pain if training distance exceeded 35 km per week.

Further, Wolf et al[39] demonstrated that approximately 60% of injuries to swimmers occurred in the pool, while 40% occurred during out of pool activities, specifically strength training. Yanai et al[12] also established that delayed initiation of GH external rotation may occur with the use of hand paddles, which may result in an increased incidence of shoulder impingement.



### 2.3.4 SUMMARY OF THE LITERATURE: DEFINITION OF SHOULDER PAIN IN SWIMMERS

The primary cause of shoulder pain in competitive swimmers is thought to be secondary shoulder impingement[10], which may be associated with instability[10,13,77,78,81], scapulothoracic dyskinesis[16,17,22,77,78,81] or the development of a rotator cuff or biceps tendinopathy[16,17,22,22,81,82]. Pain is experienced as the rotator cuff tendons and subacromial bursa are subject to mechanical irritation, inflammation and microtrauma through repeated compression under the bony arch of the acromion during overhead activity[16,17,22].

Factors associated with increased risk for the development of shoulder impingement include a history of previous shoulder injuries[40]; scapulothoracic dyskineses (Section 2.2.5, page 16) and freestyle stroke flaws (Section 2.2.4, page 15). In addition swimming stroke specialty[39], training distance and time[22,39], the use of hand paddles[12] and dry land training[39] may all exacerbate the risk of developing shoulder impingement in swimmers. The early identification and accurate diagnosis of shoulder impingement is required to minimise the incidence of shoulder impingement, and prevent the development of a chronic rotator cuff or biceps tendinopathy in swimmers.

## 2.4. IDENTIFICATION AND DIAGNOSIS OF SHOULDER IMPINGEMENT

Hudson[2] described a shoulder assessment as the process of determining the *"mechanism of injury, related past medical history, and notable deficits in ROM, strength and stability, anatomic sensitive structures upon palpation, neurologic involvement, and functional limitations."* For the purpose of this review, the assessment of mechanism of injury, pain, impingement, deficits in ROM, scapula dyskinesis and pectoralis minor muscle length will be discussed.

Swimmers presenting with shoulder impingement complain of pain either posterior-superior or anterio-inferior to the GH joint complex. This pain may occur at rest; post training only; with varying degrees during training; or be of sufficient intensity to prevent a swimmer from training and performing dry land shoulder specific activities. Further, pain due to impingement often elicits a painful arc of movement during active abduction, which primarily affects the recovery phase of swimming[13,16,17,33].

### 2.4.1 PAIN

Pain may be assessed using a variety of scales including the visual analogue scale (VAS), the verbal rating scale (VRS) and the numeric rating scale (NRS)[23]. Williamson and Hoggart[23] found all three of these pain rating scales to be both reliable and valid. However the numerical rating scale was determined to be the most sensitive to describing pain intensity. Current literature supports the use of multi-dimensional pain scales to provide specific information regarding the area of pain, the shoulder position causing pain, and the level of activity resulting in pain. Further, numerous self-report tools have been developed in an attempt to obtain objective measures for pain, level of satisfaction and function.

These include shoulder specific questionnaires such as the Penn Shoulder Score (PSS), Constant Shoulder Score (CSS) or American Shoulder and Elbow Surgeons Score (AMSESS). The PSS[15] is a condition specific, self-report, 100-point questionnaire, which utilises a multi-level 10 point numeric rating scale for pain, a single level 10 point numeric rating scale for satisfaction and a Likert scale for shoulder function. The PSS is only the second self-report tool to include level of satisfaction with current shoulder function[15]. Leggin et al[15] found the PSS to be both valid when compared to the CSS (r = 0.85) and the AMSESS (r = 0.87) and reliable. Excellent test-retest reliability for each subsection was recorded, with pain intraclass correlation coefficient (ICC) = 0.88, satisfaction ICC = 0.93 and function ICC = 0.93. Further, McClure et al[86] utilised the PPS as an outcome measure when determining the effects of a six week exercise programme on shoulder impingement. There were significant relationships between PSS scores and external rotation force; and PSS scores and internal rotation ROM. Clinically, measurement of pain is largely weighted on the subjective assessment of the individual's pain experience. Therefore, clinical tests that reproduce pain associated with impingement are used to assess the value of treatment and rehabilitation programmes[10].

### 2.4.2 IMPINGEMENT TESTS

The most common impingement tests used in clinical practice include the Jobe Supraspinatus (Empty Can), Patte, Hawkins and Neer's Tests[87]. Cools et al[16] demonstrated that an impingement test is positive when it elicits a person's pain response. Therefore positive Jobe and Hawkins tests indicate subacromial impingement. The reproduction of anterior shoulder pain during Neer's test indicates subacromial impingement, but posterior shoulder pain is regarded as internal impingement. Johansson and Ivarson[87] determined a perfect kappa (κ=1), for the intra-examiner reliability for the Jobe, Neer's, Hawkins and Patte tests. Further, the inter-examiner reliability for Neer's and Patte's Test was perfect (κ=1), while the Hawkins Test scored κ=0.91 and Jobe Test scored κ=0.94. Further, Bak et al[13] determined that Neer's test is less sensitive (0.39) and more specific (1.00) than Hawkins Test (sensitivity = 0.80 and specificity = 0.76). Similarly, Hegedus et al[88] found Neer's test to have a sensitivity of 0.79 and specificity of 0.53; while the Hawkins test's sensitivity was 0.79 and specificity was 0.59. In summary, the Neer's and Hawkins tests are predominantly utilised to detect shoulder impingement in athletes in the majority of studies[2,13,16,33,73]. Both tests are easily reproducible and highly reliable in identifying participants with sub-acromial pain due to impingement. However, these tests are unable to delineate the underlying structural involvement due to low specificity[2,13,16,33,73].

### 2.4.3 RANGE OF MOTION

Swimmers have a greater range of shoulder motion than the non-swimming population[89]. Zemek et al[90] reported that elite swimmers have greater joint hypermobility and shoulder hyperlaxity compared to recreational swimmers. The upper quarter ROM required by a swimmer, to perform the freestyle stroke includes GH flexion and rotation, and thoracic rotation[10]. A swimmer requires 150˚ to 170˚ of GH flexion and 40˚to 50˚ of internal rotation to achieve an early catch and high elbow stroke; and 60˚to 90˚ of thoracic rotation to ensure optimal body roll during pull through.

Overhead athletes have displayed common adaptations to their GH rotational ROM, with increased external rotation and decreased internal rotation ROM[17,91,92]. The universal goniometer is commonly used in clinical practice to measure joint ROM. Riddle et al[93] examined the intra- and inter-rater reliability of passive shoulder ROM, without controlling patient position. The ICC for intra-rater reliability were GH flexion = 0.98, GH abduction = 0.98, GH external rotation = 0.99 and GH internal rotation = 0.94. Inter-rater reliability had an ICC = 0.26 to 0.90. Sabari et al[94] demonstrated similar results for the intra-rater reliability of active and passive shoulder ROM, in supine and seated positions. The ICC for intra-rater reliability were active GH flexion = 0.95-0.97 and GH abduction = 0.97-0.99; whereas passive GH flexion = 0.94-0.95 and GH abduction = 0.95-0.98. Further, a moderate level of agreement (ICC = 0.64-0.61) was determined between goniometric shoulder measurements in seated and supine testing positions. Greater measures of active GH abduction ROM were obtained in 77% to 80% of participants when supine[94]. Three dimensional motion analysis systems have been used in a number of studies to determine upper extremity kinematics[28,73,86]. However, the lack of standardisation of set-up and measurement protocols, the failure to distinguish joint angles obtained from anatomical and functional frames and the problematic soft tissue artefact compensation currently opposes the use of these systems for upper extremity kinematic measurement in a clinical setting[28,73,86,95].

Numerous studies have used electromagnetic tracking systems to investigate the biomechanical coupling between the shoulder joint complex and the thoracic spine[26,27,54]. Although these systems are reliable and specific, they require specialised equipment and skilled personnel. In addition, some studies have used a flexirule technique[28] or inclinometer[73] to examine the effect of posture on shoulder range of movement. However, both these techniques measure the range of thoracic flexion and extension only[28,73]. Blanch[10] described a method of measuring thoracic rotation in swimmers, which is essential in the pull through phase of freestyle. The swimmer sat in an upright posture with the arms elevated to 90˚ and hands clasped together.

An instruction to rotate to the left and right was given. The angle between the midline and hands was then measured. A normalised range of 60˚-90˚ of thoracic rotation was established[10]. The validity and reliability of this testing procedure has not been established, but it allows thoracic rotation to be measured practically within a clinical setting.

### 2.4.4 SCAPULA DYSKINESIS

Kibler[3] described the lateral scapula slide test as a quantitative measure of scapula stabiliser strength. This test comprises three positions, namely *"arm by side"*; *"hands on hips"* where the serratus anterior and lower trapezius muscles are active; and *"arms at or below 90˚"*, where the serratus anterior, lower trapezius, upper trapezius and rhomboids are approximately 40% active. A difference in measurement between each side of greater than 1.5 cm is regarded as pathological and indicates scapula dyskinesis. Odom et al[96], demonstrated moderate to high intra-rater (ICC = 0.84-0.88) and inter-rater (ICC = 0.77-0.85) reliability for the lateral scapula slide test, dependant on position of measurement (Table 2.3). These results are supported by Kibler[3].

**Table 2.3:** *Intra- and Inter-rater reliability for the lateral scapula slide test[3].*

| Position | Intra-rater reliability | Inter-rater reliability |
|---|---|---|
| Arm by side | 0.85-0.87 | 0.83-0.85 |
| Hands on Hips | 0.84-0.88 | 0.77-0.81 |
| Arms at or below 90˚ | 0.85-0.86 | 0.78-0.83 |



Scapula asymmetry may be further investigated with the use of Moiré topography, which is more sensitive than the lateral scapula slide test. However, this is an expensive tests that requires specialised equipment[3,33]. Therefore, the lateral scapula slide test is a practical and reliable test to determine scapula asymmetry[3].

### 2.4.5 PECTORALIS MINOR MUSCLE LENGTH

Pectoralis minor shortening is associated with anterior tilting and internal rotation of the scapula[17,21,51]. According to Sahrmann[97], the distance between the posterior aspect of the acromion and treatment table should not exceed 2.54 cm when supine. Currently, literature describes a variety of methods of measuring pectoralis minor length. Petersen et al[98] investigated the validity and reliability of four objective techniques for measuring forward shoulder posture due to an overly active (short) pectoralis minor muscle.

All measurements were conducted with the participants standing. The Baylor square measured the distance from the C7 spinous process to the anterior tip of the acromion. The double square measured the distance from the wall (participants back flush against the wall) to the anterior tip of the left acromion. Sahrmann's technique required participants to stand against a wall, with the radial borders of the index fingers against the wall at ear height.

A goniometer was used to measure the GH flexion ROM obtained with full GH external rotation ROM. Lastly, scapula position was measured horizontally from the vertebral border of the scapula to the spinous process of the third thoracic vertebra. The intra-rater reliability for each technique was reported as ICC = 0.91 for the Baylor square, ICC = 0.89 for the double square, ICC = 0.89 for Sahrmann's Technique, and ICC = 0.91 for the scapula positional test[98]. However, validity compared to radiographic measurements could not be established.

Lewis et al[99] investigated the intra-rater reliability and diagnostic accuracy of a pectoralis minor muscle length test in participants with and without shoulder symptoms, in supine. A rigid plastic right angle was utilised as the measurement tool. There was an intra-rater reliability of ICC = 0.92 - 0.93 for length testing in asymptomatic participants and an ICC = 0.90 - 0.93 for length testing in symptomatic participants. The test was highly sensitive (1.00) but not specific. Further, the average pectoralis minor muscle length in both groups of participants was approximately 6 cm. In summary, the method of pectoralis minor muscle length testing proposed by Lewis et al[99] is favourable due to the higher intra-rater reliability and sensitivity of this method, compared to the methods described by Petersen et al[98]. Further, testing is performed in supine as opposed to standing. Therefore body position and posture may be easily controlled.



### 2.4.6 SUMMARY OF THE LITERATURE: IDENTIFICATION AND DIAGNOSIS OF SHOULDER IMPINGEMENT

The early identification and accurate diagnosis of shoulder impingement in swimmers may occur if a swimmer complains of pain at rest; post-training only; or with varying degrees during training; posterior-superior or anterio-inferior to the GH joint complex[16,17,33,67], and if clinical tests reproduce the swimmer's shoulder pain. Typically, the clinical tests used to diagnose shoulder impingement include a positive Neer's and/or Hawkins test[2,13,16,33,73,87,88]. In addition, a deficiency in GH ROM[10,17,89-92], scapula dyskinesis[3,33,96] and a shortened pectoralis minor muscle[17,21,51] may be associated with shoulder impingement.

Therefore effective treatment of shoulder impingement should focus on reducing pain, improving GH ROM, enhancing scapula kinesis by addressing scapulothoracic muscle imbalances and improving pectoralis minor muscle length. The treatment modalities used to achieve these desired results are discussed in the next section, which reviews the current management of shoulder impingement.

## 2.5 MANAGEMENT OF SHOULDER IMPINGEMENT

Current evidence for the management of shoulder impingement recommends trigger point and soft tissue therapy[10,19,31]; manual joint therapy[19,31,100], stretching of the posterior shoulder joint capsule, pectoralis major and minor muscles[10,19,24,31,32] and rehabilitation[10,19,24,31-34,101].

### 2.5.1 TRIGGER POINT AND SOFT TISSUE THERAPY



Simons et al[102] described a myofascial trigger point as *"a localised area of hyperirritability within a taut skeletal muscle band or fascia that is aggravated by compression, and may elicit referred pain, tenderness and occasional autonomic responses[102]."* Any skeletal muscle subject to chronic strain through repetitive overuse and overload may develop myofascial trigger points[10,102]. Blanch[10] reported that swimmers are most susceptible to trigger points in the infraspinatus, teres minor and subscapularis muscles. Further, swimmers seldom develop trigger points in the musculature of the supraspinatus, scalene, subclavius and triceps[10]. Hidalgo-Lozano et al[103] demonstrated the presence of active trigger points in the supraspinatus (67%), infraspinatus (42%) and subscapularis (42%) muscles in participants with unilateral shoulder impingement. These participants had a significantly greater number of active trigger points and lower pressure pain thresholds, compared to a control group with no shoulder impingement. There was also a significant positive correlation between the number of trigger points and pain intensity in the shoulder impingement group. Blanch et al[104] determined that massage and trigger point therapy of swimmers' infraspinatus muscle increased GH internal rotation ROM. Further, Bang et al[19] reported that supervised exercise in conjunction with manual therapy (joint and soft tissue therapy) was superior to a rehabilitation programme in the treatment of shoulder impingement. The combined therapy group received joint mobilisations (according to Maitland) and soft tissue massage, in addition to rehabilitation. Manual therapy was primarily directed to the shoulder joint, but may also have extended to the shoulder girdle, cervical and upper thoracic spine.

The rehabilitation programme followed by both groups included three sets of 10 repetitions each of shoulder flexion, scaption, rowing and horizontal extension-external rotation using a resistance band; seated press-up and elbow push-ups to fatigue or a maximum of 25 repetitions each; and anterior and posterior shoulder stretches performed as three sets of sustained 30 second stretching, with a 10 second rest period between stretches[19]. Both the combined therapy and rehabilitation groups were treated twice weekly over a period of three weeks.

Although both groups showed significant improvements in pain and function, there were greater improvements in the combined therapy group (pain improved by 70% and function by 35%) compared to the rehabilitation group (pain improved by 35% and function by 17%). There was also a 16% improvement in muscle strength in the combined therapy group, when compared to the rehabilitation group[19]. In addition, Senbursa et al[100] demonstrated that combined therapy (manual therapy and rehabilitation) showed earlier improvements in pain, function and strength compared to a rehabilitation programme in the treatment of shoulder impingement. The combined therapy group received scapula and GH joint mobilisations; massage of the supraspinatus muscle; radial nerve stretching; and rehabilitation; three times per week over a four week period. Both the combined therapy and rehabilitation-only groups followed an exercise protocol including active ROM, stretching and strengthening of the rotator cuff, rhomboids, levator scapulae and serratus anterior muscles, as described by Baltaci[105]. This rehabilitation programme was followed daily for 10-15 minutes over the four week period[100]. However, the studies conducted by Bang et al[19] and Senbursa et al[100] used a combination of soft tissue and joint mobilisations and it is thus difficult to ascertain which factors contributed to the improved results. Further, the soft tissue techniques used were poorly described and could thus encompass trigger point therapy, specific soft tissue mobilisations or massage. Therefore, further research is required to determine the effects of trigger point therapy and specific soft tissue mobilisation in the treatment of shoulder impingement.

### 2.5.2 MANUAL JOINT THERAPY

The effect of manual joint therapy on pain experienced in shoulder impingement has been evaluated in three studies[19,100,106]. Conroy et al[106] determined the effect of joint mobilisation as a treatment component for shoulder impingement. Both the experimental and control group received combined therapy three times per week over a three week period. The combined therapy included the application of hot packs to the posterior-superior aspect of the shoulder for 15 minutes, followed by 45 – 60 minutes of rehabilitation.

Exercises included active shoulder ROM pendular movements; chair press, isometric GH internal and external ROM, and exercises to improve scapulohumeral rhythm; cane-assisted GH flexion and external rotation stretches; towel-assisted GH internal rotation stretch; and non-involved arm-assisted GH horizontal adduction stretch, performed within the limits of pain free GH ROM. Therapy was concluded with 10 minutes of soft tissue mobilisation, however the experimental group received SA and GH joint mobilisations (based on Maitland and Foley styles) for 15 minutes prior to the soft tissue mobilisations. The experimental group demonstrated significantly improved pain, when compared to the control group.

Additionally, both groups showed significant improvements in GH flexion, abduction, external and internal rotation ROM; and function, following the respective treatment protocols. Therefore, joint mobilisations significantly improve pain in the treatment of shoulder impingement. Similar results were obtained by Bang et al[19] and Senbursa et al[100] (Section 2.5.1, page 29). However, Bang et al[19] used a combined therapy approach which included manual joint mobilisation (based on Maitland's style) techniques targeted at restricted movement in the upper quarter (shoulder and spine), soft tissue massage and a rehabilitation programme. Further, Senbursa et al[100] utilised the combined effects of scapular and GH mobilisation (unspecified technique), massage of the supraspinatus muscle, radial nerve stretching and a rehabilitation programme, to determine the effects of rehabilitation on shoulder impingement, with and without manual therapy. Bang et al[19] and Senbursa et al[100] determined that there was a significant decrease in pain in the combined therapy groups, compared to the rehabilitation-only groups. However, these results cannot be attributed to manual joint therapy in isolation, and further research is needed to determine the effects of specific joint mobilisations applied to the upper quarter (cervical and thoracic spine, GH joint and scapula) in the treatment of shoulder impingement.

### 2.5.3 SOFT TISSUE FLEXIBILITY

Shoulder impingement is associated with scapula dyskinesis (Section 2.2.5, page 16)[3,6,10,21,24,51,71,72,107]. Muscle inhibition[3,6,21,24,51,71] and excessive soft tissue tightness[11,17,21,51,107] contribute to the development of scapula dyskinesis. Inflexibility of the pectoralis minor muscle may lead to increased scapula anterior tilting and internal rotation[17,21,51,107]. In addition, a tight posterior shoulder joint capsule may further enhance scapula anterior tilt[11,17,21,51]. Limited pectoralis minor and posterior shoulder capsule length may either be causative factors of scapula dyskinesis, or secondary factors that develop as a result of altered scapula kinematics[11,107]. Soft tissue flexibility exercises for the posterior shoulder capsule and pectoralis minor muscle are recommended in the treatment of shoulder impingement[11,11,19,20,24,31,32,86,107].

### a) Stretching the Posterior Shoulder Capsule

Posterior shoulder capsule tightness is thought to contribute to shoulder impingement by creating anterior and superior translation of the humerus during passive GH flexion, and reducing GH internal rotation ROM[11]. Weldon et al[24] observed that swimmers participated in independent or assisted stretches of the anterior shoulder capsule prior to swim training, but neglected to stretch the posterior shoulder capsule.

This practice may be associated with an acquired increase in shoulder ROM. It was recommended that swimmers with shoulder pain should not stretch the anterior shoulder capsule, but should rather perform posterior shoulder capsule stretches.

There are currently three known methods of independently stretching the posterior shoulder capsule: the *"towel stretch"*[86], *"cross-body stretch"*[11] and *"sleeper stretch"*[20]. McClure et al[11] compared stretching procedures for posterior shoulder tightness in asymptomatic individuals with reduced GH internal rotation. The cross-body stretch group showed significant improvements in GH internal rotation, compared to the control group. There were no improvements in GH internal rotation in the sleeper stretch group, compared to both the control group and the cross-body stretch group. However, effective scapula stability is required to isolate the stretch to the posterior capsule and prevent compensatory scapula elevation. Thus the *"sleeper stretch"* is preferred[11,20].

### b) Stretching the Pectoralis Minor

There is a paucity of literature regarding stretching of pectoralis minor for shoulder impingement. Borstad et al[107] studied the efficacy of three pectoralis minor stretching methods in the general population. The unilateral corner self-stretch, sitting manual stretch and supine manual stretch were assessed. The greatest length change in the pectoralis minor muscle was achieved following the unilateral corner stretch (2.24 cm), which was superior to both the supine manual stretch (1.69 cm) and the sitting manual stretch (0.77 cm). Further, the unilateral corner self-stretch is the only pectoralis minor stretch that may be performed independently. An optimal length of the posterior shoulder capsule and pectoralis minor muscle ensures adequate scapula posterior tilting and external rotation[11,17,21,51,107]. Therefore, scapula dyskinesis may be effectively improved by performing the *"sleeper stretch"*[11,20] and unilateral corner stretch[107], three to five times daily for a period of 15 to 30 seconds per stretch[11,19,31,32,86].

### 2.5.4 SUMMARY OF THE LITERATURE: MANAGEMENT OF SHOULDER IMPINGEMENT

In summary, current scientific evidence recommends numerous management techniques for the treatment of shoulder impingement. In addition, the precise soft tissue and manual therapy techniques utilised in the treatment of shoulder impingement[10,19,31,100] are not specified. Further, previous studies that investigated the effects of manual therapy on shoulder impingement have incorporated both soft tissue and manual therapy techniques in the combined therapy groups[10,19,31,100].

It is thus difficult to deduce whether significant changes were due to soft tissue therapy, manual therapy or both. In addition, all studies discussed in this section included various soft tissue flexibility exercises and rehabilitation, indicating a lack of scientific agreement between studies for the optimal rehabilitation of shoulder impingement. The effects of rehabilitation on shoulder impingement require further exploration.

## 2.6 REHABILITATION OF SHOULDER IMPINGEMENT

Numerous studies have described the use of rehabilitative exercises in the treatment of shoulder impingement. Although studies have emphasised the importance of rehabilitation, minimal consensus exists regarding optimal protocols for the management of shoulder impingement[19,24,31-33,86]. These studies are summarised in Tables 2.4 to 2.7, where an outline of the studies investing the effects of rehabilitation, as well as the components, structures and summary of effects of the rehabilitation programmes are described.

Conroy et al[106] investigated the effects of joint mobilisation as a component of comprehensive treatment for shoulder impingement on pain (VAS), active GH ROM (goniometry) and function (reaching overhead 135˚, across the body and behind the head). Fourteen participants diagnosed with shoulder impingement were randomly assigned to either the experimental or control group. Both groups performed a rehabilitation programme consisting of a chair press, isometric GH internal and external rotation and exercises to improve scapulohumeral rhythm; cane-assisted GH flexion and external rotation stretches; towel-assisted GH internal rotation stretch; and non-involved arm-assisted GH horizontal adduction stretch, within the limits of pain free GH ROM over a three week period. This programme was supervised three times a week and participants performed the exercises three times per day. As discussed in Section 2.5.2 (page 31), the experimental group received manual joint therapy in conjunction with the rehabilitation programme.

There was a significant improvement in pain in the experimental group, when compared to the control group. Further, both groups showed significant improvements in GH mobility and function. The lack of differences detected between groups for GH mobility and function in this study may be due to an inadequate sample size, an insensitive functional scale and nonspecific goniometric ROM measurements.

Bang et al[19] compared the effects of three weeks of supervised exercise with and without manual physical therapy on pain (VAS), muscle strength (isometric tests for GH abduction, internal and external rotation) and function (functional assessment questionnaire) in 52 participants with shoulder impingement. The experimental group received manual therapy in conjunction with a rehabilitation programme, whereas the control group only performed the rehabilitation programme (Section 2.5.1, page 30). The rehabilitation programme was performed twice weekly for a three week period, using a resistance band. The exercises included flexion, scaption, rowing, horizontal extension-external rotation, seated press-up and elbow push-up (25 repetitions or to fatigue). Three sets of ten repetitions, with a 60 second rest between sets were performed for each exercise. In addition, the corner stretch and cross body stretch were performed three times, and sustained for 30 seconds, with a 10-second rest period between repetitions. There were significant reductions in pain and function in both groups. However, the experimental group showed a significantly greater improvement in pain and function, compared to the control group. Further, there were significant improvements in isometric strength in the experimental group, compared to the control group. However, the results of this study may unintentionally be skewed due to the unknown reliability of the functional assessment questionnaire.

Senbursa et al[100] showed similar results for participants with shoulder impingement. Pain (VAS), GH ROM (goniometry) and function (functional assessment questionnaire) were assessed in 30 participants whom were randomly assigned to either the experimental or control group. As discussed in Section 2.5.1 (page 30), the experimental group received manual therapy in conjunction with rehabilitation. The control group received rehabilitation only. Both groups performed the same rehabilitation programme. The rehabilitation programme included active range of motion, stretching and strengthening exercises for the rotator cuff, rhomboids, levator scapula and serratus anterior muscles with a resistance band, as described by Baltaci[105]. Exercises were performed daily for 10-15 minutes over the four week intervention period. There were significant improvements in night pain and pain with motion in both groups. However, the experimental group demonstrated significantly greater improvements in pain at rest and function than the control group.

The experimental group also showed significant improvements in GH flexion, abduction and external rotation compared to the control group. However, the results of this study may be distorted due to the small sample size and unknown reliability of the functional assessment questionnaire.

McClure et al[86] observed the effects of a progressive six week rehabilitation programme on shoulder function and three dimensional kinematics in participants with shoulder impingement. Thirty nine of fifty nine participants successfully completed the six week rehabilitation programme and follow-up testing at six months post intervention. Rotator cuff and scapula strengthening exercises were performed once daily as three sets of 10 repetitions, using a resistance band. The exercises included GH external rotation, internal rotation, extension, abduction, and flexion; and scapular retraction. Stretches of the GH posterior capsule, pectoralis minor muscle and upper thoracic spine (into extension) were performed one to two times daily as three sets with a 30 second hold. A chin tuck exercise was also performed three times hourly to address upper quarter posture. There were significant improvements in GH internal and external rotation ROM following the intervention, compared to baseline measures. There significant improvements in levels of pain, satisfaction and function as measured by the Penn Shoulder Score at the six week follow-up, compared to baseline measures. These findings were sustained at a six month follow-up. Significant positive correlations also occurred between the PSS and external rotation force; and between the PSS and GH internal rotation ROM. However, there were no improvements in thoracic posture following the rehabilitation programme. The high rate of attrition (33%) could potentially have biased the results of this study. Further, the absence of a control group fails to ascertain that the results obtained in this study were due to the progressive six week rehabilitation programme.

In contrast, Kluemper et al[32] showed a significant improvement in the relaxed forward shoulder posture in 39 competitive swimmers that performed a six week rehabilitation programme, compared to swimmers participating in normal swim-training activities. A progressive three week resistance band protocol was used. The number of repetitions of each exercise was increased by five repetitions per week. The protocol commenced with three sets of 10 repetitions, per exercise, in week one. At week four, resistance was increased and the progression of repetitions was re-started. The exercises included scapula retraction, external rotation and shoulder flexion for lower trapezius activation. Pectoralis major and minor partner-stretching was also included in the protocol. Unfortunately, this study was pseudo-randomised. Two independent swimming clubs were used to recruit healthy swimmers and each club formed either the experimental or control group.

The effect of a six week rehabilitation programme may have been diluted due to this unintentional sample selection bias. Further, the control group had a greater representation of females (73%) compared to the experimental group (58%) and total male representation (69%), which may have resulted in the larger measurements obtained in the experimental group. Lastly, the participants' desire to show improved posture may have influenced the measurements taken and thus confounded the results of this study.

Finally, Wang et al[101] compared the efficacy of a customised versus standardised rehabilitation programmes in forty five participants with shoulder disorders. The customised exercise group received exercises based on Sahrmann's shoulder classification system that included self-stretching and strengthening exercises of the scapular stabilisers, rotator cuff and scapulohumeral muscles. The standardised exercise group performed GH flexion, extension, abduction, internal and external rotation with a resistance band. All prescribed exercises were performed as one set of five repetitions with a five second hold per repetition, twice daily and five times per week. There were significant improvements in pain (VAS) and the strength of middle and lower trapezius muscles at weeks four and eight in both groups. However, pain intensity and function (Flexilevel Scale of Shoulder Function) and shoulder strength (abductors and external rotators) improved significantly in both groups at week eight only. There were no significant differences in GH abduction ROM. Thus, the findings of this study suggest that a customised rehabilitation programme is not superior to standard rehabilitation for shoulder disorders. The failure of this study to detect differences between groups for pain, function, GH ROM and shoulder strength may be due to the unequal distribution of shoulder disorder classifications, resulting in the standardised exercise group primarily addressing humeral impairments. In addition, the small sample size, lack of a true control group and short duration of the study could have potentially warped the results.



In summary rehabilitative exercises may be beneficial in reducing pain[19,86,100,101], improving level of satisfaction[86], function[86,101], GH range of motion[86,101,106], muscular strength[86,101] and posture[32] in individuals with shoulder pain. However, a disparity exists regarding the optimal exercise regime, as well as the frequency and intensity of exercise programmes in the treatment of shoulder pain. Thus, a progressive rehabilitation protocol is recommended, where the exercises are performed two to three times weekly, over a four to eight week period[19,31,32]. Rehabilitative exercises prescribed for shoulder impingement should include scapulothoracic and rotator cuff muscular strengthening[10,19,24,31-34,101], as well as functional strengthening[4,10,31]. The precise exercises required for strengthening the scapulothoracic and rotator cuff musculature requires further investigation.

**Table 2.4:** *Outline of studies that investigated the effects of rehabilitation protocols on shoulder pain.*

| Authors | Study design | Sample | Diagnosis | Inclusion criteria | Exclusion criteria | Outcome measures | Results |
|---|---|---|---|---|---|---|---|
| Bang et al[19] | Prospective Randomized Clinical Trial | 52 participants (30 male and 22 female) | Shoulder impingement | 18-65 years of age, pain with Neer's and/or Hawkins Test, Pain with active Shoulder abduction or isometric shoulder abduction, internal or external rotation | Change in medication to weeks prior to onset of study, other form of treatment for shoulder pain in study, history of rotator cuff tear, adhesive capsulitis, dislocation, subluxation or fracture, history of cervical, shoulder or upper back surgery, history of systemic or neurological disease and physiotherapy or chiropractic treatment for shoulder, neck or back in last 12 months | Pain (VAS), Isometric strength, Function (Functional Assessment Questionnaire) | Significant decrease in pain ($p < 0.0001$) and increase in function ($p < 0.0001$) for both groups. Strength improved significantly ($p = 0.02$) in experimental group only. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Conroy et all[106] | Clinical Trial | 14 participants (8 male and 6 female) | Shoulder impingement | Pain over superolateral shoulder, deficit in humeral elevation, painful subacromial compression, limited functional patterns in elevated position, upper quadrant clearing exam. | Shoulder instability, primary scapulothoracic dysfunction, stage II and III adhesive capsulitis, third degree musculotendinous tears, AC joint disease, calcific tendinitis or bursitis, degenerative bony or ligamentous changes, neurological involvement, unstable fracture of humerus, clavicle or scapula | Pain (VAS), Impingement Signs, AROM, Functional Skills | Significant improvement in pain ($p = 0.005$) for the experimental group only. Both groups significantly improved in GH abduction ROM ($p = 0.0005$), GH flexion ROM ($p = 0.002$), GH external rotation ROM ($p = 0.01$), GH internal rotation ROM ($p = 0.0005$) and function ($p < 0.03$). |
| Kluemper et al[32] | Prospective pseudo-randomised clinical trial | 39 competitive swimmers (14 male and 25 female) | None | Elite level swimmers, high-school and college swimmers. | Shoulder pain inhibiting or limiting swimming and dry-land training | Forward shoulder posture | Significant improvement ($p < 0.05$) in forward shoulder posture for the experimental group (-9.6 ± 7.3 mm) compared to the control group (-2.0 ± 6.9mm). |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| McClure et al[86] | Prospective repeated measures clinical trial | 39 participants (18 male and 21 female) | Shoulder impingement | Three of the following: Positive Neer impingement test, positive Hawkins test, pain with active shoulder elevation, pain with palpation of rotator cuff tendons, pain with isometric resisted abduction, pain in the C5 or C6 dermatome region | Signs of complete rotator cuff tear or acute inflammation, cervical spine-related symptoms, GH instability or previous shoulder surgery | Pain, satisfaction and function (Penn Shoulder Score), ROM, Isometric strength | Significant improvement ($p < 0.001$) in pain, satisfaction and function; and range of external and internal rotation at 6 weeks.<br>Improvements in pain, satisfaction and function were maintained at 6 months.<br>Significant positive correlations between the PSS and external rotation force ($r = 0.39$; $p = 0.01$); and between the PSS and GH internal rotation ROM ($r = -0.54$; $p = 0.001$) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Senbursa et al[100] | Prospective randomised clinical trial | 30 participants | Shoulder Impingement | 30-55 years of age, shoulder pain with no major trauma, no treatment at another physiotherapy clinic in 2 years, loss of active and passive shoulder motion or painful ROM, MRI as a reference of standard | History of frozen shoulder, disorders of AC joint, degenerative arthritis of GH joint, calcifying tendonitis, shoulder instability, post-traumatic disorders, shoulder surgery and/or elbow, hand, wrist and cervical spine disorders | Pain (VAS), ROM, Functional Assessment Questionnaire | Significant improvements in night pain ($p < 0.02$) and pain with motion ($p = 0.01$) in both groups. Significantly greater improvement in pain at rest ($p = 0.02$) and function ($p = 0.002$) for the experimental group, compared to the control group (pain at rest improved insignificantly and function: $p = 0.008$).<br>GH flexion, abduction and external rotation ROM improved significantly ($p < 0.05$) in the experimental group only. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wang et al[101] | Prospective randomised clinical trial | 30 participants | Shoulder disorders | Age >21 years, existing shoulder pain for longer than 10 days | Physiotherapy treatment within the last 6 months, concurrent neck or thoracic disorders, systemic disease such as rheumatoid arthritis or diabetes mellitus | Pain (VAS), ROM, Isometric strength and Flexilevel Scale of Shoulder Function | Significant improvement ($p < 0.001$) in pain (VAS) and middle and lower trapezius muscle strength in both groups at week 4 and 8.<br>Significant improvement in pain intensity and function (Flexilevel scale of shoulder function) ($p = 0.009$) and shoulder strength (abductors: $p = 0.004$ and external rotators: $p = 0.02$) in both groups at week 8.<br>GH abduction ROM improved in both groups at week 8, but insignificantly ($p = 0.05$). |

**Table 2.5:** *Outline of components of rehabilitation protocols for shoulder pain.*

| Authors | Treatment groups | ROM exercises | Strengthening exercises | Flexibility exercises | Manual Therapy | Other |
|---|---|---|---|---|---|---|
| Bang et al[19] | Supervised exercise with and without manual therapy | Not reported | Resistance band exercises for shoulder flexion, scaption, rowing, horizontal extension-external rotation, seated press-up and elbow push-up | Anterior shoulder corner stretch and posterior shoulder cross body stretch | Techniques for specific movement limitations in upper quarter (shoulder and spine) | N/A |
| Conroy et al[106] | Supervised exercise with and without manual therapy | Pendular exercise with postural correction within pain free ROM | Chair press, Isometric internal and external rotation, scapulohumeral rhythm exercises | Cane assisted flexion and external rotation, towel-assisted internal rotation stretch, non-involved arm-assisted horizontal adduction | Mobilisations based on Maitland and Foley (inferior glide, anterior glide, posterior glide and traction) | Soft tissue mobilisation post treatment for 10 minutes |
| Kluemper et al[32] | Normal swim training activities with and without shoulder rehabilitation | None | Resistance band exercises for scapular retraction, external rotation, shoulder flexion | Partner-assisted stretches for pectoralis major and minor | None | None |
| McClure et al[86] | Standard exercise group only | None | Resistance band exercises for shoulder external rotation, internal rotation, extension, abduction, flexion and scapular retraction | Internal rotation towel stretch, cross body stretch, upper thoracic extension stretch, doorway pectoral muscle stretch, shoulder flexion stretch and shoulder external rotation stretch | None | Chin-tuck exercise (3 x hour, 3 second hold) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Senbursa et al[100] | Conservative treatment with and without manual therapy | Active ROM | Resistance band exercises targeting the rotator cuff, levator scapulae, rhomboids and serratus anterior | Stretching (not reported) | Deep friction massage on supraspinatus, radial nerve mobilisation, scapular mobilisation and GHJ mobilisation | Proprioceptive neuromuscular facilitation including rhythmic stabilisation and hold-relax |
| Wang et al[101] | Customised versus standard exercises | None | None | Customised exercises based on Sahrmann's shoulder classification system.<br>Standard exercises including resistance band flexion, abduction, extension, external and internal rotation. | None | None |

**Table 2.6:** *Outline of structure of rehabilitation protocols for shoulder pain.*

| Authors | Frequency | Duration | Supervised/ Unsupervised | Exercise intensity | Progression of exercises | Monitoring of compliance |
|---|---|---|---|---|---|---|
| Bang et al[19] | 2 x week | 3 weeks | Supervised | Strengthening: 3 sets of 10 repetitions per exercise<br>Flexibility: 3 Sets of 30 second hold with 10 second rest per stretch | None | Not reported |
| Conroy et al[106] | 3 x week | 3 weeks | Supervised | Not reported | None | Not reported |
| Kluemper et al[32] | 3 x week | 6 weeks | Supervised | Strengthening: 3 sets of 10 repetitions pre exercise<br>Flexibility: 2 sets of 30 second holds | Repetitions increase by 5 per week. At week three, resistance band strength was increased and repetitions repeated | Not reported |
| McClure et al[86] | Daily | 6 weeks | Unsupervised | Strengthening: 2-3 sets of 10 repetitions per exercise<br>Flexibility: 3 sets of 30 seconds | None | Exercise adherence log |
| Senbursa et al[100] | 3 x weekly | 4 weeks | Supervised | 10-15 minutes | Not reported | Not reported |
| Wang et al[101] | 2 x daily, 5 x weekly | 8 weeks | Supervised | 1 set of 5 repetitions with 5 second hold per repetition | Increasing repetitions or resistance | Exercise Log |

**Table 2.7:** *Summary of effects of rehabilitation protocols on outcome measures.*

| Authors | Pain | Active ROM | Passive ROM | Muscle power | Function | Other |
|---|---|---|---|---|---|---|
| Bang et al[19] | + | - | - | + Manual Therapy Group only | + | |
| Conroy et al [106] | + Manual therapy group only | + | + | 0 | + | |
| Kluemper et al[32] | - | - | - | - | - | + Forward shoulder posture for the rehabilitation group |
| McClure et al[86] | + | - | + (external and internal rotation only) | + (abduction, external and internal rotation force) | + | |
| Senbursa et al[100] | + | - | + (flexion, abduction and external rotation) | - | + | |
| Wang et al[101] | + | - | + (abduction only) | + | + | |

**Key:** *+ = significant difference, 0 = no difference, - = not measured*

### 2.6.1 SCAPULOTHORACIC REHABILITATION

Secondary shoulder impingement is associated with a delayed activation of the scapulothoracic stabilising muscles[16-19]. Scapulothoracic strengthening exercises are used extensively in the treatment of shoulder impingement with varying results[10,19,24,31-34,101]. However, there is currently little agreement regarding the most effective scapulothoracic rehabilitative exercises for shoulder impingement.

The upper quarter is afforded proximal stability through the dynamic orientation of the scapula, allowing for the optimal distal movement of the shoulder, elbow, wrist and hand. Mottram[30] described a scapula setting exercise in which the scapula is orientated 15˚-30˚ forward of the coronal plane. The recruitment of the lower trapezius and serratus anterior muscles is isolated, thus allowing scapula upward and external rotation, as well as posterior tilt. Initially this activation exercise is performed with arm by side and progressed to mid and outer range of GH flexion and abduction. Load may then be gradually increased by adjusting the lever length of the arm and adding additional weight. Mottram et al[108] examined the ability of 13 healthy participants to learn optimal scapula setting with and without assistance. An experienced physiotherapist instructed participants on how to perform the scapula orientation exercise for five minutes. A motion analysis system was used to collect kinematic data on the participant's right scapula at rest; with assisted positioning of the scapula in optimal orientation; and during the first of three attempts by the participant to return to this position, unassisted. Scapula upward rotation and posterior tilt was significantly greater in assisted scapula orientation compared to the resting position. Additionally, EMG activity recorded as participants performed 150° of GH flexion in the scapula plane with an unassisted scapula orientation, demonstrated significantly higher activity in the upper, middle and lower trapezius muscles compared to the resting scapula position. There was also a significant positive correlation between assisted and unassisted positioning for optimal scapula orientation. It may thus be possible to teach a participant to consistently reproduce an unfamiliar movement pattern. Thus, optimal scapula orientation may be included in home-based rehabilitation programmes.

Roy et al[109] investigated the upper limb motor strategies in participants with and without shoulder impingement syndrome. The upper limb motor strategy of 20 healthy participants and 33 participants with shoulder impingement was assessed during tasks that required participants to reach towards two targets in the frontal and oblique planes respectively.

Participants with shoulder impingement demonstrated significantly greater ipsilateral thoracic rotation, GH external rotation, and clavicular elevation; increased upper trapezius muscle activity and delayed activation of the lower trapezius muscle, during reaching compared to healthy participants. Unfortunately scapular motion was not investigated in this study[109]. However, shoulder impingement is coupled with reduced scapula upward rotation and posterior tilt, resulting in the delayed activation and concomitant strength of the serratus anterior and lower trapezius muscles[3,6,17,21,24,51,71,72]. Therefore, the use of rehabilitative exercises that emphasise low activation of upper trapezius and high activation of inferior trapezius and serratus anterior may correct the upper limb motor strategies of participants with shoulder impingement.

The prone push-up plus exercise has high activation of serratus anterior[34,92,110]. Ludewig et al[111] demonstrated a relatively low upper trapezius/serratus anterior muscle activation ratio (< 30%) for all phases of the push-up, except the eccentric non-plus phase. This ratio is vitally important to ensure adequate scapula posterior tilt and upward rotation during the push-up plus, to avoid shoulder impingement. The prone push-up plus may also be regressed to prone kneeling or a wall push-up plus, to accommodate an individual's strength. However, Escamilla et al[34] reported a substantial increase in upper trapezius muscle activation when healthy individuals performed a wall push-up plus. Upper trapezius muscle activation increases clavicle elevation and decreases scapula posterior tilt in participants with shoulder impingement[21,51,72]. Therefore a wall push-up plus should be avoided in the rehabilitation of shoulder impingement. In addition, Tucker et al[110] demonstrated that participants with shoulder impingement had similar activation levels of the serratus anterior, upper trapezius and inferior trapezius muscles when performing a standard push-up, compared to healthy participants. However, middle trapezius muscle activity was greater in participants with shoulder impingement when performing a push-up plus on an unstable surface (Bosu ball) and during standard push-up plus motions, compared to healthy participants. Therefore, it is essential that a standard push-up be performed on a stable surface in the rehabilitation of shoulder impingement. In summary, the prone push-up plus is recommended as the exercise of choice in the rehabilitation of shoulder impingement. However, this exercise should be performed on a stable surface initially; regressed to prone kneeling, if required; and progressed to an unstable surface. Other exercises which may activate the serratus anterior muscle include the dynamic hug, forward punch, proprioceptive neuromuscular facilitation (PNF) scapular depression and protraction movements, the full can or scaption and the wall slide[6,10,34,101,112].

Optimal lower trapezius muscle activity is thought to occur during the following exercises: prone flexion at 135˚ of GH abduction with GH external rotation; prone rowing; standing external rotation at 90˚ of GH abduction; PNF scapula clock; PNF diagonal patterns; standing high scapula rows; and scaption below 80˚ or above 120˚[34,92,112]. Cools et al[113] evaluated 12 commonly used scapula strengthening exercises based on muscle activation ratios. A low upper trapezius/lower trapezius ratio (<60%) was determined for side lying forward flexion, side lying external rotation and prone flexion at 135˚ GH abduction with GH external rotation exercises respectively. In addition, different upper trapezius/lower trapezius activation ratios were determined for the high row (<80%); forward flexion and scaption with external rotation (significantly <100% respectively) exercises. A low upper trapezius/lower trapezius ratio is important in the rehabilitation of shoulder impingement to allow for adequate scapula upward rotation[6,17,21,51,71] and posterior tilt[21,51,72]. None of the exercises investigated fulfilled the criteria for optimal upper trapezius/serratus anterior ratios.

Thus, the most effective exercises for scapula dyskinesis in shoulder impingement require low muscle activation ratios between the upper trapezius/serratus anterior[111] and upper trapezius/lower trapezius[113]. These ratios are best achieved when performing a prone push-up plus[34,92,110,111], and the prone flexion exercise at 135˚ of GH abduction with GH external rotation[34,92,112,113].

### 2.6.2 ROTATOR CUFF REHABILITATION

Shoulder impingement is associated with weakness and muscular imbalances between the GH internal and external rotators[114]. Electromyographic studies have shown reduced activation of the supraspinatus and infraspinatus muscles in shoulder impingement[115]. However, Blanch[10] suggested that swimmers seldom experience weakness of the rotator cuff. Instead, swimmers with shoulder pain are thought to lack the external rotation endurance in the impingement shoulder, compared to the unaffected shoulder[89]. Rotator cuff exercises are performed by focusing on scapula stability and may therefore be classified as scapula control and proprioceptive exercises[10,31].

Escamilla et al[34] studied the EMG activity of shoulder muscles in common rehabilitative exercises. The rotator cuff, deltoid and scapula muscles had a high to very high EMG activity in numerous exercises, including but not limited to external and internal rotation at 0˚ and 90˚ abduction, the push-up plus, standing dynamic hug, forward punch and rowing exercises. Further, the *“full can”* exercise demonstrated higher infraspinatus and subscapularis EMG activity, and similar supraspinatus and lower deltoid EMG activity, compared to the *“empty can”* exercise.

A possible explanation for these findings is that the *"full can"* or scaption exercise allows for GH external rotation, which is generated by the contraction of the infraspinatus, teres major and minor muscles[5,46]. Therefore, the *"full can"* or scaption exercise is preferential in place of the *"empty can"* exercise, due to the lower risk of impingement associated with the exercise.

Similarly, Reinold et al[116] recorded EMG activity of the rotator cuff and deltoid musculature during common shoulder external rotation exercises in 10 healthy participants. The prone *"full can"* exercise produced the greatest amount of supraspinatus (82%), middle deltoid (87%) and posterior deltoid (88%) muscle activity, compared to prone and standing external rotation at 90˚ of GH abduction. However, as this exercise was performed in the prone position, the reported middle and posterior deltoid muscle activity could differ when performed in standing. Further, the greatest combined EMG activity for infraspinatus and teres minor occurred with shoulder external rotation in side lying (infraspinatus: 62%; teres minor: 67%); standing external rotation in the scapula plane at 45˚ of GH abduction (infraspinatus: 53%; teres minor: 55%); and prone external rotation in 90˚ of GH abduction (infraspinatus: 50%; teres minor: 48%). However, the teres minor produces a scapula adduction torque and is a weak adductor of the humerus, irrespective of humeral rotation. Further, due to its posterior orientation at the shoulder, the teres minor generates a weak horizontal abduction torque[34,116]. Thus, teres minor activity is thought to be similar to that of the infraspinatus during GH external rotation, yet not as active as the infraspinatus during GH abduction, flexion and scaption. Reinold et al[116] and Escamilla et al[34] reported that teres minor EMG activity was moderate and exhibited similar activity to the infraspinatus during prone flexion at 90˚to 135˚ of GH abduction with external rotation, compared to GH abduction, flexion and scaption in standing.

In summary, based on current evidence the optimal rehabilitation of shoulder impingement requires increased activation of the supraspinatus and infraspinatus muscles[114,115], and improved endurance of the GH external rotators (infraspinatus and teres minor)[10]. The exercises which most adequately address these requirements include the *"full can"*, push-up, rowing and prone flexion exercise at 90˚to135˚ of GH abduction with GH external rotation[34,116].

### 2.6.3 THORACIC POSTURE REHABILITATION

Kibler[3] proposed that postural exercises which focus on the correction of an excessive thoracic kyphosis should be included in shoulder rehabilitation programmes. As previously discussed (Section 2.2.1, page 9), scapula orientation is partly dependant on cervical and thoracic posture[43]. An erect posture may sufficiently orientate the scapula to ensure optimal shoulder ROM and resultant upper limb function[28]. Further, a rehabilitation programme which is designed to enhance the role of the scapula will contribute to scapulothoracic muscle strengthening[10]. However, focussed scapulothoracic rehabilitative exercises are required to obtain the greatest possible improvement in scapulothoracic muscle strength.

Numerous studies have recommended the inclusion of thoracic posture rehabilitation in participants with shoulder impingement, however few state the exact rehabilitative exercises required[21,28,29,43,51,73,74]. Ludewig et al[51] suggested that the maintenance of upright posture during activities of daily living and shoulder exercises is required, and that exercises focusing on the improvement of thoracic extension ROM, strength and endurance should be considered in participants with shoulder disorders, specifically shoulder impingement. McMullen et al[4] described a kinetic chain rehabilitation programme of the shoulder, which was associated with a clinical reduction in shoulder pain that did not respond to conventional shoulder rehabilitation.

The kinetic chain rehabilitation protocol included functional movement patterns, which are thought to promote sequential muscle activation and co-ordination of the proximal segments, to elicit the desired shoulder movement. This may be illustrated by analysing the coupled motion used in the performance of the lawn mower[3,6,92,109] or shoulder dump exercise[4] (Figure 2.3) and sternal lift[4] (Figure 2.4) or robbery[92] exercise. The shoulder dump or lawn mower exercise is performed in a split stance position, with the forward hip and trunk flexed, while the opposite arm extends towards the forward foot. Motion is initiated by transferring weight to the rear leg, extending the forward hip and extending and rotating the trunk open towards the rear leg. This results in active scapula retraction and GH external rotation[3,4,6,92,109]. Similarly, the robbery exercise as described by Kibler et al[3] is likened to the sternal lift exercise. Both versions of this exercise use reciprocal thoracic flexion-extension with an emphasis on thoracic extension and scapula retraction. Reciprocal hip and thoracic flexion is increased to enhance scapula retraction and posterior tilt. Further, the robbery exercise incorporates GH external rotation with thoracic extension and scapula retraction.

**Figure 2.3:** *The shoulder dump or lawn mower exercise as described by McMullen et al*[4].



**Figure 2.4:** *The sternal lift exercise as described by McMullen et al*[4].

Kibler et al[117] used EMG analysis to establish that the lawnmower and robbery exercises were both effective in activating the serratus anterior and lower trapezius muscles. Further, unilateral arm elevation is coupled with thoracic extension and ipsilateral rotation which is significantly correlated to scapula upward (external) rotation (as discussed in Section 2.3.1)[26,27,54]. This evidence provides support for the theory of thoracic coupling and scapula motion in both the shoulder dump and sternal lift exercises[4]. These functional exercises may also be progressed by adding dumbbells, resistance bands and lower extremity lateral lunges or stepping[4,6,92].

Maenhout et al[118] highlighted the potential effects of the kinetic chain rehabilitation on scapula muscle activity. Leg extension was added to a push-up. Ipsilateral leg extension increased serratus anterior activation; and contralateral leg extension increased lower trapezius muscle activity during a push-up exercise. Therefore, hip ROM and muscular strength may affect scapula muscle activity in the performance of kinetic chain exercises.

### 2.6.4 SUMMARY OF THE LITERATURE: REHABILITATION OF SHOULDER IMPINGEMENT

There is an increasing body of evidence to support the efficacy of exercise in the treatment of shoulder impingement[4,10,19,24,31-34,101]. Studies have shown that improvements in pain[19,86,101], level of satisfaction[86], shoulder ROM[19,86], shoulder strength[19,101], function[19,86,101], and forward shoulder posture[28,32] may be achieved through a variety of rehabilitative exercises performed for six[19,32,101] to eight weeks[101]. However, shoulder impingement may be associated with scapula dyskinesis, which may not be adequately addressed through standard rehabilitation programmes[51,86]. Furthermore, the potential coupling mechanism between the thoracic spine, scapula and GH joint musculature, as well as upper quadrant posture, has received limited attention in current literature.

## 2.7 SUMMARY OF THE LITERATURE

Shoulder pain is the primary injury complaint in swimmers[12,24,32,35]. The repetitive GH adduction and internal rotation required for forward propulsion when swimming, subjects the shoulder joint complex to injury[12,22,24,32,36]. It is theorised that secondary shoulder impingement may be largely responsible for the development of shoulder pain in swimmers[10], and may be associated with GH instability[10,13,77,78,81], scapulothoracic dyskinesis[16,17,22,77,78,81], or the development of a rotator cuff or biceps tendinopathy[16,17,22,22,81,82].

Scapulothoracic dyskinesis is potentially the primary cause of shoulder impingement in swimmers[3,6,10,17,21,24,28,29,43,51,69-74]. Pain[10,69,70], muscular imbalances[3,6,17,21,24,51,71,72] and abnormal cervical and thoracic posture[28,29,43,73,74] adversely affect the length-tension relationships of the shoulder girdle musculature resulting in poor scapula orientation, decreased sub-acromial space, mal-tracking of the humeral head, and ultimately decreased GH ROM[21,28,29,51,73]. Scapulothoracic dyskinesis may be related to freestyle stroke flaws due to the biomechanical coupling occurring between the joints of upper quarter[5,12,20,62,68].

Unilateral arm elevation is coupled with scapula upward rotation and posterior tilt[26,29]; thoracic extension[26,27,54]; thoracic ipsilateral lateral flexion[26,27,53,55] and rotation[26,27,53,54]. Therefore, the potential risk for shoulder impingement in the freestyle stroke may be reduced by ensuring an increased tilt angle (thoracic lateral flexion)[12,20,64]; symmetric body roll (thoracic rotation)[12,20,64]; and a *"high elbow pull through"* (optimal GH ROM)[12,68].

The current evidence based management of shoulder impingement includes trigger point and soft tissue therapy[10,19,31]; manual joint therapy[19,31,100], stretching of the posterior shoulder joint capsule, pectoralis major and minor muscles[10,19,24,31,32] and rehabilitation[10,19,24,31-34,101]. The lack of consensus between studies on the rehabilitative exercises recommended for shoulder impingement, as well as the failure to adequately consider the biomechanical coupling between the joints of the upper quarter, has prompted the experimental phase of this thesis. Thus, the effects of scapulothoracic rehabilitation on shoulder pain in competitive swimmers is investigated.

# CHAPTER 3: THE EFFECTS OF SCAPULOTHORACIC REHABILITATION ON SHOULDER PAIN IN COMPETITIVE SWIMMERS

## 3.1 INTRODUCTION

Competitive swimmers have a high incidence of shoulder pain[12,22,24,32,35,39], which may be related to the development of secondary shoulder impingement[10]. The primary cause of shoulder impingement in swimmers may be scapulothoracic dyskinesis[3,6,10,17,21,24,28,29,43,51,69-74], which may occur simultaneously with freestyle stroke flaws[5,12,20,62,68]. Currently, literature promotes various manual therapy techniques[10,19,31,100], and rehabilitation exercises[10,19,24,31-34,101] in the management of shoulder impingement. It has been established that six[19,32,101] to eight[101] week rehabilitation programmes for shoulder impingement may be associated with a reduction in pain[19,86,101]; and improvements in level of satisfaction[86], GH ROM[19,86], shoulder strength[19,101], function[19,86,101], and forward shoulder posture[28,32]. However, the rehabilitation of scapula dyskinesis has not yet been comprehensively examined[51,86]. In addition, current literature does not adequately consider the potential coupled relationship between the thoracic spine, scapula and GH joint in the rehabilitation of shoulder impingement. Accordingly, the aim of the experimental phase of this thesis was to determine the effects of combined scapula and thoracic (scapulothoracic) rehabilitation, compared to isolated scapula (standard) rehabilitation on shoulder pain and dysfunction in competitive swimmers. The study objectives have been described in Section 1.3 (page 2).



## 3.2 METHODOLOGY

### 3.2.1 PARTICIPANTS AND STUDY DESIGN

This study had a true experimental design. Fifty participants were recruited from local swimming clubs in Cape Town through presentations to swimmers and coaches. This included information regarding the study, such as eligibility, location, procedure and voluntary participation. Eligible participants were required to complete an informed consent form (Appendix I).

### a) Inclusion criteria

Male and female swimmers between the ages of 18 to 30 years were eligible to participate in this study. Participants were required to perform a minimum of five swim training sessions per week, and three dry land training sessions per week. Participants were only included in this study if freestyle was the primary swim stroke. Participants who presented with unilateral shoulder pain that had persisted for at least 14 days were included in the study. In addition, the shoulder pain needed to be reproduced at or above 90° of active GH flexion. The shoulder pain also needed to be elicited during the Neer's and/or Hawkins tests, which were assessed during the familiarisation session.

### b) Exclusion criteria

Participants with bilateral shoulder pain; a history of shoulder surgery or traumatic shoulder injury; or cervical or neurological involvement were excluded from the study. Participants that reported posterior shoulder pain during the Neer's Test were excluded from the study. According to Cools et al[16] posterior shoulder pain elicited by the Neer's test is indicative of primary or internal impingement. Participants were also excluded if they received any form of manual physiotherapy over the nine-week duration of this study.

## 3.2.2 SAMPLE SIZE DETERMINATION

Data from a previous study[101] that measured the pain response of shoulder disorders to different rehabilitation programmes was used to ensure that the sample size would provide sufficient statistical power. Pain response to rehabilitation was selected to determine the required sample size, as pain was the primary outcome measure of this study. Required sample size for pain scores was calculated using a smallest meaningful difference of 2, and a standard deviation of 1.2. With statistical significance accepted as $p < 0.05$, groups of 12, 16 and 20 participants would provide 80%, 90% and 95% statistical power for pain respectively. Therefore, 50 participants were recruited for this study to ensure sufficient statistical power if some participants were unable to complete the study.

### 3.2.3 SAMPLING METHOD – RANDOMISATION AND BLINDING

Participants were randomly assigned to either the experimental or control groups. Randomisation was conducted by asking participants, in no particular order, to draw one of 50 cardboard cards from an envelope. An equal number of cards were labelled either “A” or “B”, where “A” indicated allocation to the experimental group, and “B” indicated allocation to the control group. An independent auditor observed the procedure to ensure randomisation. The experimental group participated in a scapulothoracic rehabilitation programme, while the control group participated in a standard rehabilitation programme which was designed to replicate evidence-based rehabilitation.

Single blinding was ensured as participants drew a code (marked on paper) from an envelope, which linked all personal information with data obtained and was undisclosed to the investigator throughout the duration of the study. An independent auditor was responsible for the list of participants’ details and unique code. Further, the scapulothoracic and standard rehabilitation programmes were conducted by two qualified physiotherapists respectively. The pre- and post-intervention testing was performed by the principal investigator.

## 3.3 STUDY PROCEDURE

Participants were required to attend a familiarisation session one week before the start of the experimental phase of this study. During the familiarisation sessions, written informed consent was obtained (Appendix I), the personal questionnaire was completed (Appendix II) and body composition measurements were performed. Active GH flexion, Neer’s test and Hawkins test were conducted as screening tests for inclusion in the study. Participants were then familiarised with all the testing. Participants were also instructed on optimal posture and scapula setting to ensure correct execution of the rehabilitation exercises.

Standard testing was conducted before, and at three, six and nine weeks after the commencement of the experimental or control rehabilitation protocols. Standard testing included the Penn Shoulder Score, assessment of pain-free active GH flexion, external and internal rotation ROM), active thoracic rotation ROM, the lateral scapula slide test, the pectoralis minor muscle length test, and a swimming time trial.

The experimental group and control group received different rehabilitation programmes, which commenced immediately after the first standard testing session, and continued for six weeks thereafter. Participants were required to perform the rehabilitation programme three times per week over the six week intervention period.

Participants were instructed to attend one supervised rehabilitation session and to perform two home-based rehabilitation sessions each week. The supervised rehabilitation sessions were necessary to assess and correct participants' performance of exercises. Exercise resistance was increased at week three. Participants were required to complete a log book to ensure compliance with the home based rehabilitation sessions. The testing procedure is summarised in Figure 3.1.

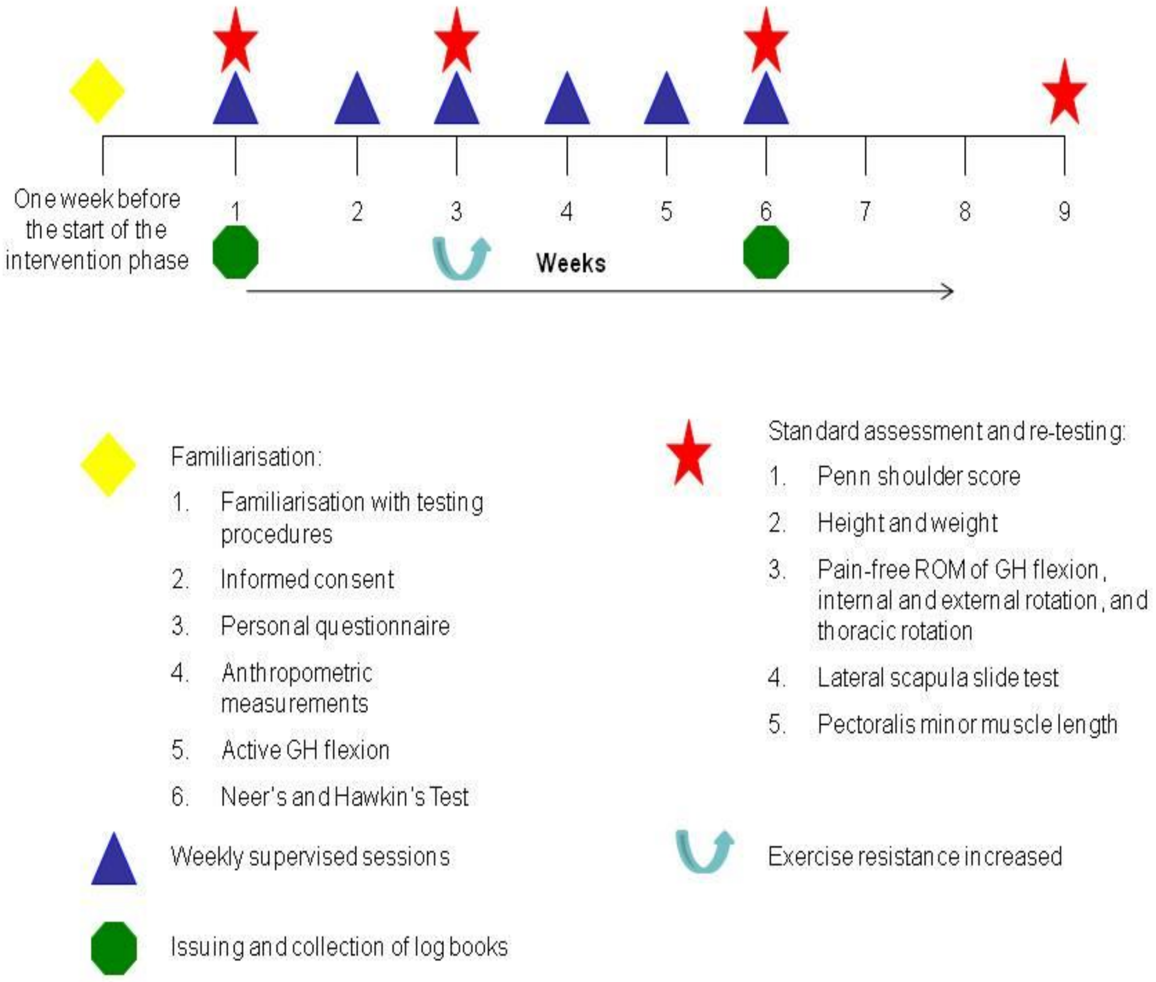



**Figure 3.1:** *Study procedure.*

### 3.3.1 FAMILIARISATION SESSION

#### a) Informed consent

Participants were required to complete an informed consent form prior to commencement of this study (Appendix I). The informed consent form stated that this study had been given ethical approval and that participation in the study was voluntary. The testing procedures and the risks, benefits and significance of the study were thoroughly explained. The participants were informed of the right to withdraw from the study at any time, and that confidentiality would be maintained.

#### b) Personal questionnaire

Participants were required to complete a questionnaire to obtain demographic data, training and competition history and injury history (Appendix II). The reliability and validity of this questionnaire was assessed in a reliability study (Section 3.3.5, page 63).

#### c) Screening tests

##### i) Active glenohumeral flexion

Active GH flexion was used as a screening test during the familiarisation session. Participants were included in the study if shoulder pain was elicited at or above 90° of active GH flexion, as this may indicate the presence of shoulder impingement[2,13]. Participants were exclude from the study if no shoulder pain was elicited during active GH flexion. Participants were seated on a stool with their feet placed firmly on the ground. The investigator instructed the participant to perform unilateral active GH flexion. Active GH flexion is considered positive if pain occurs at or above 90° of active GH flexion. Participants were required to indicate the presence of pain with a yes/no answer. If pain was elicited, the participant indicated the location of the pain. Both left and right shoulders were tested once, and the pain response for each shoulder was recorded.

### ii) Neer's test

Neer's test was used a screening test during the familiarisation session. Participants were included in the study if anterior shoulder pain was elicited during the test, as this indicates the presence of subacromial impingement. Participants were excluded from the study if posterior shoulder pain was elicited during the test, as this indicates the presence of primary or internal impingement[16]. Participants were seated on a stool with their feet firmly on the ground. The investigator stabilised the scapula by depressing it and then performing forced maximal GH flexion with the other hand[16]. Neer's test is considered positive if it elicits a pain response. Participants were required to indicate the presence of pain with a yes/no answer. If pain was elicited, the participant indicated the location of the pain. Both left and right shoulders were tested once, and the pain response for each shoulder was recorded.

### iii) Hawkins test

The Hawkins test was used as a screening test during the familiarisation session. A positive Hawkins test occurs by eliciting the participant's pain response and is an indication of subacromial impingement[16]. Participants were seated on a stool with their feet firmly supported on the ground. The investigator stabilised the scapula of the shoulder to be tested by applying downward pressure with one hand. The participant's arm was then placed over the investigator's arm, and positioned at 90° of GH flexion[13,16]. Hawkins test is considered positive if it elicits a pain response. Participants were required to indicated the presence of pain with a yes/no answer. Both left and right shoulders were tested once, and the pain response for each shoulder was recorded.



### d) Anthropometric Measurements

Body mass was recorded using a calibrated scale (Zhongshan YESHM Commodities Co., Ltd. 1999, Ultra-portable personal scale) and stature was recorded using a stadiometer. Body fat was expressed as the sum of seven skin folds (biceps, triceps, subscapular, suprailiac, calf, thigh and abdomen)[119].

### 3.3.2 STANDARD ASSESSMENT

#### a) The Penn Shoulder Score

Shoulder function was assessed using the Penn Shoulder Score[15]. Permission to use this questionnaire was granted by Mr. Brian Leggin, University of Pennsylvania Medical Centre. This self-report measurement tool consists of a 100-point scale, which is sub-divided into 3 categories, namely pain, satisfaction and function (Appendix III). Pain at rest, with normal activity and during strenuous activities; and satisfaction relating to the level of shoulder function, were measured with a subscale where 0 indicated *"no pain"* and 10 indicated *"severe pain".* Function was measured by 20 questions related to shoulder function, in which the subscale provided included *"no difficulty", "some difficulty", "much difficulty", "can't do at all"*, and *"did not do before injury"*[15].

#### b) Glenohumeral flexion; external, internal and total rotation, range of motion

Pain-free ROM of GH flexion, external and internal rotation was measured using a hand-held goniometer. Glenohumeral flexion ROM was measured in a seated position, on a chair with mid back support. Participants were instructed to maintain an upright posture, while lifting the arm up as high as possible without pain. The instantaneous axis of rotation was the mid-point between the greater tuberosity of the humerus and the root of the spine of the scapula. The stable arm of the goniometer was placed perpendicular to the ground, with the moving arm parallel to the humeral shaft, in neutral rotation. Both the left and right shoulders were measured three times and the average ROM was recorded. Glenohumeral rotation ROM was measured in supine. Participants were positioned with the shoulder at 90° of GH abduction and the elbow at 90° of flexion. Participants were instructed to move the hand into a thumb down position for external rotation and thumb up position for internal rotation. The instantaneous axis of rotation was the olecranon of the elbow. The stable arm of the goniometer was placed perpendicular to the ground and the moving arm parallel to the shaft of the ulna. The left and right shoulders were measured three times and the average ROM was recorded[94,101]. Glenohumeral total rotation ROM was calculated by adding the average ROM measured for GH external and internal rotation ROM.

### c) Thoracic rotation range of motion

Thoracic rotation was measured in a seated position, with participants feet placed firmly on the ground. Both arms were supported on a 270° half-moon chalk board, at 90° of GH flexion. The elbows were fully extended with neutral humeral rotation (palms face up) and participants were instructed to maintain contact between arms by keeping the medial borders of the 5th fingers of the hands together during ROM testing. This position was marked as the starting position on the chalk board. Participants were then instructed to rotate to the left and right within their pain-free ranges of motion. A mark was placed on the chalk board, in line with and parallel to the 5th fingers. The degree of rotation was then measured by extending the marks drawn until the lines intersected to form two angles. These angles represented left and right thoracic rotation respectively and were measured with a goniometer. Thoracic rotation was repeated three times to either side, and an average ROM was recorded for left and right thoracic rotation respectively. A similar method has been described by Blanch[10]. The reliability of this testing procedure was assessed in a reliability study (Section 3.3.5, page 63).

### d) Lateral scapula slide test

The lateral scapula slide test was used to assess muscle strength of scapula stabilisers. The test was performed in standing, with the participant assuming three different upper limb positions namely *"arms by side"*, *"hand on hips"* and *"arms at 90° of GH abduction"* with internal rotation (determined by goniometer measurement). The investigator marked the inferiomedial angles of the left and right scapulae. A reference point was marked as the nearest spinous process to the inferiomedial angle. The distance (cm) between the reference point and inferiomedial angles of the scapula was measured using a tape measure for each of the three different upper limb positions. An average of two measurements for each position was recorded[3]. The reliability of this testing procedure was determined prior to the conduction of this study in a reliability study (Section 3.3.5, page 63).

### e) Pectoralis minor muscle length

Pectoralis minor muscle length was measured according to the method described by Lewis et al[99]. Participants were positioned in supine on a treatment table with their elbows flexed and rested against the lateral wall of the abdomen, with their hands resting gently against their abdomen.

The investigator measured the distance from the treatment table, to the posterior acromion using a rigid transparent plastic right angle with a height of 12 cm and a base of 8cm. Without exerting downward pressure on the shoulder, the base of the right angle is placed on the treatment table, with the vertical side placed adjacent to the lateral aspect of the acromion. Both left and right shoulders were measured twice and the average distance was recorded for left and right pectoralis minor length respectively[99]. The reliability of this testing procedure was determined prior to the conduction of this study in a reliability study (Section 3.3.5, page 63).

**f) 100 m freestyle swimming time trial**

Freestyle is the most common swimming stroke specialty[39] and elite level swimmers complete approximately 35 km per week in training[22]. Each training session is divided into sets that range from a distance of 50 m to 200 m, which are repeated numerous times. Therefore a distance of 100 m was selected to assess swimming performance. A hand-held stop watch was used to measure 100 m freestyle time trial during individual training sessions. The examiner consulted with the respective coaches to ensure that time trials occurred concurrently with the standard assessments. Participants performed individual warm-ups prior to the 100 m freestyle time trial. Participants were instructed to swim the 100 m freestyle time trial at race pace. A three minute rest period between each time trial was the average recommended rest time by coaches. The average time of two 100m freestyle time trials was recorded.



### 3.3.3 REHABILITATION PROGRAMMES

Participants were required to perform a rehabilitation programme three times per week over the six-week intervention period. Participants were instructed to attend one supervised rehabilitation session per week and to perform two home-based rehabilitation sessions each week. Correct postural alignment was emphasised for both the experimental and control rehabilitation programmes.

The experimental group rehabilitation programme was based on the kinetic chain approach, as described by McMullen et al[4]. The exercises included the shoulder dump and sternal-lift[4], the push-up plus, rowing and scaption with external rotation as described by Escamilla et al[120] and a unilateral pectoralis minor self stretch[31]. This rehabilitation programme included both scapula and thoracic rehabilitation (Appendix IV). The control group performed a rehabilitation programme that emphasised isolated scapula rehabilitation, as described by Escamilla et al[120] and Kluemper et al[32].

The control rehabilitation programme included the push-up plus, rowing and scaption with external rotation, as well as pectoralis major and minor stretches (Appendix V). In this study, exercise progression followed the progressive three week resistance band protocol described by Kluemper et al[32]. Each exercise commenced with three sets of 10 repetitions, in week one. The number of repetitions of each exercise was increased by five repetitions per week. At week four, resistance was increased and the progression of repetitions was re-started. Participants were required to complete a log book to ensure compliance with the home-based rehabilitation sessions. Weekly supervised rehabilitation sessions were necessary to assess and correct participants' performance of exercises.

### 3.3.4 LOG BOOK

Participants were required to complete a log book to ensure compliance with the home based rehabilitation sessions. Participants were required to document training sessions, training distances, pain experienced and exercises completed during the six-week rehabilitation programme. The log book was collected at the six week mark (Appendix VI).

### 3.3.5 RELIABILITY STUDY

A reliability study (Appendix VII) was conducted to assess the intra- and inter-rater reliability for anthropometric measurements; goniometric assessments of GH flexion, internal and external rotation, and thoracic rotation; the lateral scapula slide test; and the measurement of pectoralis minor muscle length. A sample of convenience was used, and five participants who met the inclusion criteria for this study, were included in the reliability study. The measurements were performed by two investigators on alternate days for one week. Therefore testing was performed day one, three and five. The data from the participants in the reliability study were not included in the primary research study.

### 3.3.6 STATISTICAL ANALYSES

Data were analysed using Statistica software (StatSoft, Inc. 2011. STATISTICA, Data Analysis Software System, Version 10. www.statsoft.com). An independent t-test was used to determine differences in nominal descriptive variables and baseline measures between the experimental and control groups. A Chi-square test was used to determine differences in ordinal descriptive variables between the experimental and control groups.

Statistical significance for the two main effects of group and time, and the interaction (group x time) of Penn shoulder *"pain"*, *"satisfaction"*, *"function"*; GH flexion, external rotation, internal rotation and total rotation ROM; thoracic rotation ROM; lateral scapula slide test; pectoralis minor muscle length; and 100 m freestyle swimming time trial, were assessed using a two-way analysis of variance (ANOVA) with repeated measures. Tukey's post hoc comparisons were performed where necessary. Pearson's linear correlation was used to determine the relationship between variables (which variables/relationships) measured for the experimental and control groups. All data are presented as the mean ± standard deviation. Statistical significance was accepted as $p < 0.05$. Percentage change was calculated as a dividend between weeks six or nine and baseline measurement, less 100. In addition, clinical effects were determined by calculating the effect size of variables measured for the experimental and control groups[121]. All data are represented as Hedges' g. Clinical effect was accepted as negligible where $g < 0.15$; small where $g = 0.15 – 0.40$; medium where $g = 0.40 – 0.75$; large where $g = 0.75 – 1.10$; very large where $g = 1.10 – 1.45$; and huge where $g > 1.45$[122].

### 3.3.7 ETHICAL CONSIDERATIONS

This study was granted ethical approval from the University of Cape Town, Faculty of Health Sciences Human research Ethics Committee (HREC REF: 264/2010) (Appendix VIII). Eligible study participants were given informed consent forms during the familiarisation session. The purpose, testing and rehabilitation protocols and the associated risks of the study were explained to participants. The participants had the right to withdraw from the study at any time. All data were regarded as confidential. This was achieved by utilising a coding system, whereby each participant's personal information was linked to a code. The document containing participant's codes and personal information was held in a locked filing cabinet by an independent auditor for the duration of the study. Further, participants will not be identified in any publications associated with this study.



#### a) Risks to Participants

All participants within this study were competitive swimmers, and were familiar with aspects of exercise and rehabilitation. The associated risks with participation within this study included a possible, temporary increase in shoulder pain, as some of the testing protocols elicited participants' pain response. However, all other tests were performed in pain-free ROM.

It is possible that some participants may have experienced delayed onset of muscle soreness after the rehabilitation exercises, due to the potential unfamiliar nature of some exercises. These risks were diminished by familiarising the participants with all testing procedures, and the careful progression of the experimental and control rehabilitation programmes.

**b) Benefits to Participants**

The study aimed to improve thoracic rotation and subsequent scapula position, thereby reducing shoulder pain experienced by swimmers. Participants were educated regarding posture and scapula positioning, and received rehabilitation programmes to address their shoulder pain. These interventions may be associated with improvements in swimming biomechanics and performance, and a potential reduction in the risk of swimming-related injuries. Participants received their anthropometric measurements, as well as a summary of the results of the study. Participants that were excluded from the study during the screening tests were referred to an appropriate medical professional for appropriate management.

## 3.4 RESULTS

### 3.4.1 PARTICIPANTS

Fifty participants were recruited for this study. Thirty-two participants were eligible for inclusion in the study. Participants were randomly assigned to the experimental and control groups. However, three participants withdrew over the duration of the testing. Therefore, the experimental and control groups consisted of fifteen and fourteen participants respectively. The study sample is summarised in Figure 3.2.

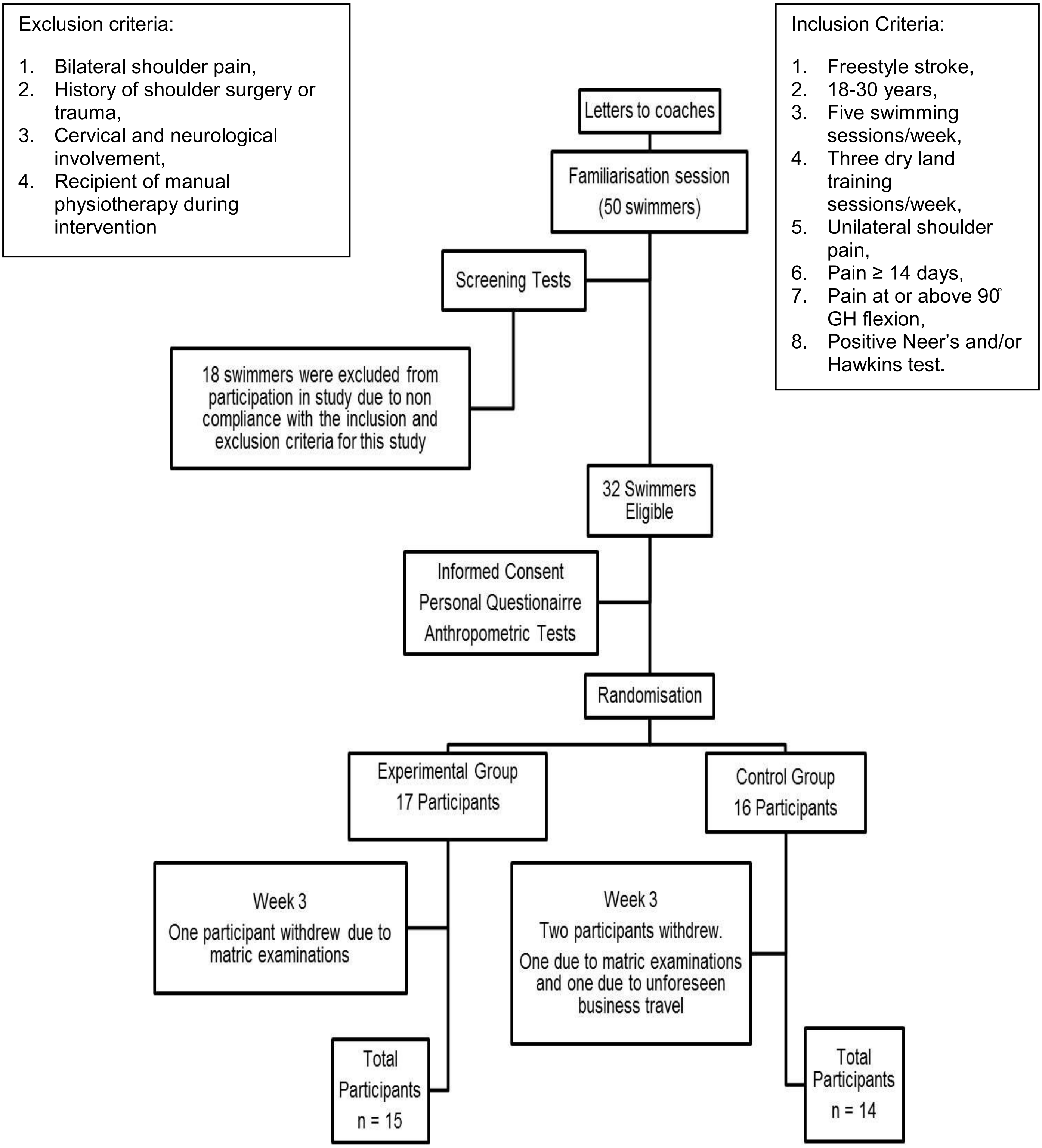



**Figure 3.2:** *Summary of study sample.*

The nominal descriptive characteristics of participants are shown in Table 3.1, and the ordinal descriptive characteristics of participants are shown in Table 3.2. There were no significant differences between groups for any of these variables.

**Table 3.1:** *Nominal descriptive characteristics of participants in the experimental (n = 15) and control (n = 14) groups. Data are expressed as mean ± standard deviation (SD).*

| Variable | | Experimental (n = 15) | Control (n = 14) |
|---|---|---|---|
| Age (years) | | 22.87 ± 7.40 | 21.57 ± 6.94 |
| Height (m) | | 1.72 ± 0.15 | 1.79 ±0.13 |
| Weight (kg) | | 65.33 ± 16.90 | 74.09 ± 15.53 |
| Sum of 7 skin folds (mm) | | 80.07 ± 21.12 | 84.45 ± 22.02 |
| Log book compliance | Average training distances (km) | 2.24 ± 1.84 | 1.57 ± 1.87 |
| | Pain (VAS) experienced while training (cm) | 0.9 ± 1.26 | 0.43 ± 0.67 |
| | Home-based rehabilitation sessions completed (%) | 31.11 ± 23.50 | 24.52 ± 25.81 |

**Table 3.2:** *Ordinal descriptive characteristics of participants in the experimental (n = 15) and control (n = 14) groups.*

| Variable | | Experimental (n = 15) | Control (n=14) |
|---|---|---|---|
| Gender | Male | 5 | 6 |
| | Female | 10 | 8 |
| Painful shoulder | Right | 10 | 8 |
| | Left | 5 | 6 |
| Positive impingement Test | Neer's | 1 | 1 |
| | Hawkins | 14 | 12 |
| | Both | 0 | 1 |
| Preferred breathing side | Right | 9 | 4 |
| | Left | 4 | 8 |
| | None | 2 | 2 |

The baseline measurements of participants in the experimental and control groups are shown in Table 3.3. There was a significant difference between groups in the subjective rating of level of satisfaction with current shoulder function.

The experimental group had significantly lower baseline satisfaction scores, compared to the control group (t = -2.26; p = 0.03). There were no significant differences between groups for any other baseline measurements.

**Table 3.3:** *Baseline measures for participants in the experimental (n = 15) and control (n = 14) groups. Data are expressed as mean ± SD.*

| Variable | | Experimental | Control |
|---|---|---|---|
| Penn Shoulder Score | Pain at rest | 1.47 ± 1.73 | 1.14 ± 1.56 |
| | Pain with activities of daily living | 1.47 ± 2.07 | 1.43 ± 1.83 |
| | Pain with strenuous activities (swimming) | 5.53 ± 1.88 | 4.79 ± 1.58 |
| | Total pain | 8.47 ± 4.85 | 7.36 ± 3.99 |
| | Satisfaction | 5.53 ± 2.83 * | 7.43 ± 1.40 |
| | Function | 51.20 ± 6.75 | 54.86 ± 6.16 |
| Range of Motion | GH flexion | 152.38 ± 9.04 | 153.45 ± 11.37 |
| | GH external rotation | 90.78 ± 9.16 | 92.88 ± 6.73 |
| | GH internal rotation | 37.61 ± 9.79 | 40.05 ± 7.48 |
| | GH total rotation | 128.39 ± 10.17 | 132.93 ± 12.38 |
| | Thoracic rotation | 61.27 ± 19.65 | 69.07 ± 12.48 |
| Lateral Scapula Slide Test | Arms by side | 10.21 ± 1.21 | 10.02 ± 1.52 |
| | Hands on hips | 10.69 ± 1.38 | 10.29 ± 1.29 |
| | Arms at 90° | 10.08 ± 1.78 | 9.77 ± 1.13 |
| Muscle Length | Pectoralis minor | 10.78 ± 1.56 | 10.72 ± 0.70 |
| Performance | 100 m time trial | 72.71 ± 14.54 | 68.46 ± 6.16 |

**p = 0.03*

### 3.4.2 THE PENN SHOULDER SCORE

#### 3.4.2.1 Pain

**a) Pain at rest**

The Penn shoulder *"pain at rest"* scores of participants in the experimental and control groups are shown in Table 3.4.

**Table 3.4:** *Penn shoulder "pain at rest" scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in Penn shoulder "pain at rest" scores.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 1.47 ± 1.73 | 1.14 ± 1.56 |
| **3** | 0.40 ± 0.74 | 0.57 ± 0.94 |
| **6** | 0.27 ± 0.80 | 0.14 ± 0.36 |
| **9** | 0.47 ± 0.92 | 0.50 ± 0.94 |



There were no significant differences between groups for Penn shoulder *"pain at rest"* scores (Figure 3.3), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 9.28; p = 0.00002). Pain improved significantly at week 3 (p = 0.002), week 6 (p = 0.0002) and week 9 (p = 0.002), compared to baseline measurements.

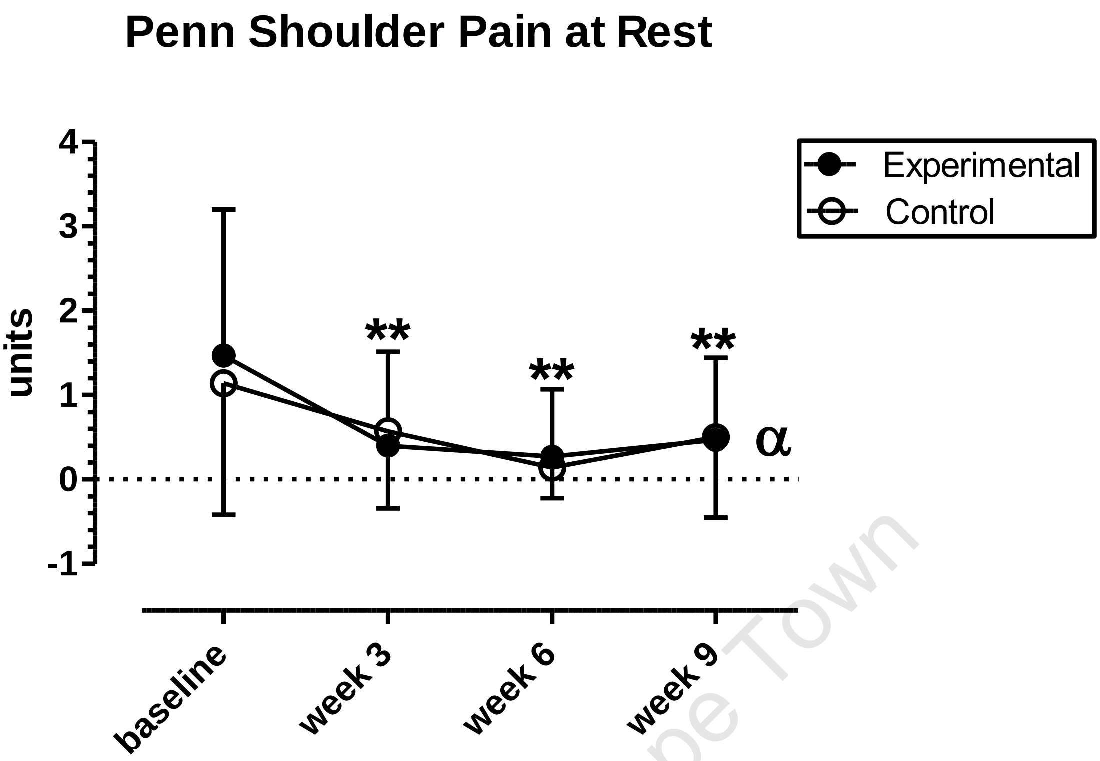



**Figure 3.3:** *Penn shoulder "pain at rest" scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in Penn shoulder "pain at rest" scores.*

*Significant differences:*

α main effect of time (p = 0.00002)
** week 3 and week 9 vs. baseline (p = 0.002)
** week 6 vs. baseline (p = 0.0002)



In addition, there were no significant differences between groups in the percentage change in Penn shoulder *"pain at rest"* scores at 6 weeks compared to baseline measurements (t = -0.31 ; p = 0.76). There were also no significant differences between groups in the percentage change in Penn shoulder *"pain at rest"* scores at 9 weeks compared to baseline measurements (t = -1.10 ; p = 0.28).

Finally, Penn shoulder *"pain at rest"* scores between groups demonstrated a small effect at week 6 (Hedges' g = 0.20; 95% confidence interval (CI): -0.53 to 0.93) and a negligible effect at week 9 (g = -0.03; CI: -0.76 to 0.70).

### b) Pain with everyday activity

The Penn shoulder *"pain with everyday activity"* scores of participants in the experimental and control groups are shown in Table 3.5.

**Table 3.5:** *Penn shoulder "pain with everyday activity" scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 week. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in Penn shoulder "pain with everyday activity" scores.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 1.47 ± 2.07 | 1.43 ± 1.83 |
| **3** | 0.73 ± 1.49 | 0.64 ± 1.15 |
| **6** | 0.47 ± 0.92 | 0.64 ± 0.84 |
| **9** | 0.53 ± 1.06 | 0.86 ± 1.17 |

There were no significant differences between groups for Penn shoulder *"pain with everyday activity"* scores (Figure 3.4), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 3.62; p = 0.02). Pain improved significantly at week 6, compared to baseline measurements (p = 0.02).

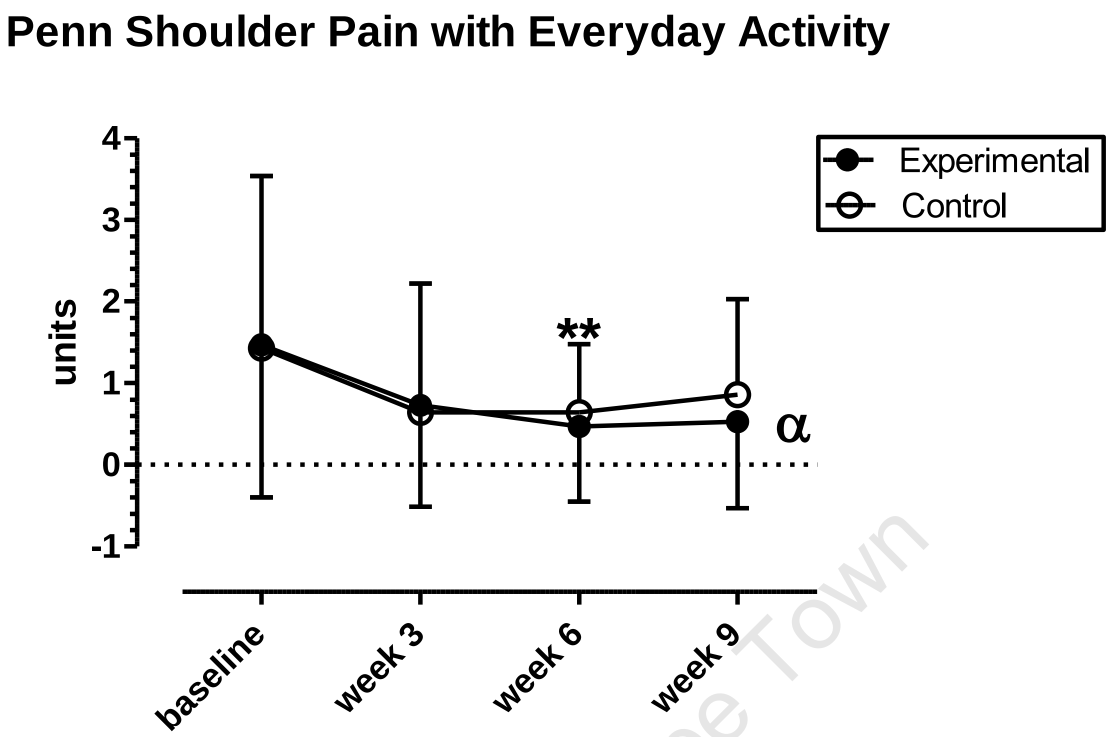



**Figure 3.4:** *Penn shoulder "pain with everyday activity" scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in Penn shoulder "pain with everyday activity" scores.*

*Significant differences:*

α main effect of time (p = 0.02)
** week 6 vs. baseline (p = 0.02)



In addition, there were no significant differences between groups in the percentage change in Penn shoulder *"pain with everyday activity"* scores at 6 weeks compared to baseline measurements (t = -0.92 ; p = 0.37). There were also no significant differences between groups in the percentage change in Penn shoulder *"pain with everyday activity"* scores at 9 weeks compared to baseline measurements (t = -0.90 ; p = 0.38).

Finally, Penn shoulder *"pain with everyday activity"* scores between groups demonstrated a small effect at week 6 (g = -0.19; CI: -0.92 to 0.54) and at week 9 (g = -0.29; CI: -1.02 to 0.44).

### c) Pain with strenuous activity (Swimming)

The Penn shoulder *“pain with strenuous activity”* scores of participants in the experimental and control groups are shown in Table 3.6.

**Table 3.6:** *Penn shoulder “pain with strenuous activity” scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in Penn shoulder “pain with strenuous activity” scores.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 5.53 ± 1.88 | 4.79 ± 1.58 |
| **3** | 3.00 ± 2.83 | 3.14 ± 2.32 |
| **6** | 1.67 ± 1.84 | 2.36 ± 1.91 |
| **9** | 1.67 ± 1.72 | 2.29 ± 2.33 |

There were no significant differences between groups for Penn shoulder *“pain with strenuous activity”* scores (Figure 3.5), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 27.32; p = 0.00001). Pain improved significantly at week 3 (p = 0.0002), week 6 (p = 0.0001) and week 9 (p = 0.0001), compared to baseline measurements. In addition, pain improved significantly at week 9, compared to week 3 measurements (p = 0.04).

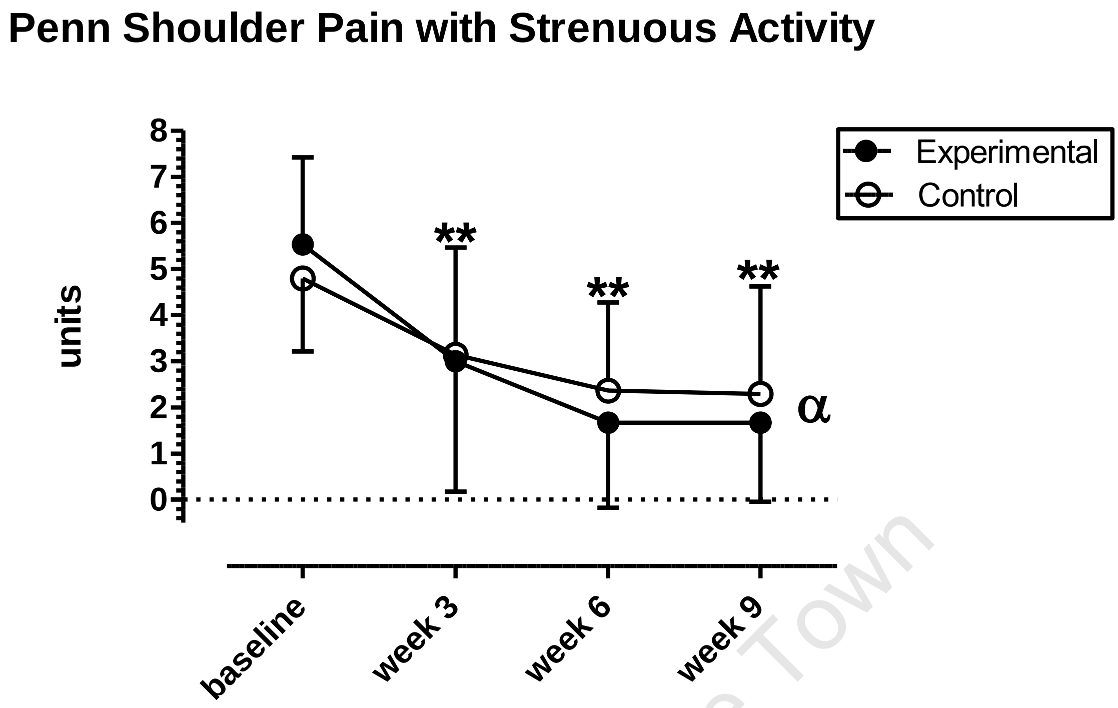



**Figure 3.5:** *Penn shoulder "pain with strenuous activity" scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 week. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in Penn shoulder "pain with strenuous activity" scores.*

*Significant differences:*

α main effect of time (p = 0.00001)
** week 3 vs. baseline (p = 0.0002)
** week 6 and week 9 vs. baseline (p = 0.0001)
** week 9 vs. week 3 (p = 0.04)

In addition, there were no significant differences between groups in the percentage change in Penn shoulder *"pain with strenuous activity"* scores at 6 weeks compared to baseline measurements (t = -1.83 ; p = 0.08). There were also no significant differences between groups in the percentage change in Penn shoulder *"pain with strenuous activity"* scores at 9 weeks compared to baseline measurements (t = -1.31 ; p = 0.20).

Finally, Penn shoulder *"pain with strenuous activity"* scores between groups demonstrated a small effect at week 6 (g = -0.36; CI: -1.09 to 0.38) and at week 9 (g = -0.30; CI: -1.03 to 0.44).

#### d) Total pain score

The Penn shoulder *“total pain”* scores of participants in the experimental and control groups are shown in Table 3.7.

**Table 3.7:** *Penn shoulder “total pain” scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in Penn shoulder “total pain” scores.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 8.47 ± 4.85 | 7.36 ± 3.99 |
| **3** | 2.67 ± 3.18 | 3.64 ± 3.71 |
| **6** | 4.13 ± 4.24 | 4.36 ± 3.52 |
| **9** | 2.40 ± 3.25 | 3.14 ± 2.32 |

There were no significant differences between groups for Penn shoulder *“total pain”* scores (Figure 3.6), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 24.580; p = 0.00001). Pain improved significantly at week 3 (p = 0.0001), week 6 (p = 0.0001) and week 9 (p = 0.0001), compared to baseline measurements.

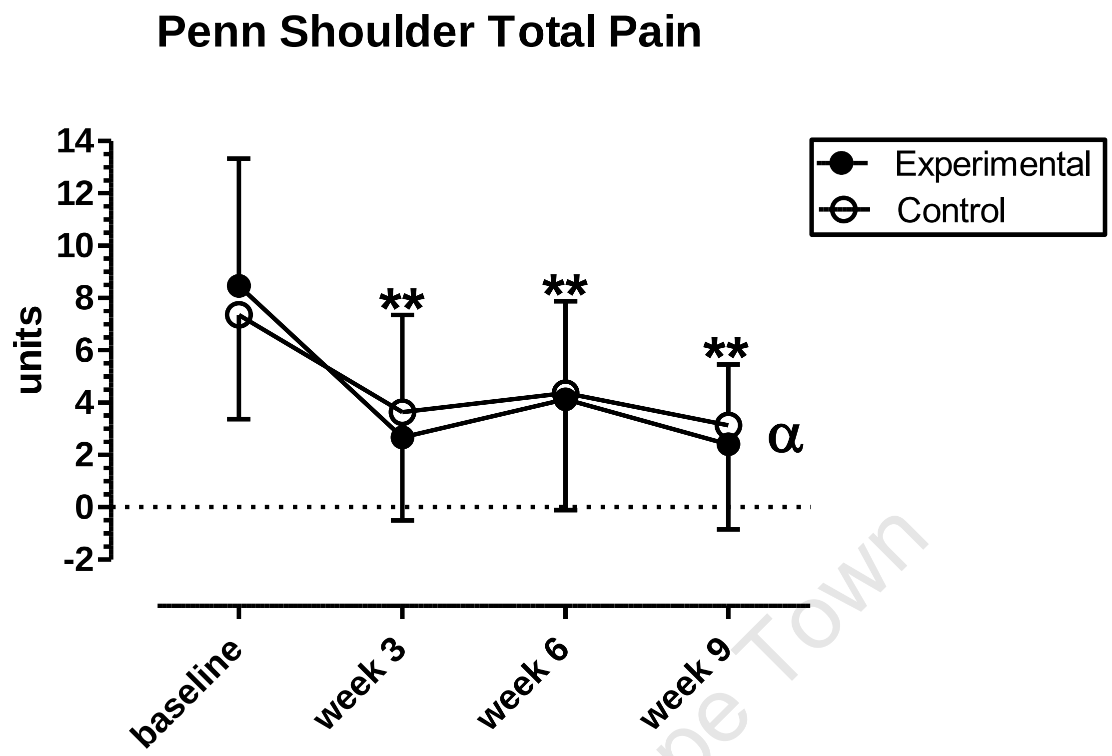



**Figure 3.6:** *Penn shoulder "total pain" scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in Penn shoulder "total pain" scores.*

*Significant differences:*

α main effect of time (p = 0.00001)

** week 3, week 6 and week 9 vs. baseline (p = 0.0001)



In addition, there were no significant differences between groups in the percentage change in Penn shoulder *"total pain"* scores at 6 weeks compared to baseline measurements (t = -1.47 ; p = 0.15). There were also no significant differences between groups in the percentage change in Penn shoulder *"total pain"* scores at 9 weeks compared to baseline measurements (t = -1.14 ; p = 0.26).

Finally, Penn shoulder *"total pain"* scores between groups demonstrated a negligible effect at week 6 (g = -0.06; CI: -0.79 to 0.37) and a small effect at week 9 (g = -0.25; CI: -0.98 to 0.48).

#### 3.4.2.2 Satisfaction

The Penn shoulder *"satisfaction"* scores of participants in the experimental and control groups are shown in Table 3.8.

**Table 3.8:** *Penn shoulder "satisfaction" scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in Penn shoulder "satisfaction" scores.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 5.53 ± 2.83 | 7.43 ± 1.40 |
| **3** | 7.47 ± 1.19 | 6.57 ± 1.74 |
| **6** | 7.67 ± 2.02 | 7.93 ± 1.33 |
| **9** | 7.80 ± 1.93 | 8.00 ± 1.04 |

There was a significant interaction between groups over time for the Penn shoulder *"satisfaction"* scores ($F_{(3, 81)}$ = 3.5861; p = 0.01723) (Figure 3.7). Satisfaction improved significantly at week 3 (p = 0.04), week 6 (p = 0.01) and week 9 (p = 0.007) for the experimental group and at week 6 (p = 0.01) for the control group, when compared to the experimental group baseline measures.

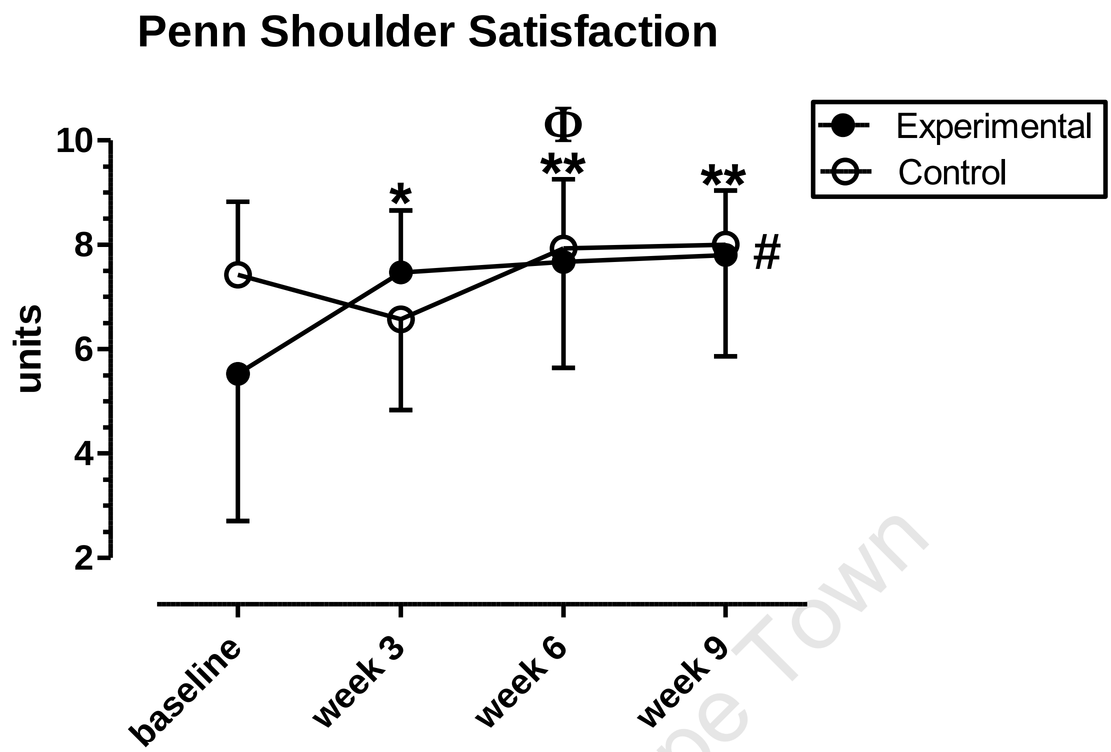



**Figure 3.7:** *Penn shoulder "satisfaction" scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in Penn shoulder "satisfaction" scores.*

*Significant differences:*

# interaction of group x time (p = 0.02)
* experimental group week 3 vs. experimental group baseline (p = 0.04)
Φ control group week 6 vs. experimental group baseline (p = 0.01)
** experimental group week 6 vs. experimental group baseline (p = 0.01)
** experimental group week 9 vs. experimental group baseline (p = 0.007)



In addition, there were no significant differences between groups in the percentage change in Penn shoulder *"satisfaction"* scores at 6 weeks compared to baseline measurements (t = -1.73 ; p = 0.09). There were also no significant differences between groups in the percentage change in Penn shoulder *"satisfaction"* scores at 9 weeks compared to baseline measurements (t = 1.82; p = 0.08).

Finally, Penn shoulder *"satisfaction"* scores between groups demonstrated a small effect at week 6 (g = -0.15; CI: -0.88 to 0.58) and a negligible effect at week 9 (g = -0.12; CI: -0.85 to 0.60).

### 3.4.2.3 Function

The Penn shoulder *"function"* scores of participants in the experimental and control groups are shown in Table 3.9.

**Table 3.9:** *Penn shoulder "function" scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in Penn shoulder "function" scores.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 51.20 ± 6.75 | 54.86 ± 6.16 |
| **3** | 56.00 ± 4.90 | 55.71 ± 4.36 |
| **6** | 58.00 ± 2.93 | 57.00 ± 5.13 |
| **9** | 56.40 ± 4.97 | 56.57 ± 5.63 |

There were no significant differences between groups for Penn shoulder *"function"* scores (Figure 3.8), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 7.1524; p = 0.0003). Function improved significantly at week 3 (p = 0.03), week 6 (p = 0.0003) and week 9 (p = 0.005), compared to baseline measurements.

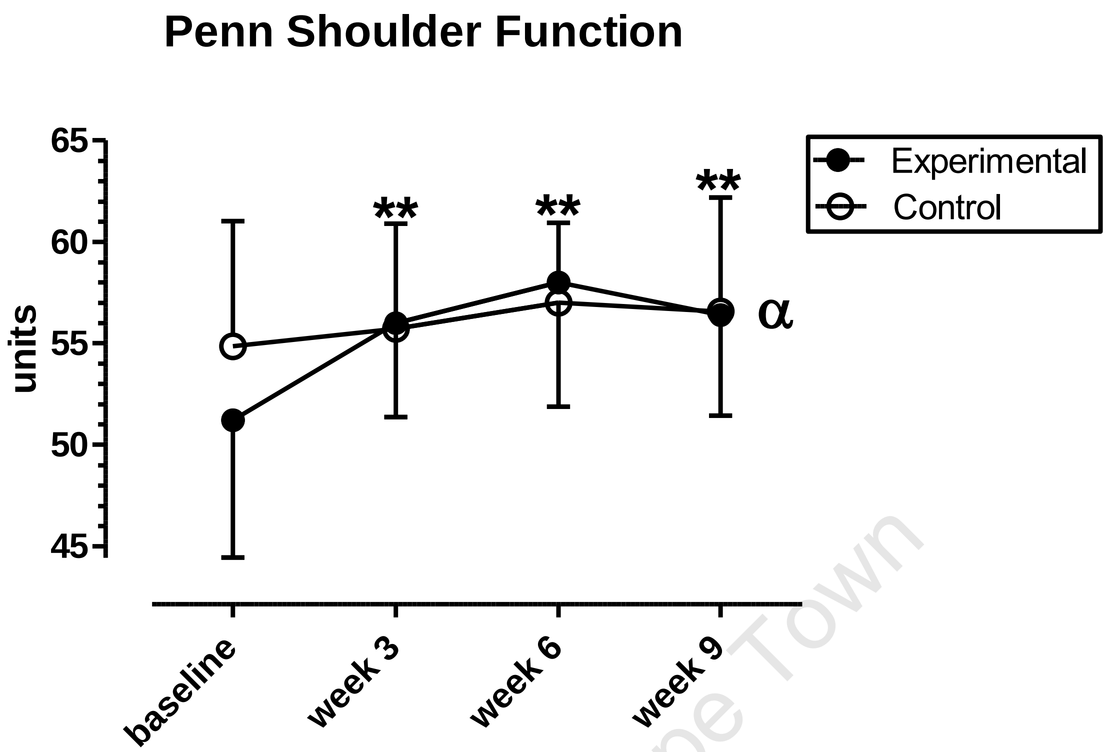



**Figure 3.8:** *Penn shoulder "function" scores (arbitrary units) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in Penn shoulder "function" scores.*

*Significant differences:*

α main effect of time (p = 0.0003)
** week 3 vs. baseline (p = 0.03)
** week 6 vs. baseline (p = 0.0003)
** week 9 vs. baseline (p = 0.005)



In addition, there were no significant differences between groups in the percentage change in Penn shoulder *"function"* scores at 6 weeks compared to baseline measurements (t = 1.85; p = 0.07). There were also no significant differences between groups in the percentage change in Penn shoulder *"function"* scores at 9 weeks compared to baseline measurements (t = 1.18; p = 0.25).

Finally, Penn shoulder *"function"* scores between groups demonstrated a small effect at week 6 (g = 0.23; CI: -0.50 to 0.97) and a negligible effect at week 9 (g = -0.03; CI: -0.76 to 0.70).

### 3.4.3 GLENOHUMERAL ROM

#### 3.4.3.1 Flexion

Glenohumeral flexion ROM of participants in the experimental and control groups are shown in Table 3.10.

**Table 3.10:** *Glenohumeral flexion ROM (degrees) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in GH flexion ROM.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 152.90 ± 9.04 | 153.45 ± 11.37 |
| **3** | 161.29 ± 9.88 | 162.90 ± 10.22 |
| **6** | 163.16 ± 6.29 | 166.19 ± 9.23 |
| **9** | 165.29 ± 8.25 | 167.90 ± 9.03 |

There were no significant differences between groups in GH flexion ROM (Figure 3.9), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 36.976; p = 0.00001). Glenohumeral flexion ROM improved significantly at week 3 (p = 0.001), week 6 (p = 0.0001) and week 9 (p = 0.0001), compared to baseline measurements. In addition, GH flexion ROM improved significantly at week 9, compared to week 3 (p = 0.01).

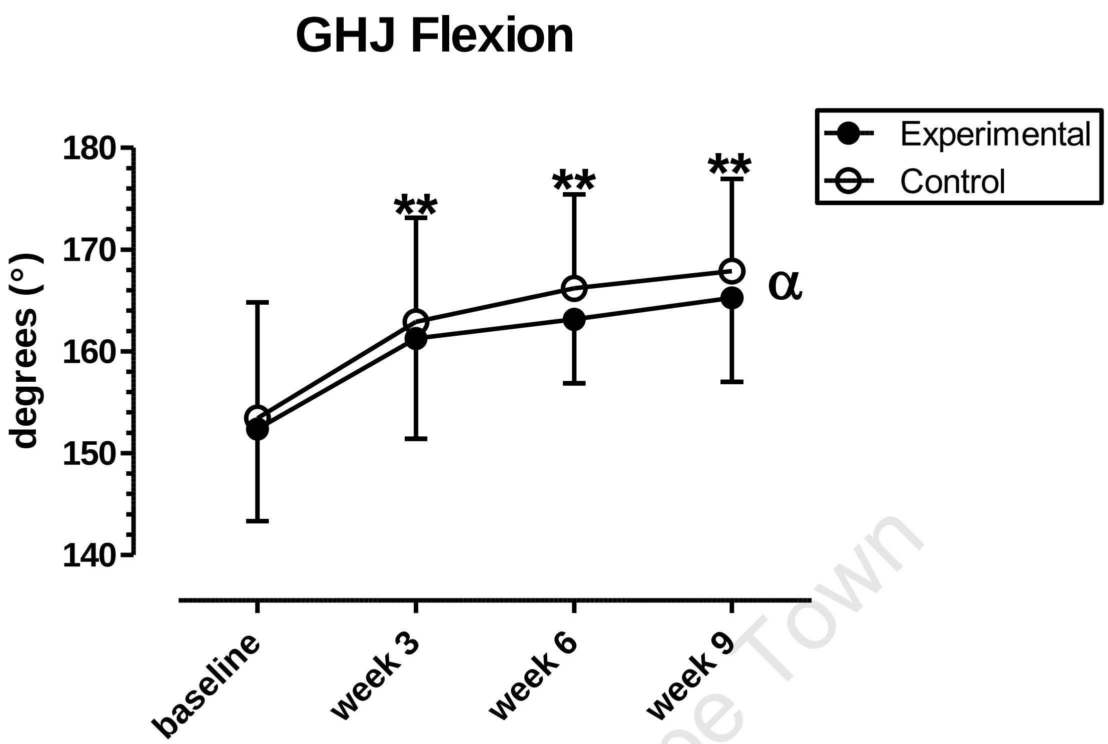



**Figure 3.9:** *Glenohumeral flexion ROM (degrees) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks Data are expressed as mean ± SD. Note: a positive change indicates an improvement in GH flexion ROM.*

*Significant differences:*

α main effect of time (p = 0.00001)
** week 3 vs. baseline (p = 0.001)
** week 6 and week 9 vs. baseline (p = 0.0001)
** week 9 vs. week 3 (p = 0.01)



In addition, there were no significant differences between groups in the percentage change in GH flexion ROM at 6 weeks compared to baseline measurements (t = -0.52; p = 0.60). There were also no significant differences between groups in the percentage change in GH flexion ROM at 9 weeks compared to baseline measurements (t = -0.42; p = 0.68).

Finally, GH flexion ROM between groups demonstrated a small effect at week 6 (g = -0.38˚; CI: -1.11˚ to 0.36˚) and at week 9 (g = -0.29˚; CI: -1.03˚ to 0.44˚).

### 3.4.3.2 External rotation

Glenohumeral external rotation ROM of participants in the experimental and control groups are shown in Table 3.11.

**Table 3.11:** *Glenohumeral external rotation ROM (degrees) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in GH external rotation ROM.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 90.78 ± 9.16 | 92.88 ± 6.73 |
| **3** | 94.76 ± 11.73 | 93.45 ± 9.04 |
| **6** | 98.33 ± 11.07 | 91.59 ± 8.55 |
| **9** | 93.89 ± 10.94 | 92.83 ± 10.45 |

There was a significant interaction between groups over time for GH external rotation ROM ($F_{(3, 81)}$ = 3.7481; p = 0.01414) (Figure 3.10). Glenohumeral external rotation ROM improved significantly at week 6 for the experimental group, when compared to baseline measurements (p = 0.003).

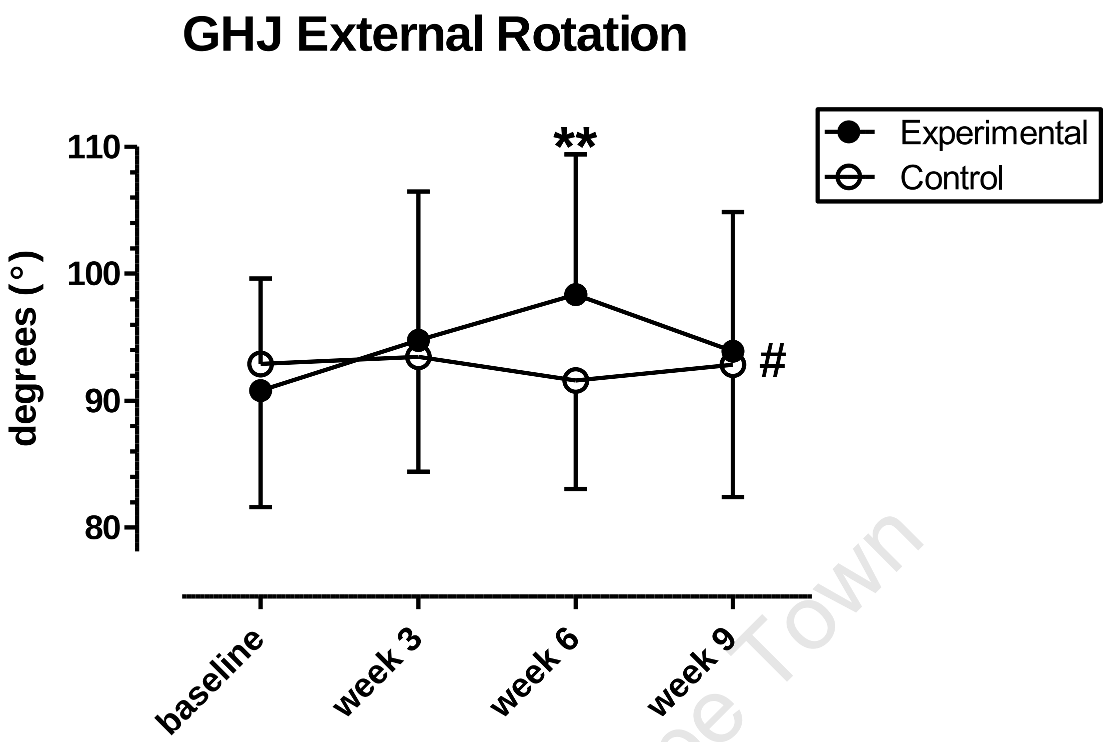



**Figure 3.10:** *Glenohumeral external rotation ROM (degrees) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in GH external rotation ROM.*

*Significant differences:*

# interaction of group x time (p = 0.01)

** experimental group week 6 vs. experimental group baseline (p = 0.003)



In addition, there was a significant differences between groups in the percentage change in GH external rotation ROM at 6 weeks compared to baseline measurements (t = 2.98; p = 0.01). However, there were no significant differences between groups in the percentage change in GH external rotation ROM at 9 weeks compared to baseline measurements (t = 1.23; p = 0.23).

Finally, GH external rotation ROM between groups demonstrated a medium effect at week 6 (g = 0.66˚; CI: -0.09˚ to 1.41˚) and a negligible effect at week 9 (g = 0.10˚; CI: -0.63˚ to 0.82˚).

### 3.4.3.3 Internal rotation

Glenohumeral internal rotation ROM of participants in the experimental and control groups are shown in Table 3.12.

**Table 3.12:** *Glenohumeral internal rotation ROM (degrees) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in GH internal rotation ROM.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 37.61 ± 9.79 | 40.05 ± 7.48 |
| **3** | 41.11 ± 9.17 | 43.14 ± 12.06 |
| **6** | 49.07 ± 14.54 | 58.76 ± 12.94 |
| **9** | 50.58 ± 12.78 | 56.55 ± 19.24 |

There were no significant differences between groups in GH internal rotation ROM (Figure 3.11), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 18.221; p = 0.00001). Glenohumeral internal rotation ROM improved significantly at week 6 (p = 0.0001) and week 9 (p = 0.0001), compared to baseline measurements. In addition, GH internal rotation improved significantly at week 6 (p = 0.0003) and week 9 (p = 0.0003), when compared to week 3.

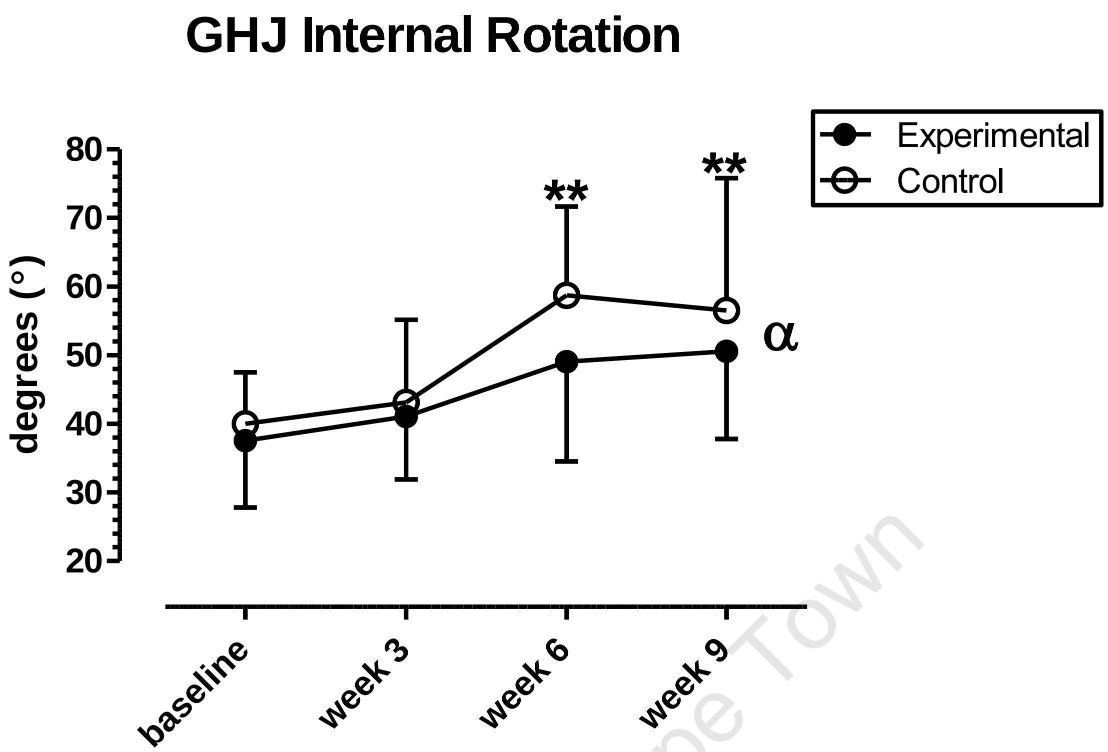





**Figure 3.11:** *Glenohumeral internal rotation ROM(degrees) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in GH internal rotation ROM.*

*Significant differences:*

α main effect of time (p = 0.00001)
** week 6 and week 9 vs. baseline (p = 0.0001)
** week 6 and week 9 vs. week 3 (p = 0.0003)

In addition, there were no significant differences between groups in the percentage change in GH internal rotation ROM at 6 weeks compared to baseline measurements (t = -0.64; p = 0.53). There were also no significant differences between groups in the percentage change in GH internal rotation ROM at 9 weeks compared to baseline measurements (t = -0.16; p = 0.87).

Finally, GH internal rotation ROM between groups demonstrated a medium effect at week 6 (g = -0.68˚; CI: -1.43˚ to 0.07˚) and a small effect at week 9 (g = -0.36˚; CI: -1.09˚ to 0.38˚).

#### 3.4.3.4 Total rotation

Glenohumeral total rotation ROM of participants in the experimental and control groups are shown in Table 3.13.

**Table 3.13:** *Glenohumeral total rotation ROM (degrees) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in total GH rotation ROM.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 128.39 ± 10.17 | 132.93 ± 12.38 |
| **3** | 135.87 ± 14.46 | 136.59 ± 15.44 |
| **6** | 147.40 ± 22.32 | 150.36 ± 18.99 |
| **9** | 144.47 ± 19.57 | 149.38 ± 24.43 |

There were no significant differences between groups in GH total rotation ROM (Figure 3.12), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 18.201; p = 0.00001). Glenohumeral total rotation ROM improved significantly at week 6 (p = 0.0001) and week 9 (p = 0.0001), compared to baseline measurements. In addition, GH total rotation ROM improved significantly at week 6 (p = 0.0003) and week 9 (p = 0.002), when compared to week 3.

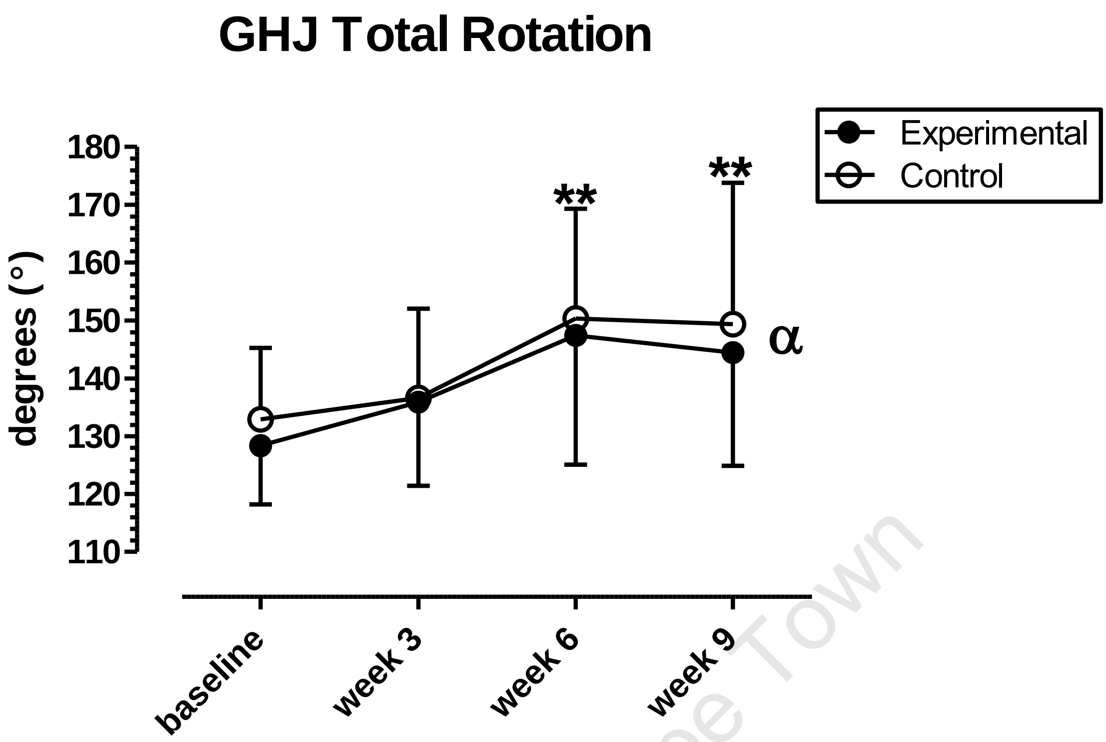



**Figure 3.12:** *Glenohumeral total rotation ROM (degrees) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in total GH rotation ROM.*

*Significant differences:*

α main effect of time (p = 0.00001)
** week 6 and week 9 vs. baseline (p = 0.0001)
** week 6 vs. week 3 (p = 0.0003)
** week 9 vs. week 3 (p = 0.002)



In addition, there were no significant differences between groups in the percentage change in GH total rotation ROM at 6 weeks compared to baseline measurements (t = 0.35; p = 0.73). There were also no significant differences between groups in the percentage change in GH total rotation ROM at 9 weeks compared to baseline measurements (t = 0.08; p = 0.94).

Finally, GH total rotation ROM between groups demonstrated a negligible effect at week 6 (g = -0.14˚; CI: -0.87˚ to 0.59˚) and a small effect at week 9 (g = -0.22˚; CI: -0.95˚ to 0.51˚).

### 3.4.4 THORACIC ROTATION ROM

Thoracic rotation ROM of participants in the experimental and control groups are shown in Table 3.14.

**Table 3.14:** *Thoracic rotation ROM (degrees) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in thoracic rotation ROM.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 61.27 ± 19.65 | 69.07 ± 12.48 |
| **3** | 71.69 ± 20.28 | 78.76 ± 15.31 |
| **6** | 76.04 ± 19.24 | 82.05 ± 13.39 |
| **9** | 78.33 ± 18.27 | 83.98 ± 13.55 |

There were no significant differences between groups in thoracic rotation ROM (Figure 3.13), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 31.100; p = 0.00001). Thoracic rotation ROM improved significantly at week 3 (p = 0.0001), week 6 (p = 0.0001) and week 9 (p = 0.0001), compared to baseline measurements. In addition, thoracic rotation ROM improved significantly at week 9, compared to week 3 (p = 0.007).

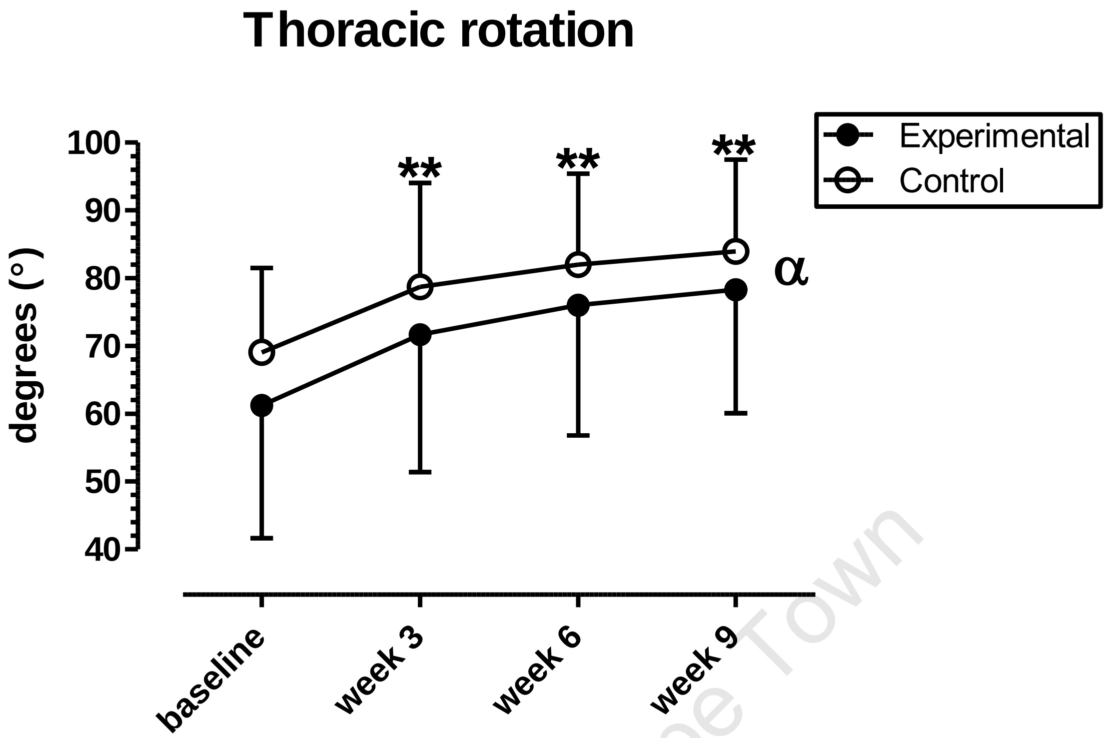



**Figure 3.13:** *Thoracic rotation ROM (degrees) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates an improvement in thoracic rotation ROM.*

*Significant differences:*

α main effect of time (p = 0.00001)
** week 3, week 6 and week 9 vs. baseline (p = 0.0001)
** week 9 vs. week 3 (p = 0.007)



In addition, there were no significant differences between groups in the percentage change in thoracic rotation ROM at 6 weeks compared to baseline measurements (t = 1.01; p = 0.32). There were also no significant differences between groups in the percentage change in thoracic rotation ROM at 9 weeks compared to baseline measurements (t = 1.08; p = 0.29).

Finally, thoracic rotation ROM between groups demonstrated a small effect at week 6 (g = -0.35˚; CI: -1.08˚ to 0.38˚) and at week 9 (g = -0.34˚; CI: -1.07˚ to 0.39˚).

### 3.4.5 LATERAL SCAPULA SLIDE TEST

#### 3.4.5.1 Arm by Side

The lateral scapula slide *"arm by side"* measurements participants in the experimental and control groups are shown in Table 3.15.

**Table 3.15:** *Lateral scapula slide "arm by side" measurements (cm) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in lateral scapula "arm by side" measurements.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 10.21 ± 1.21 | 10.02 ± 1.52 |
| **3** | 10.17 ± 1.14 | 9.82 ± 1.42 |
| **6** | 9.38 ± 1.05 | 9.29 ± 1.28 |
| **9** | 9.54 ± 1.03 | 9.57 ± 1.16 |

There were no significant differences between groups for the lateral scapula slide *"arm by side"* measurements (Figure 3.14), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 9.5946; p = 0.00002). "*Arm by side"* measurements improved significantly at week 6 (p = 0.0002) and week 9 (p = 0.006), compared to baseline measurements. In addition, *"arm by side"* measurements improved significantly at week 6 (p = 0.001) and week 9 (p = 0.04), compared to week 3.

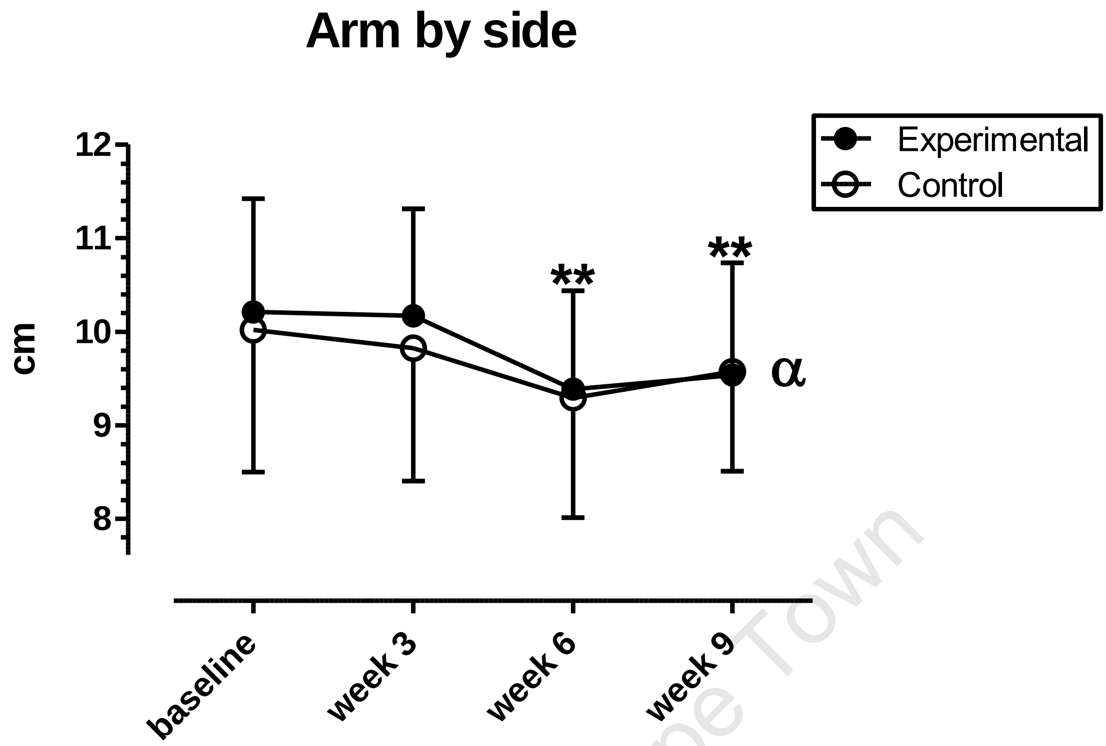



**Figure 3.14:** *Lateral scapula slide "arm by side" measurements (cm) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in lateral scapula "arm by side" measurements.*

*Significant differences:*

α main effect of time (p = 0.00002)
** week 6 vs. baseline (p = 0.0002)
** week 6 vs. week 3 (p = 0.001)
** week 9 vs. baseline (p = 0.006)
** week 9 vs. week 3 (p = 0.04)



In addition, there were no significant differences between groups in the percentage change in lateral scapula slide *"arm by side"* measurements at 6 weeks compared to baseline measurements (t = -0.21; p = 0.83). There were also no significant differences between groups in the percentage change in lateral scapula slide *"arm by side"* measurements at 9 weeks compared to baseline measurements (t = -0.58; p = 0.57).

Finally, lateral scapula slide *"arm by side"* measurements between groups demonstrated a negligible effect at week 6 (g = 0.07 cm; CI: -0.65 to 0.80 cm) and at week 9 (g = -0.03 cm; CI: -0.76 to 0.70 cm).

### 3.4.5.2 Hands on hips

The lateral scapula slide *“hands on hips”* measurements participants in the experimental and control groups are shown in Table 3.16.

**Table 3.16:** *Lateral scapula slide “hands on hips” measurements (cm) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in lateral scapula “hands on hips” measurements.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 10.69 ± 1.38 | 10.29 ± 1.29 |
| **3** | 10.15 ± 1.22 | 10.15 ± 1.16 |
| **6** | 9.60 ± 1.00 | 9.12 ± 1.03 |
| **9** | 9.74 ± 1.03 | 9.68 ± 1.34 |

There were no significant differences between groups for the lateral scapula slide *“hands on hips”* measurements (Figure 3.15), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 12.024; p = 0.00001). “*Hands on hips”* measurements improved significantly at week 6 (p = 0.0001) and week 9 (p = 0.001), compared to baseline measurements. In addition, *“hands on hips”* measurements improved significantly at week 6, compared to week 3 (p = 0.001).

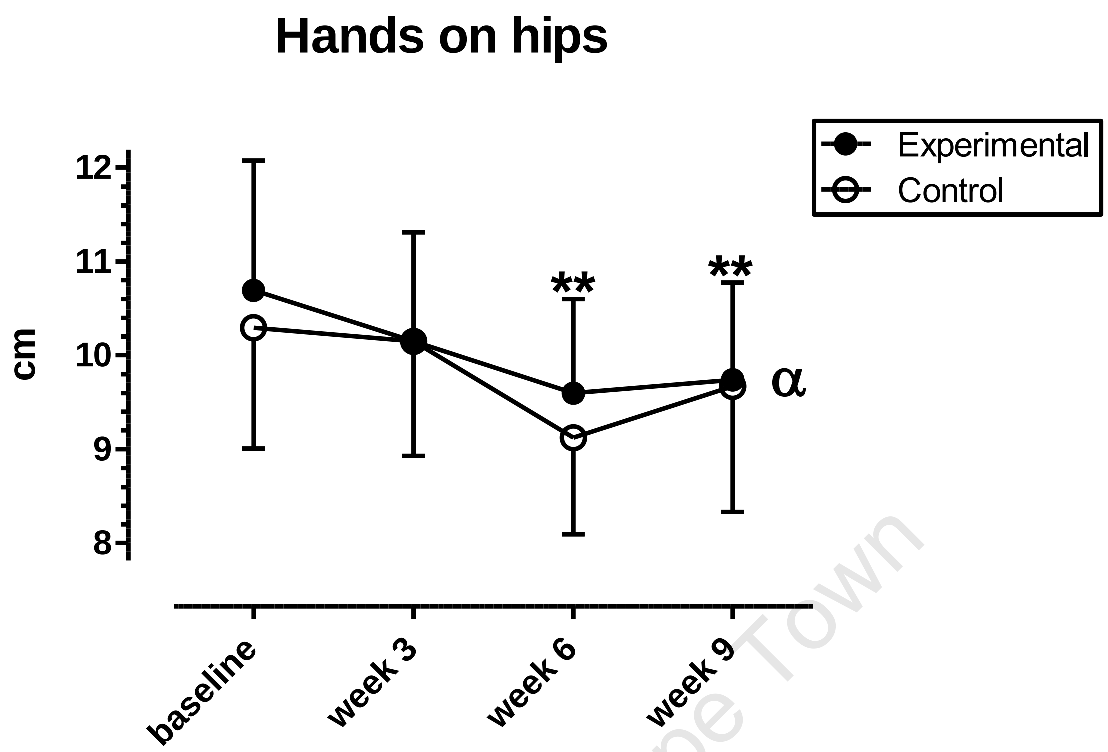



**Figure 3.15:** *Lateral scapula slide "hands on hips" measurements (cm) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in lateral scapula "hands on hips" measurements.*

*Significant differences:*

α main effect of time (p = 0.00001)
** week 6 vs. baseline (p = 0.0001)
** week 6 vs. week 3 (p = 0.001)
** week 9 vs. baseline (p = 0.001)



In addition, there were no significant differences between groups in the percentage change in lateral scapula slide *"hands on hips"* measurements at 6 weeks compared to baseline measurements (t = 0.44; p = 0.66). There were also no significant differences between groups in the percentage change in lateral scapula slide *"hands on hips"* measurements at 9 weeks compared to baseline measurements (t = -0.66; p = 0.51).

Finally, lateral scapula slide *"hands on hips"* measurements between groups demonstrated a medium effect at week 6 (g = 0.46 cm; CI: -0.28 to 1.20 cm) and a negligible effect at week 9 (g = 0.06 cm; CI: -0.67 to 0.79 cm).

### 3.4.5.3 Arm at 90˚ of GH abduction

The lateral scapula slide *"arms at 90˚ of GH abduction"* measurements participants in the experimental and control groups are shown in Table 3.17.

**Table 3.17:** *Lateral scapula slide "arms at 90˚ of GH abduction" measurements (cm) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in lateral scapula "arms at 90˚ of GH abduction" measurements.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 10.08 ± 1.78 | 9.77 ± 1.13 |
| **3** | 9.40 ± 1.37 | 9.83 ± 1.25 |
| **6** | 9.39 ± 1.52 | 8.69 ± 0.95 |
| **9** | 9.17 ± 1.08 | 9.33 ± 1.06 |

There were no significant differences between groups for the lateral scapula slide *"arms at 90˚ of GH abduction"* measurements (Figure 3.16), whereas there was a significant difference in measurement over time ($F_{(3, 81)}$ = 4.2897; p = 0.007). *"Arms at 90˚ of GH abduction"* measurements improved significantly at week 6, compared to baseline measurements (p = 0.008).

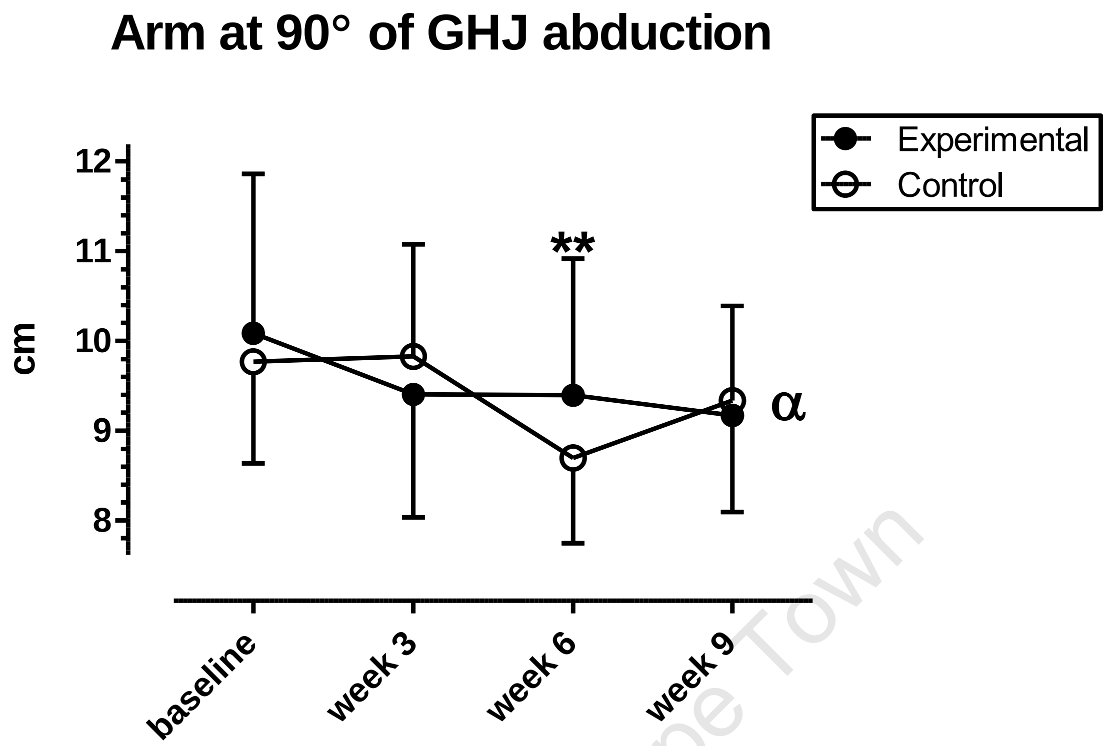



**Figure 0.16:** *Lateral scapula slide "arms at 90˚ of GH abduction" measurements (cm) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in lateral scapula "arms at 90˚ of GH abduction" measurements.*

*Significant differences:*

α main effect of time (p = 0.007)
** week 6 vs. baseline (p = 0.008)



In addition, there were no significant differences between groups in the percentage change in lateral scapula slide *"arms at 90˚ of GH abduction"* measurements at 6 weeks compared to baseline measurements (t = 0.89; p = 0.38). There were also no significant differences between groups in the percentage change in lateral scapula slide *"arms at 90˚ of GH abduction"* measurements at 9 weeks compared to baseline measurements (t = -0.66; p = 0.51).

Finally, lateral scapula slide *"arms at 90˚ GH abduction"* measurements between groups demonstrated a medium effect at week 6 (g = 0.53 cm; CI: -0.21 to 1.27 cm) and a small effect at week 9 (g = -0.15 cm; CI: -0.87 to 0.58 cm).

### 3.4.6 PECTORALIS MINOR MUSCLE LENGTH

The pectoralis minor muscle length measurements participants in the experimental and control groups are shown in Table 3.18.

**Table 3.18:** *Pectoralis minor muscle length measurements (cm) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in pectoralis minor muscle length measurements.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 10.78 ± 1.56 | 10.72 ± 0.70 |
| **3** | 10.95 ± 1.63 | 10.85 ± 1.28 |
| **6** | 11.18 ± 1.76 | 11.14 ± 1.41 |
| **9** | 12.01 ± 1.52 | 11.66 ± 1.29 |

There were no significant differences between groups for pectoralis minor muscle length measurements (Figure 3.17), whereas there was a significant difference in measurement over time ($F_{(3,\ 81)}$ = 14.186; p = 0.00001). Pectoralis minor muscle length was significantly reduced at week 9, compared to baseline measurements (p = 0.0001).

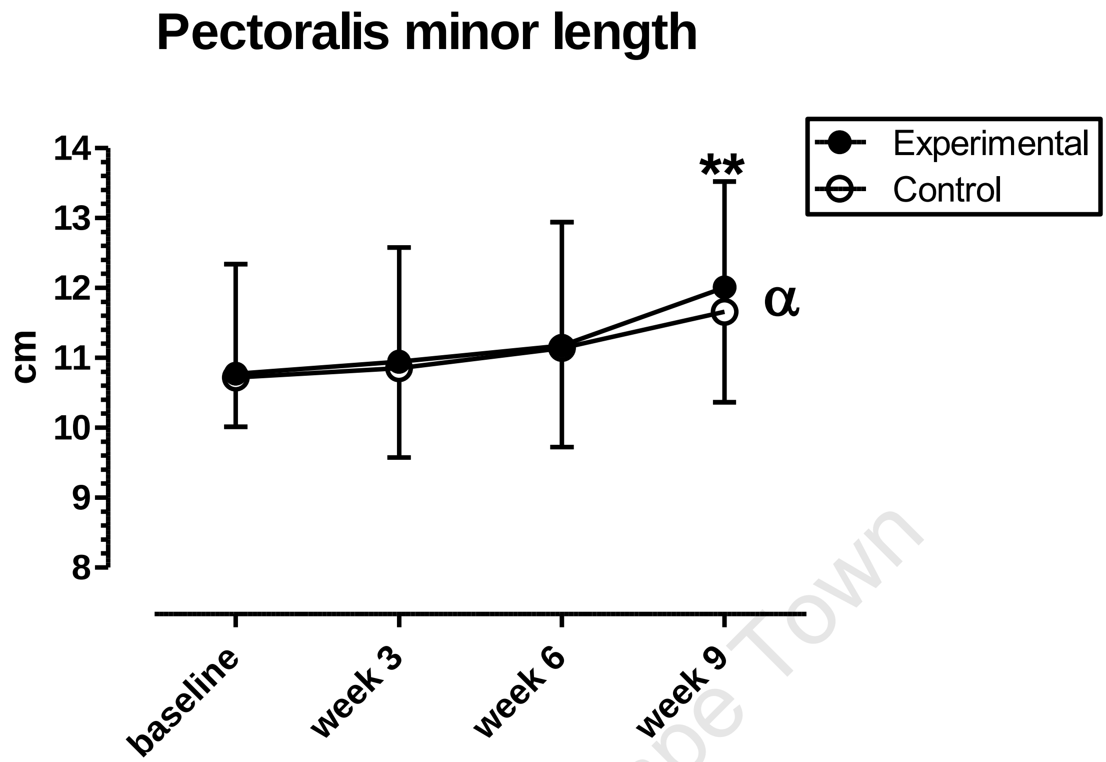



**Figure 3.17:** *Pectoralis minor muscle length measurements (cm) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in pectoralis minor muscle length measurements. An increase in units of measurement (cm) reflects a "shortening" of the pectoralis minor muscle.*

*Significant differences:*

α main effect of time (p = 0.00001)
** week 9 vs. baseline (p = 0.0001)



In addition, there were no significant differences between groups in the percentage change in pectoralis minor muscle length measurements at 6 weeks compared to baseline measurements (t = -0.05; p = 0.96). There were also no significant differences between groups in the percentage change in pectoralis minor muscle length measurements at 9 weeks compared to baseline measurements (t = 0.76; p = 0.45).

Finally, pectoralis minor muscle length measurements between groups demonstrated a negligible effect at week 6 (g = 0.02 cm; CI: -0.70 to 0.75 cm) and a poor small effect at week 9 (g = 0.24 cm; CI: -0.49 to 0.97 cm).

### 3.4.7 100 M FREESTYLE SWIMMING TIME TRIAL

The 100 m freestyle swimming time trials of participants in the experimental and control groups are shown in Table 3.19.

**Table 3.19:** *100 m freestyle swimming time trials (seconds) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6 and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in 100 m freestyle swimming time trial.*

| Week | Experimental | Control |
|---|---|---|
| **Baseline** | 72.71 ± 14.54 | 68.46 ± 6.16 |
| **3** | 72.49 ± 14.47 | 68.00 ± 5.99 |
| **6** | 70.91 ± 14.36 | 67.67 ± 6.03 |
| **9** | 71.79 ± 14.16 | 68.10 ± 6.09 |

There was a significant interaction between groups over time for 100 m freestyle swimming time trials ($F_{(3, 81)}$ = 10.823; p = 0.00001) (Figure 3.18). The 100 m freestyle swimming time trial improved significantly at week 6 (p = 0.0001) and week 9 (p = 0.0001) for the experimental group and at week 6 (p = 0.0007) for the control group, compared to baseline measurements. In addition, 100 m freestyle time trial for the experimental group, improved significantly at week 6 (p = 0.0001) and week 9 (p = 0.002) compared to week 3. Further, 100 m freestyle time trial for the experimental group, improved significantly at week 9, compared to week 6 (p = 0.0001).

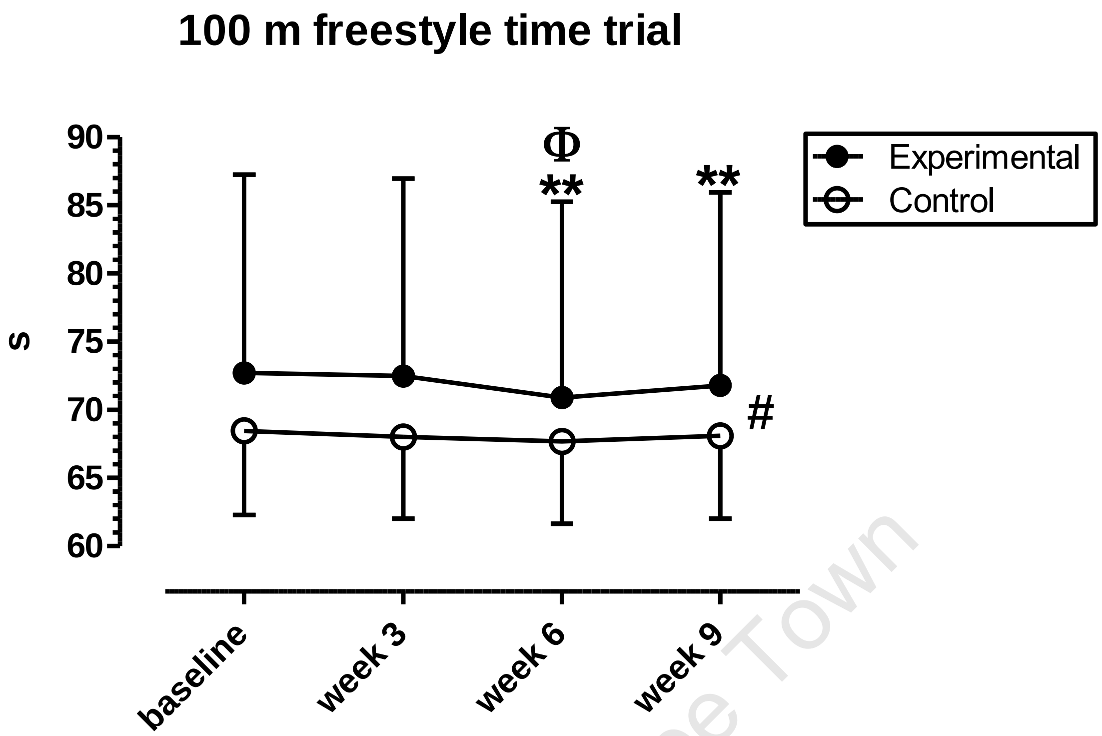



**Figure 3.18:** *100 m freestyle swimming time trials (seconds) of participants in the experimental (n = 15) and control (n = 14) groups. Tests were conducted at baseline and at 3, 6, and 9 weeks. Data are expressed as mean ± SD. Note: a positive change indicates a reduction in 100 m freestyle swimming time trial.*

*Significant differences:*

# interaction of group x time (p = 0.00001)
Φ control group week 6 vs. control group baseline (p = 0.0007)
** experimental group week 6 and week 9 vs. experimental group baseline (p = 0.0001)
** experimental group week 6 vs. experimental group week 3 (p = 0.0001)
** experimental group week 9 vs. experimental group week 3 (p = 0.002)
** experimental group week 9 vs. experimental group week 6 (p = 0.0001)



In addition, there was a significant differences between groups in the percentage change in 100 m freestyle swimming time trials between groups at 6 weeks compared to baseline measurements (t = -3.99; p = 0.0004). However, there were no significant differences between groups in the percentage change in 100 m freestyle swimming time trials at 9 weeks compared to baseline measurements (t = -1.61; p = 0.12).

Finally, 100 m freestyle swimming time trials between groups demonstrated a small effect at week 6 (g = 0.28 s; CI: -0.45 to 1.01 s) and at week 9 (g = 0.32 s; CI: -0.41 to 1.06 s).

## 3.4.8 CORRELATIONAL ANALYSES

### 3.4.8.1 Penn shoulder "satisfaction" and "total pain" scores

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively, to baseline measures in Penn shoulder *"satisfaction"* and *"total pain"* scores for the total, experimental or control groups (Table 3.20).

### 3.4.8.2 Penn shoulder *"function"* and *"total pain"* scores

There were significant negative correlations between the differences of week 3 to baseline measures in Penn shoulder *"function"* and *"total pain"* scores for the total group (r = -0.53; p = 0.003) and the experimental group (r = -0.56; p = 0.03). No significant correlations were found between the differences of week 3 to baseline measures in Penn shoulder *"function"* and *"total pain"* scores for the control group (r = -0.41; p = 0.15). No significant correlations were found between the differences of week 6 to baseline measures in Penn shoulder *"function"* and *"total pain"* scores for the total group (r = -0.37; p = 0.05), experimental group (r = -0.45; p = 0.89) or the control group (r = -0.11; p = 0.70). There were significant negative correlations between the differences of week 9 to baseline measures in Penn shoulder *"function"* and *"total pain"* scores for the total group (r = -0.62; p = 0.0001) and the experimental group (r = -0.83; p = 0.0001). No significant correlations were found between the differences of week 9 to baseline measures in Penn shoulder *"function"* and *"total pain"* scores for the control group (r = -0.33; p = 0.24).

In summary a negative correlation indicates that as pain decreases, satisfaction or function improves. A positive correlation indicates that as pain decreases, satisfaction or function deteriorates. A summary of the relationships between Penn shoulder *"satisfaction"* and *"function"* and Penn shoulder *"total pain"* is provided in Table 3.20.

**Table 3.20:** *Relationships between Penn shoulder "satisfaction" and "function" and Penn shoulder "total pain". Note '+' indicates a positive correlation, and '-' indicates a negative correlation.*

| Correlation | Total Group | | | Experimental Group | | | Control Group | | |
|---|---|---|---|---|---|---|---|---|---|
| **Penn shoulder *"satisfaction"* and *"total pain"*** | **Relationship** | **r** | **p** | **Relationship** | **r** | **p** | **Relationship** | **r** | **P** |
| **Week 3 to baseline** | - | 0.28 | 0.14 | - | 0.21 | 0.45 | - | 0.23 | 0.42 |
| **Week 6 to baseline** | - | 0.30 | 0.11 | - | 0.43 | 0.11 | + | 0.32 | 0.27 |
| **Week 9 to baseline** | - | 0.31 | 0.10 | - | 0.28 | 0.32 | - | 0.17 | 0.55 |
| **Penn shoulder *"function"* and *"total pain"*** | | | | | | | | | |
| **Week 3 to baseline** | - | 0.53 | ***0.003*** | - | 0.56 | ***0.03*** | - | 0.41 | 0.15 |
| **Week 6 to baseline** | - | 0.37 | 0.05 | - | 0.45 | 0.89 | - | 0.11 | 0.70 |
| **Week 9 to baseline** | - | 0.62 | ***0.0001*** | - | 0.83 | 0.0001 | - | 0.33 | 0.24 |

*Note: A negative correlation (-) indicates that as pain decreases, satisfaction or function improves. A positive correlation (+) indicates that as pain decreases, satisfaction or function deteriorates.*

#### 3.4.8.3 Penn shoulder "satisfaction" and "function" scores

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively, to baseline measures in Penn shoulder *"satisfaction"* and *"function"* scores for the total, experimental or control groups (Appendix IX).

#### 3.4.8.4 Penn shoulder *"total pain"* scores and 100 m freestyle swimming time trial

There were no significant correlations between the differences of week 3 to baseline measures in Penn shoulder *"total pain"* scores and 100 m freestyle swimming time trial for the total group (r = -0.32; p = 0.87) and the control group (r = 0.04; p = 0.90). A significant positive correlation for the differences of week 3 to baseline measures in Penn shoulder *"total pain"* scores and 100 m freestyle swimming time trial occurred for the experimental group (r = 0.57; p = 0.03). There were no significant correlations between the differences of week 6 to baseline measures in Penn shoulder *"total pain"* scores and 100 m freestyle swimming time trial for the total group (r = 0.35; p = 0.06), the experimental group (r = 0.33; p = 0.23) or the control group (r = 0.07; p = 0.82). There were no significant correlations between the differences of week 9 to baseline measures in Penn shoulder *"total pain"* scores and 100 m freestyle swimming time trial for the total group (r = 0.43; p = 0.19), the experimental group (r = 0.42; p = 0.12) or the control group (r = 0.26; p = 0.37).

#### 3.4.8.5 Penn shoulder *"satisfaction"* scores and 100 m freestyle swimming time trial

There were no significant correlations between the differences of week 3 to baseline measures in Penn shoulder *"satisfaction"* scores and 100 m freestyle swimming time trial for the total group (r = -0.16; p = 0.39), experimental group (r = -0.20; p = 0.47) and the control group (r = 0.18; p = 0.53). There were no significant correlations between the differences of week 6 to baseline measures in Penn shoulder *"satisfaction"* scores and 100 m freestyle swimming time trial for the total group (r = -0.19; p = 0.33), the experimental group (r = -0.05; p = 0.85) or the control group (r = 0.10; p = 0.74). There was a significant negative correlation between the differences of week 9 to baseline measures in Penn shoulder *"total pain"* scores and 100 m freestyle swimming time trial for the total group (r = -0.39; p = 0.04). No significant correlations between the differences of week 9 to baseline measures in Penn shoulder *"total pain"* scores and 100 m freestyle swimming time trial occurred for the experimental group (r = -0.35; p = 0.20) or the control group (r = -0.05; p = 0.87).

#### 3.4.8.6 Penn shoulder *"function"* scores and 100 m freestyle swimming time trial

There were no significant correlations between the differences of week 3 to baseline measures in Penn shoulder *"function"* scores and 100 m freestyle swimming time trial for the total group (r = -0.20; p = 0.29) and the control group (r = 0.29; p = 0.32).

A significant correlation between the differences of week 3 to baseline measures in Penn shoulder *"function"* scores and 100 m freestyle swimming time trial for the experimental group (r = -0.58; p = 0.02). A significant negative correlation between the differences of week 6 to baseline measures in Penn shoulder *"function"* scores and 100 m freestyle swimming time trial occurred for the total group (r = -0.40; p = 0.03). There were no significant correlations between the differences of week 6 to baseline measures in Penn shoulder *"satisfaction"* scores and 100 m freestyle swimming time trial for the experimental group (r = -0.23; p = 0.41) or the control group (r = -0.35; p = 0.22). A significant negative correlation between the differences of week 9 to baseline measures in Penn shoulder *"function"* scores and 100 m freestyle swimming time trial occurred for the total group (r = -0.37; p = 0.05). There were no significant correlations between the differences of week 9 to baseline measures in Penn shoulder *"satisfaction"* scores and 100 m freestyle swimming time trial for the experimental group (r = -0.38; p = 0.16) or the control group (r = -0.43; p = 0.13).

In summary a negative correlation indicates that as 100 m freestyle swimming time trial improves, pain decreases and satisfaction or function improves. A positive correlation indicates that as 100 m freestyle swimming time trial improves, pain increases and satisfaction or function deteriorates. A summary of the relationships between Penn shoulder *"pain", "satisfaction"* and *"function"* and 100 m freestyle swimming time trial is provided in Table 3.21.

**Table 3.21:** *Relationships between Penn shoulder "total pain", "satisfaction" and "function" and100 m freestyle swimming time trial. Note '+' indicates a positive correlation, and '-' indicates a negative correlation.*

| Correlation | Total Group | | | Experimental Group | | | Control Group | | |
|---|---|---|---|---|---|---|---|---|---|
| **Penn shoulder *"total pain"* and 100 m freestyle swimming time trial** | **Relationship** | **r** | **p** | **Relationship** | **r** | **p** | **Relationship** | **r** | **P** |
| **Week 3 to baseline** | - | 0.32 | 0.87 | + | 0.57 | ***0.03*** | + | 0.04 | 0.90 |
| **Week 6 to baseline** | + | 0.35 | 0.06 | + | 0.33 | 0.23 | + | 0.07 | 0.82 |
| **Week 9 to baseline** | + | 0.43 | 0.19 | + | 0.42 | 0.12 | + | 0.26 | 0.37 |
| **Penn shoulder *"satisfaction"* and 100 m freestyle swimming time trial** | | | | | | | | | |
| **Week 3 to baseline** | - | 0.16 | 0.39 | - | 0.20 | 0.47 | + | 0.18 | 0.53 |
| **Week 6 to baseline** | - | 0.19 | 0.33 | - | 0.05 | 0.85 | + | 0.10 | 0.74 |
| **Week 9 to baseline** | - | 0.39 | ***0.04*** | - | 0.35 | 0.20 | - | 0.05 | 0.87 |
| **Penn shoulder *"function"* and 100 m freestyle swimming time trial** | | | | | | | | | |
| **Week 3 to baseline** | - | 0.20 | 0.29 | - | 0.58 | ***0.02*** | + | 0.29 | 0.32 |
| **Week 6 to baseline** | - | 0.40 | ***0.03*** | - | 0.23 | 0.41 | - | 0.35 | 0.22 |
| **Week 9 to baseline** | - | 0.37 | 0.05 | - | 0.38 | 0.16 | - | 0.43 | 0.13 |

*Note: A negative correlation (-) indicates that as 100 m freestyle swimming time trial improves, pain decreases and satisfaction or function improves. A positive correlation (+) indicates that as 100 m freestyle swimming time trial improves, pain increases and satisfaction or function deteriorates.*

### 3.4.8.7 Glenohumeral flexion ROM and Penn shoulder *"total pain"* score

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively to baseline measures in GH flexion ROM and Penn shoulder *"total pain"* scores for the total, experimental or control groups (Table 3.22).

### 3.4.8.8 Glenohumeral external rotation ROM and Penn shoulder *"total pain"* score

There were no significant correlations between the differences of week 3 to baseline measures in GH external rotation ROM and Penn shoulder *"total pain"* scores for the total group (r = 0.002; p = 0.99), experimental group (r = -0.05; p = 0.85) and the control group (r = 0.15; p = 0.61). There were no significant correlations between the differences of week 6 to baseline measures in GH external rotation ROM and Penn shoulder *"total pain"* scores for the total group (r = 0.30; p = 0.12) and the experimental group (r = 0.31; p = 0.26). A positive significant correlation between the differences of week 6 to baseline measures in GH external rotation ROM and Penn shoulder *"total pain"* scores occurred for the control group (r = 0.76; p = 0.002). There were no significant correlations between the differences of week 9 to baseline measures in GH external rotation ROM and Penn shoulder *"total pain"* scores for the total group (r = 0.22; p = 0.25), experimental group (r = 0.14; p = 0.61) and the control group (r = 0.45; p = 0.12).

### 3.4.8.9 Glenohumeral internal rotation ROM and Penn shoulder *"total pain"* score

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively, to baseline measures in GH internal rotation ROM and Penn shoulder *"total pain"* scores for the total, experimental or control groups (Table 3.22).

### 3.4.8.10 Thoracic rotation ROM and Penn shoulder *"total pain"* score

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively, to baseline measures in thoracic rotation ROM and Penn shoulder *"total pain"* scores for the total, experimental or control groups (Table 3.22).In summary a negative correlation indicates that as Penn shoulder *"total pain"* scores decrease, GH and thoracic rotation ROM improves.  A positive correlation indicates that as Penn shoulder *"total pain"* scores decrease, GH and thoracic rotation ROM decreases. A summary of the relationships between GH and thoracic rotation ROM and Penn shoulder *"total pain"* score is provided in Table 3.22.

**Table 3.22:** *Relationships between GH and thoracic rotation ROM and Penn shoulder "total pain" score. Note: '+' indicates a positive correlation, and '-' indicates a negative correlation.*

| Correlation | Total Group | | | Experimental Group | | | Control Group | | |
|---|---|---|---|---|---|---|---|---|---|
| **GH flexion ROM and Penn shoulder *"total pain"*** | **Relationship** | **r** | **p** | **Relationship** | **r** | **p** | **Relationship** | **r** | **P** |
| **Week 3 to baseline** | + | 0.28 | 0.14 | + | 0.41 | 0.13 | + | 0.21 | 0.46 |
| **Week 6 to baseline** | + | 0.16 | 0.40 | - | 0.25 | 0.37 | + | 0.52 | 0.06 |
| **Week 9 to baseline** | - | 0.01 | 0.95 | + | 0.16 | 0.56 | - | 0.25 | 0.38 |
| **GH external rotation ROM and Penn shoulder *"total pain"*** | | | | | | | | | |
| **Week 3 to baseline** | + | 0.002 | 0.99 | - | 0.05 | 0.85 | + | 0.15 | 0.61 |
| **Week 6 to baseline** | + | 0.03 | 0.12 | + | 0.31 | 0.26 | + | 0.76 | ***0.002*** |
| **Week 9 to baseline** | + | 0.22 | 0.25 | + | 0.14 | 0.61 | + | 0.45 | 0.12 |
| **GH internal rotation ROM and Penn shoulder *"total pain"*** | | | | | | | | | |
| **Week 3 to baseline** | - | 0.15 | 0.43 | - | 0.005 | 0.99 | - | 0.24 | 0.41 |
| **Week 6 to baseline** | + | 0.19 | 0.33 | + | 0.26 | 0.35 | + | 0.01 | 0.97 |
| **Week 9 to baseline** | + | 0.34 | 0.07 | + | 0.48 | 0.07 | + | 0.24 | 0.42 |
| **Thoracic rotation ROM and Penn shoulder *"total pain"*** | | | | | | | | | |
| **Week 3 to baseline** | - | 0.17 | 0.39 | - | 0.01 | 0.97 | - | 0.30 | 0.30 |
| **Week 6 to baseline** | - | 0.06 | 0.76 | + | 0.22 | 0.43 | - | 0.36 | 0.21 |
| **Week 9 to baseline** | - | 0.26 | 0.18 | - | 0.15 | 0.58 | - | 0.33 | 0.26 |

*Note: A negative correlation indicates that as Penn shoulder "total pain" scores decrease, GH and thoracic rotation ROM improves. A positive correlation indicates that as Penn shoulder "total pain" scores decrease, GH and thoracic rotation ROM decreases.*

#### 3.4.8.11 Glenohumeral flexion and external rotation ROM

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively, to baseline measures in GH flexion and external rotation ROM for the total, experimental or control groups (Appendix IX).

#### 3.4.8.12 Glenohumeral internal rotation ROM and external rotation ROM

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively, to baseline measures in GH internal and external rotation ROM for the total, experimental or control groups (Appendix IX).

#### 3.4.8.13 Glenohumeral flexion ROM and thoracic rotation ROM

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively to baseline measures in GH flexion ROM and thoracic rotation ROM for the total, experimental or control groups (Appendix IX).

#### 3.4.8.14 Glenohumeral external rotation ROM and thoracic rotation ROM

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively to baseline measures in GH external rotation ROM and thoracic rotation ROM for the total, experimental or control groups (Appendix IX).

#### 3.4.8.15 Glenohumeral internal rotation ROM and Penn shoulder *"function"* score

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively, to baseline measures in GH internal rotation ROM and Penn shoulder *"function"* scores for the total, experimental or control groups (Appendix IX).

#### 3.4.8.16 Penn shoulder *"total pain"* and lateral scapula slide test *"hands on hips"* position

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively, to baseline measures in Penn shoulder *"total pain"* scores and lateral scapula slide test *"Hands on hips"* position for the total, experimental or control groups (Appendix IX).

### 3.4.8.17 Thoracic rotation ROM and lateral scapula slide test *"hands on hips"* position

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively, to baseline measures in thoracic rotation ROM and lateral scapula slide test *"Hands on hips"* for the total, experimental or control groups (Appendix IX).

### 3.4.8.18 Glenohumeral flexion ROM and 100 m freestyle swimming time trial

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively to baseline measures in GH flexion ROM and 100 m swimming time trial for the total, experimental or control groups (Table 3.23).

### 3.4.8.19 Glenohumeral external rotation ROM and 100 m freestyle swimming time trial

There were no significant correlations between the differences of week 3 to baseline measures in GH external rotation ROM and 100 m swimming time trial for the total group (r = 0.10; p = 0.59) and experimental group (r = -0.35; p = 0.90). A positive significant correlation between the differences of week 3 to baseline measures in GH external rotation ROM and 100 m freestyle swimming time trial occurred for the control group (r = 0.62; p = 0.02). There were no significant correlations between the differences of week 6 to baseline measures in GH external rotation ROM and 100 m swimming time trial for the total group (r = - 0.21; p = 0.28), experimental group (r = 0.25; p = 0.37) and the control group (r = - 0.17; p = 0.57) . There were no significant correlations between the differences of week 9 to baseline measures in GH external rotation ROM and 100 m swimming time trial for the total group (r = 0.07; p = 0.70), experimental group (r = 0.19; p = 0.51) and the control group (r = 0.03; p = 0.92).

### 3.4.8.20 Glenohumeral internal rotation ROM and 100 m freestyle swimming time trial

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively to baseline measures in GH internal rotation ROM and 100 m swimming time trial for the total, experimental or control groups (Table 3.23).

#### 3.4.8.21 Thoracic rotation ROM and 100 m freestyle swimming time trial

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively to baseline measures in thoracic rotation ROM and 100 m swimming time trial for the total, experimental or control groups. A summary of the relationships between GH flexion ROM; GH external rotation ROM; GH internal rotation ROM; thoracic rotation ROM, and 100 m freestyle swimming time trial is provided in Table 3.23.

#### 3.4.8.22 Lateral scapula slide test *“hands on hips”* position and 100 m freestyle time trial

There were no significant correlations between the differences of week 3, 6 or 9 measures respectively to baseline measures in lateral scapula slide test *“hands on hips”* position and 100 m swimming time trial for the total, experimental or control groups (Appendix IX).

**Table 3.23:** *Relationships between GH and thoracic rotation ROM and 100 m freestyle swimming time trial. Note: '+' indicates a positive correlation, and '-' indicates a negative correlation.*

| Correlation | Total Group | | | Experimental Group | | | Control Group | | |
|---|---|---|---|---|---|---|---|---|---|
| **GH flexion ROM and 100 m freestyle swimming time trial** | **Relationship** | **r** | **p** | **Relationship** | **r** | **p** | **Relationship** | **r** | **p** |
| **Week 3 to baseline** | + | 0.25 | 0.20 | + | 0.50 | 0.06 | + | 0.01 | 0.97 |
| **Week 6 to baseline** | + | 0.13 | 0.50 | - | 0.02 | 0.95 | + | 0.44 | 0.12 |
| **Week 9 to baseline** | + | 0.21 | 0.27 | + | 0.22 | 0.43 | + | 0.14 | 0.63 |
| **GH external rotation ROM and 100 m freestyle swimming time trial** | | | | | | | | | |
| **Week 3 to baseline** | + | 0.10 | 0.95 | - | 0.03 | 0.90 | + | 0.62 | ***0.02*** |
| **Week 6 to baseline** | - | 0.21 | 0.28 | + | 0.25 | 0.37 | - | 0.17 | 0.57 |
| **Week 9 to baseline** | + | 0.07 | 0.70 | + | 0.19 | 0.51 | + | 0.03 | 0.91 |
| **GH internal rotation ROM and 100 m freestyle swimming time trial** | | | | | | | | | |
| **Week 3 to baseline** | + | 0.06 | 0.76 | + | 0.35 | 0.20 | - | 0.13 | 0.65 |
| **Week 6 to baseline** | + | 0.30 | 0.12 | + | 0.25 | 0.38 | - | 0.03 | 0.91 |
| **Week 9 to baseline** | - | 0.004 | 0.98 | + | 0.0.6 | 0.82 | - | 0.46 | 0.10 |
| **Thoracic rotation ROM and 100 m freestyle swimming time trial** | | | | | | | | | |
| **Week 3 to baseline** | + | 0.02 | 0.91 | - | 0.09 | 0.76 | + | 0.15 | 0.61 |
| **Week 6 to baseline** | - | 0.04 | 0.85 | + | 0.10 | 0.72 | - | 0.35 | 0.23 |
| **Week 9 to baseline** | + | 0.20 | 0.29 | + | 0.39 | 0.15 | - | 0.18 | 0.54 |

*Note: A negative correlation indicates that 100 m freestyle swimming time trial improves, GH and thoracic rotation ROM improves. A positive correlation indicates that as100 m freestyle swimming time trial improves, GH and thoracic rotation ROM decreases.*

### 3.4.9 SUMMARY OF RESULTS

In summary, the main findings of this study were that a six week rehabilitation programme significantly reduced Penn shoulder *"total pain"* score (p =0.00001); improved Penn shoulder *"function"* score (p = 0.0003), GH flexion ROM (p = 0.00001), GH internal rotation ROM (p = 0.00001), thoracic rotation ROM (p = 0.00001); and enhanced scapula stability (Lateral scapula slide test: *"Arm by side"* p = 0.00002; *"Hands on hips"* p = 0.00001; *"Arms at 90° GH abduction"* p = 0.007). There were significant interactions between groups over time for Penn shoulder *"satisfaction"* scores (p = 0.02); GH external rotation ROM (p = 0.01) and 100 m freestyle swimming time trial (p = 0.00001). However, these significant interactions occurred due to significant differences in the experimental group, mostly compared to baseline measures, but sometimes compared to week 3 measures.

Clinically, medium effects were reported for GH external rotation ROM (g = 0.66), GH internal rotation ROM (g = -0.68); and lateral scapula slide test: *"Hands on hips"* (g = 0.46) and *"Arms at 90° GH abduction"* (g = 0.53) at week 6. These results were maintained as small effects at week 9, for GH internal rotation ROM (g = -0.36) and lateral scapula slide test: *"Arms at 90° GH abduction"* (g = - 0.15). Small effects were reported for Penn shoulder *"pain at rest"* (g = 0.20), *"pain with everyday activity"* (g = -0.19), *"pain with strenuous activity"* (g = -0.36), *"satisfaction"* (g = -0.15) and *"function"* (g = 0.23); GH flexion ROM (g = -0.38); thoracic rotation ROM (g = -0.35) and 100 m freestyle swimming time trial at week 6 (g = 0.28). These results were sustained as small effects at week 9, with the exception of Penn shoulder *"pain at rest"* (g = -0.03), *"satisfaction"* (g = -0.12) and *"function"* (g = -0.03) which demonstrated negligible effects. No clinical effect for lateral scapula slide test: *"Arm by side"* was recorded.

The total group demonstrated significant negative correlations between Penn shoulder *"function"* and *"total pain"* scores at week 3 (p = 0.003) and week 9 (p = 0.0001); Penn shoulder *"function"* and 100 m freestyle swimming time trial at week 6 (p = 0.03); and Penn shoulder *"satisfaction"* and 100 m freestyle swimming time trial at week 9 (p = 0.04) compared to baseline measures. The experimental group demonstrated a significant positive correlation between Penn shoulder *"total pain"* and 100 m freestyle swimming time trial (p = 0.03); and significant negative correlations between Penn shoulder *"function"* and *"total pain"* (p = 0.03), and Penn shoulder *"function"* and 100 m freestyle swimming time trial (p = 0.02) at week 3 compared to baseline measures. Lastly, the control group demonstrated a significant positive correlations between GH external rotation ROM and 100 m freestyle swimming time trial at week 3 (p = 0.02); and GH external rotation ROM and Penn shoulder *"total pain"* at week 6 (p = 0.002) compared to baseline measures.

## 3.5 DISCUSSION

The use of rehabilitative exercises in the treatment of shoulder impingement has been extensively investigated and discussed. Studies have shown that improvements in pain[19,86,101], level of satisfaction[86], GH ROM[19,86], shoulder strength[19,101], function[19,86,101], and forward shoulder posture[28,32] may be achieved through a variety of rehabilitative exercises performed for six[19,32,101] to eight weeks[101]. Current literature advocates rehabilitation of the rotator cuff and scapula musculature[19,24,31-33,86]; and recommends the inclusion of thoracic posture rehabilitation[21,28,29,43,51,73,74] in the management of shoulder impingement. However, there is minimal consensus regarding optimal rehabilitation protocols for the management of shoulder impingement. Further, current evidence is based on studies that investigated participants diagnosed with shoulder impingement and/or disorders from the general population[19,86,100,101,106]. Importantly, only one study has been conducted on competitive swimmers with healthy shoulders[32]. To date and to the knowledge of this author, no study has investigated the effect of scapulothoracic rehabilitation on shoulder pain in competitive swimmers. Considering the lack of evidence, a scapulothoracic rehabilitation programme (experimental group) was developed and compared to a standard rehabilitation programme (control group). The scapulothoracic rehabilitation programme incorporated thoracic posture, rotator cuff and scapula musculature rehabilitation exercises. The standard rehabilitation programme included rotator cuff and scapula musculature rehabilitation. In this study, both rehabilitation programmes resulted in significant improvements in pain, satisfaction, function, GH and thoracic rotation ROM, scapula stability and 100 m freestyle swimming time trial. The failure to detect differences between groups may be attributed to the small dose effect of the additional exercises in the scapulothoracic rehabilitation programme.



### 3.5.1 PARTICIPANTS

#### 3.5.1.1 Sample Size

Recent studies that investigated the effects of rehabilitation and/or manual therapy in the treatment of shoulder impingement had sample sizes of between 14 and 52 participants[19,32,86,100,101,106]. Five of these studies included participants diagnosed with shoulder impingement and/or disorders from the general population[5,19,100,101,106], whereas one study examined competitive swimmers with healthy shoulders[32]. Further, a variety of rehabilitation exercises and manual therapy techniques have been used in these studies, which limits the potential for accurate and objective comparison between studies.

It is thus difficult to deduce whether the beneficial results obtained in these studies could be applicable to competitive swimmers with shoulder pain due to impingement. Therefore participants included in this study were elite level swimmers with unilateral shoulder impingement. It is recognised that, although the sample size was sufficient to ensure statistical power (Section 3.2.2, page 55), a larger sample size would have allowed for better representation of the effect of scapulothoracic rehabilitation on shoulder impingement in swimmers. Unfortunately, the number of swimmers that fulfilled the criteria to participate in this study was small.

#### 3.5.1.2 Descriptive Characteristics

There were no significant differences between groups in age, stature or log book compliance with home-based rehabilitation exercises. There was a similar representation of gender, painful shoulder, preferred breathing side and positive impingement test in both groups. Current literature highlights that swimmers are more likely to develop shoulder impingement on the breathing side[12]. In this study, 25 participants reported a preferred breathing side, compared to four participants with no reported preferred breathing side.

#### 3.5.1.3 Baseline Measurements

No significant differences occurred in baseline measurements of pain, function, GH and thoracic rotation ROM, scapula stability, pectoralis minor muscle length and 100 m freestyle time trial between groups. However, there was a significant difference in the baseline measurement of Penn shoulder *"satisfaction"* scores between groups (Table 3.3, page 68).

The experimental group reported a significantly lower Penn shoulder *"satisfaction"* score than the control group at baseline measurement, indicating a greater level of subjective dissatisfaction with the current state of their shoulder condition. This may have resulted in a higher level of critical analysis when completing the self-report Penn shoulder score in the experimental group. However, Leggin et al[15] determined that a low baseline Penn shoulder score, irrespective of the sub-scale; would allow for greater prospective change than a higher baseline score. Thus, the potential for change in Penn shoulder *"satisfaction"* scores may have been easier to achieve in the experimental group, compared to the control group.

### 3.5.2 THE PENN SHOULDER SCORE

This study showed a significant improvement in Penn shoulder *"pain"* (Section 3.4.2.1, page 70); "*satisfaction"* (Figure 3.7, page 78); and *"function"* (Figure 3.8, page 80) scores over time. Clinically, a six week rehabilitation programme had a small effect on Penn shoulder *"pain", "satisfaction"* and *"function"*. The effect on Penn shoulder *"pain"* was only sustained for *"pain with everyday activity"* and *"pain with strenuous activity"* a follow-up three weeks after completion of the rehabilitation programmes. The effect on Penn shoulder *"satisfaction"* and *"function"* was not sustained at a follow-up three weeks after the completion of the rehabilitation programmes. No significant correlations were found for the differences in measurements between Penn shoulder *"satisfaction"* and *"total pain"* scores or Penn shoulder *"satisfaction"* and *"function"* scores. However, significant negative correlations between the differences in measurement for Penn shoulder *"function"* and *"total pain"* scores were found for the total group at week 3 and 9; and the experimental group at week 3 (Table 3.20, page 102). In addition, no significant correlation was determined for the differences in measurements for GH internal rotation ROM and Penn Shoulder *"function"* scores (Appendix IX). Therefore, participants' Penn shoulder *"satisfaction"* scores may be a factor influenced by variables other than pain and function.

Studies have shown that a significant improvement in pain and function may be achieved through a variety of rehabilitative exercises performed for six to eight weeks[19,86,100,101]. Bang et al[19] demonstrated a significant decrease in pain (VAS) and increase in function (functional assessment questionnaire) for manual therapy plus exercise and exercise only groups. However, the manual therapy plus exercise group showed significantly more improvement in pain and function than the exercise only group. Similarly, Senbursa et al[100] demonstrated a significant decrease in pain at rest and pain with motion (VAS) and increase in function (functional assessment questionnaire) for the manual therapy plus exercise and exercise only groups. The manual therapy plus exercise group showed significantly greater improvement in pain at rest and function than the exercise only group. However similar significant improvement in pain with motion occurred between groups[100]. Further, Wang et al[101] showed a significant decrease in pain (VAS) and improvement in Flexilevel Scale of Shoulder Function score, irrespective of whether participants were provided with customised or standard rehabilitation exercises in the treatment of shoulder disorders.

The findings of this study are supported by McClure et al[86], where the Penn Shoulder Score was used to determine the effects of a six week rehabilitation programme on pain, satisfaction and function in participants with shoulder impingement. A significant decrease in pain; and significant increase in satisfaction and function occurred over time, in participants with shoulder impingement.

A significant increase in Penn shoulder *“satisfaction”* scores occurred in the experimental group when compared baseline measures, at week 3. This may be related to the experimental group reporting significantly lower Penn shoulder *“satisfaction”* scores at baseline measurement, when compared to the control group (Table 3.3, page 68). As a result, the experimental group may have had greater potential to improve Penn shoulder *“satisfaction”* scores, than the control group. Further, McClure et al[86] determined a significant negative correlation between the Penn Shoulder Score and GH internal rotation ROM, which indicated that an improvement in GH internal rotation ROM was associated with an improvement in functional scores. However, in this study there were no significant correlations between the differences in measurements of the Penn shoulder *“function”* score and GH internal rotation ROM (Appendix IX).

The significant negative correlations for the differences in measurements between the Penn shoulder *“function”* and *“total pain”* scores determined for the total group at week 3 and 9; and the experimental group at week 3 of this study (Table 3.20, page 102), support the small clinical effects obtained. The correlations suggest an inversely proportional relationship between Penn shoulder *“total pain”* and *“function”* scores. Thus as Penn shoulder *“total pain”* scores reduced, Penn shoulder *“function”* scores improved. Further, pain within the shoulder girdle leads to inhibition of the scapula stabilising muscles[3,6,69,70]. The serratus anterior and inferior trapezius are primarily inhibited in shoulder impingement, resulting in decreased scapula upward rotation and posterior tilting[3,6,21,24,51,51,69,70,72]. An associated reduction in GH flexion ROM occurs[6]. Thus pain inhibits ROM and function. Therefore the small clinical effects obtained for Penn shoulder *“pain”*, *“satisfaction”* and *“function”* were lower than expected. It is recommended that rehabilitation programmes be supplemented with manual therapy in clinical practice to enhance pain reduction[10,19,31,100]. Further, the long term effects and sustainability of these results are unknown and needs to be investigated.

### 3.5.3 GLENOHUMERAL ROM

This study showed significant improvements in GH flexion ROM (Figure 3.9, page 82), GH internal rotation ROM (Figure 3.11, page 86), GH external rotation ROM (Figure 3.10, page 84) and total GH rotation ROM (Figure 3.12, page 88) over time. Clinically, a six week rehabilitation programme had a small effect on GH flexion ROM and a medium effect on GH external and internal rotation ROM. The small effect on GH flexion ROM and a small effect on GH internal rotation ROM were sustained at a follow-up three weeks after completion of the rehabilitation programme. These small-medium clinical effects of rehabilitation obtained for GH ROM are greater than expected, considering the small-negligible effects of rehabilitation on the Penn shoulder score.

It is possible that the effect of pain on the scapula stabilising muscles outweighed the effect of pain on GH ROM, and this theory is supported by the lack of significant correlations between the respective GH ROM and Penn shoulder *"total pain"* scores. It may thus be deduced that to obtain small-medium effects, rehabilitation programmes should be enhanced by manual therapy[10,19,31,100] and performed for a minimum of six weeks[19,32,101]. The possibility of obtaining larger clinical effects by following rehabilitation programmes for nine to twelve weeks is not known. In addition, there were no significant correlations were for the differences in measurements between GH flexion ROM and Penn shoulder *"total pain"* scores (Appendix IX) or GH internal rotation ROM and Penn shoulder *"total pain"* scores (Appendix IX). However, a significant positive correlation between the differences in measurement for GH external rotation ROM and Penn shoulder *"total pain"* scores were found for the control group at week 6 (Table 3.22, page 107). Further, no significant correlations were found for the differences in measurements between GH flexion ROM and GH external rotation ROM (Appendix IX) or GH internal rotation ROM and GH external rotation ROM (Appendix IX). The results of this study concur with current literature that rehabilitation is effective in improving GH ROM in shoulder impingement. Studies have investigated the effects of rehabilitation protocols on GH ROM, with varying results. Wang et al[101] illustrated that GH abduction ROM improved but not significantly after eight weeks of either customized or standard rehabilitation exercises. Further McClure et al[86] determined that a six week rehabilitation programme significantly improved GH internal rotation ROM and GH external rotation ROM. Lastly, Conroy et al[106] found a three week rehabilitation programme with or without manual therapy to be effective in significantly improving GH abduction ROM, GH flexion ROM, GH external rotation ROM and GH internal rotation ROM. These results may possibly be attributed to a reduction in pain and/or the functional rehabilitative exercises (shoulder dump or lawnmower and sternal lift or robbery exercise).

A significant improvement in Penn shoulder *"total pain"* scores; GH flexion ROM; GH external, internal and total rotation ROM occurred in this study. The reduction in pain may have facilitated the scapula stabilising muscles, scapula kinesis and thus GH ROM (as discussed in Section 3.5.2, page 115). Further, full range of GH flexion requires GH external rotation during normal scapulohumeral rhythm[21,43,51].

It may thus be postulated that an improvement in GH flexion should produce associated improvements in GH external rotation range of movement. However, no significant correlations were found between the differences in GH flexion ROM and GH external rotation ROM in this study (Appendix IX). Overhead athletes are also susceptible to adaptations in GH rotational ROM, where GH external rotation ROM increases and GH internal rotation ROM decreases[17,91,92]. However, this study showed improvements in GH external and internal rotation ROM over time following rehabilitation. Further, no significant correlations were determined between the differences of week 3, 6 and 9 to baseline measurements of GH internal and external rotation ROM (Appendix IX). Thus, in this study total GH rotational ROM increased as both GH external and internal rotation ROM improved. The improvement in total GH rotation ROM may be beneficial in reducing the risk of shoulder impingement[12, 20]. However, there was only a significant positive correlation between the differences in measurements for GH external rotation ROM and Penn shoulder *"total pain"* scores for the control group, at week 6 (Table 3.22, page 107). Thus, as Penn shoulder *"total pain"* scores improved, GH external rotation ROM decreased or remained unchanged.

A significant increase in GH external rotation ROM occurred in the experimental group when compared to baseline measures, at week 6. This may be related to the control group performing a single exercise (scaption with external rotation) for GH external rotation, as opposed to the two exercises (scaption with external rotation and shoulder dump) performed in the experimental group. Further, GH external rotation ROM obtained when performing the scaption with external rotation exercise could be less than that obtained in the shoulder dump exercise. The shoulder dump exercise utilises whole body movement and extensive biomechanical coupling occurs during the execution of this exercise[3,4,6,92,109]. In addition, the attainment of a significant improvement in GH external rotation ROM in the experimental group may also be attributed to the sternal lift which utilises reciprocal thoracic flexion-extension with emphasis on thoracic extension and scapula retraction and posterior tilt[4]. Thoracic extension has been coupled to unilateral arm elevation[26,27,54]. Normal scapulohumeral rhythm is required for arm elevation and entails scapula upward rotation and posterior tilting, together with GH external rotation to allow the greater tuberosity to clear the acromion[3,5,21,43,51]. Therefore, the sternal lift exercise may have improved scapula kinesis and allowed for greater GH external rotation to occur.

### 3.5.4 THORACIC ROTATION ROM

This study showed no significant interaction between groups for thoracic rotation. However, there was a significant improvement in thoracic rotation ROM over time (Figure 3.13, page 90).

Clinically, a six week rehabilitation programme had a small effect on thoracic rotation ROM, which was sustained at a follow-up three weeks after completion of the rehabilitation programme.

This small clinical effect is consistent with the small-medium effect of rehabilitation on GH ROM (Section 3.5.3, page 116) and small-negligible effect of rehabilitation on Penn shoulder score (Section 3.5.2, page 115). However, the small effect for both scapulothoracic and standard rehabilitation programmes was not expected.

A plausible explanation for this may be that both rehabilitation programmes enhanced scapula kinesis and GH flexion ROM. No significant correlations were determined between the differences in measurements for thoracic rotation ROM and Penn Shoulder *"total pain"* scores (Appendix IX); thoracic rotation ROM and GH flexion ROM (Appendix IX); thoracic rotation ROM and GH external rotation ROM (Appendix IX); and thoracic rotation ROM and lateral scapula slide test *"hands on hips"* position (Appendix IX). However, Crosbie et al[26] found a significant correlation between upper thoracic rotation ROM and scapula kinesis, and GH flexion ROM. Additionally, uncertainty exists regarding the long term effects and sustainability of rehabilitation on thoracic rotation ROM.

The inclusion of thoracic posture rehabilitation in the treatment of shoulder impingement has been recommended in numerous studies, but the precise rehabilitative exercises required have not been specified[21,28,29,43,51,73,74]. Cervical and thoracic posture partly determines scapula orientation, thus ensuring optimal shoulder ROM and upper limb function[28,43,73]. Kluemper et al[32] established that a six week rehabilitation programme significantly improved thoracic kyphosis angle (forward shoulder posture) in competitive swimmers. An excessively large thoracic kyphosis (slouched posture) may be associated with reduced thoracic extension ROM. Further, an associated reduction in thoracic rotation[26,27,54] ipsilateral thoracic lateral flexion[26,27,53,55], upward scapula rotation[26] and range of unilateral arm elevation[26,27,53,54] occurs due to biomechanical coupling between the thoracic spine and shoulder joint complex. This finding was supported by Bullock et al[28], where GH flexion ROM was significantly greater in an erect posture, compared to a slouched posture. Similarly, Kebaetse et al[29] examined thoracic position effect on shoulder range of motion, strength and three dimensional scapular kinematics.

Shoulder elevation ROM was significantly greater in an erect posture compared to a slouch posture. In addition, when performing GH flexion from 90˚ to 180˚, scapula elevation was significantly greater; scapula upward rotation was significantly lower; and scapula posterior tilt was significantly lower in the slouched posture compared to an erect posture. Further, Crosbie et al[26] showed that upper thoracic rotation ROM was significantly correlated with scapula upward rotation and scapular external rotation. Thus an improvement in thoracic rotation ROM may be associated with a simultaneous increase in GH flexion ROM and improvement in scapula kinesis.

The results of this study contrast current literature, as there were no significant correlations between the differences in measurements for thoracic rotation ROM and GH flexion ROM (Appendix IX). Further, there were no significant correlations between differences in measurements for thoracic rotation ROM and lateral scapula slide test *"hands on hips"* position (Appendix IX). These contrasting results may be due to the method used to measure thoracic rotation. This method was derived from Blanch[10] and adapted by supporting the swimmers' arms on a 270˚ half-moon chalk board, at 90˚ GH flexion to exclude the possibility of losing the GH joint position. Participants were instructed to rotate to the left and right side, three times and an average of the sum of the measurements was taken. As each ROM was marked on the board and only measured by a goniometer at completion of all three measurements, contamination of measurements may have occurred, due to participants having a visual mark to reach or supersede. Further, the mobilisation effect of the repeated rotation on the thoracic spine is unknown.

Stewart et al[53] and Willems et al[55], determined that improvements in thoracic rotation may result in a simultaneous improvements in thoracic lateral flexion. These improvements in biomechanics may increase the tilt angle obtained by swimmers during the freestyle stroke. Yanai et al[12] determined that by increasing a swimmer's tilt angle, the GH flexion ROM required at the initial catch phase of swimming is reduced. Thoracic lateral flexion angle was not measured within this study, as the author believed thoracic rotation to be more beneficial to swimming stroke biomechanics due to the biomechanical coupling nature of the thoracic spine and shoulder joint complex. Thus, it is recommended that future research should include the assessment of thoracic lateral flexion, and swimming stroke biomechanics to determine the effects of a rehabilitation programme on swimming stroke mechanics. Further, the relationship between thoracic lateral flexion, thoracic rotation, tilt angle and swimming stroke biomechanics should be investigated.

### 3.5.5 LATERAL SCAPULA SLIDE TEST

This study measured scapula dyskinesis using Kibler's lateral scapula slide test[3] and showed significant improvements in scapula kinesis at six weeks post intervention in *"arm by side"* , *"Hands on hips"* and *"Arms at 90° of GH abduction"* in both the experimental and control groups. Clinically, a six week rehabilitation programme had a medium effect on lateral scapula slide *"Hands on hips"* and *"Arms at 90° GH abduction"*. A sustained small effect at a follow-up three weeks after completion of the rehabilitation programme occurred for lateral scapula slide *"Arms at 90° GH abduction"* position. The medium clinical effect of rehabilitation on scapula stability is greater than expected, as the effects obtained for Penn shoulder score were small-negligible (Section 3.5.2, page 115).

A small-medium effect was also obtained for GH ROM (Section 3.5.3, page 116) and thoracic rotation ROM (Section 3.5.4, page 118) respectively. Pain in the shoulder girdle results in scapula dyskinesis[3,6,21,24,51,51,69,70,72]. However, in this study no significant correlations between scapula kinesis and pain were determined (see below). Further, the significant correlation between upper thoracic rotation ROM and scapula kinesis as determined by Crosbie et al[26], is not supported in this study. Finally, the sustainability of these results over an extended period of time is unknown. No significant correlations were found for differences in measurement between lateral scapula slide test *"Hands on hips"* position and Penn shoulder *"total pain"* score (Appendix IX); or lateral scapula slide test *"Hand on hips"* position and thoracic rotation ROM (Appendix IX).

Scapula dyskinesis is associated with muscle inhibition[3,6,21,24,51,71] and excessive soft tissue tightness[11,17,21,51,107]. Numerous studies have investigated the EMG activity of the scapula musculature to determine the most beneficial strengthening exercises for scapulothoracic rehabilitation[6,10,34,92,101,110-113]. McClure et al[86] examined the effects of a progressive six week rehabilitation programme on shoulder function and three dimensional kinematics in participants with shoulder impingement. No differences in scapula kinematics were reported before and after the six week rehabilitation programme. The six week rehabilitation programme included a single scapulothoracic rehabilitation exercise, rotator cuff rehabilitation exercises, flexibility exercises and upper quarter postural awareness. Further, scapula retraction was only introduced to participants during the second phase of the progressive six week rehabilitation programme. To date, scapula dyskinesis has not been significantly improved through rehabilitation[51,86]. The results of this study differ from those demonstrated by McClure et al[86]. The differences in findings may possibly be attributed to the inclusion of four scapulothoracic rehabilitative exercises in both the experimental and control group programmes of this study.

Further, these exercises (prone push-up plus, rowing, scaption with GH external rotation and prone flexion at 135° GH abduction with GH external rotation exercise) were selected as they focus on low muscle activation ratios between the upper trapezius/serratus anterior and upper trapezius/lower trapezius muscles[34,92,110-113]. According to Kibler[3], serratus anterior and lower trapezius muscle activity is demonstrated in the *"arm by side"* and *"hands on hips"* positions; while 40% activity of the serratus anterior, lower trapezius, upper trapezius and rhomboid muscles is demonstrated in the *"arms at 90° of GH abduction"* position. It is recommended that future research examines the effects of scapulothoracic rehabilitation on scapula muscle activity and kinematics.

### 3.5.6 PECTORALIS MINOR MUSCLE LENGTH

This study demonstrated a significant increase in pectoralis minor muscle length at week 9 (Figure 3.17, page 98), following the termination of the rehabilitation programmes at the end of week 6. Clinically, a six week rehabilitation programme illustrated a negligible effect at week 6 and an inadequate small effect at a follow-up three weeks after completion of the rehabilitation programmes.

Excessive soft tissue tightness in the pectoralis minor muscle increases scapula internal rotation and anterior tilting[17,21,51]. Borstad et al[107] determined the unilateral corner stretch to be the most effective means of stretching the pectoralis minor muscle. Current literature advocates that flexibility exercises should be performed daily, held for 15 to 30 seconds and repeated three to five times, with a 10 second rest between repetitions[11,19,31,32,86]. In this study, both rehabilitation programmes included the unilateral corner stretch. Participants performed this stretch three times a week, for two sets of 30 second holds. These stretching parameters were selected as swimmers invariably stretch prior to every training session. Although the inclusion of the unilateral corner stretch in their stretch prior to training was recommended, compliance (see Section 3.5.8, page 124) could not be assured. The difference in stretching parameters used in this study compared to those recommended in current literature could explain the significant reduction in pectoralis minor muscle length. Further, the validity of the method used to measure pectoralis minor muscle length, as described by Lewis et al[99], is unknown. Consequently, a functional length of the pectoralis minor muscle may be of greater value than an improvement in pectoralis minor muscle length. It is recommended that future studies investigate the effect of scapulothoracic rehabilitation on the length-tension relationships of the shoulder girdle complex. In addition, the specific pectoralis minor muscle length required to generate optimal force and/or strength should be considered, and the potential biomechanical advantages of a short pectoralis minor muscle in swimmers require further investigation.

### 3.5.7 100 M FREESTYLE SWIMMING TIME TRIAL

This study assessed swimming performance by means of a 100 m freestyle time trial. Significant improvements in 100 m freestyle time trial occurred over time (Figure 3.18, page 100). Clinically, a six week rehabilitation programme illustrated a small effect at week 6, which was sustained at a follow-up assessment three weeks after completion of the rehabilitation programmes. This effect was unexpected, as there is a lack of evidence regarding the effect of rehabilitation on swimming performance. However, the small clinical effect of rehabilitation on 100 m freestyle swimming time trial is consistent with those effects obtained for the Penn shoulder score, GH ROM (Section 3.5.3, page 116), thoracic rotation ROM (Section 3.5.4, page 118) and lateral scapula slide test (Section 3.5.5, page 120). Due to the short duration of this study, the long term effects of these results are unknown. It is thus recommended that clinicians include rehabilitation in the treatment and prevention of shoulder impingement in competitive swimmers.

There was a significant positive correlation between the differences in measurement for 100 m freestyle swimming time trial and Penn Shoulder *"total pain"* scores, and a significant negative correlation between differences in measurements for 100 m freestyle swimming time trial and Penn shoulder *"function"* scores in the experimental group at week 3 (Table 3.21, page 105). In addition, there was a significant negative correlation between the differences in measurement for 100 m freestyle swimming time trial and Penn shoulder *"satisfaction"* scores for the total group at week 9 (Table 3.21, page 105). Lastly, there was a significant positive correlation between the differences in measurement for GH external rotation ROM and 100 m swimming time trial in the control group at week 3 (Table 3.23, page 111). To date, no previous study has investigated the effect of scapulothoracic rehabilitation on performance in competitive swimmers with shoulder impingement. Considering this lack of evidence, a 100 m freestyle time trial (measured by hand held stop watch) was selected as the performance parameter.

The findings of this study suggest that a six week rehabilitation programme significantly improves 100 m freestyle swimming time trial in competitive swimmers with shoulder impingement. Penn shoulder *"function"* scores were negatively correlated with 100 m freestyle swimming time trial for the experimental group, at week 3. However, 100 m freestyle swimming time trial improved significantly for the experimental group at week 6, compared to baseline measures.

The delay in improvement in performance may be due to the fact that participants still experienced sufficient shoulder pain to interfere with training and/or competition, illustrated by the significant positive correlation between Penn shoulder *"total pain"* scores and 100 m freestyle swimming time trial for the experimental group, at week 3. Further, a significant positive correlation occurred between GH external rotation ROM and 100 m freestyle swimming time trial for the control group, at week 3. This indicates that participants following the standard rehabilitation programme initially experienced a reduction in GH external rotation ROM. These findings highlight the potential adverse side-effects of rehabilitation, as participants may be returning to full training and/or competition pre-maturely.

The 100 m freestyle swimming time trial was measured with a hand held stop watch which may have resulted in measurement error. Potential measurement error was reduced by taking the average of two 100 m freestyle time trials. Measurement errors would also have been consistent across the study. However, the possible effect of measurement error on the results of 100 m freestyle swimming time trial cannot be ignored.

There were no significant correlations between GH flexion ROM; GH internal rotation ROM; thoracic rotation ROM; scapula kinesis, and 100 m freestyle swimming time trial, in this study. Additional research is required to determine the outcome of a scapulothoracic rehabilitation programme on freestyle stroke biomechanics. Further, the effects of a scapulothoracic rehabilitation programme on freestyle stroke flaws including excessive GH flexion[12], excessive GH internal rotation ROM[12,20,62,68] and delayed initiation of GH external rotation[5,12,20], need to be investigated.

### 3.5.8 LIMITATIONS OF STUDY

The main potential limitation of this study was participant compliance. The participants in both the experimental and control groups were required to complete the respective rehabilitation programmes three times a weeks. Each participant attended one supervised rehabilitation session and performed two unsupervised home-based rehabilitation sessions per week. Walther et al[123] determined that supervised exercise was not superior to a home based rehabilitation programme for the treatment of shoulder impingement. Further, McClure et al[86] utilised an unsupervised progressive six week rehabilitation programme to determine the effects on shoulder function and three dimensional kinematics in participants with shoulder impingement. An exercise adherence log was used to control for participant compliance. Similarly, Wang et al[101] utilised an exercise log to control for participant compliance when comparing the efficacy of a customized versus standardised rehabilitation programme in individuals with shoulder disorders.

Thus, this study used a self-report log book to ensure compliance with unsupervised home based rehabilitation sessions. However, log book compliance was poor (Table 3.1, page 67). Further, the possibility exists that participants could have failed to perform their respective rehabilitation sessions for a specific day, yet stated otherwise. In this event, results obtained in this study could be inaccurate and falsely representative of the effects of rehabilitation on shoulder pain in competitive swimmers.

Another potential limitation of this study is that only the effects of rehabilitation on shoulder impingement in swimmers were assessed. Current literature advocates the use of manual therapy in conjunction with rehabilitation in the treatment of shoulder impingement[19,100,106]. Combined therapy (manual therapy and rehabilitation) has shown significantly greater improvements in pain[19,100,106], function[100] and isometric muscle strength[19], compared to rehabilitation only. However, these studies fail to accurately describe the manual therapy techniques used. Further, a variety of management protocols for shoulder impingement exists[19,24,31-33,86,100,106].

A further limitation of this study is the potential for contamination amongst the sample. Participants in the experimental and control groups trained in squads and may have been aware of the differences in the rehabilitation programmes. Participants may have believed that their rehabilitation programme they were performing was superior to the alternative programme. This perception may have influenced the participant's subjective ratings of the Penn shoulder *"pain"*, *"satisfaction"* and *"function"* scores.

In addition, in this study the effectiveness of rehabilitation on shoulder impingement was assessed over a nine week period. The respective rehabilitation programmes were performed for six weeks and a follow up assessment was conducted three weeks after completion of the respective rehabilitation programmes. To date, current literature recommends that rehabilitation for shoulder impingement be performed for six[19,32,101] to eight weeks[101]. However, the long term effects of the results obtained in this study and current literature are not known. Therefore it is recommended that rehabilitation programmes for shoulder impingement should be between nine to twelve weeks in length, and that participants should be reassessed at three and six months after completing the rehabilitation programmes.

Finally, participants completed their respective rehabilitation programmes while continuing to perform their normal daily swim training routines. As discussed in the literature review, the potential risk of aggravating shoulder impingement during swim training may be associated with abnormal swimming biomechanics such as a cross-over hand entry or thumb-first hand entry[20]; dropped elbow or excessively high elbow pull through[10,12,20,68]; unilateral breathing pattern; and concomitant lateral and body roll asymmetry[12,20]; as well as training distance and time[22,39]. Currently, the effects of continued daily swim training routines on shoulder impingement are not known. Therefore, it is recommended that the future studies investigating the effects of rehabilitation of shoulder impingement in swimmers should be combined with altered or reduced training regimes.

## 3.6 SUMMARY

In summary, swimmers may be at increased risk for the development of shoulder impingement when they breathe unilaterally[12,20]; exhibit reduced GH external rotation ROM[12,20]; suffer from scapula dyskinesis[3,6] and have poor cervical and thoracic posture[28,29,43,73,74]. The results of this study support the notion that a six week rehabilitative programme is effective in reducing pain [19,86,101], improving level of satisfaction [86], shoulder range of motion [19,86] and function [19,86,101] in the treatment of shoulder impingement. Clinically, this study highlights the benefits of rehabilitation in the treatment of shoulder impingement in swimmers. However, rehabilitation should only be commenced once a swimmer has sufficient pain-free GH ROM and should be performed for a minimum of six weeks.

# CHAPTER 4: SUMMARY AND CONCLUSION

The shoulder joint complex is highly susceptible to injury due to this repetitive overuse and overload[22,32,36]. Thirty-five percent of competitive swimmers may experience shoulder pain sufficient to interfere with or inhibit participation in training[12]. Secondary shoulder impingement is thought to be the primary cause of shoulder pain in swimmers[10].

Shoulder impingement in swimmers may be associated with instability, rotator cuff and bicep tendon pathologies, scapular dyskinesis, and GH internal rotation deficits[16,17,22]. These pathological mechanisms are all aggravated by an increased thoracic kyphosis and flexed posture, which may be commonly observed in swimmers. In addition, biomechanical coupling occurs between all joints of the upper quarter. Unilateral arm elevation is associated with upward scapula rotation[26], thoracic extension[26,27,54], ipsilateral thoracic lateral flexion[26,27,53,55] and rotation[26,54]. Thus, the risk of shoulder impingement may be reduced with an increased tilt angle (thoracic lateral flexion), and the maintenance of a symmetrical body roll (thoracic rotation)[12,20] when performing the freestyle stroke. Currently there is equivocal evidence for the management and rehabilitation of shoulder impingement in swimmers[10,19,24,31-34,100,101]. There is also a lack of evidence regarding the role of posture and trunk control in shoulder rehabilitation programmes. Therefore the overall aim of this study was to determine the effects of combined scapula and thoracic (scapulothoracic) rehabilitation, compared to isolated scapula (standard) rehabilitation on shoulder pain in competitive swimmers. Based on the evidence provided in this thesis, the study objectives as described in Section 1.3.2 (page 3) may be answered as follows:

> *To determine whether there were significant differences in Penn shoulder "pain", "satisfaction" and "function" scores; GH flexion, external rotation, internal rotation and total rotation ROM; thoracic rotation ROM; scapula stability; pectoralis minor muscle length and 100 m freestyle swimming time trial; between an experimental group that performed a scapulothoracic rehabilitation programme, and a control that performed a standard rehabilitation programme, over a nine week study period.*

In this study, there were significant interactions between groups over time for the outcome measures of Penn shoulder *"satisfaction"* scores, GH external rotation ROM and 100 m freestyle swimming time trial. Further, both the experimental and control group showed significant changes in the majority of outcome measures at week 3, week 6 and/or week 9. Penn shoulder *"pain"*, *"satisfaction"* and *"function"* scores; GH ROM; thoracic rotation ROM; scapula kinesis and 100 m freestyle swimming time trial all showed favourable changes that reflect the benefits of rehabilitation in the management of shoulder impingement.

There were no significant differences between groups. Scapula musculature exercises were incorporated in both the scapulothoracic and standard rehabilitation programmes. There is a possibility that the dose effect of the additional exercises in the scapulothoracic rehabilitation programme was too small to detect significant differences between groups.

*To determine whether there were significant relationships between Penn shoulder "pain", "satisfaction" and "function" scores; GH flexion, external rotation, internal rotation and total rotation ROM; thoracic rotation ROM; scapula stability; pectoralis minor muscle length and 100 m freestyle swimming time trial.*

In this study, there were significant negative correlations between Penn shoulder *"function"* and *"total pain"* scores; Penn shoulder *"function"* and 100 m freestyle swimming time trial; and Penn shoulder *"satisfaction"* and 100 m freestyle swimming time trial, for the total group. The experimental group demonstrated a significant positive correlation between Penn shoulder *"total pain"* score and 100 m swimming time trial. In addition, there were significant negative correlations between Penn shoulder *"total pain"* and *"function"*; and Penn shoulder *"function"* and 100 m freestyle swimming time trial, for the experimental group. Finally, there was a significant positive correlation between GH external rotation ROM and Penn shoulder *"total pain"* scores, for the control group. Therefore, rehabilitation programmes for the management of shoulder impingement in swimmers may facilitate a reduction in pain; and improvements in satisfaction, function and swimming performance.

*To determine the clinical effects of scapulothoracic and standard rehabilitation programmes on Penn shoulder "pain", "satisfaction" and "function" scores; GH flexion, external rotation, internal rotation and total rotation ROM; thoracic rotation ROM; scapula stability; pectoralis minor muscle length and 100 m freestyle swimming time trial.*

Small to medium clinical effects were reported for GH external rotation ROM; GH internal rotation ROM; and lateral scapula slide test: *"Hands on hips"* and *"Arms at 90° GH abduction".* Small effects were reported for Penn shoulder *"pain with everyday activity"* and *"pain with strenuous activity"*; GH flexion ROM; thoracic rotation ROM and 100 m freestyle swimming time trial. Small-negligible effects were reported for Penn shoulder *"pain at rest"*, *"satisfaction"* and *"function"*. No clinical effect for lateral scapula slide test: *"Arm by side"* occurred. These findings emphasise the benefits of rehabilitation in the treatment of shoulder impingement in swimmers. Thus clinicians should incorporate rehabilitation into their treatment regimens for shoulder impingement in swimmers. A progressive rehabilitation programme is recommended for a minimum of six weeks.

Care should be taken not to pre-maturely implement rehabilitative exercises in the treatment plan, to avoid aggravating swimmer's shoulder pain. Further, a swimmer should only return to full swim training and competition, once they are able to complete two to three rehabilitation sessions without flaring their shoulder pain. Interim training may include kicking only or limited distance full stroke (pain respective); non-weight bearing cardiovascular exercise (e.g.: cycling or elliptical training) and other dry-land training with the exception of upper body weight training. Hence, the working relationship and communication between coaches and clinicians needs to be improved. The implementation of  preventative, pre-season shoulder rehabilitation programmes to reduce the risk of shoulder impingement should also be considered by clinicians working with swimmers.

Based on the findings in this study, modifications to the rehabilitation programme are recommended to further evaluate the effects of scapulothoracic rehabilitation on shoulder impingement in competitive swimmers. Suggested modifications include a progressive nine to twelve week rehabilitation programme; the addition of a posterior capsule stretch; stretches to be performed three to five times daily and held for 15 to 30 seconds[11,19,31,32,86]; and structured supervised rehabilitation sessions. Recommendations for future research include the measurement of thoracic lateral flexion ROM; the inclusion of a thoracic mobilisation exercise and/or manual therapy (mobilisations to the thoracic spine and shoulder girdle); and altered swim training routines.

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## APPENDIX I

# INFORMED CONSENT FORM

## A study to determine the effect of scapulothoracic rehabilitation on shoulder pain in competitive swimmers

Dear Participant

I am a Masters candidate with the Division of Physiotherapy, University of Cape Town. I will be conducting a study to determine the effects of upper back and shoulder blade rehabilitation on the improvement of shoulder pain experienced by competitive swimmers. The most common cause of shoulder pain in swimmers is known as shoulder impingement. This is the entrapment of the rotator cuff muscles (deep stabilising muscles of the shoulder) between the shoulder blade and upper arm bone. Although a vast amount of research exists regarding the physiotherapeutic treatment, management and rehabilitation of shoulder impingement, few studies have addressed the shoulder in conjunction with upper back posture and position. The study will determine whether improvement in shoulder pain and range of motion, as well as upper back rotation, can be achieved by focusing on strengthening of the muscles of the upper back and those supporting the shoulder blade against the upper back. Further, the results of this study will serve as a platform upon which a swimming specific treatment protocol can be developed.



All information obtained within this study will be used to assist me with the requirements for my thesis for the Master of Science in Physiotherapy degree. This study has been granted Ethical Approval by the Human Research Ethics Committee, Faculty of Health Sciences, University of Cape Town (264/2010).

### DESCRIPTION OF RESEARCH

You will be placed into one of two groups, by drawing a card labelled A or B from a hat. Each group will receive a rehabilitation program, whereby the focus within the Group B is placed on the standardised care of strengthening the muscles of the shoulder and shoulder blade whilst the focus within Group A, is placed on the experimental regime of strengthening the muscles of the back, shoulder and shoulder blade.

You will be asked to attend a total of six weekly appointments, with the duration of:

- 1 hour – week one and three
- 30 minutes for the remaining appointments,

as well as a final follow-up appointment at week 9, for the duration of 30 minutes.

For each session, you will be required to get to the physiotherapy practice at Edward III, Ground Floor, Edward Street, Tygervalley. You will be re-imbursed your travel costs at the completion of each weekly session, within the study. Further, you will be asked to complete the rehabilitation programs provided at least twice more during each week in your own time. You will be issued a rehabilitation log book, in which to note the date, training distances, pain experienced and exercises completed for all home-based sessions, over the 6 week period. This log book is to be handed in at the six week mark.

Please note that should you choose to participate within this study, you will be required to cease all other forms of physiotherapeutic treatment you are currently receiving (including sports massage), for the duration of this study which is 9 weeks. This may potentially result in your current shoulder pain increasing and/or persisting for a slightly longer duration, than if you received standard physiotherapy treatment.

This study will be supervised by Dr. Theresa Burgess and Ms Romy Parker, senior lecturers in physiotherapy at the University of Cape Town.

Please take your time to read this form thoroughly, before signing.

Prior to your inclusion within this study, you will be expected to complete and sign this form, complete a personal questionnaire and undergo the following anthropometric tests and two shoulder specific tests:

**Anthropometric Tests**

These tests are done in order to assess your body mass and fat percentage. The testing procedure will require you to stand barefoot on a scale, to obtain your body mass. Further seven skin folds measurements will be taken with a calliper, which gently pinches the skin, lifting it away from your muscle at your bicep and tricep, upper back, just below the shoulder blade, above your hip, on your calf, thigh and abdomen.

**Shoulder Specific Tests***

Please note that the following tests are used to provoke pain. As a result a certain amount of discomfort can be expected during these tests.

**a. Neer's Test**

You will be required to sit on a chair and elevate your arm as high as possible, without pain. The physiotherapist will then stabilise your shoulder blade and gently attempt to take your shoulder further into the range of elevation. If you experience pain, you will be required to mark the level of pain on a line between the parameters of no pain and severe pain. Both left and right shoulders will be tested.

**b. Hawkins Test**

Again, you will be seated. The physiotherapist will place one of her hands on your shoulder. The arm being tested will be placed on top of the physiotherapists arm. Again, she will gently move your arm inwards, taking your hand towards your abdomen. Should you experience pain you will be required to mark the level of pain on a line between the parameters of no pain and severe pain. Both left and right shoulders will be tested.

*Should you present with shoulder pain which falls beyond the scope of this study, you will be referred to an appropriate medical professional for assistance.

**At the Initial Assessment**

You will be asked to complete a questionnaire regarding your shoulder function related to activities of daily living and sport. A physical assessment including your height and weight, shoulder and thoracic range of motion, muscular length and strength tests will be conducted. You will be familiarised with all testing procedures utilised within this study, by way of explanation. Any questions and/or concerns will be answered and addressed appropriately. Upon completion of the initial assessment, you will be issued with a rehabilitation program. Here, you will be expected to perform 5 repetitions of each of the exercises with a chosen elastic band. The physiotherapist will assess your movement execution and correct you where required. Should the chosen elastic band be too easy to use, one of greater difficulty will be issued.

**Testing Protocol**

The testing protocol to be utilised during the initial assessment and re-assessments at week three, six and nine, is described below. Please note that for the physical assessment, you will be required to wear shorts.

**1. Penn Shoulder Score**

This is a 2 page questionnaire which is divided into three sections, relating to shoulder pain, satisfaction level and function. It consists of a number of scales ranging from 0-10 or according to difficulty. You will be required to answer all questions, by circling the relevant answer. It will take you approximately 10 minutes to complete the questionnaire.

**2. Anthropometric Data**

**a. Body mass**

Your body mass will be measured by you standing in your costume on a scale. Two measurements will be taken and the average recorded.

**b. Height**

Your height will be measured by you standing up straight in your costume, with your back to a wall and heels flush against it. A ruler will be placed on top of your head and a line drawn to mark your height.

**3. Range of Motion**

**a. Shoulder elevation**

This will be measured whilst you are sitting on a chair. A mark will be made on your shoulder using a skin pencil, to obtain the axis of rotation. You will be asked to sit up straight and elevate your arm short of pain. This measurement will be taken by a goniometer and repeated three times. Please note that both the right and left shoulders will be measured.

**b. Shoulder Rotation**

Measurement will be done whilst you are lying on your back, on a treatment bed. The arm being measured will be placed so that your elbow is in line with your shoulder, and your thumb is pointing up to your ear. A mark will be made on your forearm, indicating the axis of rotation, using a skin pencil. You will then be asked to move your thumb towards the floor. Thereafter, you will be requested to move your little finger to the floor. Measurements will be taken in both positions and repeated three times each. Both shoulders will be measured.

**c. Thoracic Rotation**

Here you will be seated on a chair, with a half-moon object placed around your chest. You will be required to sit with your arms onto of the half-moon object, so that your elbows and wrists are in line with your shoulders. Your palms should face up and the little fingers must be kept in contact with each other. Once this position has been assumed, you will be requested to rotate to the left and right. This will again be repeated three times to each side.

**4. Scapula Slide Test**

During this test you will stand comfortably in your costume. A skin pencil will be used to mark a variety of landmarks on your shoulder blade and spine. Measurements will then be performed twice per shoulder, in each position including arms by side, hands on hips and hands in line with shoulders.

**5. Muscle Length**

This will be assessed when you lie on your back with elbows bent and placed next to your abdomen. You may rest your hands on top of your stomach. A plastic transparent square will be used to measure the distance between your shoulder and the treatment table. This measurement will be performed on both the left and right and repeated twice.

**6. Swimming Time Trial**

You will also be required to complete a 100m freestyle time trial during one of your training sessions. The average time of two 100m freestyle time trials will be recorded by your coach.

**On Subsequent Appointments**

All subsequent appointments will be used to assess the correct execution of movement, within the rehabilitation protocol issued. This will be done in groups of five persons. At week two, four and five, resistance band strength will be altered should the rehabilitation protocol be too easy on the current band. Re-assessment (using the protocol described above) will be performed at week three, six and nine.

**Potential Risks:**

The associated risks with participation within this study include:

- A possible, temporary increase in current shoulder pain experienced, during the initial assessment and re-assessment, as some of the testing protocols utilised may cause shoulder pain. However, every effort will be made to minimise the extent of pain during testing. Testing will be discontinued if any sustained increase in your shoulder pain occurs during any of the testing procedures.
- Your shoulder and back muscles might be a little bit stiff or sore after the rehabilitation program, as you might not be used to some of the exercises that you will be asked to perform to strengthen the shoulder. This stiff or sore sensation is a normal occurrence after unusual exercise, and will usually disappear within 3 to 4 days after the exercise.

**Benefits**

The invention offered within Group A is of an experimental nature. This intervention will only be of benefit to you, if the outcome of this study is proven to be positive. Please note that the rehabilitation programme, offered as standardised care, has already been shown to be beneficial in reducing shoulder pain experienced by competitive swimmers.

You will receive your body composition and anthropometric measurements, as well as a summary of the results of the study. You will also receive a rehabilitation program that will help to strengthen the shoulder and that may help to reduce the amount of shoulder pain that you experience in the future. Please note that during the study you will only be given access to one of the rehabilitation programs, however upon completion of the study, both rehabilitation programs will be made available to you.



**Summary of Time Requirements**

The table below illustrates what you, as participant within this study, can expect at every week. This is further detailed in Figure 1.

| Week | Description | Time |
|---|---|---|
| One | Initial Assessment<br>Issue rehabilitation programme | 1 Hour |
| Two | Group exercise session and adjust resistance bands where required | 30 minutes (5 per group) |
| Three | Re-assessment<br>Check exercises and adjust resistance bands where required | 1 Hour |
| Four | Group exercise session and adjust resistance bands where required | 30 minutes (5 per group) |
| Five | Group exercise session and adjust resistance bands where required | 30 minutes (5 per group) |
| Six | Re-assessment<br>Log books to be returned | 30 minutes |
| Nine | Final re-assessment and feedback | 30 minutes |

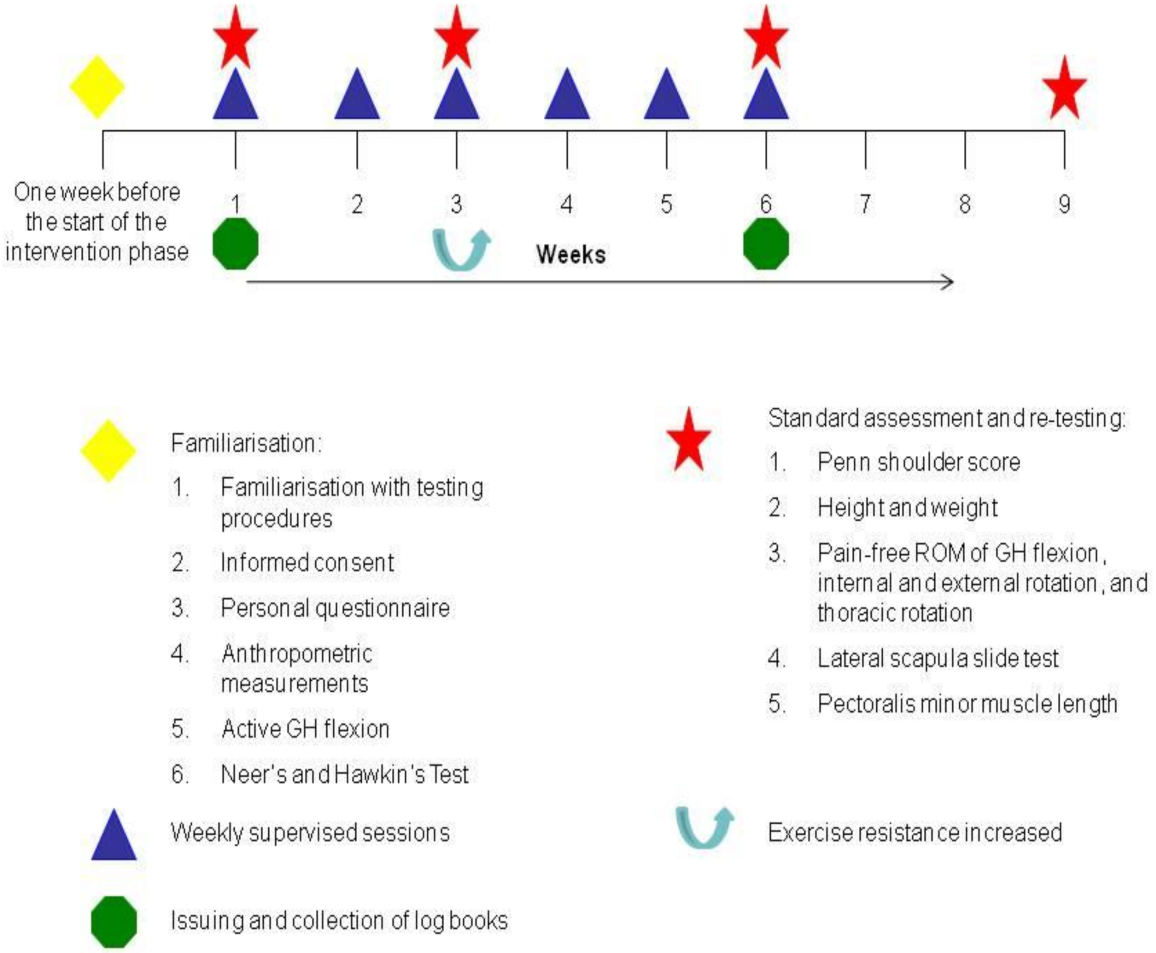


**Figure 1:** *Study procedure.*

**Questions or Concerns**

If at any time you have any questions or concerns about this study, please feel free to contact any of the individuals listed below. Please be assured that all enquires will remain private and confidential.

Investigator: Megan Dutton

| | |
|---|---|
| Physical Address: | Edward III, Ground Floor |
| | Edward Street |
| | Tygervalley |
| Tel number: | 082 787 5753 |
| E-mail: | megandutton@gmail.com |

Supervisor: Theresa Burgess

| | |
|---|---|
| Physical Address: | Division of Physiotherapy |
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| | Groote Schuur Hospital |
| | Anzio Road, Observatory |
| | 7725 |
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| Fax number: | (021) 406 6323 |
| E-mail: | theresa.burgess@uct.ac.za |

Professor Marc Blockman

Chairperson, Faculty of Health Sciences Research Ethics Committee

| | |
|---|---|
| Physical Address: | E52 – 23 Old Main Building |
| | Groote Schuur Hospital |
| | Observatory |
| | 7925 |
| Tel number: | (021) 406 6492 |
| Fax number: | (021) 406 6411 |

Please note that UCT does offer a no-fault insurance that will cover all participants in the event that something may go wrong. This insurance will provide prompt payment of compensation for any trial-related injury according to the Association of the British Pharmaceutical Industry (ABPI) guidelines (1991). These guidelines recommend that UCT, without any legal commitment, should compensate you without you having to prove that UCT is at fault. An injury is considered trial-related if, and to the extent that, it is caused by study activities. You must notify the study investigators immediately of any injuries during the trial, whether they are research-related or other related complications. UCT reserves the right not to provide compensation if, and to the extent that, your injury came about because you chose not to follow the instructions that you were given while taking part in the study. Your right in law to claim compensation for injury where you prove negligence is not affected.

Your participation within this study is completely voluntary and you have the right to withdraw from this study at any time, without providing reasons. You may ask questions at any time and all information recorded will be held private and confidential. This will be achieved by utilising a coding system, whereby each participant's personal information will be linked to a code. The document containing participant's codes and personal information will be held in a locked filing cabinet, by an independent auditor for the duration of the study. Further, participants will not be identified in any publications associated with this study.

By placing your signature below, it serves as confirmation that you have had adequate time to read through and understand the consent form and are willing to participate in this study. Your signature is further confirmation that you are aware of the possible risks associated with this study.



| ________________________ | ________________________ | ____________ |
|---|---|---|
| Signature of Volunteer | Name (please print) | Date |

| ________________________ | ________________________ | ____________ |
|---|---|---|
| Signature of Investigator | Name (please print) | Date |

## APPENDIX II

# PERSONAL QUESTIONNAIRRE

Subject Code: ____________________ Date:____________

### 1. Personal Data

Please complete the table below

| | |
|---|---|
| **Name** | |
| **Surname** | |
| **Date of Birth** | |
| **Age** | |
| **Swimming Club** | |
| **Coach** | |



### 2. Contact Information

Please complete the table below

| | |
|---|---|
| **Telephone No: Home** | |
| **Work** | |
| **Cell** | |
| **E-mail Address** | |
| **Postal Address** | |

## 3. General Health Status

Do you suffer from any of the following? If yes, please specify how frequently i.e.: twice a week and what medication you make use of, if applicable.

| Condition | Yes | No | Frequency | Medication used |
|---|---|---|---|---|
| Asthma | | | | |
| Diabetes | | | | |
| Hypertension | | | | |
| Epilepsy | | | | |
| Dizziness | | | | |
| Nausea | | | | |
| Migraines | | | | |
| Pins and needles in both arms at the same time | | | | |
| Glove like pins and needles or excessively sweaty palms | | | | |

## 4. Swimming Experience

4.1 What is your favourite stroke?______________________________________

4.2 What is your favourite competition distance? ___________________________

4.3 What is your personal best time for your favourite competition distance?

_______________________________________________________________

4.4 When did you achieve your personal best time? Year:_____________________

4.5 What is your preferred breathing side during freestyle swimming?

| Left | Right |
|---|---|
| | |

4.6 Please indicate your frequency of training per **week**, by marking an X in the appropriate box.

| **Hours** | 0-30min | 30min-1hr | 1-2hrs | 2-3hrs | 3-4hrs | 4-5hrs | 5-6hrs | 6-7hrs | 7-8hrs | 8-9hrs | 9-10hrs | 10hrs + |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Swimming | | | | | | | | | | | | |
| Strength Training | | | | | | | | | | | | |
| Other (specify) | | | | | | | | | | | | |

## 5. Injury History

Please indicate whether you have sustained any of the following injuries, by marking an X in the yes/no column. If yes, please complete the entire row of questions.

| **Injury** | **Yes** | **No** | **Side (where applicable)** | | **Date of Injury** | **Is the injury still present?** | |
|---|---|---|---|---|---|---|---|
| | | | **Left** | **Right** | | **Yes** | **No** |
| Whiplash | | | | | | | |
| Headache | | | | | | | |
| Neck Injury | | | | | | | |
| Shoulder muscle tear | | | | | | | |
| Upper arm muscle tear | | | | | | | |
| Pain down either or both arms | | | | | | | |
| "Tennis Elbow" | | | | | | | |
| Upper Back Pain | | | | | | | |
| Lower Back Pain | | | | | | | |

## APPENDIX III[15]

# THE PENN SHOULDER SCORE

### Pain and Satisfaction Subscales

| Please circle the number closest to your pain or satisfaction | Office use only |
|---|---|
| Pain at rest, with your arm by your side:<br>0 1 2 3 4 5 6 7 8 9 10<br>No pain — Worst pain possible | ____<br>(10 - # circled) |
| Pain with normal activities (eating, dressing, bathing):<br>0 1 2 3 4 5 6 7 8 9 10<br>No pain — Worst pain possible | ____<br>(10 - # circled)<br>(score 0 if not applicable) |
| Pain with strenuous activities (reaching, lifting, pushing, pulling, throwing, swimming):<br>0 1 2 3 4 5 6 7 8 9 10<br>No pain — Worst pain possible | ____<br>(10 - # circled)<br>(score 0 if not applicable) |
| Pain Score = | ________/30 |
| How satisfied are you with your current level of function of your shoulder?<br>0 1 2 3 4 5 6 7 8 9 10<br>Highly dissatisfied — Highly satisfied | ____<br>/10<br>( # circled) |

*Reprinted with the permission of Mr. Brian Leggin, University of Pennsylvania Medical Centre.
** Minor adaptations have been made to ensure the metric units used are applicable to standard South African units.

# The Penn Shoulder Score

## Function Subscale

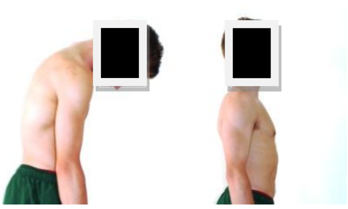
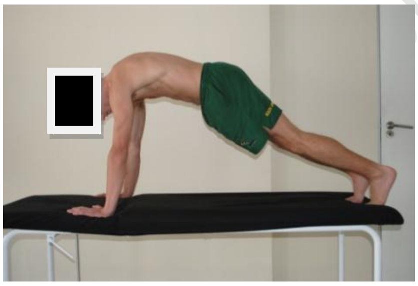
| Please circle the number that best describes the level of difficulty you might have performing each activity | No difficulty | Some difficulty | Much difficulty | Can't do at all | Did not do <u>before</u> injury |
|---|---|---|---|---|---|
| 1. Reach the small of your back to tuck in your shirt with your hand | 3 | 2 | 1 | 0 | X |
| 2. Wash the middle of your back/hook a bra | 3 | 2 | 1 | 0 | X |
| 3. Perform necessary toilet activities | 3 | 2 | 1 | 0 | X |
| 4. Wash the back of opposite shoulder | 3 | 2 | 1 | 0 | X |
| 5. Comb hair | 3 | 2 | 1 | 0 | X |
| 6. Place hand behind head with elbow held straight out to the side | 3 | 2 | 1 | 0 | X |
| 7. Dress self (including put on coat and pull off shirt overhead) | 3 | 2 | 1 | 0 | X |
| 8. Sleep on affected side | 3 | 2 | 1 | 0 | X |
| 9. Open a door with affected arm | 3 | 2 | 1 | 0 | X |
| 10. Carry a bag of groceries with affected arm | 3 | 2 | 1 | 0 | X |
| 11. Carry a small suitcase/briefcase with affected arm | 3 | 2 | 1 | 0 | X |
| 12. Place a soup (500g-1kg) can on shelf at shoulder level without bending elbow | 3 | 2 | 1 | 0 | X |
| 13. Place a 3-5kg container on shelf at shoulder level without bending elbow | 3 | 2 | 1 | 0 | X |
| 14. Reach a shelf above your head without bending your elbow | 3 | 2 | 1 | 0 | X |
| 15. Place a soup can (500g-1kg) on a shelf overhead without bending your elbow | 3 | 2 | 1 | 0 | X |
| 16. Place a 3-5kg container on shelf overhead without bending elbow | 3 | 2 | 1 | 0 | X |
| 17. Perform usual hobby | 3 | 2 | 1 | 0 | X |
| 18. Perform household chores (cleaning, laundry, cooking) | 3 | 2 | 1 | 0 | X |
| 19. Throw overhand/swim/overhead racquet sports (circle all that apply to you) | 3 | 2 | 1 | 0 | X |
| 20. Work full time at your regular job | 3 | 2 | 1 | 0 | X |

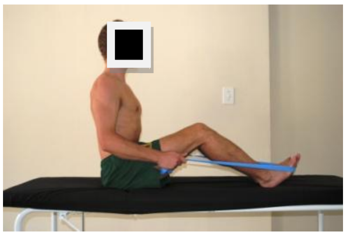
SCORING
Total of columns = _____(a)
Number of Xs x 3 =_____(b), 60-_____(b) = _____(c) (if no Xs are circled, function score = total columns)
Function score = _____(a) + _____(c)=_____ x 60 ____/60

*Reprinted with the permission of Mr. Brian Leggin, University of Pennsylvania Medical Centre.
** Minor adaptations have been made to ensure the metric units used are applicable to standard South African units.

## APPENDIX IV

# EXPERIMENTAL GROUP REHABILITATION PROGRAMME

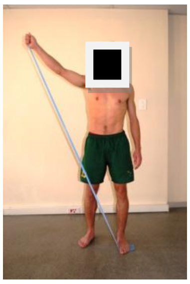
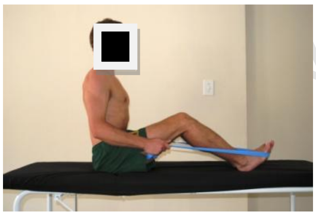
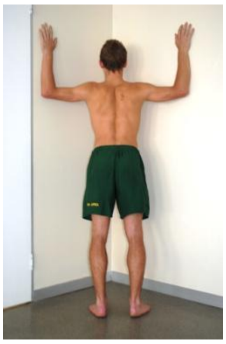
| Exercise | Description |
|---|---|
| **Sternal "Chest" Lift**<br> | Stand with feet shoulder width apart and coccyx over heels. Slouch forwards with the upper body, so that your arms hang relaxed on your mid-thigh. "Grow tall" by pretending you are a puppet and someone is pulling your head up from a string attached to your head – trying to get your back as straight as possible and touch the ceiling with head. Lift the chest bone up slightly. Relax your shoulders. Tuck your chin in, so that your head is level and not facing up. Hold this position for 5 counts. |
| **Shoulder Dump**<br> | ***Similar to dumping a container backwards**<br><br>Stand in a split stance with your left foot forward. Bend over your left hip, bringing your right arm to the left knee. Your trunk should be bent forward and rotated towards the left. Shift your weight onto your right (back) foot. Straighten your upper body and rotate it to the right. Keep your right arm in the same position as the starting position, so that your hand ends up behind your right shoulder, at head height. Repeat this on the left. |
| **Push-up Plus**<br> | Start on your hands and knees as though you were going to perform a push-up. Ensure your hands are directly below your shoulders and shoulder width apart. Keep your elbows "soft". Push away from the ground as much as you can, so that your shoulder blades lie flush on your upper back. Avoid rounding your back. Hold for 5 counts and repeat. |
| **Scaption with External Rotation (Full Can)**<br> | Stand with feet hip width apart and knees "soft". Place the elastic band below your feet. Grab the elastic with one hand in a fist, so that your thumb always faces up. Ensure your elbow remains straight, but soft. Extend your straight arm up, so that your elbow is in line with your ear, next to your head. Make sure that your hips remain square and do NOT rotate. Repeat with the other arm. |

| | |
|---|---|
| **Rowing**<br> | Sit with your legs extended and the elastic band wrapped around your feet. Grab each end of the elastic band in a hand, with palms facing each other and thumbs up. Ensure an upright posture. Initiate the movement by keeping shoulder blades down, pinching them together and then bringing the arms back. Control back to the start and repeat. |
| **Fly 1**<br> | Ly on your stomach, with hands slightly wider than shoulder width apart and palms facing down. Keep your nose in contact with the ground. Extend your arms through the middle fingers, as much as possible. Pull shoulder blades down to the hips, but keep the arms “long”. Lift the hands off the ground, as high as possible, without lifting your legs. Hold for 5 counts and repeat. |
| **Pectoralis Minor Self-stretch**<br> | Place your hands at shoulder height on each side of a door frame or in the corner of a room. Maintain a straight back. Lean forward into the door or corner. Hold this position for 30 seconds. Repeat twice. |

**Please note: all photographs included in the dissertation were taken by the author. The model consented to all photographs being included in this dissertation.*

# APPENDIX V

# CONTROL GROUP REHABILITATION PROGRAMME

| Exercise | Description |
| --- | --- |
| **Push-up Plus**  | Start on your hands and knees as though you were going to perform a push-up. Ensure your hands are directly below your shoulders and shoulder width apart. Keep your elbows "soft". Push away from the ground as much as you can, so that your shoulder blades lie flush on your upper back. Avoid rounding your back. Hold for 5 counts and repeat. |
| **Scaption with External Rotation (Full Can)**  | Stand with feet hip width apart and knees "soft". Place the elastic band below your feet. Grab the elastic with one hand in a fist, so that your thumb always faces up. Ensure your elbow remains straight, but soft. Extend your straight arm up, so that your elbow is in line with your ear, next to your head. Make sure that your hips remain square and do NOT rotate. Repeat with the other arm. |
| **Rowing**  | Sit with your legs extended and the elastic band wrapped around your feet. Grab each end of the elastic band in a hand, with palms facing each other and thumbs up. Ensure an upright posture. Initiate the movement by keeping shoulder blades down, pinching them together and then bringing the arms back. Control back to the start and repeat. |
| **Pectoralis Minor Self-stretch**  | Place your hands at shoulder height on each side of a door frame or in the corner of a room. Maintain a straight back. Lean forward into the door or corner. Hold this position for 30 seconds. Repeat twice. |

**Please note: all photographs included in the dissertation were taken by the author. The model consented to all photographs being included in this dissertation.*

## APPENDIX VI

# EXAMPLE OF PARTICIPANT'S LOG BOOK

**WEEK 1**

**REHAB DAY 1**

Date:_______________________ Training Distance:______________

1. Did you experience pain during training?

| | |
|---|---|
| Yes | No |

If yes, please rate your pain by ticking the appropriate box:

| | |
|---|---|
| Pain after training only | |
| Pain which did not interfere with training | |
| Pain which limited my training i.e.: was only able to kick or do half the set | |
| Pain which prevented further training | |

2. Please tick which group of exercises you performed.

| | |
|---|---|
| Group A | |
| Group B | |

3. Did you experience pain whilst performing the exercises?

| | |
|---|---|
| Yes | No |

If yes, please rate your pain by drawing a line on the following scale:

__________________________________________________________

No pain Most Severe pain imaginable

# APPENDIX VII

# RELIABILITY STUDY: INTRA-RATER RELIABILITY OF PARAMETERS REQUIRED FOR THE EFFECT OF SCAPULOTHORACIC REHABILITATION ON SHOULDER PAIN IN COMPETITIVE SWIMMERS

## VII.I BACKGROUND

Intra-rater reliability is the ability of an examiner to accurately perform a specific testing method repeatedly, over a period of time. It is essential in clinical practice as independent practitioners commonly utilise tests to re-evaluate and determine a specific patient's progress in injury healing and response to treatment protocols.

## VII.II AIM

The aim of this reliability study was to determine:

1. The reliability of the Penn shoulder score
2. The intra-rater reliability for the hand held goniometric measurement of GH flexion, external and internal rotation ROM; as well as thoracic rotation ROM.
3. The intra-rater reliability for performing and measuring the scapula lateral slide test, utilising a tape measure; and
4. The intra-rater reliability for the measurement of pectoralis minor muscle length using a tape measure.

## VII.III METHODS

### VII.III.I PARTICIPANTS

Five female (n = 5) subjects participated in the study. The subjects were recreational swimmers between 21 and 47 years of age.

### VII.III.II TESTING PROCEDURE

The five subjects were requested to attend three assessment sessions over a period of one week, every alternate day, at a physiotherapy practice based on Edward Street in Tygervalley, Cape Town. Each subject was measured by both the investigator and a colleague, in independent consultation rooms, at every assessment session. Therefore 6 assessments per subject were conducted.

Each assessment included the completion of the Penn shoulder score and measurement of skin-folds; GH flexion, external and internal rotation ROM, as well as thoracic rotation ROM; lateral scapula slide test and pectoralis minor muscle length test.

### a) Anthropometric Measurements

Body mass was recorded using a calibrated scale (Zhongshan YESHM Commodities Co., Ltd. 1999, Ultra-portable personal scale) and stature was recorded using a stadiometer. Body fat was expressed as the sum of seven skin folds (biceps, triceps, subscapular, suprailiac, calf, thigh and abdomen)[119].

### b) The Penn shoulder score

Shoulder function was assessed using the Penn Shoulder Score[15]. Permission to use this questionnaire was granted by Mr. Brian Leggin, University of Pennsylvania Medical Centre. This self-report measurement tool consists of a 100-point scale, which is sub-divided into 3 categories, namely pain, satisfaction and function (Appendix III). Pain at rest, with normal activity and during strenuous activities; and satisfaction relating to the level of shoulder function, were measured with a subscale where 0 indicated *"no pain"* and 10 indicated *"severe pain".* Function was measured by 20 questions related to shoulder function, in which the subscale provided included *"no difficulty", "some difficulty", "much difficulty", "can't do at all"*, and *"did not do before injury"*[15].

### c) Glenohumeral flexion; external, internal and total rotation ROM

Pain-free ROM of GH flexion, external and internal rotation was measured using a hand-held goniometer. Glenohumeral flexion ROM was measured in a seated position, on a chair with mid back support. Participants were instructed to maintain an upright posture, while lifting the arm up as high as possible without pain. The instantaneous axis of rotation was the mid-point between the greater tuberosity of the humerus and the root of the spine of the scapula. The stable arm of the goniometer was placed perpendicular to the ground, with the moving arm parallel to the humeral shaft, in neutral rotation. Both the left and right shoulders were measured three times and the average ROM was recorded. Glenohumeral rotation ROM was measured in supine. Participants were positioned with the shoulder at 90° of GH abduction and the elbow at 90° of flexion. Participants were instructed to move the hand into a thumb down position for external rotation and thumb up position for internal rotation. The instantaneous axis of rotation was the olecranon of the elbow.

The stable arm of the goniometer was placed perpendicular to the ground and the moving arm parallel to the shaft of the ulna. The left and right shoulders were measured three times and the average ROM was recorded[94,101].

**d) Thoracic rotation range of motion**

Thoracic rotation was measured in a seated position, with participants feet placed firmly on the ground. Both arms were supported on a 270° half-moon chalk board, at 90° of GH flexion. The elbows were fully extended with neutral humeral rotation (palms face up) and participants were instructed to maintain contact between arms by keeping the medial borders of the 5$^{th}$ fingers of the hands together during ROM testing. This position was marked as the starting position on the chalk board. Participants were then instructed to rotate to the left and right within their pain-free ranges of motion. A mark was placed on the chalk board, in line with and parallel to the 5$^{th}$ fingers. The degree of rotation was then measured by extending the marks drawn until the lines intersected to form two angles. These angles represented left and right thoracic rotation respectively and were measured with a goniometer. Thoracic rotation was repeated three times to either side, and an average ROM was recorded for left and right thoracic rotation respectively. A similar method has been described by Blanch[10].

**e) Lateral scapula slide test**

The lateral scapula slide test was used to assess muscle strength of scapula stabilisers. The test was performed in standing, with the participant assuming three different upper limb positions namely *"arms by side"*, *"hand on hips"* and *"arms at 90° of GH abduction"* with internal rotation (determined by goniometer measurement). The investigator marked the inferiomedial angles of the left and right scapulae. A reference point was marked as the nearest spinous process to the inferiomedial angle. The distance (cm) between the reference point and inferiomedial angles of the scapula was measured using a tape measure for each of the three different upper limb positions. An average of two measurements for each position was recorded[3].

### f) Pectoralis minor muscle length

Pectoralis minor muscle length was measured according to the method described by Lewis et al[99]. Participants were positioned in supine on a treatment table with their elbows flexed and rested against the lateral wall of the abdomen, with their hands resting gently against their abdomen. The investigator measured the distance from the treatment table, to the posterior acromion using a rigid transparent plastic right angle with a height of 12 cm and a base of 8cm. Without exerting downward pressure on the shoulder, the base of the right angle is placed on the treatment table, with the vertical side placed adjacent to the lateral aspect of the acromion. Both left and right shoulders were measured twice and the average distance was recorded for left and right pectoralis minor length respectively[99].

## VII.III.III DATA ANALYSIS

Measurements were recorded on independent data collection sheets for examiner and co-examiner. This data was then collaborated into an Excel spreadsheet (Microsoft Corporation, Redmond, USA).

## VII.III.VI STATISTICAL ANALYSES

Data were analysed using Statistica software (StatSoft, Inc. 2004. STATISTICA, Data Analysis Software System, Version 10. www.statsoft.com). Correlations between data were determined using Cronbach's α, where a perfect $\alpha = 1$. Intra-rater reliability was accepted as $\alpha \geq 0.7$. All data are presented as the mean ± standard deviation.

## VII.VI RESULTS

The results for each parameter tested are shown in the tables which follow.

**Table VII.I:** *The reliability of the Penn shoulder score for participants in the reliability study (n = 5).*

| The Penn Shoulder Score | Mean ± Standard Deviation | Cronbach's α |
|---|---|---|
| Pain | 28.40 ± 12.70 | 0.81* |
| Satisfaction | 12.40 ± 3.71 | 0.83* |
| Function | 137.40 ± 28.44 | 0.87* |

*Cronbach's α ≥ 0.7 indicates satisfactory reliability.*

**Table VII.II:** *The intra-reliability of the examiner for specific testing methods of participants in the reliability study (n = 5).*

| Variable | | Mean ± Standard Deviation | Cronbach's α |
|---|---|---|---|
| **Anthropometric measurements (mm)** | Sum of 7 Skin Folds | 323.10 ± 152.71 | 0.99* |
| **Muscle Length (cm)** | Pectoralis Minor Muscle Length | 29.42 ± 2.39 | 0.81* |
| **Range of Motion (˚)** | GH flexion | 469.00 ± 15.60 | 0.78* |
| | GH external rotation | 254.20 ± 16.96 | 0.81* |
| | GH internal rotation | 138.20 ± 31.30 | 0.71* |
| | Thoracic rotation | 169.00 ± 26.53 | 0.70* |
| **Lateral Scapula Slide Test (cm)** | Arm by side | 2.62 ± 0.43 | 0.81* |
| | Hands on Hips | 2.45 ± 0.33 | 0.96* |
| | Arm at 90˚ GH abduction | 2.91 ± 0.24 | 0.72* |

*Cronbach's α ≥ 0.7 indicates satisfactory intra-rater reliability.*



## VII.V SUMMARY AND CONCLUSION

Intra-rater reliability is expressed as Cronbach's α, where a perfect score is equal to one. Acceptable intra-rater reliability is regarded as Cronbach's α ≥ 0.7. Therefore the results of the intra-rater reliability tested for each of the parameters required for the purposes of this study, show satisfactory reliability.

## APPENDIX VIII

# ETHICAL APPROVAL

UNIVERSITY OF CAPE TOWN

**Health Sciences Faculty**
**Research Ethics Committee**
**Room E52-24 Groote Schuur Hospital Old Main Building**
**Observatory 7925**
**Telephone** [021] 406 6626 • **Facsimile** [021] 406 6411
**e-mail:** shuretta.thomas@uct.ac.za

**22 June 2010**

**HREC REF: 264/2010**

**Ms M Dutton**
**c/o Dr T Burgess**
Physiotherapy
Health & Rehab

Dear Ms Dutton

**PROJECT TITLE: THE EFFECT OF SCAPULOTHORACIC REHABILITATION ON SHOULDER PAIN IN COMPETITIVE SWIMMERS.**

Thank you for carefully addressing the queries from the Faculty of Health Sciences Human Research Ethics Committee in the letter dated 21st June 2010.

It is a pleasure to inform you that the Ethics Committee has **formally approved** the above-mentioned study.

**Approval is granted for one year till the 30th June 2011.**

Please submit an annual progress report if the research continues beyond the expiry date. Please submit a brief summary of findings if you complete the study within the approval period so that we can close our file.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

**Please quote the REC. REF in all your correspondence.**

Yours sincerely

pp

**PROFESSOR M BLOCKMAN**
**CHAIRPERSON, HSF HUMAN ETHICS**
Federal Wide Assurance Number: FWA00001637.

**S Thomas**

UNIVERSITY OF CAPE TOWN

FACULTY OF HEALTH SCIENCES

HUMAN RESEARCH ETHICS COMMITTEE

−2 JUL 2012

HEALTH SCIENCES FACULTY
UNIVERSITY OF CAPE TOWN

# FHS016: Annual Progress Report

HREC office use only (FWA00001637; IRB00001938)

This serves as notification of annual approval, including any documentation described below.

☑ Approved — Annual progress report

☐ Not approved — See attached comments

| | | | |
|---|---|---|---|
| Expiry date | 29 July 2013 | | |
| Signature<br>Chairperson of the HREC | | Date | 1/7/2012 |

**Principal Investigator to complete the following:**

## 1. Protocol information

| | |
|---|---|
| Date | 26 June 2012 |
| HREC REF Number | 264/2010 |
| Protocol title | The Effect of Scapulothoracic Rehabilitation on Shoulder Pain in Competitive Swimmers. |
| Protocol number (if applicable) | N/A |
| Principal Investigator | Megan Dutton |
| Department / Office Internal Mail Address | [illegible]<br>[illegible] |

| | | |
|---|---|---|
| 1.1 Does this protocol receive US Federal funding? | ☐ Yes | ✓ No |
| 1.2 Has sponsorship of this study changed? If yes, please attach a revised summary of the budget. | ☐ Yes | ✓ No |

## 2. List of documentation

264/2010

The Effect of Scapulothoracic Rehabilitation on Shoulder Pain in Competitive Swimmers

PI: Megan Dutton (DTTMEG002)

# APPENDIX IX

# NON-SIGNIFICANT CORRELATIONAL RESULTS

## IX.I PENN SHOULDER "SATISFACTION" AND "FUNCTION" SCORES

There were no significant correlations between the differences of week 3 to baseline measures in Penn shoulder *"satisfaction"* and *"function"* scores for the total group (r = 0.09; p = 0.66), the experimental group (r = -0.24; p = 0.40) or the control group (r = 0.29; p = 0.31). There were no significant correlations between the differences of week 6 to baseline measures in Penn shoulder *"satisfaction"* and *"function"* scores for the total group (r = -0.10; p = 0.61), the experimental group (r = -0.29; p = 0.29) or the control group (r = -0.10; p = 0.74). There were no significant correlations between the differences of week 9 to baseline measures in Penn shoulder *"satisfaction"* and *"function"* scores for the total group (r = 0.11; p = 0.57), the experimental group (r = -0.05; p = 0.87) or the control group (r = 0.23; p = 0.43).

## IX.II GLENOHUMERAL ELEVATION AND EXTERNAL ROTATION ROM

There were no significant correlations between the differences of week 3 to baseline measures in GH flexion and external rotation ROM for the total group (r = 0.06; p = 0.76), experimental group (r = 0.13; p = 0.64) and the control group (r = -0.12; p = 0.68). There were no significant correlations between the differences of week 6 to baseline measures in GH flexion and external rotation ROM for the total group (r = -0.09; p = 0.63), experimental group (r = -0.21; p = 0.45) or the control group (r = 0.27; p = 0.36). There were no significant correlations between the differences of week 9 to baseline measures in GH flexion and external rotation ROM for the total group (r = 0.07; p = 0.72), experimental group (r = 0.01; p = 0.96) and the control group (r = 0.24; p = 0.40).

## IX.III GLENOHUMERAL INTERNAL AND EXTERNAL ROTATION ROM

There were no significant correlations between the differences of week 3 to baseline measures in GH internal and external rotation ROM for the total group (r = 0.12; p = 0.53), experimental group (r = 0.30; p = 0.27) and the control group (r = -0.24; p = 0.41). There were no significant correlations between the differences of week 6 to baseline measures in GH internal and external rotation ROM for the total group (r = 0.07; p = 0.72), experimental group (r = 0.29; p = 0.30) or the control group (r = 0.11; p = 0.71).

There were no significant correlations between the differences of week 9 to baseline measures in GH internal and external rotation ROM for the total group (r = -0.10; p = 0.60), experimental group (r = 0.08; p = 0.77) and the control group (r = -0.27; p = 0.34).

In summary, a negative correlation indicates that as GH external rotation ROM improves, GH flexion or internal rotation ROM decreases. A positive correlation indicates that as GH external rotation ROM improves, GH flexion or internal rotation ROM improves. A summary of the relationships between GH flexion and internal rotation ROM and GH external rotation ROM is provided in Table IX.I.

## IX.IV GLENOHUMERAL ELEVATION ROM AND THORACIC ROTATION ROM

There were no significant correlations between the differences of week 3 to baseline measures in GH flexion ROM and thoracic rotation ROM for the total group (r = 0.09; p = 0.65), experimental group (r = 0.02; p = 0.95) and the control group (r = 0.21; p = 0.47). There were no significant correlations between the differences of week 6 to baseline measures in GH flexion ROM and thoracic rotation ROM for the total group (r = 0.19; p = 0.31), experimental group (r = 0.46; p = 0.08) or the control group (r = -0.21; p = 0.47). There were no significant correlations between the differences of week 9 to baseline measures in GH flexion ROM and thoracic rotation ROM for the total group (r = 0.24; p = 0.21), experimental group (r = 0.35; p = 0.21) and the control group (r = 0.12; p = 0.68).

## IX.V GLENOHUMERAL EXTERNAL ROTATION ROM AND THORACIC ROTATION ROM

There were no significant correlations between the differences of week 3 to baseline measures in GH external rotation ROM and thoracic rotation ROM for the total group (r = -0.37; p = 0.05), experimental group (r = -0.44; p = 0.10) or the control group (r = -0.29; p = 0.32). There were no significant correlations between the differences of week 6 to baseline measures in GH external rotation ROM and thoracic rotation ROM for the total group (r = -0.22; p = 0.26), experimental group (r = -0.36; p = 0.19) or the control group (r = -0.17; p = 0.56). There were no significant correlations between the differences of week 9 to baseline measures in GH external rotation ROM and thoracic rotation ROM for the total group (r = 0.03; p = 0.89), experimental group (r = -0.05; p = 0.86) and the control group (r = 0.10; p = 0.73).

In summary, a negative correlation indicates that as thoracic rotation ROM improves, GH flexion or external rotation ROM decreases. A positive correlation indicates that as thoracic rotation ROM improves, GH flexion or external rotation ROM improves. A summary of the relationships between GH flexion and external rotation ROM and thoracic rotation ROM is provided in Table IX.II.

## IX.VI GLENOHUMERAL INTERNAL ROTATION ROM AND PENN SHOULDER *"FUNCTION"* SCORE

There were no significant correlations between the differences of week 3 to baseline measures in GH internal rotation ROM and Penn shoulder *"function"* scores for the total group (r = -0.28; p = 0.14), experimental group (r = -0.46; p = 0.09) and the control group (r = -0.11; p = 0.70). There were no significant correlations between the differences of week 6 to baseline measures in GH internal rotation ROM and Penn shoulder *"function"* scores for the total group (r = -0.23; p = 0.22), experimental group (r = -0.21; p = 0.44) and the control group (r = -0.08; p = 0.78). There were no significant correlations between the differences of week 9 to baseline measures in GH internal rotation ROM and Penn shoulder *"function"* scores for the total group (r = 0.001; p = 0.99), experimental group (r = -0.09; p = 0.76) and the control group (r = 0.11; p = 0.72).

## IX.VII PENN SHOULDER *"TOTAL PAIN"* AND LATERAL SCAPULA SLIDE TEST *"HANDS ON HIPS"* POSITION

There were no significant correlations between the differences of week 3 to baseline measures in Penn shoulder *"total pain"* scores and lateral scapula slide test *"Hands on hips"* position for the total group (r = 0.12; p = 0.52), experimental group (r = -0.31; p = 0.27) and the control group (r = 0.49; p = 0.07). There were no significant correlations between the differences of week 6 to baseline measures in Penn shoulder *"total pain"* scores and lateral scapula slide test *"Hands on hips"* position for the total group (r = -0.22; p = 0.25), experimental group (r = -0.39; p = 0.15) and the control group (r = 0.18; p = 0.54). There were no significant correlations between the differences of week 9 to baseline measures in Penn shoulder *"total pain"* scores and lateral scapula slide test *"Hands on hips"* position for the total group (r = 0.008; p = 0.97), experimental group (r = -0.25; p = 0.37) and the control group (r = 0.21; p = 0.46).

**Table IX.I:** *Relationship between GH flexion and internal rotation ROM and GH external rotation ROM. Note: '+' indicates a positive correlation and '-' indicates a negative correlation.*

| Correlation | Total Group | | | Experimental Group | | | Control Group | | |
|---|---|---|---|---|---|---|---|---|---|
| **Glenohumeral elevation and external rotation ROM** | **Relationship** | **r** | **p** | **Relationship** | **r** | **p** | **Relationship** | **r** | **p** |
| **Week 3 to baseline** | + | 0.06 | 0.76 | + | 0.13 | 0.64 | - | 0.12 | 0.68 |
| **Week 6 to baseline** | - | 0.09 | 0.63 | - | 0.21 | 0.45 | + | 0.27 | 0.36 |
| **Week 9 to baseline** | + | 0.07 | 0.72 | + | 0.01 | 0.96 | + | 0.24 | 0.40 |
| **Glenohumeral internal and external rotation ROM** | | | | | | | | | |
| **Week 3 to baseline** | + | 0.12 | 0.53 | + | 0.30 | 0.27 | - | 0.24 | 0.41 |
| **Week 6 to baseline** | + | 0.07 | 0.72 | + | 0.29 | 0.30 | + | 0.11 | 0.71 |
| **Week 9 to baseline** | - | 0.10 | 0.60 | + | 0.08 | 0.77 | - | 0.27 | 0.34 |

*Note: A negative correlation (-) indicates that as GH external rotation ROM improves, GH flexion or internal rotation ROM decreases. A positive correlation (+) indicates that as GH external rotation ROM improves, GH flexion or internal rotation ROM improves.*

**Table IX.II:** *Relationship between GH flexion and external rotation ROM and thoracic rotation ROM. Note: '+' indicates a positive correlation and '-' indicates a negative correlation.*

| Correlation | Total Group | | | Experimental Group | | | Control Group | | |
|---|---|---|---|---|---|---|---|---|---|
| **Glenohumeral elevation ROM and thoracic rotation ROM** | **Relationship** | **r** | **p** | **Relationship** | **r** | **p** | **Relationship** | **r** | **p** |
| **Week 3 to baseline** | + | 0.09 | 0.65 | + | 0.02 | 0.95 | + | 0.21 | 0.47 |
| **Week 6 to baseline** | + | 0.19 | 0.31 | + | 0.46 | 0.08 | - | 0.21 | 0.47 |
| **Week 9 to baseline** | + | 0.21 | 0.21 | + | 0.35 | 0.21 | + | 0.12 | 0.68 |
| **Glenohumeral external rotation ROM and thoracic rotation ROM** | | | | | | | | | |
| **Week 3 to baseline** | - | 0.37 | 0.05 | - | 0.44 | 0.10 | - | 0.29 | 0.32 |
| **Week 6 to baseline** | - | 0.22 | 0.26 | - | 0.36 | 0.19 | - | 0.17 | 0.56 |
| **Week 9 to baseline** | + | 0.03 | 0.89 | - | 0.05 | 0.86 | + | 0.10 | 0.73 |

*Note: A negative correlation (-) indicates that as thoracic rotation ROM improves, GH flexion or external rotation ROM decreases. A positive correlation (+) indicates that as thoracic rotation ROM improves, GH flexion or external rotation ROM improves.*

## IX.VII THORACIC ROTATION ROM AND LATERAL SCAPULA SLIDE TEST ***"HANDS ON HIPS"*** POSITION

There were no significant correlations between the differences of week 3 to baseline measures in thoracic rotation ROM and lateral scapula slide test *"Hands on hips"* for the total group (r = -0.29; p = 0.12), experimental group (r = -0.19; p = 0.49) and the control group (r = -0.40; p = 0.15). There were no significant correlations between the differences of week 6 to baseline measures in thoracic rotation ROM and lateral scapula slide test *"Hands on hips"* for the total group (r = -0.22; p = 0.26), experimental group (r = -0.24; p = 0.39) and the control group (r = -0.18; p = 0.54). There were no significant correlations between the differences of week 9 to baseline measures in thoracic rotation ROM and lateral scapula slide test *"Hands on hips"* for the total group (r = 0.08; p = 0.68), experimental group (r = -0.09; p = 0.76) and the control group (r = 0.25; p = 0.39).

In summary, a negative correlation indicates that as lateral scapula slide test *"Hands on hips"* position improves, Penn Shoulder *"total pain"* decreases and thoracic rotation ROM improves. A positive correlation indicates that as lateral scapula slide test *"Hands on hips"* position improves, Penn Shoulder *"total pain"* increases and thoracic rotation ROM decreases. A summary of the relationships between GH flexion and external rotation ROM and thoracic rotation ROM is provided in Table IX.III.

## IX.VII LATERAL SCAPULA SLIDE TEST ***"HANDS ON HIPS"*** POSITION AND 100 M FREESTYLE SWIMMING TIME TRIAL

There were no significant correlations between the differences of week 3 to baseline measures in lateral scapula slide test *"hands on hips"* position and 100 m swimming time trial for the total group (r = - 0.09; p = 0.84), the experimental group (r = - 0.52; p = 0.05) and the control group (r = 0.15; p = 0.60). There were no significant correlations between the differences of week 6 to baseline measures in lateral scapula slide test *"hands on hips"* position and 100 m swimming time trial for the total group (r = - 0.13; p = 0.49), experimental group (r = - 0.13; p = 0.64) and the control group (r = - 0.21; p = 0.47) . There were no significant correlations between the differences of week 9 to baseline measures in lateral scapula slide test *"hands on hips"* position and 100 m swimming time trial for the total group (r = - 0.09; p = 0.66), experimental group (r = - 0.12; p = 0.35) and the control group (r = - 0.39; p = 0.47).

**Table IX.III:** *Relationship between Penn shoulder "total pain" and thoracic rotation ROM; and lateral scapula "hands on hips" position. Note: '+' indicates a positive correlation and '-' indicates a negative correlation.*

| Correlation | Total Group | | | Experimental Group | | | Control Group | | |
|---|---|---|---|---|---|---|---|---|---|
| **Penn shoulder *"total pain"* and lateral scapula *"Hands on hips"* position** | **Relationship** | **r** | **p** | **Relationship** | **r** | **p** | **Relationship** | **r** | **p** |
| **Week 3 to baseline** | + | 0.12 | 0.52 | - | 0.31 | 0.27 | + | 0.49 | 0.07 |
| **Week 6 to baseline** | - | 0.22 | 0.25 | - | 0.39 | 0.15 | + | 0.18 | 0.54 |
| **Week 9 to baseline** | + | 0.008 | 0.97 | - | 0.25 | 0.37 | + | 0.21 | 0.46 |
| **Thoracic rotation ROM and lateral scapula *"Hands on hips"* position** | | | | | | | | | |
| **Week 3 to baseline** | - | 0.29 | 0.12 | - | 0.19 | 0.49 | - | 0.40 | 0.15 |
| **Week 6 to baseline** | - | 0.22 | 0.26 | - | 0.24 | 0.39 | - | 0.18 | 0.54 |
| **Week 9 to baseline** | + | 0.08 | 0.68 | - | 0.09 | 0.76 | + | 0.25 | 0.39 |

*Note: A negative correlation (-) indicates that as lateral scapula slide test "Hands on hips" position improves, Penn Shoulder "total pain" decreases and thoracic rotation ROM improves. A positive correlation (+) indicates that as lateral scapula slide test "Hands on hips" position improves, Penn Shoulder "total pain" increases and thoracic rotation ROM decreases.*