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THE INFLUENCE OF A SINGLE BOUT OF SWIMMING TRAINING ON SCAPULAR UPWARD ROTATION AND MUSCLE STRENGTH IN JUNIOR CLUB SWIMMERS

By

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of MSc (Med) in the field of Biokinetics

Johannesburg, April 2015

South Africa

DECLARATION

I, Graham Hatch, hereby declare that the work in this thesis is my own work, all the sources I have used have been referenced and this thesis has not been previously submitted at another university with the aim of obtaining a degree.



_____ 30/04/2015

Signed **Date**

Abstract

Background: Swimming requires repetitive overhead movements that may lead to shoulder injury. Dysfunctions in the movements of the scapula have been associated with injury to overhead athletes in other sports. In addition, most of the current research describing scapular dysfunction in swimmers has assessed adults, with few studies assessing adolescent swimmers.

Objectives: The purpose of this study was to assess scapular position and muscle strength in junior club level swimmers following a single session of swimming training.

Methods: Thirty-two club level swimmers between the ages of 14 and 18 years from swimming clubs in the Johannesburg area participated in the study. A clinical screening protocol consisting of: scapular upward rotation was measured at 0˚, 90˚ and 180˚ of humeral abduction. Isometric strength of the upper and lower trapezius and serratus anterior muscles was performed using a hand held dynamometer. Shoulder pain was also assessed using a visual analogue scale. Testing was performed prior to and immediately after a single bout of swimming training. Changes in scapular upward rotation and strength pre- and post-training were compared using a student's t-test ($p \leq 0.05$).

Results: The total group of swimmers (n=32) were 14.2 ± 1.7 years; 166.9 ± 10 cm tall and weighed 59.2 ± 9.6 kg. Scapular upward rotation at 90^{o} increased on both the dominant and non-dominant sides by 13.8% (p=0.0002) and 18.2% (p<0.0001) respectively post-training. Upward rotation of the scapula at 180^{o} also increased by 2.6% in the dominant (p=0.0399) and by 5.3% in the non-dominant (p=0.0003) arms. Post-training bilateral differences in scapular position were found with the dominant side showing less scapular upward rotation at both 90˚ (p= 0.0179) and 180˚ (p= 0.0095) of humeral abduction when compared to the non-dominant side. Upper trapezius and serratus anterior strength increased post-training, whereas lower trapezius strength decreased by 12.8% in the dominant (p=0.0011) and by 14.9% non-dominant (p<0.0001) arms.

Conclusion: Following a single bout of swimming training, upward scapular rotation increases with concomitant increases in upper trapezius strength and significant decreases in lower trapezius strength. Furthermore, differences in upward rotation exist which may predispose swimmers to shoulder injury.

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Definitions of Terms

Abduction- Movement of the arm in the frontal plane away from the midline. [1]

Adduction- Movement of the arm in the frontal plane towards the midline. [1]

Anterior- The position of a point or body part that is located near the front.[2]

Arthrokinematics- The way two joint surfaces move in relation to one another. [3]

Depression- The inferior movement of the scapula during which the medial border remains approximately parallel to the spinous processes of the thoracic vertebrae. [1]

Downward rotation- The movement of the scapula whereby the glenoid faces inferiorly. [1]

Elevation- The superior movement of the scapula during which the medial border of the scapula remains approximately parallel to the spinous processes of the thoracic vertebrae. [1]

Extension- The movement of the arm during which the angle of a joint decreases. [1]

External rotation- The motion of the shoulder joint and arm where the anterior aspect rotates away from the midline. [1]

Inferior- The position of a point or body part that is closer towards the feet in relation to another point or body part. [2]

Internal rotation- The motion of the shoulder joint and arm where the anterior aspect rotates towards the midline. [1]

Isometric Strength – When the tension in a muscle equals the resistance to shortening and the muscle length remains relatively constant. [4]

Lateral- The position or body part that is further away from the midline of the body. [2]

Medial- The position or body part that is closer to the midline of the body. [2]

Posterior- The position of a point or body part that is located near towards the back. [2]

Protraction- The movement of the scapula whereby the scapula follows the contour of the rib cage during a combination of scapular abduction and internal rotation of the glenoid. [3]

Retraction- The movement of the scapula whereby the scapula follows the contour of the rib cage during a combination of scapular adduction and external rotation of the glenoid. [3]

Superior- The position of a point or body part that is closer towards the head in relation to another point or body part. [2]

Synovial joint- A joint that consists of a joint cavity, articular cartilage which is surrounded by a synovial membrane or capsule. [1, 3]

Upward rotation- The movement of the scapula whereby the glenoid faces superiorly. [1]

List of abbreviations

- AC: Acromioclavicular
- D: Dominant
- EMG: Electromyography
- GH: Glenohumeral
- HHD: Hand Held Dynamometer
- Km: Kilometre
- LT : Lower trapezius muscle
- MT: Middle trapezius muscle
- N: Newton
- ND: Non-Dominant
- ROM: Range of Motion
- SA: Serratus anterior muscle
- SC: Sternoclavicular
- SLAP : Superior labral tear anterior to posterior
- UT: Upper trapezius muscle

Chapter 1 – Introduction

1.1. The problem and setting

Swimming has grown to be one of the most popular sports in the world, with competitions taking place from a primary school level right the way up to the level of the Olympic Games. In order to be competitive, swimmers need to spend a large amount of time training in the pool, with elite swimmers training up to about 30 hours per week.[5] Distances of 10 to 14km per day are often swum, six to seven days per week, therefore the swimmers perform approximately 2500 rotations of the shoulder each day.[6] These repetitive overhead movements involve large moment arm forces which are being created by the swimmer in order to drag the water and propel the swimmer forward as quickly as possible.[1]

There are four swimming strokes that are used at competitions namely: front crawl or freestyle, backstroke, breast stroke and butterfly. The front crawl or freestyle stroke is by far the most common stroke that is swum during training, with 60%-80% of the total amount of time being spent on this stroke.[7] South African swimmers are seen as no different to their international counter parts in choice of swimming stroke during training. According to a study done by Puckree and Thomas (2006), 69% of the swimmers in their study reported that they swam freestyle for the bulk of the training time.[7]

During freestyle the majority of the force generated to move the swimmers body through the water originates from the shoulder girdle.[9] This places a large amount of stress on the shoulder joints and their surrounding soft tissues.

Considering the combination of the large amount of forces and the repetitive overhead nature of the task, shoulder pain is the most common complaint in swimmers.[10,11] The research done by Puckree and Thomas (2006) also showed that swimmers between the ages of 15 and 16 years old were significantly more injured (23%) when compared to their older counterparts.[7] They attributed this finding to the rapid growth that occurs in this age group.

'Swimmers shoulder' is a syndrome which may be related to sub-acromial impingement, tendinopathy of the rotator cuff and long portion of biceps brachii, shoulder instability, labral tear or acromioclavicular (AC) injury.[6,9] In clinical practice it is anecdotally accepted that there is a link between abnormal scapular kinematics, humeral head position and sub-acromial impingement. Normal scapular kinematics are essential for efficient glenohumeral

motion [12] however the repetitive overhead tasks, such as those performed in swimming, are likely to disrupt the normal scapulohumeral rhythm and could possibly play a crucial role in the development of 'swimmers shoulder'.[5, 13]

Possible reasons for the disruption in scapulohumeral rhythm during swimming include weakness and fatigue of the scapular upward rotators which work to position the scapula optimally during overhead tasks.[7] Su et al., (2004) observed significant fatigue related drops in strength of the scapular upward rotators in competitive swimmers over a single training session.[8] During their study they also observed that the swimmers who displayed signs of sub-acromial impingement showed a decreased upward rotation of the inferior angles of the scapula.

To date, only a few studies have investigated what biomechanical changes occur about the muscles of the shoulder girdle after a single bout of swimming training.[5, 10, 14] Establishing what changes occur to the strength of the scapular upward rotators and resultant movement of the scapula may enhance intervention strategies for swimmers who have the potential to develop 'swimmers shoulder'.

There appears to be a lack of consensus in the literature relating to strength of scapular stabilizers and scapular rotation. In addition to this the majority of studies that have been done to date are done on elite and college age swimmers. There has also been very little data that has been collected on junior swimmers to date. The lack of consensus may also be due to the differences in methodology of the studies in quantifying the changes in strength of the scapular stabilizers, as well as the change in scapular inclination. Therefore it is difficult to draw reliable conclusions from the currently available literature. It seems that there is some degree of fatigue that occurs in the scapular stabilizers in swimmers with both symptomatic and asymptomatic shoulders. However, the effect that this has on scapular kinematics is unclear.

1.2. Aim

The primary aim of this study was to assess the effect of fatigue associated with a single bout of swimming on the strength of the scapular stabilisers, as well as the upward rotation of the scapulae. The secondary aim was to determine if change in the position of the scapulae could be linked to pain.

1.3. Objectives

1. To compare scapular stabiliser strength and scapular inclination before and after a bout of swim training.
2. To determine the amount of shoulder pain before and after a single bout of swim training.
3. To determine if there was any association between the amount of shoulder pain and changes in shoulder strength and scapular upward rotation after a single bout of swim training.

1.4. Hypothesis

The strength of the scapular stabilisers or upward rotation of the scapula will be significantly altered following a single bout of swim training.

Chapter 2 - Literature Review

2.1. Introduction

The ability to make precise hand movements necessary for normal daily activities as well as athletic activities such as swimming is the result of the intricate interplay between the muscles, bones and ligaments which make up the shoulder complex. As much of the propulsive forces in swimming are generated by the shoulder girdle there is potential for fatigue which may result in a loss of normal shoulder mechanics that potentially leads to stress on the soft tissues around the joint. This chapter discusses the origins of swimming, anatomy and biomechanics of a normal shoulder and how it functions during swimming. Finally, the epidemiology of "swimmers shoulder" and pathomechanics of shoulder pain in swimmers will also be discussed.

2.2. History of swimming

Swimming can be dated back to ancient times, but did not become an organised sport until the early 19th century.[15] Cave paintings depict prehistoric man swimming out of necessity, as a means of crossing rivers and lakes. Artwork depicting people of both sexes swimming as a means of relaxation, work, bathing as well as fighting have been found in many countries such as; Egypt, Greece, Persia, Italy, Spain and even the Far East.[16] The ability to swim indicated either a high or low socio-economic status depending on the particular society. In ancient Egypt the pharaohs used to teach their children to swim and the young nobles used swimming as a means of demonstrating their physical prowess. Japanese women used to dive for pearls whilst Somali slaves were made to dive for gold nuggets in the Americas.[16]

In the early 19th Century swimming became a competitive sport as the National Swimming Society of Great Britain began to hold competitions, where most swimmers used breaststroke.[15] Swimming became an Olympic event in 1896 and featured freestyle and breaststroke, whilst backstroke was added at the 1904 games and butterfly was introduced in the 1956 Melbourne games. Women's swimming became an Olympic event in 1912 and the same events as the men have been swum since then.[15]

Of the four strokes that are swum competitively, freestyle is the stroke that is swum for the majority of the time during training.[7] Elite swimmers have been reported to spend an average of 53% of their training time swimming freestyle, with significantly less time being dedicated

to butterfly (13%), backstroke (21%) and breaststroke (13%).[9] Puckree and Thomas (2006) showed that in KwaZulu Natal 69% of the 90 swimmers that participated in their study reported that they spent the bulk of their time swimming freestyle during training.[8] The actual distances that elite swimmers perform during training ranges from 9 to 110 km per week, with a weekly average of 40 km per week equating to approximately 6 to 18 km per day.[9]

2.2.2. Mechanics of freestyle swimming

The freestyle swimming stroke demonstrates the complexity and control of shoulder movement that is needed in order to produce forward motion. The arthrokinematics are best described if the stroke is broken down into specific phases. There are two phases that make up the freestyle stroke being; the pull-through phase and the recovery phase.[7]

The pull-through phase begins with the leading hand entering the water and initiating the pull in the water.[7] The glenohumeral (GH) joint is externally rotated and abducted in this position with the scapula upwardly rotated and adducted. During the mid pull-through phase the hand moves towards the midline following an S-shaped curve. During this phase the GH joint is neutrally rotated in 90 degrees of abduction and the scapula has moved into protraction and is upwardly rotated. At this point the body has also rolled between 40 to 60 degrees from the horizontal position.[7] The late pull-through phase is characterised by the exit of the hand from the water and the beginning of the recovery phase of the stroke. The GH joint is placed in an internally rotated, adducted and extended position with the scapula downwardly rotated and adducted. The body has rolled back towards the horizontal during this phase.[7]

The recovery phase is characterised by the elbow lifting out of the water and the body rolling in the opposite direction to the pull-through phase.[7] The GH joint is placed in an externally rotated and abducted position with the scapula downwardly rotated and adducted. The identifying feature of the mid recovery phase is the initiation of breathing as the head turns to the side with a maximal body roll of between 40 to 60 degrees. There is 90 degrees of GH abduction and the humerus is externally rotated.[7] The scapula is upwardly rotated and protracted. The body then begins to roll back towards the horizontal swimming position characterising the late recovery phase up to the point where the hand enters the water again. In this phase the GH joint is maximally abducted and externally rotated and the scapula is protracted and upwardly rotated.[7]

2.2.3. Incidence of shoulder injuries in swimmers.

Considering the combination of the large amounts of forces and the repetitive overhead nature of the task, shoulder pain is the most common complaint in swimmers.[10, 11] Walker et al., (2012)[17] confirmed in their 12 month study of 74 competitive swimmers ranging from 11-27 years that shoulder injuries are common. They found that shoulder injuries accounted for 23-38% of the injuries in competitive swimmers and reported an injury incidence rate of 0.2 - 0.3 per 1000km swum.

Puckree and Thomas (2006) assessed adolescent swimmers (15 to 16 years old) in KwaZulu-Natal (KZN) and reported that this age group sustained significantly more injures (23%) compared to their older counterparts.[7] Freestyle was related to 70% of the injuries reported in their study. The average length of a training session for a swimmer in KZN is 90 minutes with an average of 11 sessions being swum in a week.

In a study of young surf lifesavers aged between the ages of 10-18 years old the incidence of injury was reported to be 2.1 per 1000 hours of training. The athletes that reported shoulder injury also reported higher number of swimming sessions, duration of sessions and distance swum during the week.[18]

2.3. Shoulder anatomy

The shoulder complex is made up of three bones namely the scapula, clavicle and humerus which in combination with the muscles that attach to them, form part of an intricate system that links the entire shoulder girdle onto the thorax.[19] There are four joints which make up the shoulder complex, namely; the Sternoclavicular (SC) joint, the acromioclavicular joint (AC), the glenohumeral (GH) joint and the scapulothoracic gliding mechanism.[20]

2.3.1. Sternoclavicular joint

The sternoclavicular joint is the only joint in the shoulder complex which physically attaches onto the axial skeleton and is formed by the articulation of the medial or sternal end of the clavicle and the manubrium of the sternum as well as the costal cartilage of the first rib.[3] A large fibrocartilage disk, similar to a meniscus, increases the congruence of the articular surfaces between the sternum and clavicle as well as transfers forces that originate from the lateral aspect of the clavicle.[3, 21] The joint is stabilised anteriorly and posteriorly by the

anterior and posterior SC ligaments with further support being given by the interclavicular ligament and the costoclavicular ligament.[21]

The SC joint is classified as a plain synovial joint but its function is more closely related to a ball-and-socket joint.[20] It serves as the fulcrum point for the movements of elevation and depression as well as abduction and adduction of the scapula.[22] The SC joint allows for between 45 to 60 degrees of elevation and five degrees of depression of the clavicle.[22] Elevation is primarily resisted by the costoclavicular ligament with depression being checked by the interclavicular ligament and the first rib.[22] Both movements of the clavicle occur in the sagittal plane. [3,22]

The SC joint also allows 15 to 20 degrees of protraction and 20 to 30 degrees of retraction of the clavicle, which occurs in the transverse plane.[3,21,22] These two movements are accompanied by rotation of the clavicle which occurs about a longitudinal axis.[3] Less than 10 degrees of anterior rotation occurs when the clavicle is depressed and from 40 to 50 degrees of posterior rotation occurs when the clavicle is elevated.[3]

2.3.2. Acromioclavicular joint

The AC joint is formed by the articulation of the lateral aspect of the clavicle with the acromion process of the scapula.[22] It is a plain synovial joint which enhances the range of motion of the humerus when it is in the glenoid.[21] The AC joint is surrounded by a thin capsule which offers little to joint integrity. As a result, the joint is reinforced by the superior and inferior AC ligaments which resist small rotary and translatory forces, in addition to the coracoclavicular ligaments which are responsible for resisting larger forces.[3,21]

The primary motions which occur at the AC joint are; internal and external rotation; anterior and posterior tilting and upward and downward rotation.[3] These motions occur around axes which are orientated to the plane of the scapula which sits 30 to 40 degrees anterior to the coronal plane. Internal and external rotation occurs around a vertical axis which allows the medial border of the scapula to lift off the thorax and the glenoid fossa to face either anteriorly or posteriorly.[3,22] The anterior and posterior tilting occurs around a coronal axis which allows the inferior angle of the scapula to lift off the thorax. Upward and downward rotation occurs around an anterior to posterior axis which is perpendicular to the plane of the

scapula.[3] Upward rotation tilts the glenoid superiorly whilst downward rotation does the opposite.

2.3.3. Glenohumeral joint

The articulation of the humerus on the scapula is known as the GH joint [3], and is seen as the main joint of the shoulder. The glenohumeral joint is comprised of the head of the humerus which rolls, glides or spins on the articular surface of the scapula known as the glenoid fossa forming a synovial ball-and-socket joint.[22] The GH joint is the most mobile joint in the body and has compromised stability and joint congruency in order to accommodate the mobility needs of the arm, elbow and hand. [3,22]

The articulation of the convex humeral head and concave glenoid fossa is the main contributory factor to the joints inherent instability as only a part of the humeral head is in contact with the glenoid at any one time.[21,22] Due to this lack of inherent stability and increased mobility around the GH joint, it depends primarily on the numerous muscles and ligaments which surround it for dynamic and static stability.[21]

Static stabilisers of the Glenohumeral joint

The rim of the glenoid fossa has a ring of fibrocartilage which makes up the glenoid labrum and serves to deepen the glenoid cavity by approximately 50%.[21] Surrounding the GH joint is a large, loose joint capsule that tightens and loosens depending on the position of the humerus. The joint capsule is reinforced by the superior, middle and inferior GH ligaments as well as the coracohumeral ligament. The inferior GH ligament is comprised of three components; the anterior and posterior bands with an axillary pouch in between.[3] These structures provide the static stability around the GH joint.

Dynamic stabilisers of the Glenohumeral joint

Active contraction of the rotator cuff musculature, which is comprised of the following muscles; supraspinatus, infraspinatus, teres minor and subscapularis, provides much of the musculotendinous support during normal motion.[22] Active joint stability is achieved in three ways:

1. Centralisation of the humeral head due to the compressive force exerted by the contraction of the rotator cuff muscles.

2. Anterior and posterior displacement is prevented by the tension generated across the tendons of the rotator cuff when there is active muscular contraction.
3. Passive tension of the tendons provides some stability.

Active stability of the GH joint relies on the co-ordinated contraction of the rotator cuff and deltoid muscles.[22] During abduction and flexion of the shoulder the deltoid muscle is the primary mover. Its action, if left unopposed would be to pull the humeral head superiorly into the subacromial space. However, the collective actions of the rotator cuff muscles offset the superior translatory force of the deltoid due to their lines of pull, and cause the humeral head to spin, thereby allowing normal glenohumeral motion to occur.[3]

Movements that occur around the GH joint include; flexion and extension, medial and lateral rotation as well as abduction and adduction.[3] Flexion and extension occurs around a coronal axis which passes through the centre of the humeral head. Medial and lateral rotation occurs about a vertical axis which passes through the humeral head and is parallel to the shaft of the humerus. Abduction and adduction occur about an anterior to posterior axis which passes through the centre of the humeral head.[3] The amount of motion in the GH is dependent on the movement of the scapula as well as arm position. Abduction in the GH joint is limited when the humerus is internally rotated, this is due to the greater tubercle that is obstructed by the coracoacromial arch.[3]

2.3.4. Scapulothoracic joint

The scapulothoracic joint is not a true joint but it is critical to optimal shoulder function.[21] It is formed by the articulation of the scapula on the thorax and is dependent on the integrity of the AC and SC joints. Any movement of the scapula has to result in movement at the other joints.

Motions of the scapula are similar to those already discussed in the AC joint. These include upward/downward rotation, internal/external rotation and anterior/posterior tilting. Upward/downward rotation of the scapula is thought to be a primary motion of the scapulothoracic joint because it is readily observed during elevation of the arm.[3] In a normal shoulder the tilting and internal and external rotation of the scapula are difficult to observe and should be thought of as secondary motions along with the available translatory motions of the scapula of elevation/depression including protraction/retraction.

Upward rotation of the scapula on the thorax plays a major role in the available range of the upper arm during flexion and abduction.[3] There are approximately 60 degrees of upward rotation of the scapula on the thorax available.

Elevation of the scapula is produced by performing a shrugging motion and depression is performed by pushing the shoulders inferiorly.[3] They are effectively translatory movements whereby the scapula slides superiorly and inferiorly along the rib cage. Elevation of the scapula requires elevation of the clavicle and minute adjustments at the AC joint in order to maintain its contact with the rib cage.

Protraction and retraction are the result of the scapula following the curve of the rib cage as the clavicle protracts or retracts and the AC joint either internally or externally rotates.[3]

Internal and external rotation of the scapula occurs at the AC joint and when excessive, is considered a pathological movement as the medial border of the scapula would lift off the contour of the ribcage.[3]

Anterior and posterior tilting of the scapula is a critical component to maintaining congruency of the scapula with the rib cage, and occurs mainly at the AC joint in combination with posterior rotation of the clavicle.[3] Isolated anterior tilting that occurs at the AC joint results in prominence of the inferior angle of the scapula and is often found in pathological conditions of the shoulder.

The scapula has many roles in optimal shoulder function which include: serving as a stable base for rotator cuff activation, synchronous rotation with the humerus during elevation in order to maintain glenohumeral congruency and acting as a link in the kinetic chain.[12]

Scapulohumeral Rhythm

The muscles which attach from the thorax onto the scapula act to dynamically position the glenoid relative to the humerus whilst the humerus is being elevated.[23] The coordination between the scapula and the humerus, known as scapulohumeral rhythm, is what gives the shoulder girdle the ability to move through a large range of motion.[3]

During normal abduction of the humerus the scapula should not move during the first 30 degrees, otherwise known as the setting phase.[3, 21, 23] During the next 60 degrees of motion the scapula abducts and upwardly rotates 1 degree for every 2 degrees that the humerus abducts. From 90 degrees until full abduction the ratio of movement between the scapula and

humerus is 1:1. Correct biomechanics of the scapula and humerus minimises the amount of stress to tissues surrounding the glenohumeral joint during overhead movements.[24]

Dynamic Scapular Stability

There seems to be consensus that scapular motions are controlled by the collective actions of the serratus anterior muscle (SA), upper trapezius muscle (UT), middle trapezius muscle (MT) and lower trapezius muscle (LT) as well as the rhomboids.[3, 10, 21, 23]

Upward rotation of the scapular during abduction of the arm allows for increased space under the coracoacromial arch.[25] The upward rotation of the scapular is primarily controlled by the actions of the SA, UT and LT muscles which form a force couple.[10] A force couple is formed when force is exerted by two different muscles which are equal in magnitude, opposite in direction acting on the same joint. The type of motion that is created by a force couple is usually a pure rotation unless other forces are exerted onto the joint.[3]

Pathogenesis of shoulder impingement

The diagnosis of shoulder impingement is one of the most common conditions diagnosed for shoulder pathology.[12] The condition was first described by Dr Charles Neer who stated that impingement involves a mechanical compression of the soft tissues which are located under the subacromial or coracoacromial arch.[23] The soft tissues found in this area are the supraspinatus tendon, sub acromial bursa as well as the long head of the biceps tendon.[3] Repetitive compression eventually leads to irritation and inflammation of these structures, and manifests as anterior or anterior-lateral-superior shoulder pain. [23, 26]

Despite the frequency with which impingement is diagnosed, it would seem that it is more a clinical sign rather than an actual diagnosis.[25] The exact aetiology of shoulder impingement has been debated since the early 1950's. A few theories as to the exact mechanism of shoulder impingement have been proposed, and it would seem that a variety of factors may be acting independently or in combination to produce the characteristic pain of impingement.[26] Consequently there are approximately nine specific diagnoses that all produce the signs of impingement.[25]

Shoulder impingement is categorised as either, external impingement which is broken down to primary or secondary impingement or internal impingement.[25]

Internal Impingement

Internal, or glenoid impingement as it sometimes referred to occurs as a result of the under surface of the rotator cuff impinging on the posterior-superior surface of the glenoid and the greater tuberosity of the humerus.[26] It is commonly found in patients younger than 35 years of age and is seen as a somewhat normal physiological occurrence which serves to protect against excessive external rotation. Sports that require a large amount of throwing with repeated bouts of abduction and external rotation can lead to the production of symptoms which present as posterior or anterior shoulder pain.[25, 27]

Internal impingement can result in articular sided tears of the posterior rotator cuff or superior labral tear from anterior to posterior (SLAP) with the possibility of both occurring in the same shoulder.[26] The exact sequence of events which leads to symptomatic internal impingement has been debated over a number of decades. Current hypothesises suggest numerous factors associated with the development of internal impingement namely; physiological remodelling of the shoulder, posterior capsule contracture.[27] These factors in combination with scapular malposition, inferior angle prominence, coracoid pain and scapular dyskinesis collectively known as SICK scapula syndrome[28] lead to changes in glenohumeral rotation, usually a deficit in internal rotation.[27]

Primary external impingement

Abnormal variations of the acromion decrease the subacromial space and may impinge on the superior aspect of the rotator cuff.[21] It normally occurs in patients older than 35 years of age and presents as anterior and or lateral shoulder pain with overhead activity. Clinical tests for shoulder impingement are usually always positive.[25]

There are a number of anatomical variations which can contribute to primary external impingement namely:

Acromial morphology: There have been three distinct shapes of the acromion that have been described in the literature namely Type 1 flat, Type 2 curved and Type 3 hooked.[26] The Type 3 acromion has been implicated in a greater incidence of rotator cuff tears due to mechanical impingement. Abnormalities in acromial morphology are the result of congenital abnormalities in the ossification centres in the acromion known as os acromiale or osteophyte formation. The acromion is formed by three separate ossification centres namely the pre-acromion, meso-acromion and the meta-acromion. Ossification normally occurs at the age of 22 – 25 years. Malunion of these ossification centres is called os acromiale.[26]

Osteophyte formation: An osteophyte is a section of irregular bone formation that occurs as a result of age, traction due to ligamentous attachments and trauma such as rotator cuff tears.[29]

Thickening of the coracoacromial ligament: The coracoacromial ligament has been implicated in subacromial impingement when there is an absence of any bony pathology.[26] Thickening of the ligament has been proposed to decrease the subacromial space thereby compressing the supraspinatus.[25,26] There is confusion as to whether the ligament thickens and causes impingement of the subacromial structures or whether the thickening of the ligament actually occurs as a result pathology in the subacromial space which puts pressure in the ligament and causes the thickening.

Secondary external impingement

Secondary external impingement is the result of decreasing the subacromial space caused by altered angulation of the acromion due to instability of the scapula, otherwise known as scapular dyskinesis.[25] It usually occurs in people under 35 years old and can lead to dysfunction of the rotator cuff. Secondary external impingement presents similarly to primary external impingement with shoulder pain being experienced antero-laterally with overhead activity. Clinical tests for impingement may be positive but there may also be signs of instability. Radiographic investigations are usually unremarkable especially the early stages.

Scapular Dyskinesis

Scapular dyskinesis is a collective term which describes the dysfunctional movements of the scapula.[30] The term means that there is an alteration of movement of the scapula during humeral movement Kibler and Sciascia (2010) state that scapular dyskinesis can be identified by the following:

- Abnormal static scapular positioning and or motion, such as either excessive or decreased upward rotation, which is characterised by prominence of the medial border of the scapular
- Prominence of the inferior angle of the scapular and/or early elevation upon elevation of the arm
- Rapid downward rotation of the scapular during lowering of the arm

According to the consensus statement from the second international conference on the scapula held in Lexington Kentucky there are numerous causes of scapular dyskinesis which include[13]:

- Bony causes such as thoracic kyphosis or clavicle fracture with non-union or malunion
- Joint causes such as AC joint instability or GH joint internal derangement.
- Neurological causes such as cervical radiculopathy, long thoracic or spinal accessory nerve palsy
- Soft tissue causes such as inflexibility, muscle weakness or altered muscle activation.

Alterations in movements of the scapula decrease the efficiency of shoulder function and may result in strain on the acromioclavicular joint, decreased sub acromial space, changes in maximal muscle activation and optimal arm position and motion.[30]

Scapulothoracic muscle strength, changes in rotation and scapular dyskinesis

To be successful in competition, a swimmer needs to spend time in the water building up fitness and refining the technique of their chosen stroke/s in order to improve their personal best times. Due to the fact that 90% of the propulsive force in swimming is produced by the upper extremities combined with the amount of time dedicated to training, and the repetitive nature of the task, injury to the shoulder in swimmers is extremely common.[11, 32] The so-called 'swimmers shoulder' is also likely to be the result of several factors such as postural malalignment, altered scapular kinematics as well as muscular imbalances.[5, 13]

Muscle strength can be measured in a number of ways from the 'gold standard' of isokinetic testing which can measure the strength of various types of muscle contractions throughout a full range of motion (ROM) [33,34], such as concentric and eccentric actions to the more affordable clinical methods which utilise handheld dynamometry. [4, 35]

Concentric muscle actions occur when the contractile forces of the muscles are greater than the resistive forces.[4] This results in a shortening of the contractile units within the muscle fibre to create a movement. Swimming and cycling are almost utilise almost exclusively concentric muscle actions.

Eccentric muscle actions are muscle actions during which the contractile units within a muscle fibre lengthen as a result of the contractile forces being less than the resistive forces.[4] Lowering a weight that is too heavy is an example of an eccentric muscle action. Isokinetic dynamometers can be used to assess both of these types of muscle actions. The term isokinetic means constant velocity and the use of an isokinetic dynamometer allows assessment **of** muscle actions to be done at preselected velocities.[33]

Isometric muscle actions occur when there is no change in the length of the contractile units within a muscle fibre.[4] This occurs when the contractile forces within the muscle are equal to the resistive forces. The most common way to assess this component of strength is using hand held dynamometry.

A study done by Cools, et al., (2010)[36] on 19 male and 16 female elite adolescent tennis players, quantified the strength of UT, LT and SA using hand held dynamometry. Table 2.1 summarises their results.

Table 2.1 The absolute muscle strength (N) of UT, LT and SA on the dominant and non-dominant sides of adolescent tennis players. [36]

Muscle tested	Absolute Muscle Strength (N)	
	Dominant Arm	Non Dominant arm
Upper trapezius	M:159 ± 47.7	148 ± 49.6
	F: 124 ± 36.7	113 ± 33
Lower trapezius	M:31.2 ± 10.7	29.9 ± 9.2
	F: 27.9 ±9.2	27.9 ± 10.0
Serratus anterior	M:155 ± 61.9	137 ± 44.8
	F: 118 ± 51.6	113 ± 50.8

Data presented as mean ± SD

In the same study on elite adolescent tennis players Cools et al., (2010)[36] reported the upward rotation of the scapula during abduction at 0, 90 and 180 degrees. They found that at 0˚ of humeral abduction the males (n=19) had an upward rotation of the scapula of 3.5 ± 2.6˚ for the non-dominant arm and 5.2 ± 4.0˚ for the dominant arm. This changed to 24.2 ± 6.2˚ of upward rotation, for the non-dominant arm and 29.2 ± 10.4˚ for the dominant arm respectively when the humerus was abducted to 90˚. During full abduction (180˚) the upward rotation of the scapula was measured at 53.0 ± 7.8˚ for the non-dominant arm and 54.1 ± 9.1˚ for the dominant arm.

The female tennis players (n=16) had an upward rotation of the scapula of 4.4 ± 4.0˚ for the non-dominant arm and 4.6 ± 3.0˚ for the dominant arm at 0˚ of humeral abduction. This changed to 21.3 ± 5.8˚ of upward rotation, for the non-dominant arm and 26.9 ± 8.3˚ for the dominant arm respectively when the humerus was abducted to 90˚. During full abduction, the upward rotation of the scapula was measured at 48.7 ± 7.5˚ for the non-dominant arm and 55.9 ± 6.5˚ for the dominant arm.[36]

Table 2.2 summarises the scapular upward rotation in the throwing and non-throwing shoulders of professional baseball players (n=27, Age 20 ± 1.6 years) at varying degrees of humeral elevation.[37]

Table 2.2 Scapular upward rotation in professional baseball players.

Humeral elevation range of motion (Degrees)	Throwing shoulder	Non-throwing shoulder
Rest	6.4 ± 4.7	4.7 ± 4.1
60	8.4 ± 6.1	5.6 ± 4.3
90	14.2 ± 6.5	10.1 ± 6.1*
120	22.4 ± 6.3	20.0 ± 5.8

* Throwing shoulder vs non-throwing shoulder p=0.04; Data presented as mean ± SD

One of the major risk factors for shoulder pain in swimming is training volume.[10] Sein et al.,(2010)[10] showed that elite swimmers who trained more than 15 h/week were twice as likely to develop pain as those who swam less. When the training volume was increased to 35 h/week the risk for developing shoulder pain was increased four-fold. Swimmers who spend large amounts of time in the water, are likely to create significant fatigue of the scapular stabilisers.

Considerable debate exists in the literature with regards to the influence that the strength of the muscles which stabilise and control the movement of the scapula has on the effect on scapular dyskinesis. Ludewig and Reynolds (2009)[39] highlight this point in their review which stated that many discrepancies exist in the literature with regards to the consistency and directions of the changes noted in scapular mechanics.

McQuade et al., (1998) [38] showed that significant change to the scapulohumeral rhythm occurred as a result of a fatiguing protocol. In their study 25 adult men between the ages of 18-45 performed maximal shoulder flexion against a pulley system which was connected to an isokinetic dynamometer. EMG and kinematic data were recorded for the duration of the test. As a result of their protocol the upper trapezius, lower trapezius, anterior and middle deltoid showed signs of fatigue, and **yet** there was an increased upward rotation of the scapula in relation to the humerus. They concluded that the scapular stabilisers are recruited

sufficiently to be susceptible to fatigue and that this was responsible for the changes in to the scapulohumeral rhythm.[38]

Forthomme et al.,(2008)[40] stated that the changes to scapulothoracic motion, as a result of fatigue of the stabilisers of the scapula, generally correspond to increased upward rotation of the scapula.

However, other studies have shown that fatiguing the shoulder muscles with repetitive overhead activities can result in significant decreases in scapular upward rotation and possible risk of shoulder injury[39]

Ludewig and Cook (2000)[41] showed a decreased activation of SA, a prominent upward rotator of the scapula, when participants were asked to perform overhead work. The resultant decreased upward rotation was only present in participants who had symptoms of shoulder impingement shoulders.

Madsen et al., (2011*)*[11] demonstrated that scapular dyskinesis occurs in non-injured swimmers throughout the course of a 100 minute long training session. Their results showed that there was an 82% increase in the prevalence of scapular dyskinesis from the start of the session until the end. They therefore, assumed that the fatigue of the scapular stabilizers could be the main contributor to the changes which they observed.

In a study of competitive swimmers between the ages of 18 to 35 years Su, et al., (2004)[8] observed changes in scapular kinematics following a single bout of training in swimmers with symptomatic shoulders and asymptomatic shoulders. Using hand held dynamometry to assess strength they observed a 13% drop in force production in the SA and a 14% drop in the UT following a single bout of swimming training for both groups.[5] In the same study the authors noted that there was a decrease in scapular upward rotation in the swimmers with symptomatic shoulders following a single training session.

In contrast to this, Van de Velde et al., (2010)[15] found no significant decrease in force production following a single two hour bout of swimming training in a group of thirty (15 male and 15 female) swimmers between the ages of 13 to 18 years. The authors explained their findings by suggesting that the scapular stabilizers in younger swimmers may be less sensitive to fatigue than in the older swimmers.

Crotty and Smith (2000)[42] were unable to demonstrate a difference in scapular position following **an** intense swimming session in 21 male high school swimmers using the lateral scapular slide test. The use of which has been disputed by Koslow et al., (2003)[43]

Crotty and Smith (2000)[42] did however show that bilateral differences were present between the dominant and non-dominant sides after the swimming session. They showed that in the non-dominant arm the scapula was more medially positioned in relation to the dominant side. This would suggest that the scapula of the non-dominant arm was more downwardly rotated following the swimming session.

The shoulder is an incredibly complex joint where there is a compromise of stability which enables mobility. This unfortunately seems to make it prone to injury in swimmers. The majority of studies that have been done to date are done on elite and college age swimmers. There has been very little data that has been collected on junior swimmers. Methodological differences between the studies in quantifying the changes in strength of the scapular stabilizers, as well as the change in scapular inclination make it difficult to draw reliable conclusions from the literature. It seems that there is some degree of fatigue that occurs in the scapular stabilizers in swimmers with both symptomatic and asymptomatic shoulders. However, the effect that this has on scapular kinematics is unclear.

Chapter 3 – Methods

3.1. Study Design

This study was a cross sectional study design.

3.2. Participant recruitment

Ten swimming clubs in the Gauteng area were contacted and invited to participate in the study, only two clubs responded. Both male and female swimmers from the ages of 14 to 18 years who swam at club level were invited to participate in the study. A convenient sample of 32 swimmers (16 male and 16 female) from the two swimming clubs in Alberton and Boksburg were recruited for the study. In order for this study to obtain a minimum statistical power of 80%, it was determined that a minimum of 20 participants were required**.** This was calculated based on a variance of 130 **N** which was obtained from the research done by Van de Velde et al., 2010[15] and at an effect size to detect the mean difference of 10 N of force.

All participants and their parents (if under the age of 18 years old) were given an information sheet (Appendices A and B) and participants over 18 years old were given a separate information sheet (Appendix C). Participants were asked to give written assent (if under 18 years old) (Appendix D) and written consent (if over 18 years old) (Appendix E). Parents were required to sign parental consent if their child was younger than 18 years of age (Appendix F). Ethics for the study was obtained from the Medical Human Research Ethics Committee at the University of the Witwatersrand (Appendix G).

3.2.1. Inclusion and Exclusion Criteria

For participation in the study the following inclusion criteria had to be met:

- Level one and two swimmers from the ages of 14 to 18 years old
- Had been training for at least one year
- Had a swimming training schedule of more than 6 sessions per week at the time of the study

Exclusion criteria include the following:

- A history of cervical or thoracic pathology
- A diagnosis of shoulder pathology in the last 6 months
- Had less than 180˚ of humeral elevation in the scapular plane
- Had a previous shoulder surgery within the last 12 months

3.3. Site of study

All testing was done at the respective club's swimming pools in the Johannesburg area where the swimmers trained.

3.4. Testing Procedures

3.4.1. Anthropometry

In order to obtain descriptive data of the population, the following variables were measured.

Height- This was measured in centimetres (cm) using a portable stadiometer (Panamedic, RSA). Participants were asked to stand barefoot with their backs against the wall and their head in the Frankfort plane whilst the measurement was being taken.

Weight- This was measured in kilograms (kg) using a portable electronic scale (Beurer GmbH, Germany). Participants were asked to step onto the scale and remain motionless until a reading was available. Weight measurements were taken in dry swimming costumes with the shirt off before the training session began.

3.4.2. Scapular Inclination

Two Pro 360 digital inclinometers (SPI-Tronic; Penn Tool Co, Maplewood, New Jersey, USA) were used to measure the changes in scapular orientation as well as the degree of humeral abduction. The use of which has shown good to excellent validity (r=0.85 – 0.92) as well as good to excellent reliability ($ICC_{3,1}$= 0.90-0.96). [44] The first inclinometer was secured perpendicular to the humerus just distal to the insertion of the deltoid and measured the degree of humeral abduction. Upward rotation of the scapula was measured using the second gravity inclinometer using methods originally described by Johnson et al. (2001), [45] and other researchers.[5, 36] Scapular upward rotation was measured in three positions: at rest with the

arm relaxed at the participants side, 90˚and 180˚ of humeral abduction. All measurements were taken three times with the average of the three measurements used for statistical analysis. Measurements were done on both the dominant and non-dominant shoulders. The dominant shoulder was measured first followed by the non-dominant side. This procedure was followed both immediately prior to and immediately following a training session.

3.4.3. Isometric strength

Isometric strength of the scapular upward rotator muscles; serratus anterior (SA) upper trapezius (UT) and lower trapezius (LT) muscles were measured using a handheld dynamometer (HHD)(compuFET; Hoggan Health Industries Inc, West Jordan, Utah, USA) the use of which has been found to be acceptable for both research and clinical use. [36, 46] The use **of** HHD has shown good to excellent reliability (r=0.89 – 0.96).[47] Handheld dynamometry was chosen because it provided the ability to quickly test and retest strength following the training session poolside, thereby reducing the chance of recovery of the involved muscles following the training session.

Strength testing was based on the positions described by Kendall et al. (2005)[48] on both the dominant as well as non-dominant arms for the following muscles:

Serratus anterior muscle**:** Participants were positioned supine with the arm elevated to 90˚ of forward flexion. The HHD was placed in the palm of the participant and a downward force was applied. The participant was then asked to perform a protraction movement by pushing the hand towards the ceiling and allowing the shoulder to lift from the plinth whilst keeping the elbow extended at all times.[36]

Upper trapezius muscle: Participants were seated, arms at their sides with the HHD positioned over the acromion process. The examiner placed a downward pressure the direction of scapular depression. The participant performed a shrug manoeuvre by elevating their shoulder superiorly against the HHD. [16,36]

Lower trapezius muscle: Participants were placed prone on a plinth with their arms at their sides and the arm being tested was elevated to 145˚ of abduction with full glenohumeral external rotation. The HHD will be placed at the lateral aspect of the radius with a downward pressure applied. The participant was then asked to flex the shoulder from this position.[36]

Isometric strength was the maximal amount of force exerted against the hand held dynamometer over a period of 5 seconds. Participants were allowed three sub maximal contractions followed by three maximal contractions which were recorded. The average of the three maximal contractions were used for statistical analysis. Two sets of measurements were made, the first before entering the pool, and the second immediately following a normal training session under the guidance of their coach. Strength testing was performed after the scapular inclination measurements were performed. Muscle strength was tested bilaterally with the dominant side being tested first.

Muscle fatigue was defined as the significant drop in isometric force production as a result of the swim training.

3.4.4. Swimming Distance

Total amount of time spent in the pool was 90 minutes**.** The training session was done under the guidance and supervision of the coach.

3.4.5. Pain

A visual analogue scale (VAS) was used to rate if there was pain in the shoulder both before and after the bout of swimming. The swimmers were asked to rate their pain on a 100mm long line. Zero mm corresponded with no pain and 100mm corresponded with maximal pain. The VAS was given to the swimmer immediately prior to performing strength and scapular inclination measurements.

3.5. Data Analysis

The anthropometric data were analysed descriptively and reported as mean ± SD. The Student's t-test were used to determine: differences between upward rotation of the scapula between pre and post the swimming; differences in absolute isometric muscle strength pre- and post- swimming training; and differences in isometric strength values between males and females, as well as swimmers of different weights. The change in VAS scores pre-swim vs. post-swim were correlated to the percentage change in strength using Pearson's correlation coefficient. Statcrunch software (Integrated analytics, LLC) was used to analyse the data. A level of 5% was determined to be significant.

Chapter 4 – Results

4.1. Demographic information

Thirty-two swimmers [male (n = 16) and female (n = 16)] volunteered to participate in this study from two different swimming clubs in the Johannesburg area. The bout of swimming training for both clubs lasted 90 minutes and swimmers only swam freestyle The group had a mean age of 14.2 ± 1.7 years, weighed 59.2 ± 9.6kg and were 167 ± 10cm tall (Table 4.1). The male swimmers had a mean age of 14.3 ± 1.7 years; weighed 61 ± 10.5kg and were 173 ± 9.4cm tall. The female swimmers had a mean age of 14.1 ± 1.8 years; weighed 57.4 ± 8.5kg and were 160.9 ± 6.2 cm tall. The majority of the swimmers in this study reported being right hand dominant (n=29).

Table 4.1: Demographic Information for the Total Group (n=32)

	Total group (n=32)	Male Swimmers (n=16)	Female Swimmers (n=16)
Age (yrs)	14.2 ± 1.7	14.3 ± 1.7	14.1 ± 1.8
Height (cm)	166.9 ± 10	173.0 ± 9.4	160.9 ± 6.3
Weight (kg)	59.2 ± 9.6	61.0 ± 10.6	57. 4 ± 8.6

4.1.2. Visual analogue scores

Table 4.2 below shows the mean and standard deviation of the visual analogue scores for the dominant **and** non- dominant shoulders pre vs post swim. In the total group there were only three reported instances of slight pain in the non-dominant shoulder and four occurrences in the dominant shoulder before the swimming session. After the swimming session there were four occurrences of a pain in the non-dominant shoulder and 6 in the dominant shoulder.

Table 4.2: Visual analogue scores for the dominant and non-dominant shoulders pre vs post swim.

	Pre Swimming session		Post Swimming session	
	Non- dominant (n=32)	**Dominant (n=32)**	**Non-dominant (n=32)**	**Dominant (n=32)**
Avg Score (mm)	0.15 ± 0.68	0.35 ± 1.13	0.44 ± 1.43	0.66 ± 1.68
Median Score	0	0	0	0
Range	3.8	5	6.8	6.8

On average the pain only increased slightly for both the dominant (0.34 ± 1.6) and non-dominant arms (0.26 ± 1.3)(Table 4.3). There was only a significant correlation between the

change in pain and scapular inclination in the non-dominant shoulder after the swimming training (r= -0.374, p=0.03) at 90 degrees of scapular upward rotation.

Table 4.3 Correlation between VAS score and scapular inclination

	Percentage change 0 deg		Percentage change 90 deg		Percentage change 180deg	
	D	ND	D	ND	D	ND
Change VAS score	-0.642 (p=0.72)	-0.113 (p=0.53)	-0.072 (p=0.07)	-0.374 (p=0.03)*	-0.079 (p=0.66)	0.264 (p=0.14)

4.2. Scapular Upward Rotation:

4.2.1. Bilateral differences in scapular orientation

Figure 4.1 below shows the upward rotation of the scapula for both the non-dominant and dominant arms with 0^{o} of humeral abduction before and after the swimming session. No differences were found between the dominant ($3.2 \pm 4.1^{\circ}$) and non-dominant ($4.1 \pm 3.8^{\circ}$, p= 0.29) shoulders for the total group before the swimming training. There were also no bilateral differences noted before the swimming session when the group was divided into males (p= 0.450) and females (p= 0.49) Furthermore, there were no differences between the dominant ($3.9 \pm 5.2^{\circ}$) and non- dominant ($2.1 \pm 6.3^{\circ}$, p= 0.11) shoulders of the total group after the swimming session, nor when the group was divided into males (p = 0.49) and females (p = 0.13)

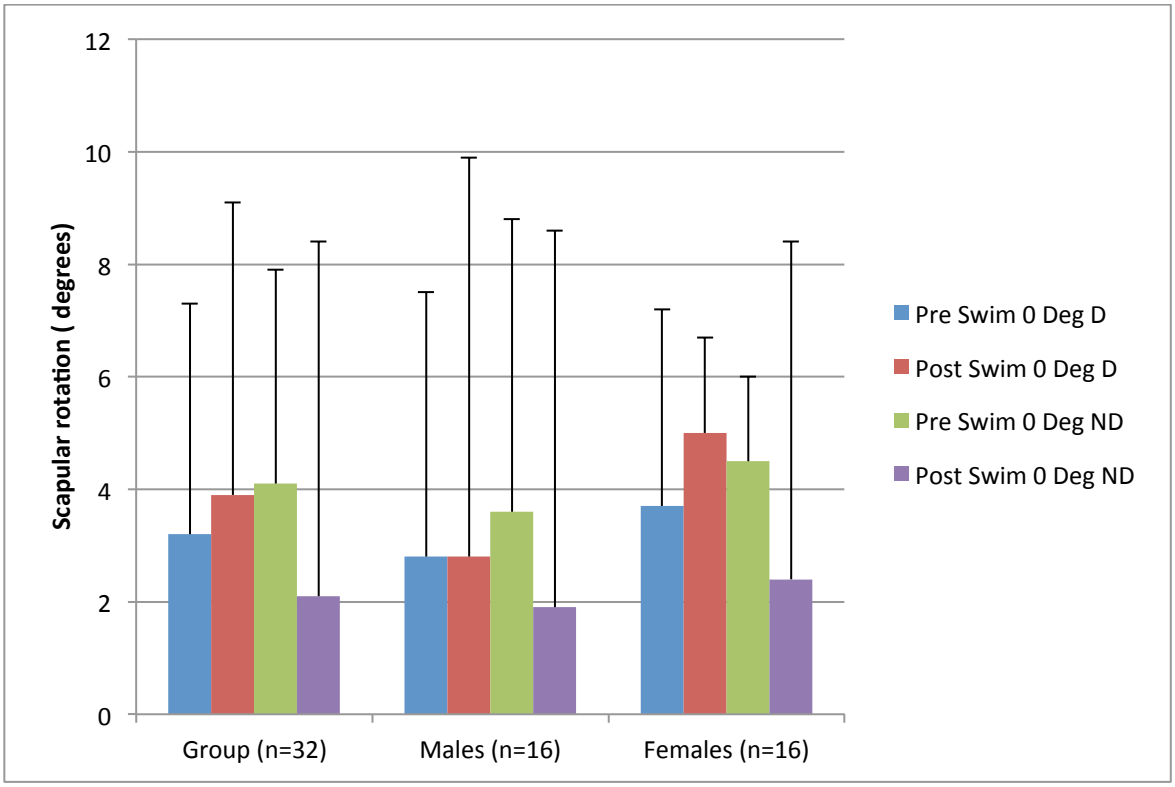


Figure 4.1: ***Pre-Swim and Post swim Scapular Rotation with 0 degrees of Humeral Abduction for the total group (n=32), and divided into males (n=16) and females (n=16)***

Abbreviations: ND= Non dominant side. D = Dominant side.

Figure 4.2 shows the upward rotation of the scapula for both the non-dominant and dominant arms at 90^{o} of humeral abduction before and after the swimming session. There were no differences between the dominant (23.2 ± 5.3˚) and non-dominant (24.2± 5.7˚, p= 0.91) shoulders of the total group before the swimming session, nor when then group was divided into males (p = 0.67) and females (p = 0.89). However, a significant difference was found between the dominant (26.5± 7.4˚) and non- dominant (29.6± 6.7˚, p= 0.02) shoulders of the total group after the swimming session, indicating a change in the bilateral symmetry of the movement pattern.

There was also a bilateral difference found in the female group, following the bout of swimming training with the dominant side (25.7± 7.7˚) having a smaller angle of inclination compared to the non-dominant side (29.3± 7.1˚; p=0.02). There were no differences bilaterally in the male group following the training (Dominant: 28.1± 7˚, and Non-dominant: 29.9± 6.5˚; p= 0.30)

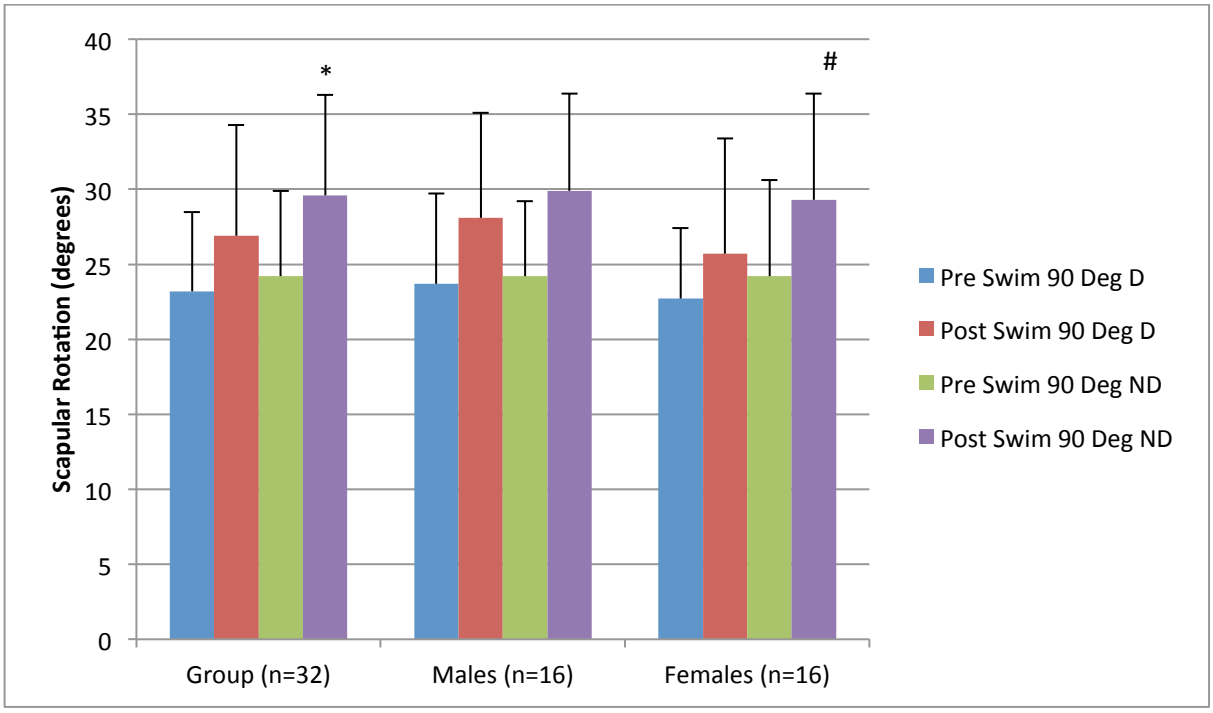


Figure 4.2 ***Pre-Swim and Post- Swim Scapular Rotation with 90 degrees of Humeral Abduction for the total group (n=32), and divided into males (n=16) and females (n=16)***

Abbreviations ND= Non dominant side. D = Dominant side.

*Total group: dominant side < non-dominant side: p =0.018

Females: dominant side < non-dominant side: p = 0.021

Figure 4.3 shows the upward rotation of the scapula before and after the swimming session with 180^{o} of humeral abduction. There was no significant difference between the dominant (55.3.± 6.1˚) and non-dominant (55.8± 5.7˚, p= 0.47) shoulders of the total group before the swimming session. No significant bilateral differences were noted before the swimming session when the total group was divided into males (D 56.7± 6.9˚ vs ND 57.5± 4.3˚; p = 0.39) and females (D 54± 5.1˚ vs ND 54.1± 6.4˚; p = 0.92).

A significant difference was found between the dominant (56.8 ± 6.7˚) and non- dominant (58.9 ± 4.7˚; p= 0.01) shoulders of the total group after the swimming session, indicating that there was a change in symmetrical movement between the sides.

When the group was divided into males and females, no significant differences were found between the dominant (58.6 ± 7.1˚) and non-dominant (59 ± 5.1˚; p= 0.66) sides in the males. However, the female group showed significantly less upward rotation of the scapula on the dominant (55 ± 5.9˚) arm when compared to the non-dominant side (58.9 ± 4.5˚; p=0.003) following the swimming session.

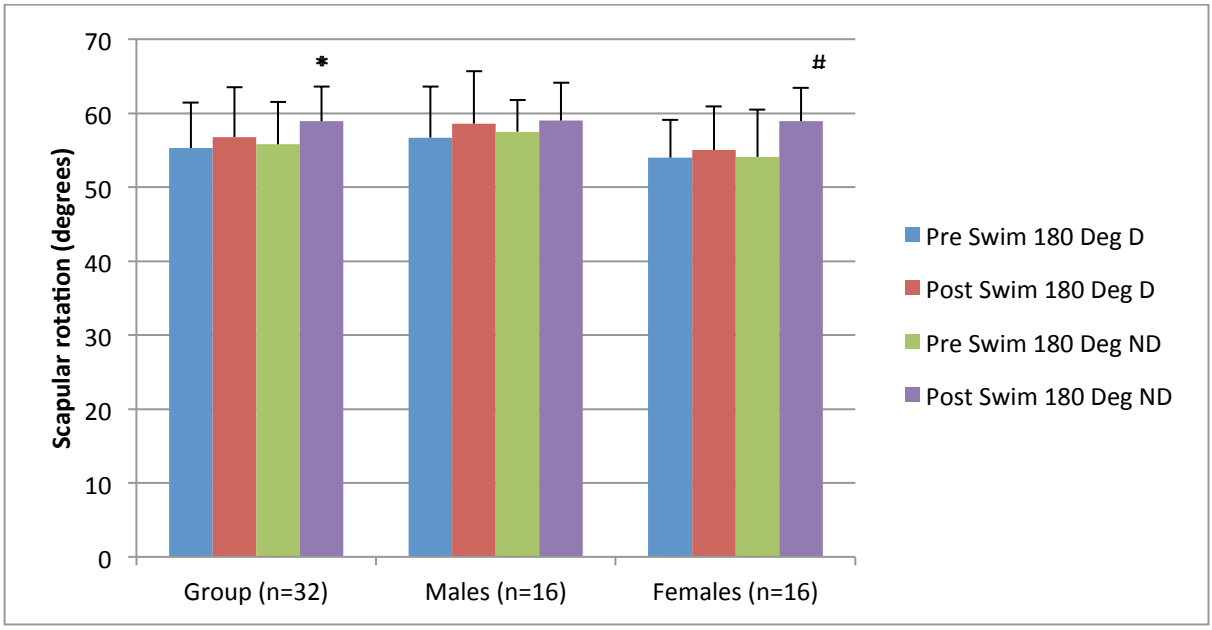


Figure 4.3 ***Pre-Swim and Post- Swim Scapular Rotation with 180 degrees of Humeral Abduction for the total group (n=32), and divided into males (n=16) and females (n=16).***

Abbreviations ND= Non dominant side. D = Dominant side.

*Total group: dominant side < non-dominant side: p =0.01

Females: dominant side < non-dominant side: p = 0.003

Figure 4,4 below shows the percentage change in scapular rotation pre versus post swim. On average, for the total group, at 0^{o} of humeral abduction, the scapular orientation changed by 17.9% and the non-dominant side changed by -95.2 % as a result of the swimming session.

When divided into gender specific groups the males showed no change on the dominant side (0%) and -89.5% change for the non-dominant side. For the female group (n=16) there was a 26% change in scapular orientation for the dominant side and -87.5% change in scapular orientation for the non-dominant side. Post-swim, although no significant differences were found, there appears to be a trend towards less upward rotation of the scapula on the non-dominant side when the humerus is at 0^{o} of abduction.

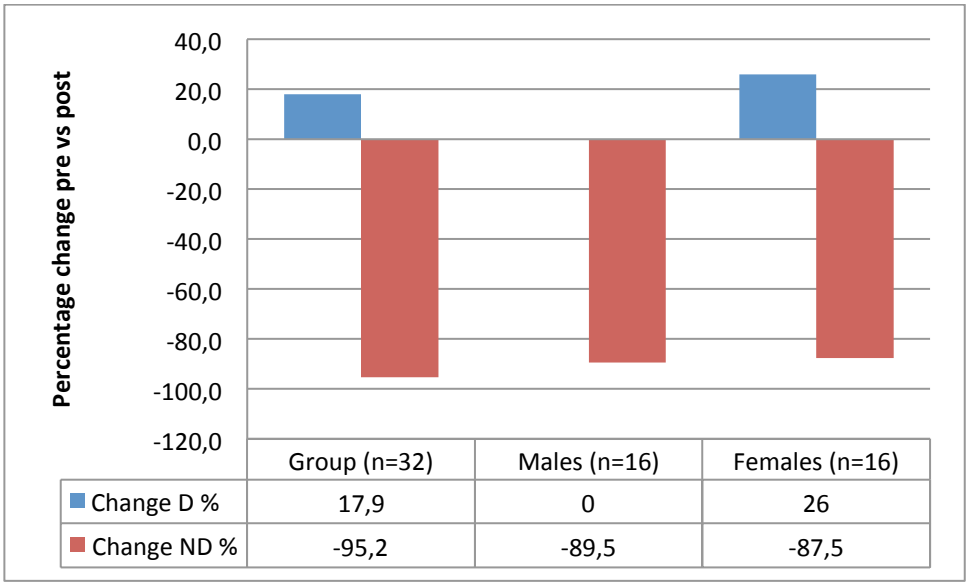


Figure 4.4: Percentage change Pre-Swim vs Post- Swim Scapular Rotation with 0 degrees of Humeral Abduction for the total group (n=32), and divided into males (n=16) and females (n=16)

Abbreviations ND= Non dominant side. D = Dominant side.

Figure 4.5 below shows the percentage change in scapular rotation pre versus post swim when the humerus was abducted to 90˚. For the total group, there was a significant increase in upward rotation of the scapula from pre- to post-testing in both the dominant (pre 23.2 ± 5.3˚ vs post 26.9 ± 7.4˚; p = 0.0002) and non-dominant sides (pre 24.2 ± 5.7˚ vs post 29.6 ± 6.7˚; p< 0.0001).

When analysing the separate groups, the males had a significant increase in scapular upward rotation post-testing for both the dominant (pre 23.7 ± 6.0 ˚ vs post 28.1 ± 7.0˚; p=0.001) and non-dominant (pre 24.2 ± 5.0˚ vs post 29.9 ± 6.5˚; p= 0.003) sides. Therefore, on average, there was a significant increase of 15.7% of scapular upward rotation on the dominant side and 19.1% on the non-dominant side.

The female group also showed a significant increase in scapular upward rotation post-testing for both the dominant (pre 22.7 ± 4.7 ˚ vs post 25.7 ± 7.7˚; p=0.049) and non-dominant (pre 24.2 ± 6.4˚ vs post 29.3 ± 7.1˚; p= 0.004) sides. Thus on average, there was a significant increase of 11.7% of scapular upward rotation for the dominant side and 17.4% for the non-dominant side.

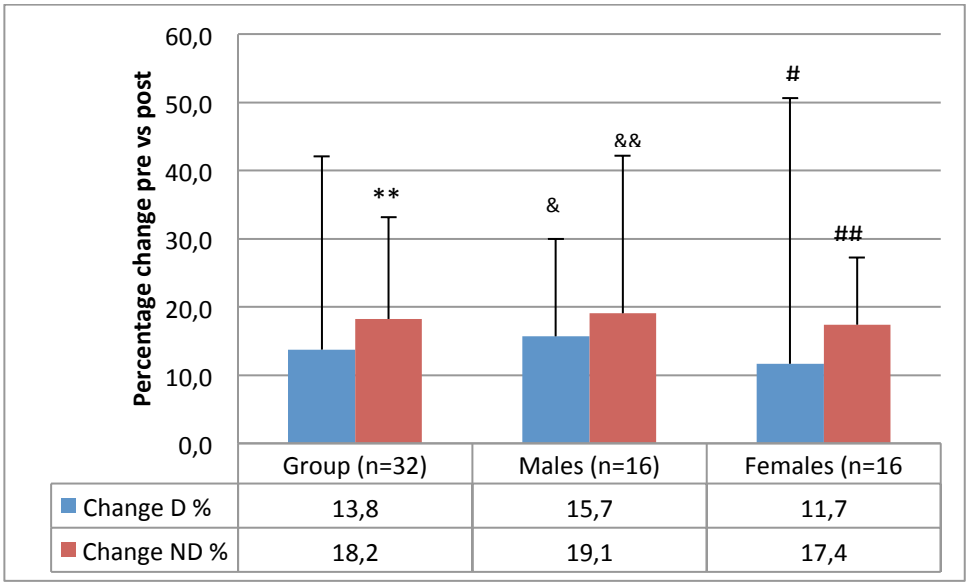


Figure 4.5: Percentage change Pre vs Post Swim Scapular Rotation with 90 degrees of Humeral Abduction for the total group (n=32), and divided into males (n=16) and females (n=16)

Abbreviations ND= Non dominant side. D = Dominant side.

*Total group: Pre vs post swimming dominant side p = 0.0002

**Total group: Pre vs post swimming non-dominant side: p < 0.0001

&Males: Pre vs post swimming dominant side: p = 0.001

&&Males: Pre vs post swimming non-dominant side: p = 0.003

Females: Pre vs post swimming dominant side: p = 0.049

##Females: Pre vs post swimming non-dominant side: p = 0.004

Figure 4.6 shows the percentage change of scapular rotation when the humerus was abducted to 180˚.The total group had a significant increase in upward rotation of the scapula. This occurred on both the dominant (pre: 55.3 ± 6.1˚ vs post 56.8 ± 6.7˚; (p = 0.04) and non-dominant sides (pre 55.8 ± 5.7˚ vs post 58.9 ± 4.7˚; p= 0.0003).

When split into groups the males showed no significant change in scapular upward rotation for both the dominant (pre 56.7 ± 6.9˚ vs post 58.6 ± 7.1˚; p=0.12) and non-dominant (pre 57.5 ± 4.3˚ vs post 59.0 ± 5.1˚; p= 0.110) sides following the swimming session. On average, there was only an increase of 3.2% of scapular upward rotation for the dominant side and 2.5% for the non-dominant side.

Following the swimming session, the female group showed a significant increase for the upward scapula rotation on the non-dominant side (pre 54.1˚ ± 6.4 vs post 58.9˚± 4.5; p= 0.001), however there was no change in scapular upward rotation for the dominant side (pre 54.0 ± 5.1˚ vs post 55.0 ± 5.9˚; p= 0.18). On average, in the female group at 90 degrees of

humeral abduction, there was a minor change of 1.8% of scapular upward rotation for the dominant side and significant change of 8.1% for the non-dominant side.

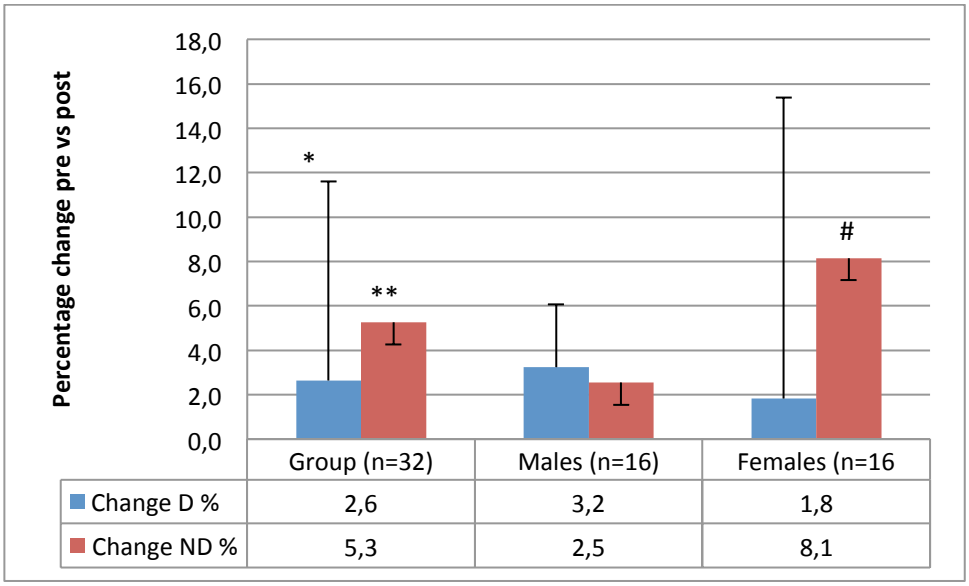


Figure 4.6: Percentage change Pre vs Post Swim Scapular Rotation with 180 degrees of Humeral Abduction for the total group (n=32), and divided into males (n=16) and females (n=16)

Abbreviations ND= Non dominant side. D = Dominant side.

*Total group: Pre vs post swimming dominant side p = 0.04

**Total group: Pre vs post swimming non-dominant side: p = 0.0003

#Females: Pre vs post swimming non-dominant side: p = 0.001

4.3. Scapular muscle strength

4.3.1. Bilateral strength differences

Table 4.4 below shows the absolute strength of the upper trapezius muscle for both the non-dominant and dominant arms before and after the swimming session. There was no significant difference between the strength of the dominant (127.1 ± 63.6N) and non-dominant (121.6 ± 61.3N, p= 0.80) sides for the total group. Furthermore, no significant bilateral differences were found before the swimming session when the group was divided into males (p= 0.93) and females (p= 0.73)

However, following the swimming session, there was a significant difference between the dominant (178.6 ± 40.6N) and non-dominant (167.2 ± 34.8N, p= 0.02) sides for UT strength of the total group. No significant bilateral differences were noted after the swimming session in male group for the dominant (195.3 ± 41.9N) and non-dominant (182.3 ± 38.7N, p= 0.19) sides. This was also the case in the female group), for the dominant (161.8 ± 32.5N) and non-dominant (152.2 ± 22.7N, p= 0.06) sides.

Table 4.4: Mean Absolute Strength of the Upper Trapezius muscle pre- and post-swimming training Male (n=16) and Female (n=16) Adolescent Swimmers

Group	Pre Swimming Session		Post Swimming Session	
	Dominant	Non-Dominant	Dominant	Non-Dominant
Total (n=32)	127.1 ± 63.6	121.6 ± 61.3	178.6 ± 40.6*	167.2 ± 34.8
Males (n=16)	141.5 ± 62.9	135.5 ± 63.1	195.3 ± 41.9	182.3 ± 38.7
Females (n=16)	112.8 ± 63	107.7 ± 58.2	161.8 ± 32.5	152.2 ± 22.7

* Total group: post-swimming session: dominant vs non-dominant, p =0.02

Table 4.5 below shows the absolute strength of the lower trapezius muscle (LT) for both the non-dominant (ND) and dominant (D) arms before and after the swimming session. There was no significant difference between strength of the dominant (37.7 ± 12.4N) and non-dominant (35.7 ± 11.0N, p= 0.463) LT muscle in the total group before the swimming session. Also, no bilateral differences were noted before the swimming session when the group was divided into males (p= 0.918) and females (p= 0.381).

When assessing the total group following the swimming training, the dominant LT muscle strength (33.4 ± 9.4N) was significantly greater than the non-dominant (31.1 ± 9.0, p<0.0001) LT muscle strength. Significant bilateral differences were also noted after the swimming session in the male group between the dominant (36.3± 8.9N) and non- dominant (35.1 ± 9.8N, p< 0.0001) sides. There was a significant bilateral difference for the female group, with the dominant (30.6 ± 9.2 N) LT muscle strength being greater than that of the non-dominant (27.1 ± 6.1 N, p<0.0001) side.

Table 4.5: Mean Absolute Strength of Lower Trapezius muscle pre- and post- swimming training in Male (n=16) and Female Adolescent swimmers (n=16)

Group	Pre Swimming Session		Post Swimming Session	
	Dominant	Non- Dominant	Dominant	Non- Dominant
Total (n=32)	37.7 ± 12.4	35.7 ± 11.0	33.4 ± 9.4	31.1 ± 9.0*
M (n=16)	42.2 ± 13.5	41.1 ± 11.4	36.3 ± 8.9	35.1 ± 9.8#
F (n=16)	33.3 ± 9.7	30.3 ± 7.7	30.6 ± 9.2	27.1 ± 6.1&

*Total group: Post dominant vs non-dominant side p <0.0001

#Male group: Post dominant vs non-dominant side p <0.0001

&Female group: Post dominant vs non-dominant side p <0.0001

Table 4.6 below shows the absolute strength of the serratus anterior muscle (SA) for both the non-dominant and dominant arms before and after the swimming session. There were no differences between strength of the dominant (193.0 ± 40.6 N) and non- dominant (184.5 ± 43.7 N, p= 0.649) SA muscles in total group before the swimming session.

No differences were noted before the swimming session in the male group in the dominant (206.8 ± 42.7 N) and non-dominant (201.9 ± 46.3 N, p= 0.414) sides. The SA muscle of the non-dominant (167.2 ± 34.2N) arm in the female group was weaker at the start of the swimming session when compared to the dominant arm (179.2 ± 34.1 N, p = 0.04).

For the group there were no differences in strength between the dominant (220.3 ± 36.2 N) and non-dominant (207.9 ± 9.0 N, p=0.981) SA muscles after the swimming session. The same was true for the SA muscle strength after the swimming session in male group for the dominant (240.3± 36.7 N) and non-dominant (230.5 ± 42.8 N, p=0.414) sides. There were also no strength differences in the female group , for the dominant (200.3 ± 22.5 N) and non-dominant (185.4 ± 26.7 N, p=0.361) sides.

Table 4.6: Mean Absolute Strength of the Serratus Anterior muscle pre- and post- swimming training in Male (n=16) and Female (n=16) Adolescent Swimmers.

Group	Pre Swimming Session		Post Swimming Session	
	Dominant	Non- Dominant	Dominant	Non- Dominant
Total (n=32)	193 ± 40.6	184.5 ± 43.7	220.3 ± 36.2	207.9 ± 41.9
M (n=16)	206.8 ± 42.7	201.9 ± 46.3	240.3 ± 36.7	230.5 ± 42.8
F (n=16)	179.2 ± 34.1	167.2 ± 34.2[&]	200.3 ± 22.5	185.4 ± 26.7

[&]Female group: Post dominant vs non-dominant side p <0.0001

4.3.2. Ipsilateral strength differences

The pre-and post-testing results for the ipsilateral differences in UT muscle strength for the total group, males and females are shown in Figure 4.7 below. The total group showed an increase in strength of 28.8% (p<0.0001) in the dominant arm and a 27.2% (p=0.0001) increase in strength for the non-dominant side following the swimming session.

A significant ipsilateral difference in UT muscle strength were noted for the males for both the dominant (p=0.0011) and the non-dominant (p=0.0016) sides following the training session. The males showed a 27.6% increase in strength of the UT muscle for the dominant side and a 25.6 % increase in the non-dominant side. Similarly the females showed significant differences in UT muscle strength for the dominant (p=0.0004) and non-dominant

(p=0.002) sides following the swimming session. In the female group there was a 30.3% increase in UT muscle strength in the dominant arm and a 29.2% increase in strength in the non-dominant arm following the swimming session.

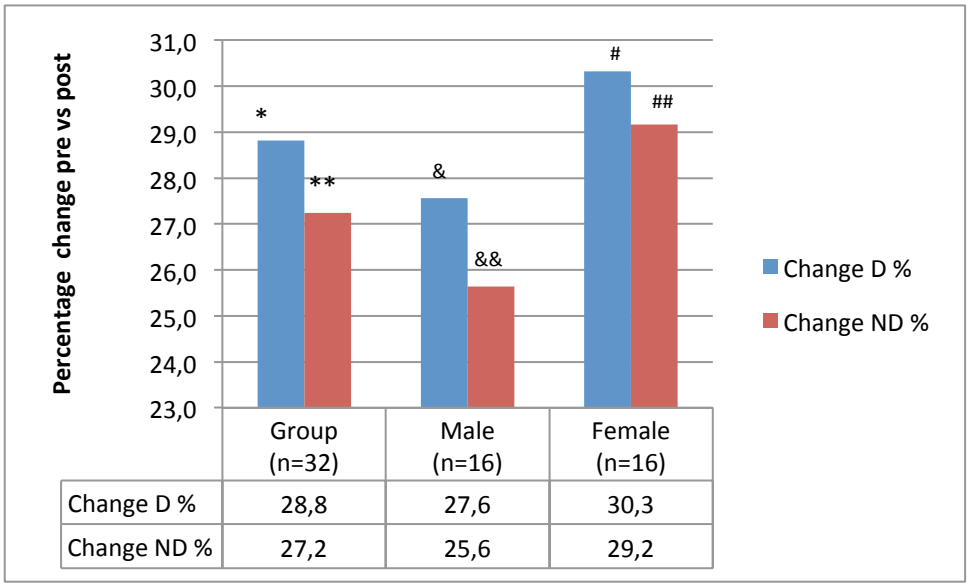


Figure 4.7: Percentage change Pre-Swim vs Post- Swim Upper Trapezius Muscle Strength for the total group (n=32), and divided into males (n=16) and females (n=16)

Abbreviations ND= Non dominant side. D = Dominant side.

*Total group: Pre vs post swimming dominant side $p < 0.0001$

**Total group: Pre vs post swimming non-dominant side: $p = 0.0001$

&Males: Pre vs post swimming dominant side: $p = 0.0011$

&&Males: Pre vs post swimming non-dominant side: $p = 0.0016$

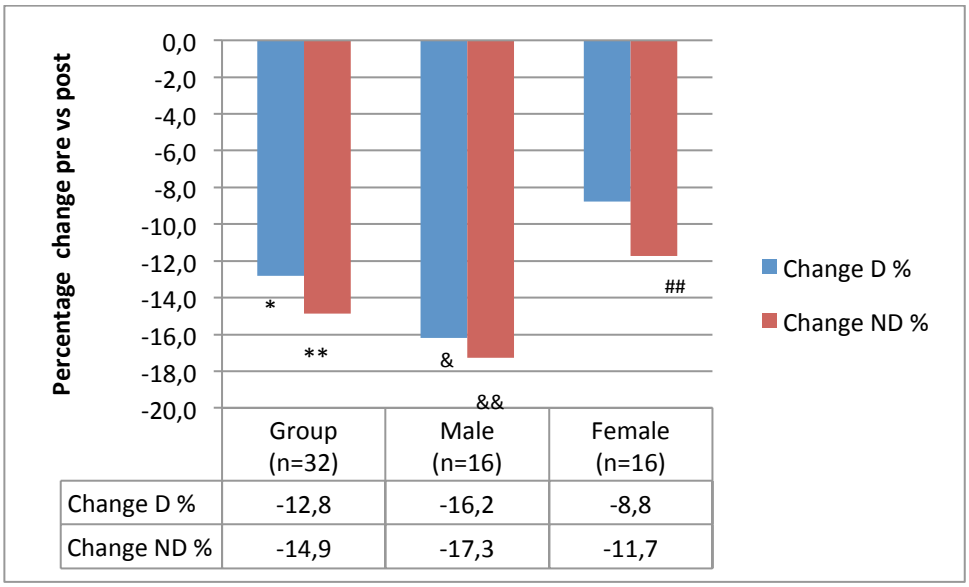
Females: Pre vs post swimming dominant side: $p = 0.0004$

##Females: Pre vs post swimming non-dominant side: $p = 0.002$

Figure 4.8 below shows the percentage change in LT muscle strength from pre to post swim. The total group showed a decrease in strength of LT muscle of 12.9 % ($p = 0.0011$) in the dominant arm and a 14.9 % ($p=0.0011$) decrease in strength for the non-dominant side following the swimming session.

Significant ipsilateral differences in LT muscle strength were noted for the males for both the dominant ($p=0.0082$) and the non- dominant ($p<0.0001$) sides. The males showed a 16.2% decrease in strength of the LT muscle for the dominant side and a 17.3 % decrease in the non-dominant side. Similarly the females showed significant differences in LT muscle strength for the dominant ($p=0.05$) and non-dominant ($p<0.0001$) sides following the swimming

session. In the female group there was an 8.8% decrease in LT muscle strength in the dominant arm and an 11.7% decrease in strength in the non-dominant arm.



	Group (n=32)	Male (n=16)	Female (n=16)
Change D %	-12,8	-16,2	-8,8
Change ND %	-14,9	-17,3	-11,7

Figure 4.8: Percentage change Pre-Swim vs Post-Swim Lower Trapezius Muscle Strength for the total group (n=32), and divided into males (n=16) and females (n=16)

Abbreviations ND= Non dominant side. D = Dominant side.

*Total group: Pre vs post swimming dominant side p =0.0011

**Total group: Pre vs post swimming non-dominant side: p = 0.0011

&Males: Pre vs post swimming dominant side: p = 0.0082

&&Males: Pre vs post swimming non-dominant side: p < 0.0001

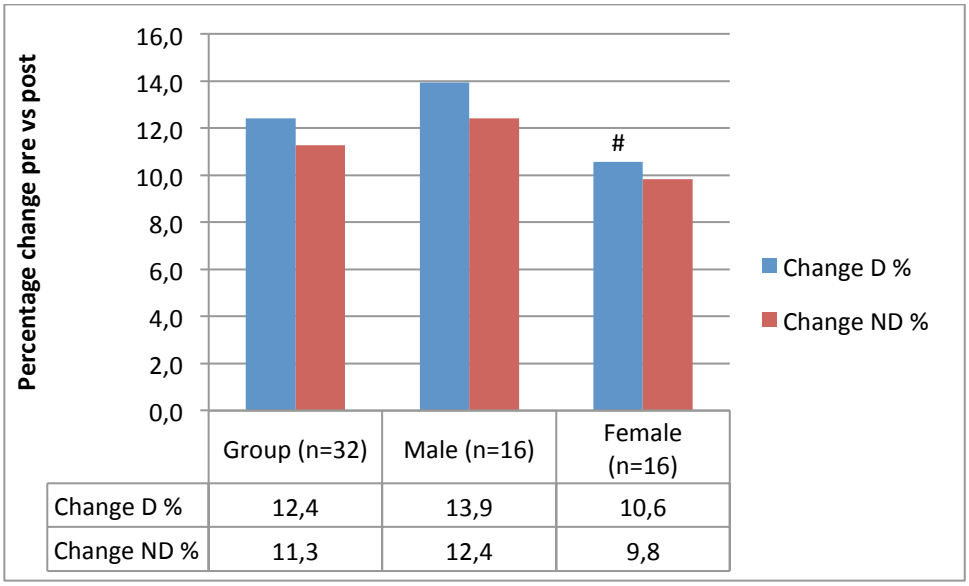
Females: Pre vs post swimming dominant side: p = 0.05

##Females: Pre vs post swimming non-dominant side: p < 0.0001

Figure 4.9 below shows the change in strength of SA muscle pre versus post swim. No significant ipsilateral differences in strength were noted in SA muscle for the group for both the dominant (p=0.293) and the non-dominant (p=0.392) sides when the pre-swim absolute strength values were compared to the post-swim values for the same side. Overall the group showed a 12.4% increase in SA muscle strength in the dominant arm and 11.3% increase in strength for the non-dominant side.

The males showed a 13.9 % increase in strength of the SA muscle for the dominant side and a 12.4% decrease in the non-dominant side. The slight increases in strength were not significant for either the dominant (p=0.925) or the non-dominant arms (p=0.823)

The females, however, showed a significant difference in SA muscle strength for the dominant (p=0.02) side and an insignificant difference in strength of the non-dominant (p=0.307) side following the swimming session. The female group showed a 10.6% increase in SA muscle strength in the dominant arm and a 9.8% increase in strength in the non-dominant arm.



	Group (n=32)	Male (n=16)	Female (n=16)
Change D %	12,4	13,9	10,6
Change ND %	11,3	12,4	9,8

Figure 4.9: Percentage change Pre-Swim vs Post-Swim Serratus Anterior Muscle Strength for the total group (n=32), and divided into males (n=16) and females (n=16)

Abbreviations ND= Non dominant side. D = Dominant side

[#] Females: Pre vs post swimming dominant side: p = 0.05

4.3.3. Relative strength bilateral differences

Table 4.7 below shows the bilateral strength measures for the upper trapezius muscles which are normalised to body weight for the total group, and then broken down to males and females. There was no significant difference between the strength of the dominant (2.23 ± 1.24N/kg) and non-dominant (2.11 ± 1.12N/kg, p= 0.112) sides for the total group. Furthermore, no significant bilateral differences were found before the swimming session when the group was divided into males (p= 0.364) and females (p= 0.115)

However, following the swimming session, there was a decreased strength of the non-dominant UT muscle (2.86 ± 0.55N/kg) when compared to the dominant side (3.05 ± 0.55N, p= 0.0009). The UT muscle on the non-dominant (3.02 ± 0.52N/kg) was weaker for the male group when compared to the dominant side (3.24 ± 0.62N/kg, p= 0.0118). This was also the case in the female group, for the dominant (2.86 ± 0.69N/kg) and non-dominant (2.7 ± 0.56N/kg, p= 0.0375) sides.

Table 4.7: Mean Relative Strength of the Upper Trapezius muscle pre- and post- swimming training in Male (n=16) and Female (n=16) Adolescent Swimmers.

Group	Pre Swimming Session		Post Swimming Session	
	Dominant	Non- Dominant	Dominant	Non- Dominant
Total (n=32)	2.23 ± 1.24	2.11 ±1.12	3.05 ± 0.55	2.86 ±0.55*
M (n=16)	2.39 ± 1.23	2.28 ± 1.12	3.24 ± 0.62	3.02 ± 0.52#
F (n=16)	2.06 ± 1.28	1.95 ± 1.13	2.86 ± 0.69	2.7± 0.56&

*Total group: Post dominant vs non-dominant side p = 0.0009

#Male group: Post dominant vs non-dominant side p = 0.0118

&Female group: Post dominant vs non-dominant side p = 0.0375

When assessing the total group following the swimming training, the relative strength of the dominant LT muscle (0.57 ± 0.18N/kg) was significantly greater than the non-dominant (0.53 ± 0.13, p=0.036) LT muscle strength (Table 4.8). No significant bilateral differences in strength were found after the swimming session in the male group between the dominant (0.6 ± 0.15 N) and non-dominant (0.57 ± 0.12N/kg, p=0.274) sides. In the female group there was a trend of the non-dominant (0.48 ± 0.13) LT muscle being weaker after the swim when compared to the dominant side (0.53 ± 0.17), however the results were not significant (p= 0.081).

Table 4.8: Mean Relative Strength of the Lower Trapezius muscle pre- and post swimming training in Male (n=16) and Female (n=16) Adolescent Swimmer.

Group	Pre Swimming Session		Post Swimming Session	
	Dominant	Non- Dominant	Dominant	Non- Dominant
Total (n=32)	0.63 ± 0.18	0.60±0.16	0.57±0.13	0.53±0.13*
M (n=16)	0.68± 0.15	0.67±0.13	0.60±0.15	0.57±0.12
F (n=16)	0.59± 0.21	0.53±0.15	0.53±0.17	0.48±0.13

*Total group: Post dominant vs non-dominant side p = 0.036

Table 4.9 below shows the relative strength of the SA muscle for both the non-dominant and dominant arms before and after the swimming session. The strength of the dominant (3.32 ± 0.81 N/kg) side was greater than the non- dominant (3.17± 0.80 N/kg, p= 0.039) SA muscle in total group before the swimming session.

No differences in relative strength were found before the swimming session in the male group in the dominant (3.44 ± 0.72 N/kg) and non- dominant (3.37 ± 0.83 N, p= 0.498) sides. The SA muscle of the non-dominant (2.97 ± 0.73 N/kg) arm in the female group was weaker at the start of the swimming session when compared to the dominant arm (3.20 ± 0.89 N/kg, p = 0.034).

When assessing the total group following the swimming session, the relative strength values for SA muscle of the non-dominant arm (3.56 ± 0.69 N/kg) were significantly weaker than the dominant (3.79 ± 0.74 N/kg) side.

No significant bilateral differences in strength were found after the swimming session in the male group between the dominant (4.02 ± 0.72 N/kg) and non- dominant (3.82 ± 0.55 N/kg, p=0.243) SA muscles. In the female group, however, the non-dominant SA muscle (3.30 ± 0.74 N/kg) was significantly weaker after the swim when compared to the dominant side (3.57 ± 0.71, p= 0.047)

Table 4.9: Mean Relative Strength of the Serratus Anterior muscle pre- and post swimming training in Male (n=16) and Female (n=16) Adolescent Swimmers.

Group	Pre Swimming Session		Post Swimming Session	
	Dominant	Non- Dominant	Dominant	Non- Dominant
Total (n=32)	3.32 ± 0.81	3.17 ± 0.80*	3.79± 0.74	3.56 ± 0.69**
M (n=16)	3.44 ± 0.72	3.37 ± 0.83	4.02 ± 0.72	3.82 ± 0.55
F (n=16)	3.20 ± 0.89	2.97± 0.73&	3.57 ± 0.71	3.30± 0.74&&

*Total group: Pre dominant vs non-dominant side p = 0.039

& Female group: Pre dominant vs non-dominant side p = 0.034

**Total group: Post dominant vs non-dominant side p = 0.028

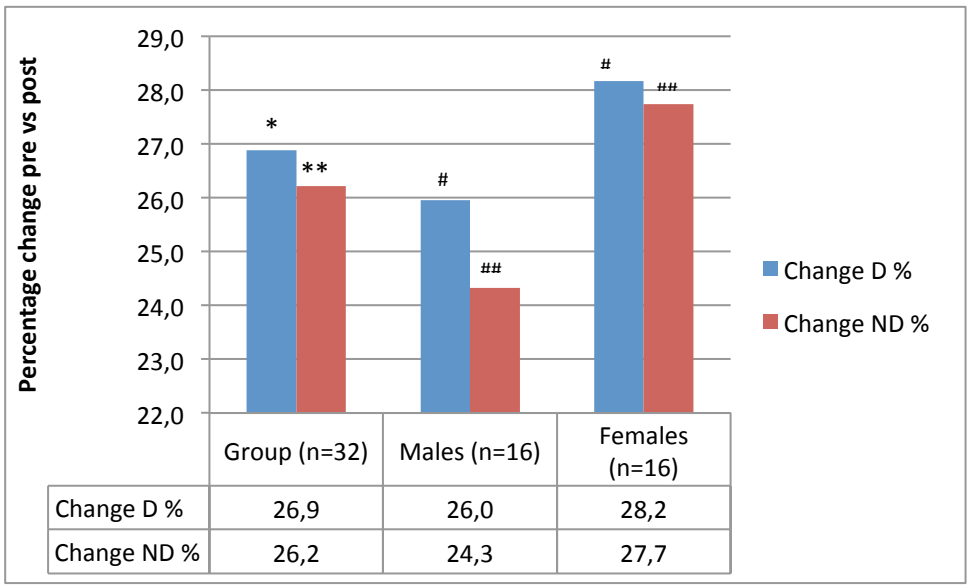
&&Female group: Post dominant vs non-dominant side p = 0.047

4.3.4. Relative ipsilateral strength

Figure 4.10 below shows the percentage change normalised strength of the UT muscle pre- and post-testing for the total group, as well as divided into males and females. The total group showed an increase in strength of 26.9% ($p<0.0001$) in the dominant arm and a 26.2% ($p<0.0001$) increase in strength for the non-dominant side following the swimming session.

A significant ipsilateral difference in UT muscle strength were noted for the males for both

the dominant (p=0.0018) and the non-dominant (p=0.003) sides following the training session. The males showed a 26.0% increase in strength of the UT muscle for the dominant side and a 24.3 % increase in the non-dominant side. Similarly the females showed significant differences in UT muscle strength pre versus post session for the dominant (p=0.002) and non-dominant (p=0.0001) sides following the swimming session. In the female group there was a 28.2% increase in UT muscle strength in the dominant arm and a 27.7% increase in strength in the non-dominant arm following the swimming session.



	Group (n=32)	Males (n=16)	Females (n=16)
Change D %	26,9	26,0	28,2
Change ND %	26,2	24,3	27,7

Figure 4.10: Percentage change of relative strength Pre-Swim vs Post- Swim Upper Trapezius Muscle Strength for the total group (n=32), and divided into males (n=16) and females (n=16)

Abbreviations ND= Non dominant side. D = Dominant side.

*Total group: Pre vs post swimming dominant side p <0.001
**Total group: Pre vs post swimming non-dominant side: p < 0.001
&Males: Pre vs post swimming dominant side: p = 0.0018
&&Males: Pre vs post swimming non-dominant side: p = 0.003
Females: Pre vs post swimming dominant side: p = 0.02
##Females: Pre vs post swimming non-dominant side: p = 0.0001

Figure 4.11 below shows the percentage change in the relative strength of LT muscle pre to post swim. The total group showed a decrease in strength of LT muscle of 11.5 % (p = 0.037) in the dominant arm and a 14.2 % (p=0.005) decrease in strength for the non-dominant side following the swimming session.

No significant ipsilateral change in LT muscle strength was noted for the males in the dominant arm when the strength values were normalised for body weight , (p=0.144) even though the relative strength dropped by 12.7% after the session. In the non- dominant arm of

the male group there was significant decrease of 16.2% in the relative strength of LT muscle following the swimming session (p=0.024) sides.

The female group showed no significant changes in LT muscle strength for the dominant (p=0.146) and non-dominant (p=0.11) sides following the swimming session. In the female group there was a 10.2% decrease in LT muscle strength in the dominant arm and an 11.6% decrease in strength in the non-dominant arm when the results were normalised for body weight.

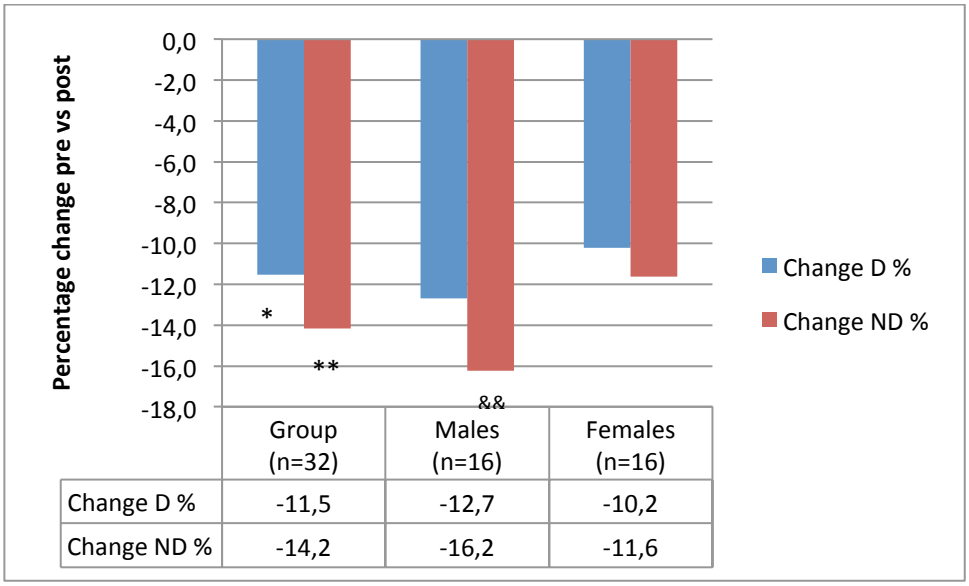


Figure 4.11: Percentage change Pre-Swim vs Post- Swim Lower Trapezius Muscle Strength for the total group (n=32), and divided into males (n=16) and females (n=16)

Abbreviations ND= Non dominant side. D = Dominant side.

*Total group: Pre vs post swimming dominant side p = 0.0037

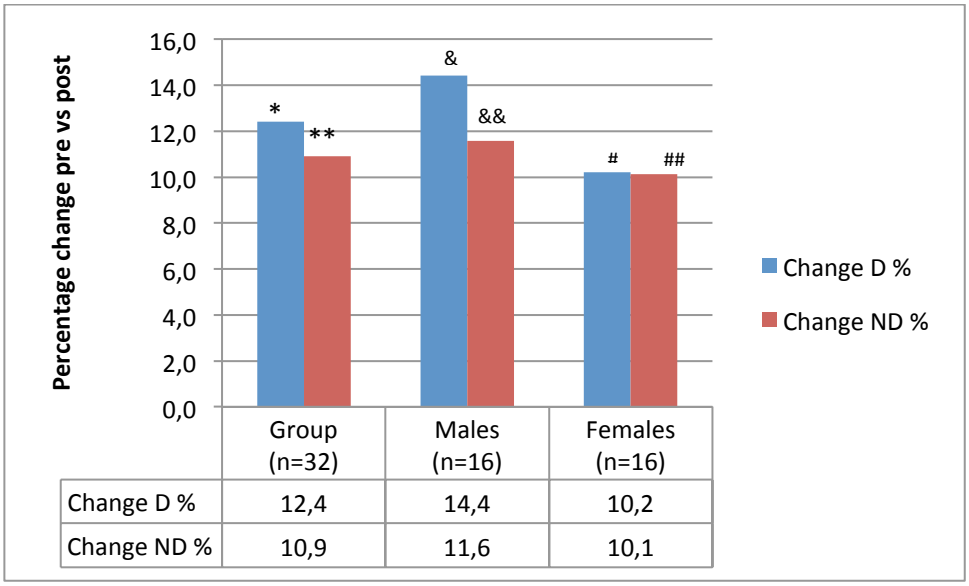
**Total group: Pre vs post swimming non-dominant side: p = 0.05

&&Males: Pre vs post swimming non-dominant side: p = 0.024

Figure 4.12 below shows the percentage change in the relative strength of SA muscle pre to post swim. Significant ipsilateral changes in strength were noted in SA muscle for the group for both the dominant (p= 0.005) and the non- dominant (p=0.001) sides when the pre-swim absolute strength values were compared to the post-swim values for the same side. Overall the group showed a 12.4% increase in SA muscle strength in the dominant arm and 10.9% increase in strength for the non-dominant side.

The males showed a 14.4 % increase in strength of the SA muscle for the dominant side and a 11.6 % increase in the non-dominant side. The increases in strength were significant for the dominant (p=0.009) and the non-dominant arms (p=0.006)

The females also showed significant increases in the relative strength of SA muscle for the dominant (p=0.028) side and of the non-dominant (p=0.007) side following the swimming session. The female group showed a 10.2 % increase in SA muscle strength in the dominant arm and a 10.1 % increase in strength in the non-dominant arm.



	Group (n=32)	Males (n=16)	Females (n=16)
Change D %	12,4	14,4	10,2
Change ND %	10,9	11,6	10,1

Figure 4.12: Percentage change Pre-Swim vs Post- Swim of the Relative Muscle Strength of Serratus Anterior for the total group (n=32), and divided into males (n=16) and females (n=16)

Abbreviations ND= Non dominant side. D = Dominant side.

*Total group: Pre vs post swimming dominant side p = 0.005

**Total group: Pre vs post swimming non-dominant side: p = 0.001

&Males: Pre vs post swimming dominant side: p = 0.009

&&Males: Pre vs post swimming non-dominant side: p = 0.006

Females: Pre vs post swimming dominant side: p = 0.028

##Females: Pre vs post swimming non-dominant side: p = 0.007

Chapter 5 - Discussion

The objective assessment of the movements of the scapula and the strength of the muscles which control those movements have been the topic of many papers in the literature. The purpose of this study was to assess what changes occur to scapular kinematics, specifically upward rotation, and strength of the muscles that control upward rotation of the scapula as a result of a swimming session.

5.1. Demographics

The heights and weights of the adolescent swimmers in this study are comparable to other studies done on swimmers within this age group.[14, 17, 49] In this study it was found that the male swimmers were on average both taller and heavier than their female counterparts.

5.2. Scapular upward rotation

5.2.1. Ipsilateral differences in scapular upward rotation

The total group had a significant increase in upward rotation in the dominant and non-dominant arms when the humerus was abducted to 90˚ following the swimming session. Clinically, patients with subacromial impingement present with an arc of pain between 90 and 120˚ of humeral abduction, this is thought to be caused by a loss of upward rotation as well as posterior tilt which results in compression of the underlying structures.[25] The increased upward rotation in this group of swimmers may be a compensatory mechanism to the motor pattern in order to prevent impingement of the structures under the subacromial arch.[58] Similar patterns have been seen in dominant arms of professional baseball players and elite junior tennis players.[36, 37, 59] The presence of upward rotation of the scapula during overhead movements clears the acromion from the underlying subacromial structures, and is thought to be essential in remaining injury free.[60] Therefore, if this group presents with a decreased amount of upward rotation, it could place them at risk of irritating the subacromial structures and lead to injury.

The increases in upward rotation found in this study are indeed contradictory to the study done by Su et al., (2004)[8].

Another factor which may explain why an increased upward rotation of the scapulae in the current study found post training, is the tightness of the latissimus dorsi muscle. The latissimus dorsi is primarily active from the early pull through to the late pull through phase of the swimming stroke.[7] As repetitive use of the latissimus dorsi occurs during the normal

freestyle stroke over the course of a swimming session it can potentially lose some of its flexibility.[61]

Laudner and Wilson (2013)[61] assessed the relationship between latissimus dorsi stiffness and scapular upward rotation at varying (30˚, 60˚, 90˚ and 110˚) angles of humeral elevation in collegiate swimmers (7 male, 12 female). They showed that a significant correlation existed between tightness of the latissimus dorsi and increased upward rotation of the scapula at all angles of humeral elevation. The scapular kinematics may be altered by the pull of latissimus dorsi on the inferior angle of the shoulder blade causing a superiolateral translation of the scapula along the thorax during humeral elevation.

5.2.2. Bilateral differences in scapular upward rotation

Pre-training testing showed no bilateral differences for any of the different positions of humeral elevation, which is comparable to research conducted on swimmers.[5,42,50] As swimming is a more symmetrical sport it is no doubt that studies assessing asymmetrical sports such as tennis and baseball, reported significant bilateral differences in upward scapular rotation.[36,37] In these cases the dominant arms had a greater degree of upward rotation compared to the non-dominant arm. The authors of these studies hypothesised that this unilateral increased upward rotation is possibly a chronic adaptation which occurs in order to produce a more efficient performance. Furthermore, in the current study, the scapular position however, changed post swimming, with the dominant side showing **less** scapular upward rotation at both 90^{o} and 180^{o} of humeral abduction when compared to the non-dominant side. This decrease may suggest an inefficient change to the swimming stroke due to fatigue following swimming training.[36,37] Many studies have implicated a decreased upward rotation of the shoulder blade to the development of shoulder pathology.[5-7, 42, 51-53]

Su et al., (2004)[8] used digital inclinometry in their study and showed that in swimmers with subacromial impingement syndrome, the arm with pathology, showed a decreased upward rotation at 45, 90 and 135 degrees of humeral elevation in the scapular plane after a one to two hour swimming session, whereas before the session no differences were noted between the painful shoulder and the pain free shoulder. This would suggest altered motor patterns occur as a result of the swimming training. For the current study the reported values for scapular rotation were measured at 90 degrees of abduction. Whereas Su et al., (2004)[8] performed humeral elevation in the scapular plane when assessing the upward rotation of the scapula making the values difficult to compare. Even when considering the differences in the

plane of motion of humeral abduction, both the current study and Su et al.,(2004)[8] show that bilateral changes in upward rotation do occur as a result of a single swimming session.

These results are in contrast to a study by Van de Velde et al., (2010)[15] who reported that the dominant side showed an increased upward rotation of the scapula as a result of a two hour long swim training session when compared to the non-dominant side. Possible explanations for the differences in the results could be that different methodologies were used in the measurement of scapular upward rotation. In the current study, scapular upward rotation was measured using digital inclinometry with a protocol first described by Johnson et al., (2001).[45] Van de Velde et al., (2010)**[15]** used the lateral scapular slide test (LSST) which measures the distance of the inferior angle from the seventh thoracic spinous process as a marker of upward rotation in centimetres during varying angles of humeral elevation.[21] The use of which has been disputed by Koslow et al., (2003) amongst others who found that the test did not show a consistently high reliability and had a low diagnostic accuracy.[43, 54] Whereas the use of digital inclinometry has shown good to excellent validity (r=0.85 – 0.92) as well as good to excellent reliability ($ICC_{3.1}$= 0.90-0.96).[30,44]

The side which a swimmer chooses to take a breath has been shown to affect stroke asymmetry in club level swimmers.[52] Seifert et al., (2005)**[52]** showed that most club level swimmers tend to turn their head to the side of the dominant arm to breathe instead of breathing bilaterally like elite swimmers. When taking a breath there is significant body roll in order to clear the shoulder and arm so that the face can come out the water during the recovery portion of the stroke. This results in a lengthened duration of the underwater pull by the opposite arm and significant modifications to the overall motor pattern.[56]

In the current study, it is possible that the adolescent swimmers were breathing mainly on the dominant side, meaning there would be increased body roll to take a breath resulting in less upward rotation of the scapula found on the dominant arm. During breathing the non-dominant arm is at the early catch phase of the stroke in a position of full flexion and slight internal rotation of the GH joint, a position where there subacromial space would be at its smallest. The increased upward rotation of the scapula shown in the non-dominant arms of the swimmers in the current study could indicate that there is a compensatory adjustment that happens in order to maintain or increase the subacromial space, thereby reducing the likelihood of injury. This hypothesis was not accounted for in the current study but it may go some way in explaining the current asymmetry found post swim in this population of

swimmers. It is recommended that future studies investigate the effect of unilateral breathing on scapula upward rotation post-swimming training.

Differences between males and females

There were no bilateral differences in scapular rotation found in the male group post-training. The female group showed **less** upward rotation of the scapula in the dominant arm compared to the non-dominant side when the humerus was abducted to 90˚. Similarly, when the humerus was abducted to 180˚the female group showed significantly less upward rotation of the scapula on the dominant compared to the non-dominant side following the swimming session.

These findings could possibly be explain those made by Sallis et al., (2001) who reported a higher rate of shoulder injury in female swimmers and water-polo players when compared to their male counterparts.[54] It is possible that the decreased upward rotation of the scapula found in the dominant arms of the female group in the current study, combined with the volume of swimming training that swimmers generally complete, may contribute to a series of events predisposing females to future pathology.

5.3. Muscle strength

The current study examined the absolute and relative isometric strength of the upper trapezius, lower trapezius and serratus anterior which are all involved in the upward rotation of the scapula during humeral movement.[3] Only a few authors have examined scapular muscle strength in swimmers[5,14], tennis players[36, 59] and baseball pitchers[62] with conflicting results.

5.3.1. Absolute muscle strength.

There were no bilateral differences found between the dominant arm and non-dominant arm for the upper trapezius, lower trapezius and serratus anterior strength before the swimming session. However, following the swimming session the strength of the UT muscle for the total group on the dominant side increased by 28.8% and the non-dominant side increased by 27.2%, thus resulting in bilateral differences following the swimming session. This could possibly be due to the decrease in the LT muscles strength post swimming which decreased by 12.8% for the dominant arm and by 14.9% in the non-dominant arm. The UT muscle are found to be overactive in sports that involve repetitive overhead motions, with the LT being underactive [63], contributing to the superior translation of the humeral head and subsequent

subacromial impingement. It is therefore, possible that the decrease in the strength of the stabilizing LT muscles is compensated for by the increase in strength of the UT muscles.

The fact that SA muscle, the main upward rotator of the scapula showed no significant ipsilateral or bilateral changes in strength following the swimming session could mean that, the UT muscles would have to increase their activity in order to maintain the upward rotation of the scapulae which may result in the increased UT muscle strength. The possibility exists that over prolonged periods of training, due to their higher activity, the UT muscles may fatigue similarly to the swimmers in the study done by Su et al., (2004)[8] who showed a 14% reduction in UT strength and a 13% reduction in SA strength following a 2 hour swimming training session in swimmers who were approximately four years older**.**

Van de Velde et al., (2010)[15] also evaluated the strength of only the UT and SA muscles following a two hour swimming training session in swimmers of similar age to the current study. They did not find any differences in the strength and concluded that no significant muscle fatigue occurred as a result of the training. They compared their findings to Su et al.,(2004)[8] and stated that perhaps the difference noted between the studies was due to age.

In the current study the age of the swimmers is also much younger than the swimmers in the study by Su et al.,(2004)[8] . Perhaps the results of the current study could be the beginning of a sequence of fatigue that occurs over a number of swimming seasons with first LT muscle fatigue, followed by UT muscles then the SA muscles.

Other studies have shown bilateral differences in the strengths of the glenohumeral rotators in swimmers, especially for external rotation on the dominant side.[64, 65] In a follow up study using isokinetic assessment Van de Velde et al., (2011)[49] were able to show bilateral differences in scapular retraction strength in junior swimmers, a movement in which the LT muscle contributes a large proportion. They showed that the scapular retractors in the dominant shoulder were significantly stronger than the non-dominant shoulder. Interestingly they also showed no bilateral differences in SA muscle.

The bilateral differences in strength found in the current study may once again be explained by a unilateral breathing pattern.[56] When breathing to one side the contralateral side must stabilize the body, which possibly requires more muscle activity.[49] However, further research to investigate this hypothesis is required as it was not accounted for in the current study.

5.3.2. Relative muscle strength.

It is important to assess strength relative to the person's body weight as this allows for comparison between individuals.[66] In the current study no bilateral differences in the relative strength of the UT and LT muscles were found before the swimming session. However, when the SA muscles were normalised for body weight, the dominant arm was found to be significantly stronger before the session when compared to the non-dominant arm. This may be as a result of the dominant arm being more functional during everyday activities apart from swimming.[49]

Following the swimming session significant changes to the relative strength of the UT muscles occurred, with an increase in strength by 26.9% for the dominant arm and 26.2 % for the non-dominant arm. Furthermore, when the UT muscles were compared bilaterally the dominant arm was found to be significantly stronger than the non-dominant arm. The relative strength for the LT muscle decreased by 11.5% and 14.2% for the dominant and non-dominant sides respectively which resulted in bilateral differences, causing the LT muscle on the dominant side to be stronger. The bilateral differences in relative SA muscle strength found before the swimming session remained following the session with the dominant arm being significantly ($p=0.039$) stronger than the non-dominant arm. The relative strength increase for the SA muscle after the swimming session was 12.4% for the dominant side and 10.9% for the non-dominant side.

Cools et al., (2010)[36] reported the relative strength values of the UT , LT and SA muscles of junior tennis players in their study. The relative strength values obtained in the current study are comparable to those with the exception of the SA muscle. The SA muscle for the swimmers in both the male (D 3.44 ± 0.72N/kg; ND 3.37 ± 0.83N/kg) and female groups (D 3.20 ± 0.89N/kg ; ND 2.97 ± 0.73N/kg) was greater than in the study done on the male (D 2.94 ± 1.02N/kg ; ND 2.66 ± 0.8N/kg) and female (D 2.52 ± 0.85N/kg ; ND 2.42 ± 0.83N/kg) tennis players.[36] The greater strength of the SA muscles in the current study's swimmers, may be a reflection of a training adaptation due to constant use of the SA muscles when swimming freestyle.

The strength of the LT muscles reported in the current study are higher than those reported by Westrick et al., (2013)[67] who studied various indices of isometric shoulder strength in healthy college age athletes who did not perform overhead activities, but similar to the dominant arms of tennis players.[36] This is could be indicative of sport specific adaptations that occur to

the scapular rotator musculature in activities which require a greater proportion of overhead movements.

5.3.3. Relationship between scapular upward rotation, muscle strength.

From the results the group showed an increased upward rotation of the scapulae following the training session as well as increased strength of the UT and SA muscles. Only the LT showed significant drops in strength as a result of the training session. Some debate exists in the literature as to the role that LT muscle plays in the upward rotation of the shoulder blade [3] and from the current study it would seem that the decrease in strength had little to no effect on the scapular upward rotation. It is generally accepted that upward rotation of the shoulder blade clears the acromion and increases the subacromial space. [21, 22, 25, 26, 52, 60]

In the current study the training session did not induce the expected fatigue in the upward rotators, a similarity shared with Van de Velde, et al, (2010)[15]. Their hypothesis was that possibly the fatigue related changes are more subtle than changes in strength alone and suggested that EMG may be a more feasible alternative for investigating the changes occurring in the muscle activity following the swimming session. The changes could therefore be related to motor control problems, as differences in the timing of muscle activation, especially the middle and lower portions of the trapezius, have been shown to influence shoulder function and possibly relate to the onset of shoulder injury.[68]

The shoulder is a complex joint with multiple force couples acting in both the scapulothoracic and glenohumeral joint in order to produce movement.[3, 10] The fact that the LT muscles in the present study showed some decrease in strength indicates that some degree of fatigue does indeed occur following a session. Perhaps there is a sequence or pattern of fatigue that occurs in the various muscles over the course of a session, or even a season, which could alter the upward rotation of the shoulder blade and predispose swimmers to shoulder injury. Furthermore, it is possible that the stabilizing LT muscle fatigues more than the prime moving UT muscles

It is also possible that the changes to strength and upward rotation that are seen in swimmers with shoulder pain[5, 69] are compensatory changes which occur as a result of existing pathology caused by the volume of training that swimmers are notorious for. Sein et al., (2010)[9] proposed that the shoulder pain in elite swimmers is a tendinopathy which is caused primarily by volume of training. The fact that the VAS scores in the current study showed little to no increase in shoulder pain might support this hypothesis.

Chapter 6

6.1. Conclusion

The findings of the current study confirm the initial hypothesis that changes to both scapular upward rotation or scapular muscle strength will be found following a single bout of swimming training.

Significant increases in upward rotation of the scapulae as result of the swimming session for both the dominant and non-dominant sides were found. These are related to the strength differences found post swimming, whereby there was an increase in UT muscle strength for both the dominant and non-dominant sides with a decrease in the strength of the LT muscles. When body weight was accounted for the SA muscles also showed a significant increase in strength which would have also contributed to the increased scapular rotation. The increases in strength in the current study did not show that significant muscle fatigue occurs as a result of a single swimming session. However, the decreased LT muscle strength post swimming could possibly be the start of a sequence of accumulative muscle fatigue that over a period of time causes greater load and subsequent fatigue of the UT and SA muscles possibly predisposing the swimmers to injury over time.

Bilateral differences in scapular upward rotation were found with the dominant arm showing less upward rotation than the non-dominant arm, possibly due to the swimmers breathing on the dominant side and affecting the stroke mechanics causing subsequent asymmetry. Bilateral strength differences in the UT, LT and SA muscles on the dominant side being significantly stronger than the non-dominant side were found following the swimming session. This also could be explained by differences in breathing patterns and hand dominance.

The current study highlights the need for further research to be done on swimmers of the same age and the need for standardised methodologies when researching the shoulder, as well as further investigation into the effect of breathing side on upward rotation, motor control patterns and strength muscle changes.

6.2. Limitations

The current study was done poolside and as such, clinical techniques were used to evaluate the strength and changes in upward rotation. This meant that the effects of the changes in these variables were only measured in one plane of motion. Future studies assessing the three-dimensional movement of the shoulder following a bout of exercise are possibly the way forward.

Time spent in the pool was recorded but not the actual distance intensity and training load. This means that the participants in this study might not have been loaded sufficiently enough to cause fatigue and therefore a decrease in strength of the upward rotators. The swimmers in this study swam 6 times per week for around 90 min per session which falls short of the 15 h/week reported by Sein et al.,(2010)[10] and may have meant that the current swimmers weren't at the level of overload to cause the decreased strength of SA muscle seen by other studies. [10,11,41]

Further research needs to be done in the differences between male and female swimmers of this age group. Even though the numbers in the total group of swimmers (n=32) tested in this study were sufficient according to the power calculation (n=20), the results showing the differences in upward rotation between genders (16 males, 16 females) falls slightly short of this number.

It is also possible that there was a learning effect due to insufficient familiarisation with the strength tests which may have resulted in the increase of the strength values seen in the UT muscles and SA muscles post swim. Additionally the warmup was not controlled for, this may have influenced the strength results.

The age range of the swimmers in this study ranged from 14-18 years of age which may make the strength results less applicable to the older swimmers.

6.3. Recommendations

Future studies could assess the strength values over the course of a week of swimming training in order to get a more consistent result. This would also aid in determining the sequence of strength changes that may be occurring over a longer time period. Additionally, the isometric strength measured in this study gave only a peak strength reading and did not evaluate the subtle changes, such as muscle activation and timing of activation, which may provide understanding of the shoulder mechanics in relation to exercise. These changes could be assess**ed** by EMG analysis.

It also may be more feasible to compare the ratios of isometric strength between the muscle groups which make up the force couples. [36] This would allow a greater understanding of the changes that occur to scapular mechanics following exercise. The addition of a control group as well as incorporating familiarisation sessions to the HHD testing would help to negate any learning effects as a result of the testing protocol.

The measurement of other variables that influence scapular position such as the predominant side that a swimmer chooses to breathe as well as the flexibility of the muscles surrounding the shoulder girdle will give a clearer picture as to what is happening in the shoulder as a result of swimming training.

Future studies should incorporate an effort scale (e.g. rating of perceived exertion (RPE)) into the testing methodology to determine the amount of load the swimmers experienced as a result of the training.

It will be useful to compare the changes across the age groups as there may be differences between 14 year olds to the 18 year olds.

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Appendix A - Child information sheet

University of the Witwatersrand

Principle Investigator: Graham Hatch

Name of study: ***The influence of a single bout of swimming training on scapular upward rotation and muscle strength in junior club swimmers***

Dear Swimmer

My name is Graham Hatch and I am completing my master's degree in Biokinetics at the University of the Witwatersrand. I am doing some research to look at what happens to the movements of the shoulder blades before and after a swimming session. This will help me in understanding what can cause injuries in who are similar in age as you.

I would like to invite you to be part of my study. Below is some information about the study and what you will need to do should you decide to be a part of the study. You can choose whether or not you want to be a part of my study.

If you do not understand something or want more information you may ask me anything about this study.

Purpose of the research

The purpose of this research is to see how the movement of the shoulder blades may change when the muscles of get tired from a swimming training session. This will help us to understand which muscles need to be strengthened and how this can try to prevent injuries.

Choice of participants: Why are you asking me?

I am doing this research on swimmers who are between the ages of 14 and 18yrs because we know very little about what happens to the movements of the blades in swimmers of your age.

Participation is voluntary: Do I have to do this?

You do not have to participate in this research. It is entirely up to you. If you decide that you don't want to be a part of this research, it is okay.

If you do say "yes" at the beginning you can change your mind later and decide to pull out of the study and this still be okay. If you do change your mind we will talk to you first to find out why, but your wishes will be respected.

You may say "no" even if your parents want you to participate in this study. You will not be forced into doing anything that you do not want to do.

The Testing: What is going to happen to me?

The testing will take place at the swimming pool at which you normally train. There will be two sets of measurements taken. For the first set you will be asked to come in half an hour earlier than you would normally come in for training. The second set of measurements will be taken straight after you get out of the swimming pool. You will be asked to do the measurements with your swimming costume on.

Before Training:
You will be asked to put your swimming costume on and then we will begin by measuring your height and then by measuring your weight (using a scale similar to a bathroom scale).

Shoulder blade movement

We will then measure the amount your shoulder blades move by using two pieces of equipment which work similarly to a spirit level on your upper arm and on the shoulder blade. Measurements will be taken at three different positions: 1) with your hands at your side 2) with your arms straight out at shoulder level and 3) with your hands as high above your head as you can get them (180 degrees). This will be done for both your left and right arms.

Muscle Strength.

You will be asked to test the strength of the muscles which help to move the shoulder blade. We will be testing 3 different muscles, and each has to be tested in a different position. To test strength you will be asked to push against a small machine that the I will be holding in their hand. You will have to push as hard as you can for 5 seconds and need to do this 5 times for each muscle. Both arms will be tested.

The 3 strength testing positions will be as follows.

1) Sitting on a bed. – I will place the handheld machine onto the tip of your shoulder and you will be asked to try and lift your shoulder towards your ear otherwise known as a shrug.
2) Lying on your back. – Once on your back you will be asked to lift your arm to 90 degrees and I will put the handheld device in the palm of your hand. You will be asked to perform a punching movement without bending your elbow or lifting your back off the bed
3) Lying on your stomach. – Once on your stomach you will be asked to move your arm to a point which his halfway between shoulder level and the point where your arm touches your ear with your thumbs pointing to the roof. I will place the hand held unit just below the thumb, on your wrist and you will lift your arm so that your thumbs move towards the roof.

After you have done the strength portion of the testing you will go and do your normal swimming training session that your coach has planned for you on the day. Once you have finished your swimming session you will be asked to do the shoulder blade movements and strength testing again in exactly the same way as before.

By doing the tests before and after your swimming training it will allow us to see if there are any changes to the way your shoulder blade moves as a result of your swimming session.

Risks: Is this bad or painful for me?

All of the testing is safe and should not cause any injury.

Payments: Do I get anything for being in the research?

You will not be paid for participating in this research.

Confidentiality: Is everybody going to know about this?

We will not tell other people that you are in this research and we won't share information about you to anyone who does not work in the research study. Information about you that will be collected from the research will be put away and no-one but the researchers will be able to see it. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is and we will lock that information up with a lock and key. It will not be shared with or given to anyone except Dr. Kerith Aginsky at the University of Witwatersrand.

Sharing the Findings: Will you tell me the results?

When we are finished the research, I will sit down with you and I will tell you about what we learnt. I will also give you a paper with the results written down.

Who to Contact: Who can I talk to or ask questions to?

You can ask me questions now or at any point in the future. You may ask any of the staff helping with the data collection. I have written a number where you can reach us or, if you are nearby; you can come and see us. If you want to talk to someone else that you know like your coach or doctor or any family member, that's okay too.

Appendix B – Parent information sheet

University of the Witwatersrand

Principal Investigator: Graham Hatch

Name of study: ***The influence of a single bout of swimming training on scapular upward rotation and muscle strength in junior club swimmers***

Introduction

My name is Graham Hatch and I am completing my MSc (Biokinetics) at the University of the Witwatersrand. I am doing some research to look at what happens to the movements of the shoulder blades before and after a swimming session in junior swimmers between the ages of 14-18 years. This will help me to understand what can cause injuries in swimmers of this age group. I would like to invite your child to participate in the study.

I am going to give you information about what the research involves.

If you have questions later, you can ask them of me, the project supervisor or any of the staff.

Purpose of the research

The purpose of this research is to see how the movement of the shoulder blades may change when the muscles of get tired from a swimming training session. This will help us to understand which muscles need to be strengthened and how this can try to prevent injuries.

Participant selection

I am doing this research on children who are between the ages 14-18 years because there have been a number of studies done on adults, however we know very little about what happens to the movements of the shoulder blades in children as a result swimming training.

I am inviting your child to take part in this research because the data gathered may help us to understand the changes in movements which may occur as a result of swimming training, thereby allowing us to develop better training programs and injury prevention strategies. We are asking if you would allow your child to participate.

Voluntary Participation

Your child's decision to participate in this study is entirely voluntary. If you choose not to consent, all the services you and your child receive at the training facility will continue and nothing will change. Your child may also choose to change their mind later and stop participating, even if they agreed earlier, and the services you and/or your child receives at this training facility will continue.

Procedures and Protocol

The testing will take place at the swimming pool which your child normally trains. There will be two sets of measurements taken. For the first set your child will be asked to come in half an hour earlier than they would normally come for training. The second set of measurements will be taken straight

after your child finishes the swimming session. All measurements will be taken with your child's swimming costume on.

Before Training:

Your child will be asked to put their swimming costume on and then we will begin by measuring their height and then by measuring weight. This will be used for descriptive statistics allowing us to compare data between various studies.

Shoulder blade movement:

We will then measure the amount of movement in the shoulder blades move by using two pieces of equipment which work similarly to a spirit level, one is placed the upper arm and the other on the shoulder blade. Readings will be taken at three different positions:

1) hands at the side side (0 degrees)
2) Arms at shoulder height (90 degrees)
3) Hands as high above the head as possible (180 degrees). This will be done for both the left and right arms.

Muscle Strength:

Then your child will be asked to test the strength of the muscles which help to move the shoulder blade. We will be testing 3 different muscles, and each has to be tested in a different position. To test strength your child will be asked to push against a handheld dynamometer that the researcher will be holding in their hand. Your child will have to push as hard as they can for 5 seconds and will be asked to do this 5 times for each muscle. Both arms will be tested.

The 3 strength testing positions will be as follows:

Sitting on a bed. – The researcher will place the handheld dynamometer onto the tip of your child's shoulder. Your child will then be asked to try and lift their shoulder towards their ear otherwise known as a shrug.

Lying down. – Once on their back your child will be asked to lift their arm to 90 degrees and the researcher will put the hand held device in the palm of your hand. they will be asked to perform a punching movement without bending their elbow or lifting their upper back off the bed

Lying on their stomach. – Once on their stomach they will be asked to move their arm to a point which his halfway between shoulder level, and the point where your arm touches your ear, with your thumbs pointing to the roof. The researcher will place the hand held unit just below the thumb, and they will lift their arm so that the thumb moves towards the roof.

After the strength portion of the testing has been done your child will complete their normal training session that the coach has planned on the day. Once your child has finished the swimming session they will be asked to repeat the measurements of the shoulder blades and strength testing in exactly the same way as before.

This will allow us to see if there are any changes to the way the shoulder blades move as a result of the swimming session.

Risks

All of the testing methods are considered safe and should not cause any injury.

Benefits

Once we have analysed the results we will have a better understanding as to what happens to the shoulder blade and strength of the shoulder muscles after a swimming session. This will help us design better training programs to help prevent injuries from occurring. Your child will receive feedback on their results.

Confidentiality

The information that we collect from this research project will be kept confidential. Information about your child that will be collected from the research will be put away and no-one but the researchers will be able to see it. Any information about your child will have a number on it instead of his/her name. Only the researchers will know what his/her number is and we will lock that information up with a lock and key. It will not be shared with or given to anyone except the principle investigator and the project supervisor.

Sharing of the results

The knowledge that we get from this study will be shared with you before it is made widely available to the public. Confidential information will not be shared. We intend to publish the results in scientific journal in order that other interested people may learn from our research, however your child will not be identified in any way and all results will be reported as a group.

Right to Refuse or Withdraw

You do not have to agree to your child taking part in this research if you do not wish to do so and refusing to allow your child to participate will not affect your treatment or your child's treatment at this Centre in any way. You may stop your child from participating in the research at any time that you wish without either you or your child losing any of your rights as an athlete here.

Who to Contact

If you have any questions you may ask them now or later, even after the study has started. If you wish to ask questions later, you may contact any of the following:

Principal Investigator: Graham Hatch

073 252 3938

grayhatch@gmail.com

Appendix C – Over 18 participant information sheet

University of the Witwatersrand

Principle Investigator: Graham Hatch

Name of study: ***The influence of a single bout of swimming training on scapular upward rotation and muscle strength in junior club swimmers***

Dear Swimmer

My name is Graham Hatch and I am completing my master's degree in Biokinetics at the University of the Witwatersrand. I am doing some research to look at what happens to the movements of the shoulder blades before and after a swimming session. This will help me in understanding what can cause injuries in swimmers who are similar in age to you.

I would like to invite you to be part of my study. Below is some information about the study and what you will need to do should you decide to be a part of the study. You can choose whether or not you want to be a part of my study.

If you do not understand something or want more information you may ask me anything about this study.

Purpose of the research

The purpose of this research is to see how the movement of the shoulder blades may change when the muscles of get tired from a swimming training session. This will help us to understand which muscles need to be strengthened and how this can try to prevent injuries.

Choice of participants

I am inviting you to take part in this research because the data gathered may help us to understand the changes in movements of the shoulder blades which may occur as a result of swimming training, thereby allowing us to develop better training programs and injury prevention strategies.

Participation is voluntary

Your decision to participate in this study is entirely voluntary. If you choose not to consent, all the services you receive at the training facility will continue and nothing will change. You may also choose to change their mind later and stop participating, even if you agreed earlier, and the services you receive at this training facility will continue.

The Testing

The testing will take place at the swimming pool at which you normally train. There will be two sets of measurements taken. For the first set you will be asked to come in half an hour earlier than you would normally come in for training. The second set of measurements will be taken straight after you get out of the swimming pool. You will be asked to do the measurements with your swimming costume on.

Before Training:

You will be asked to put your swimming costume on and then we will begin by measuring your height and then by measuring your weight (using a scale similar to a bathroom scale).

Shoulder blade movement

We will then measure the amount your shoulder blades move by using two pieces of equipment which work similarly to a spirit level on your upper arm and on the shoulder blade. Measurements will be taken at three different positions: 1) with your hands at your side 2) with your arms straight out at shoulder level and 3) with your hands as high above your head as you can get them (180 degrees). This will be done for both your left and right arms.

Muscle Strength.

You will be asked to test the strength of the muscles which help to move the shoulder blade. We will be testing 3 different muscles, and each has to be tested in a different position. To test strength you will be asked to push against a small machine that I will be holding . You will have to push as hard as you can for 5 seconds and need to do this 5 times for each muscle. Both arms will be tested.

The 3 strength testing positions will be as follows.

Sitting on a bed. – I will place the handheld machine onto the tip of your shoulder and you will be asked to try and lift your shoulder towards your ear otherwise known as a shrug.

Lying on your back. – Once on your back you will be asked to lift your arm to 90 degrees and I will put the handheld device in the palm of your hand. You will be asked to perform a punching movement without bending your elbow or lifting your back off the bed

Lying on your stomach. – Once on your stomach you will be asked to move your arm to a point which his halfway between shoulder level and the point where your arm touches your ear with your thumbs pointing to the roof. I will place the hand held unit just below the thumb, on your wrist and you will lift your arm so that your thumbs move towards the roof.

After you have done the strength portion of the testing you will go and do your normal swimming training session that your coach has planned for you on the day. Once you have finished your swimming session you will be asked to do the shoulder blade movements and strength testing again in exactly the same way as before.

By doing the tests before and after your swimming training it will allow us to see if there are any changes to the way your shoulder blade moves as a result of your swimming session.

Risks

All of the testing is safe and should not cause any injury.

Payments

You will not be paid for participating in this research.

Confidentiality

We will not tell other people that you are in this research and we won't share information about you to anyone who does not work in the research study. Information about you that will be collected from the research will be put away and no-one but the researchers will be able to see it. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is and we will lock that information up with a lock and key. It will not be shared with or given to anyone except Dr. Kerith Aginsky at the University of Witwatersrand.

Sharing the Findings

The knowledge that we get from this study will be shared with you before it is made widely available to the public. Confidential information will not be shared. We intend to publish the results in scientific journal in order that other interested people may learn from our research, however you will not be identified in any way and all results will be reported as a group.

Who to Contact

You can ask me questions now or at any point in the future. You may ask any of the staff helping with the data collection. I have written a number where you can reach us or, if you are nearby; you can come and see us. If you wish to talk to someone else that you know like your coach or doctor or any family member, before giving your consent, you may.

Appendix D – Child assent form

Participant

I (print name) _____ want to participate in study: ***The influence of a single bout of swimming training on scapular upward rotation and muscle strength in junior club swimmers.***

I understand the research is about how the shoulder blades move before and after a swim training session and I have been told about the testing procedures and understand what I will be asked to do.

I understand that I will be swimming, some of which may be as hard as I can. I understand that there is always a risk of injury associated with high-intensity exercise.

I understand that I can stop at any time, and I will not be in trouble in any way if I do.

I have told the researcher about any sicknesses or any injuries I have that may be made worse if I take part in the study.

I understand that the information obtained from the test will be kept secret, and my personal details will be kept private. However, the information obtained may be used for statistical analysis or scientific purpose with my right to privacy retained.

I accept that the testers will take every precaution to ensure that nothing bad happens to me when I take part in the testing incidents will occur.

Participant signature Date_____

Parent/Guardian name (if under the age of 18)_____

Parent/Guardian signature Date_____

Name of Researcher _____

Signature of Researcher /person taking the assent_____

Date_____

Witness_____ Date_____

Appendix E - Participant Consent form (over 18)

Informed Consent

Participant

I (print name) _____ want to participate in study: ***The influence of a single bout of swimming training on scapular upward rotation and muscle strength in junior club swimmers.***

I understand the research is about how the shoulder blades move before and after a swim training session and I have been told about the testing procedures and understand what I will be asked to do.

I understand that I will be swimming, some of which may be as hard as I can. I understand that there is always a risk of injury associated with high-intensity exercise.

I understand that participation in the study is entirely voluntary and that I can stop at any time. I shall in no way be prejudiced should I choose to withdraw from the study.

I have told the researcher about any sicknesses or any injuries I have that may be made worse if I take part in the study.

I understand that the information obtained from the test will be kept secret, and my personal details will be kept private. However, the information obtained may be used for statistical analysis or scientific purpose with my right to privacy retained.

I accept that the testers will take every precaution to ensure that nothing bad happens to me when I take part in the testing incidents will occur.

Participant signature _____ Date_____

Name of Researcher _____

Signature of Researcher /person taking the assent_____

Date_____

Witness_____ Date_____

Appendix F - Parental Consent

I (print name) _____ hereby give consent for my child____ _____ to participate in the study: ***The influence of a single bout of swimming training on scapular upward rotation and muscle strength in junior club swimmers.***

on the following terms:

I have been informed about the study procedures and understand what my child will be required to do.

I understand that my child will be partaking in physical exercise, some of which may be at maximal intensity. I understand that there is always a risk of injury associated with high-intensity exercise.

I understand that I can withdraw my consent, freely and without prejudice towards my child or myself, at any time.

I have told the testing personnel about any illness or physical defect that my child may have, that could contribute to the level of risk.

I understand that the information obtained from the test will be treated confidentially, with my child's right to privacy assured. However, the information obtained may be used for statistical analysis or scientific purpose with my right to privacy retained.

I accept that the testing personnel will take every precaution to ensure that no incidents will occur.

Participant signature_____ Date___ _____

Parent/Guardian name (if under the age of 18)_____

Parent/Guardian signature _____ Date_____

Researcher Name:_____ Date _____

Witness _____ Date_____

Appendix G - Ethics clearance

M130456

R14/49 Mr Graham Hatch

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130456

NAME: (Principal Investigator)	Mr Graham Hatch
DEPARTMENT:	Centre for Exercise Science & Sports Medicine Medical School
PROJECT TITLE:	The Influence of a Single Bout of Swimming Training on Scapular Upward Rotation and Muscle strength in Junior Club Swimmers
DATE CONSIDERED:	26/04/2013
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr Kerith Aginsky
APPROVED BY:	Professor PE Cleaton-Jones. Chairperson, HREC (Medical)

DATE OF APPROVAL: 12/06/2013

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**.

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix H – Plagiarism declaration

Postgraduate Office, Faculty of Health Sciences
Wits Medical School, 7 York Road, PARKTOWN, 2193, Johannesburg • Tel: (011) 717 2746 • Fax: (011) 717 2719 • e-mail: healthgrp@health.wits.ac.za

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I GRAHAM HATCH (Student number: 516059) am a student registered for the degree of MSc Med (BIOKINETICS) in the academic year 2014.

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.

Signature: _____ Date: 4/12/2014

Appendix I – Turnitin Report

GrahamHatchThesisFINAL3.docx

ORIGINALITY REPORT

12%	7%	10%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.ncbi.nlm.nih.gov Internet Source	1%
2	Guy E. Alvarez. "Obesity and Sympathetic Neural Activation", Medicine & Science in Sports & Exercise, 05/2004 Publication	<1%
3	axelprofilen.se Internet Source	<1%
4	van der Linden, M.L.. "Knee kinematics in functional activities seven years after total knee arthroplasty", Clinical Biomechanics, 200706 Publication	<1%
5	Y. Yildiz. "Shoulder terminal range eccentric antagonist/concentric agonist strength ratios in overhead athletes", Scandinavian Journal of Medicine and Science in Sports, 6/2006 Publication	<1%
6	wiredspace.wits.ac.za Internet Source	<1%
7	G DAVIES. "The Shoulder in Swimming", The	<1%

Appendix J - Data Sheet

Data Collection Sheet

Influence of single swim training on scapular upward rotation and muscle strength in junior swimmers.

Participant Number _____

Researcher:_____

Date:_____

Age:_____

Symptomatic shoulder :

Left	Right	None

Anthropometry

Height (cm):_____

Weight (kg):_____

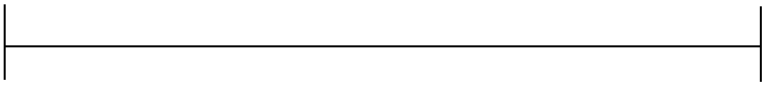
Scapula upward rotation – Before training

	Left			**Right**		
0 degrees						
90 degrees						
180 degrees						

Hand Held Dynamometry – Before training

	Left			**Right**		
Upper Trapezuis						
Serratus Anterior						
Lower trapezuis						

VAS – Before Training



Scapula upward rotation – After training

	Left			**Right**		
0 degrees						
90 degrees						
180 degrees						

Hand Held Dynamometry – After training

	Left			Right		
Upper Trapezuis						
Serratus Anterior						
Lower trapezuis						

VAS – After Training

