A Systematic Review of the Aetiology of Shoulder Injuries

and the Associated Preventative Strategies

Within Competitive Swimmers.

by

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Declaration

This dissertation is my own work, and all material that is not my own is fully acknowledged. No part of this work has been submitted elsewhere**.**

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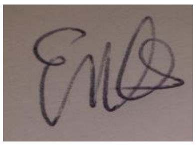
I would like to take this opportunity to thank both of my parents for the ongoing support they have provided me with throughout my education, and I would secondly like to thank all of the tutors at the University Centre for the assistance they have provided whilst studying for my degree**.**



ELISE MAE BRADLEY-SMITH

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ABSTRACT

***Background**:* The prevalence to shoulder injuries within swimming is high, especially in swimmers of adolescent age and early twenties. The aim of this study was to review the aetiology of shoulder injuries associated with competitive swimming and the associated preventative strategies.

***Methods**:* data was collected through conducting thorough searches of both Academic Search Elite and SportDiscus.

Results: after applying all inclusion and exclusion criteria 1339 articles were narrowed down to 19 for a full review and were separated into two categories. Journals associated with aetiological factors (N=12), and journals associated with preventative strategies (N=7).

Conclusions: Muscle imbalances of the Internal: External rotator muscles were the main factors associated with shoulder injuries, other implications such as tight pectoral muscles, weak muscles stabilizing the scapular and shoulder were secondary factors in the prevalence of shoulder injuries in swimmers. Additionally, strengthening the external rotator cuff muscles, strengthening exercises to stabilise the scapular and improve the forward head and rounded shoulder posture of swimmers were primary preventative strategies, due to the impact this posture has on the decrease of sub-acromial space and the increase of shoulder pain and impingement. Stretching the pectoral muscles was also another associated preventative strategy.

Chapter 1 **Introduction**

1.1 **Introduction to Competitive Swimming**

Following the win of the Olympic bid in 2005, Great Britain has seen an increase in the participation of swimming. Although figures are still in their infancy, they clearly demonstrate an increase in participation through the removal of barriers such as finance; sport recognition; facilities and the involvement of role models within communities. Since June 2013, Sport England has announced an increase in swimming of 48,800 participants and a net gain of 125,000 people participating in swimming 30 minutes or more per week, (Swimming, 2013). The Welsh Government set up a strategy to increase participation in both the young and elderly (ages 16 and under, and 64 and over) by offering free swimming in local authority swimming pools, it now invests £3.5m per year in free swimming (Welsh Government, 2012). Additionally, since 2012, the Scottish Government has invested £1.2m in a scheme known as "Swimming Top Up", to improve the setup of swimming lessons for children in primary schools. (Sport Scotland, 2013). As a result of government strategies and initiatives, children at a young age, are now introduced to improved swimming schemes as part of either their school curriculum or home life. For many children, part of their enjoyment for swimming can lead to them becoming competitively involved; this can lead to them becoming part of a swimming club. Children often join swimming clubs at around the age of eight; this prepares them for their first competitions around the age of nine.

Within UK competitive swimming today, there are 192,765 members which are part of 1,151 swimming clubs (ASA, 2013). Competitive swimming clubs have swimmers who are of different ages and abilities and will have different 'squads'. These squads allow swimmers to train with other children who are of a similar age and ability. In a squad with swimmers of a higher ability, you would usually find swimmers training between four and seven times a week; and the elite swimmers who train at international standard training up to ten times per week.

Swimming places physical demands upon the body, including power; strength; endurance and co-ordination. Mental demands also play a part in the success of swimmers which consist of determination; dedication and motivation. For a competitive swimmer to achieve success in this sport, they must have the ability to train to develop and enhance all of their physical aspects, but also to cope with the mental demands of the sport. These components are traits swimmers need in order to train and win in this demanding sport. Due to the physical demands of the sport, elite swimmers have a greater mental toughness which can result in them being more susceptible to injury as they often train more intensely and push themselves into “pain zones” whereas other swimmers don’t as they strive to be the best. (Driska et al, 2012) Additionally, competitive swimmers have the pressure of attending multiple training sessions per week, which are seldom not attended unless under exceptional circumstances, resulting in little rest or recovery days throughout the swimming season.

Recent studies have concluded that there are several aetiological factors which are associated with shoulder injuries in swimmers. Tate et al (2012) suggested that shoulder pain is positively correlated with increased repetitive upper extremity usage in swimming, with competitive swimmers training approximately 11,000–15,000 yd/d, six to seven times per week. This results in the swimmer carrying out around 16,000 shoulder revolutions per week; this is a primary factor leading to shoulder pain in swimmers. (Hibberd et al, 2012).

Swimming involves excessive overhead movement patterns, involving continuous humeral circumduction. This is a factor contributing to shoulder pain being one of the most common musculoskeletal complaints within swimming, Tovin (2006). The demands of swimming, places the shoulder under an abnormal range of motion, and the variety and combination of the range of motion of the shoulder due to it being a ball and socket joint, leads to the joint and surrounding muscles being prone to injury. The technique of all four strokes in swimming places stress on the muscles, tendons and joints of the shoulder, with Becker (2011) identifying that tendonitis is a common shoulder problem sustained by swimmers and that it is not caused primarily by one stroke. Becker also suggested that the stretching of the bicep long tendon and the supination of the forearm during many phases of each stroke is an initial contributor to tendonitis. This combined with the continuous, repetitive training patterns of swimmers puts stress on the shoulders which has been shown to result in injury from repetitive micro-trauma. (Pink and Tibone, 2000).

Muscle imbalance has been shown to play a substantial role in the onset of a shoulder injury in swimmers, there are studies (Ramsi et al, 2004) Miguel et Al, 2012) whose findings agree that the ratio of internal : external rotator muscle strength of a swimmer affects the stability of the swimmers shoulder and shoulder ratio of protractors: retractors muscle strength (Van de Velde et al, 2011) has also been shown to affect shoulder stability.

In addition to this, Abgarov et al (2012) stated that swimming technique has an influence on the prevalence of shoulder injuries as the overhead, repetitive motions can result in fatigue of muscles leading to poor technique and injury.

1.2 Rationale

Due to a gap in literature, there is a need to identify the most common shoulder injuries obtained by swimmers which is directly affecting the swimming career of many athletes. It is also necessary to find an effective method of preventing these shoulder injuries in order to enhance the development of the swimmer in a safe way which would lower the risk of a shoulder injury, improve performance and to decrease the overall time swimmers are out of training.

This review will be beneficial to various sources including physiotherapists, sports therapists and other rehabilitation specialists, as information regarding the common aetiological factors will be discussed along with current preventative strategies which can be put in place to help prevent the common shoulder injuries associated with competitive swimming.

As a result, swimming coaches may also include appropriate preventative techniques within the training regime of the swimmers, and also have a deeper understanding into the causes of shoulder injuries, possibly leading to a decrease in such injuries and enhanced performance by swimmers. Swimmers themselves may also benefit from this research as they will have a developed understanding of how they can prevent the onset of an injury, by being more aware of the aetiological factors of shoulder injuries and also what they may do to reduce the risk of shoulder injuries from occurring throughout their swimming career.

1.3 Aim of the research:

To review the aetiology of shoulder injuries associated with competitive swimming and the associated preventative strategies.

1.4 Objectives of the research:

- Identify common injuries associated with swimming;
- Identify aetiological factors of shoulder injuries in swimming;
- Review the strategies associated with shoulder injury prevention in swimming;
- Which preventative strategies are the most effective?

1.5 Hypothesis

That there will be one main aetiological factor of shoulder injuries and one key preventative strategy.

1.6 Null hypothesis

That there is no main aetiological factor of shoulder injuries and there will be no key preventative strategy.

Chapter 2 Review of literature

2.1 Physiological Characteristics and Capabilities of Swimmers.

Swimmers have a high respiratory capacity in comparison to non-swimmers and athletes of other sports (Aspenes and Karlsen, 2012). Elite swimmers Vo2 max ranges from 66 to 80ml/kg/min (Jorgić et al, 2011), and the development of both the aerobic and anerobic energy systems are necessary for peak swimming performance (Aspenes and Karlsen, 2012). Postponing fatigue is what all competitive swimmers aspire to do and Soares et al (2010) states that the use of the anaerobic threshold system is a threshold which establishes margin between balanced and unbalanced lactate production, which is essential for effective swim training. This is usually done through training at a 1:2, 1:3 or 1:4 hard work to rest ratio. This method of training also corresponds with the high intensity, energetic demands of a racing scenario (Avalos et al, 2003). Wenger and Bell (1986) reiterate that the intensity of training rather than volume training is more beneficial for athletic development and improving performance. Although the research of Wenger and Bell (1986) is over 20 years old, the more current research of Soares et al (2010) restates these findings indicate that training the anaerobic training system is the most effective way for swimmers to enhance their performance, indicating little change in swimming training methods since the late 1980's. However, as the anaerobic system lasts only a few seconds, this type of training does not reflect the demands of distance events such as the 800m and 1500m, where the aerobic system is largely in use. This does not explain the high VO2 Max which swimmers have if they were to be frequently training the anaerobic system. It is important for coaches to understand the energy systems utilised by swimmers during different stages of swimming events so that the planning of training sets can be specific to individual swimmers.

2.2 Biomechanics - swimming techniques.

Unlike other sports where the propulsive force is initiated through the ground reaction force, in swimming, the propulsive force in generated through pulling the body over the arm. The propulsive forces in swimming are often generated by the upper extremities through movements such as adduction and internal rotation movements of the shoulder. (Kluemper et al, 2006) The pull-through phase, as suggested by Ramsi et al (2004) composes approximately 70% of the entire swim stroke, and is characterized by internal rotator muscles and adduction motions of the glenohumeral joint.

2.3 Impact of injuries on swimming

In a study conducted by Ristolainen et al (2010) it was found that the swimmers who were ranked higher by FINA standards were training around 767 Hours per year in comparison athletes of a similar status participating in sports such as ski-ing (552 hours), soccer (511 hours) and running (548 hours). It has also been reported that 35% of elite swimmers have suffered with a shoulder pain which inhibits training and progress in the sport (Mcmaster, 1999). These two facts provide a possible link between increase swim volume and occurrence on shoulder injuries Brushøj et al (2007) also found that of the swimmers who had surgery on their shoulder, after two to nine months, the return rate to the sport was low (56%) this suggests that a surgical route in order to repair the damaged tissues may not be the most effective method in allowing swimmers to continue in the sport, and that the prevention of these types of injuries is possibly a more appropriate and effective way to enable swimmers to continue their career and not have time out from the occurrence of a shoulder injury. In addition to this, Abgarov et al (2012) reported that 45% of swimmers took time off from training, with high prevalence between the ages of 15 and 22 and the onset of injury highest at age 18. These figures suggest additional research in this field would be highly useful as the prevalence of shoulder injuries is high within this cohort of swimmers.

2.4 Common aetiological factors associated with swimming

Literature suggests there are several factors leading to shoulder injury in swimmers. Rupp et al (1995) evaluated 22 elite swimmers, and found anterior-inferior instability in 50% and dysfunction of the scapulo-thoracic joint in 55%. It was also found that muscle imbalance of the internal to external rotator cuff muscles in comparison to non-swimmers to be the most prevalent characteristics of swimmers with shoulder injuries. Additionally, Kluemper et al (2006) also suggested that, the shoulder’s internal rotator and adductor muscles become stronger and hypertrophied in comparison to the antagonist muscles. It was revealed in an analysis of adduction to abduction strength ratio of swimmers was 2.05:1 compared to 1.53:1 in non-swimmers, and 1.89:1 in swimmers verses 1.35:1 in non-swimmers for internal/external rotation strength ratio.

Additionally, Brushøj et al (2007) found that during arthroscopic findings of 18 swimmers who had a painful shoulder, labral pathology was the most common injury obtained by the swimmers, followed by a sub-acromial impingement. In addition to this, Tate et al (2012) identified that high school swimmers were the most symptomatic group of swimmers in a study of 236 competitive female swimmers. It was also identified that increased disability and shoulder pain was associated with greater exposure to swimming. These figures may be largely reliable due to the large number of participants involved within the study. In addition to this, Kluemper et al (2006) identified that reduced shoulder flexibility and Latissimus dorsi tightness were common symptoms in young swimmers, and in swimmers ages 12 and over, pectoralis minor tightness and decreased core endurance were associated with symptoms of shoulder pain.

Jeffrey and Johnson (1987), found that shoulder pain is the most common musculoskeletal complaint in swimmers. It was identified that the supraspinatus and biceps tendinitis are the main anatomical locations which were involved in shoulder pain. Additionally, Page (2011) suggested that the supraspinatus tendon is at high risk of irritation which subsequently may result in injury. This is due to the contact it would have with the acromion when the humerus is abducted to 90° and internally rotated at 45°.

2.5 Preventative strategies

Ristolainen et al (2012) investigated the reasons behind athletes ending their career in sport. It was concluded that shoulder injury was the primary reason as to why swimmers careers were abruptly ended. Explanations behind this could be the repetitive motions of swimming and overuse of muscles resulting in the fatigue and failure of muscles to adhere to the correct stroke mechanics, enhancing the scope for injury (Mohesen et al, 2012). There are multiple preventative strategies which propose similar methods of preventing shoulder injuries which are vital in avoiding the long-term consequences of swimming injuries. Stretching the tight muscles of the chest including the pectoral muscles and strengthening the antagonistic muscles may be an appropriate intervention for correcting a positional or postural fault, such as forward shoulder posture caused by muscle imbalance (Klumper et al, 2006), and risk of shoulder injury may also be reduced if these techniques are adopted (Kendall et al, 1993 and Sahrmann, 2002). Additionally, Bak and Magnusson (1997) also suggest that the strength ratio of external to internal rotator muscles is seen to be symptomatic of shoulder problems, and therefore specific shoulder stabilizing programmes which strengthen and balance out the differences of the internal to external rotators, may decrease the frequency of shoulder injuries within swimmers. However, McMaster and Troup (1993) identified in a survey of 1262 swimmers, factors interfering with shoulder pain in swimmers were weight training, use of hand paddles, kickboard use, stretching, and various resistance activities. This research contradicts other research which suggests stretching; carrying out latex band resistance exercises is shown to improve the muscle imbalance which takes place within the internal : external rotator muscles (Klumper et al, 2006).

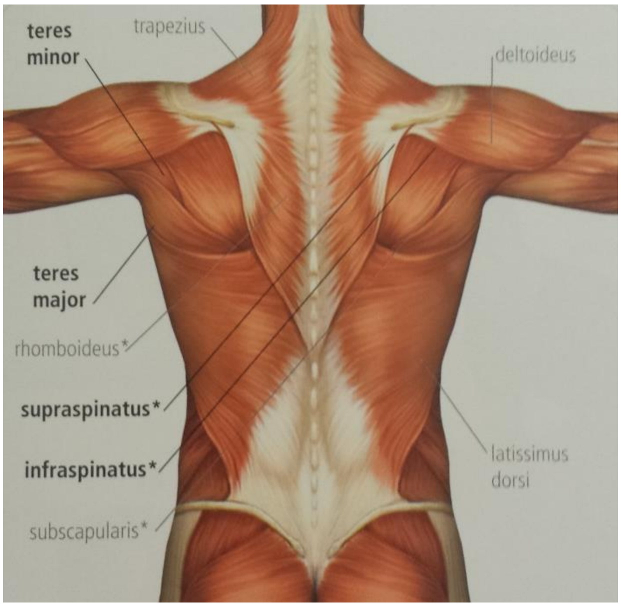
By dropping the elbow during the recovery phase of freestyle, Fox et al (2012) states that "if the swimmer decreases the degree of humeral internal rotation" they will avoid the pain caused by subacromial impingement. This preventative method may also reduce the risk of irritation caused by the contact of the acromion with the supraspinatus tendon which Page (2011) suggested is affected when the humerus is abducted to 90° and internally rotated at 45°. However, this method of preventing subacromial impingement and irritation of the supraspinatus tendon may not be appropriate for swimmers to carry out; as by dropping the elbow would involve a change in the swimming technique which may not be the most efficient or fastest way for the swimmer.

Swanik et al (2002) suggest that in their study of 26 swimmers (13 male, 13 female), that the treatment for athletes with a shoulder injury includes a decrease in yardage, the prescription of anti-inflammatory medication, and specific treatments before and after practice. However, the researchers do not specify the type of injuries that the exercises are to rehabilitate and categorize all shoulder injuries into having the same treatment.

2.6 Anatomy of the Shoulder Joint

The shoulder is the most flexible joint in the body and it is a relatively unstable joint due to it sacrificing stability for mobility. Hyde and Gengenbach (2006) stated that the shoulder is a synovial, ball and socket joint, which largely relies on the muscles rather than the ligaments for stability. In swimmers, the glenohumeral and the acromio-clavicular joint are two joints largely affected by training loads, resulting in an uneven strength ratio and weaknesses in the surrounding shoulder muscles. The acromio-clavicular joint compromises of the meeting point between the clavicle and the scapula, and the glenohumeral joint is where the humerus and scapula meet. (Mcleod, 2010)

The shoulder (glenohumeral joint) is stabilised by the rotator cuff muscles. These muscles consist of the supraspinatus, which is responsible for the movement of the arm up and away from the body. The subscapularis, initiates internal rotation of the arm, the infraspinatus stabilises external rotation of the arm. The teres minor elevates and stabilises internal arm rotation. (Lucero, 2012) There are many studies Kluemper et al (2006), Batalha et al (2012), Ramsi et al (2004) which all agree that when one of more of the rotator muscles are weak or damaged, the bones of the shoulder joint are not held stable, leading to excessive movement causing inflammation and shoulder pain. Figure one below displays a posterior view of the back and shoulders, labelled are the rotator cuff muscles and other anatomical locations of the shoulder and back which are muscles largely used and dominated by swimmers.



(Figure 1 – Manocchia, 2011)

Chapter 3 **Methods**

The application to carry out this study was monitored and approved by Hull University Ethics Committee prior to beginning this research.

3.1 **Databases**

A comprehensive search of online databases SportsDiscus and Academic Search Elite was undertaken to identify relevant articles for the systematic review.

Academic Search Elite	HTTP://WWW.EBSCOHOST.COM/ACADEMIC/ACADEMIC-SEARCH-ELITE
SportDiscus	HTTP://WWW.EBSCOHOST.COM/ACADEMIC/SPORTDISCUS-WITH-FULL-TEXT

All searches were carried out between 23/02/2014 and 14/03/2014.

3.2 Keywords

The search carried out consisted of a combination of all of the following words listed in the Table 1 below:

Table 1 - Keywords

Keyword 1	Keyword 2	Keyword 3
Swimming	Shoulder	Injury
	Injury	Impingement
	Prevent	rotator-cuff
		Tendonitis
		Bicep
		scapular
		overuse
		stretching
		prevent
		Gleno-humeral
		biceps tendon
		over-training
		technique

The key words were selected for the searches as they were deemed the most suitable for searching and selecting relevant articles for the systematic review. The words are common terms used to define shoulder injuries in swimmers.

All searches included “keyword 1” within the search; this was to narrow down articles and to ensure specificity to swimming. A combination of “keyword 2” and “keyword 3” were also used to obtain relevant articles. In the initial search, a total of 39 searches were carried out and this yielded 1339 articles.

A Boolean search mode was used to create the search. For example with the terms “Swimming” AND “Shoulder” AND “Injury” *or* “Swimming” AND “Prevent” AND “impingement”

3.3 Selection Criteria

To enable to most relevant data to be extracted from the search, specific inclusion and exclusion criteria was applied to the search.

- All research had to be written in the English language;
- All articles are to be written post 2003 ;

- All research had to be specific to competitive swimmers not leisure swimmers or swimmers of any other genre;
- Swimmers could be of any nationality;
- Articles may contain subjects of both genders;
- All subjects have to be human;
- Subjects within studies must be over 12 and under 65 years of age;
- Article can consist or quantitative or qualitative data;
- Articles are to be excluded if published as abstracts.

3.4 Justification of Inclusion/Exclusion Criteria

The justification behind the inclusion and exclusion criteria, for the systematic review is due to the rationale of the review stating that current preventative methods would be discussed throughout the study; hence journals published prior to 2003 were excluded from the study. To enable specificity to competitive swimming, only competitive swimmers were to be used within the studies, and to ensure diversity within the review, journals may include swimmers of any gender and of any nationality but the articles must be published in the English language so it could be interpreted by the researcher. Additionally, participants included within the studies must be between the ages of 12 and 65 as, muscle, bone and joint structure may not yet be fully developed or participants may have other health problems such as osteoporosis which could have affected the validity of results discussed within the review. Articles published as abstracts were also excluded as appropriate information would not be fully extractable. Additionally, articles must have included human subjects due to non-human subjects resulting in information which was non-specific to competitive swimmers. Finally, articles were considered for the final review if the data was either qualitative or quantitative, as information could still have been extracted to then be discussed within the findings of the searches.

3.5 Data Collection

All data was collected manually through the two online databases. The first protocol was to type in all the combinations of key words to present all possible articles available for use prior to applying inclusion/exclusion criteria. In the Appendix, Tables 5-7 presents the results from the initial search of Academic Search Elite, and Tables 8-10 are results from the initial search of SportDiscus. The second protocol was to apply the first stage of exclusion criteria, this excluded articles not published in the English Language. Tables 11-13 within the Appendix further display the results from this stage of the search. The third stage of the literature search was to apply additional exclusion criteria which were to exclude articles not published in the English language and articles which were published before 2003. Tables 14-16 in the Appendix present results from the third search. *(Please note that these figures are combined results from both databases).* The final search consisted of individually screening the articles from the third search according to the relevance of the title to the subject area, and applying any remaining inclusion and exclusion criteria which is stated below. The results from this final search are displayed in Table's 17-19 of the Appendix.

Remainder of inclusion/exclusion criteria:

- All research had to be specific to competitive swimmers not leisure swimmers or swimmers of any other genre;
- Swimmers could be of any nationality;
- Articles may contain subjects of both genders;
- All subjects have to be human;
- Subjects within studies must be over 12 and under 65 years of age;
- Article can consist or quantitative or qualitative data.

In addition, Figure 2 below displays a flow chart which summarizes the findings and displays the inclusion/exclusion criteria process and the elimination of articles which are not suitable for the final review.

3.6 Data Analysis

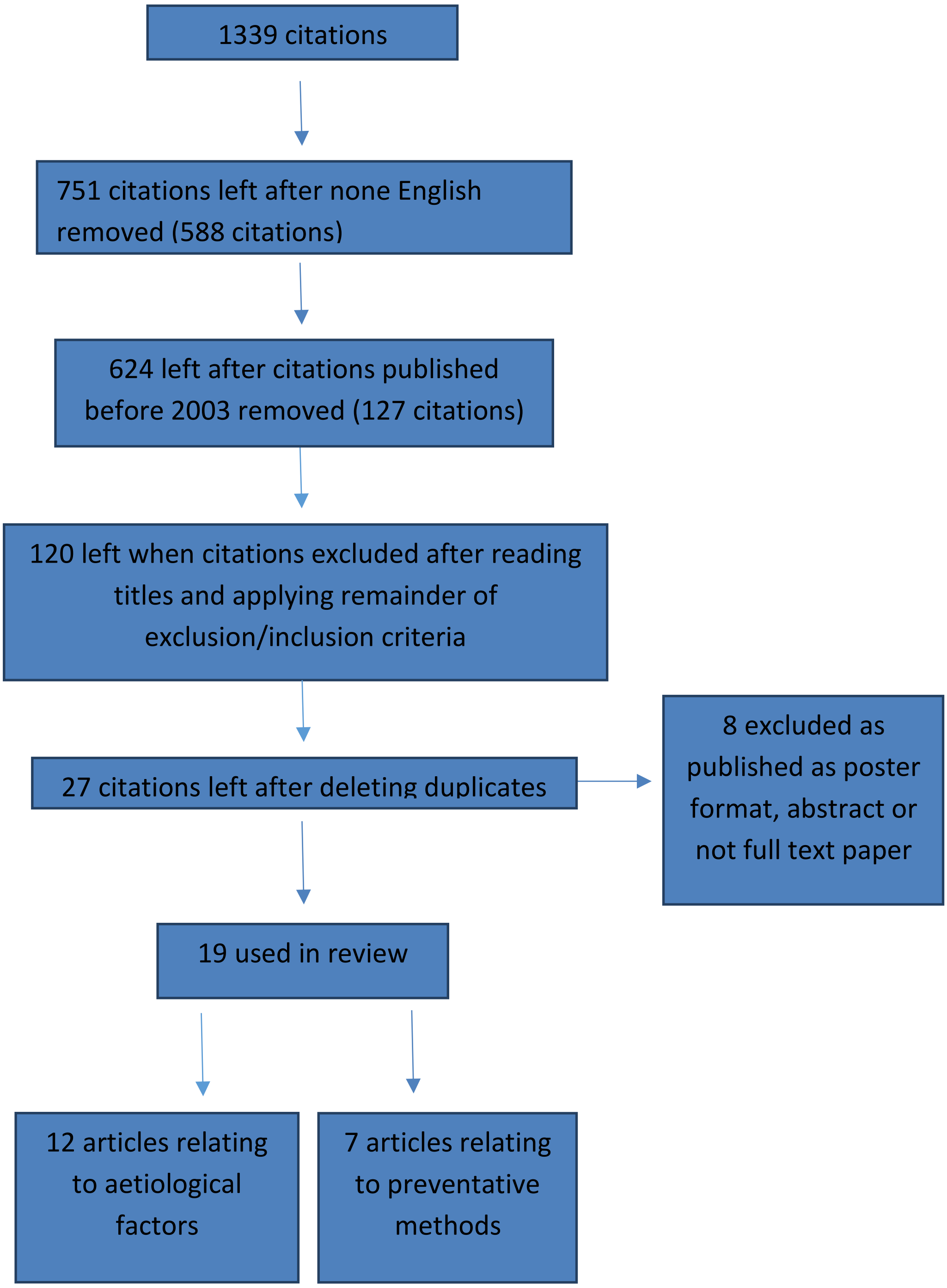
When all articles had been identified as being relevant to the final review, they were placed into one of two folders which were named aetiological journals or prevention journals. The two tables within the results section displays a summary for each journal that was considered for the final review. This method of summarising articles was chosen as it had been used by all researchers that have had their articles published on the Cochrane Calibration.

In addition to the Summary Table, to enable the best articles to be considered for the systematic review, the hierarchy method established by Greenhalgh (1997) was used to enable readers to see how each study was considered based on their comparison to other studies that were returned from the search. This hierarchy method was used for the citations which were to be used within the final review. Each of the articles used were condensed into a table format to summarise and display the author, year, study design, number of participants, groups, procedure and the outcome of each study, and the final column to display the grade in which the article had been given.

Table 2. The hierarchy of Evidence Scale (Greenhalgh, 1997)

Grade	**Description**
I	Strong evidence from at least one systematic review of multiple well-designed randomised controlled trials.
II	Strong evidence from at least one properly designed randomised controlled trial of appropriate size.
III	Evidence from well-designed trials without randomisation, single group pre-post, cohort, time series or matched case-controlled studies.
IV	Evidence from well-designed non-experimental studies from more than one centre or research group.
V	Opinions of respected authorities, based on clinical evidence, descriptive studies or reports of expert committees.
VI	Views of colleagues/peers.

Figure 2


1339 citations
751 citations left after none English removed (588 citations)
624 left after citations published before 2003 removed (127 citations)
120 left when citations excluded after reading titles and applying remainder of exclusion/inclusion criteria
27 citations left after deleting duplicates
8 excluded as published as poster format, abstract or not full text paper
19 used in review
12 articles relating to aetiological factors
7 articles relating to preventative methods

Chapter 4 **Results**

A total of 18 articles were included for the systematic review. All articles were found through two databases SportDiscus and Academic Search Elite. The 18 articles were split into two categories - aetiological factors, or preventative strategies. The two tables below summarize the findings of the articles relating to aetiological factors leading to shoulder injuries in swimmers, and the other table is a summary of articles relating to the prevention of shoulder injuries in swimmers.

4.1 **Aetiological Factors**

A total of 11 articles were identified in relation to aetiological factors associated with shoulder injuries in competitive swimmers. Four of which were cross-sectional studies, three were descriptive, four were experimental, one was a retrospective analysis and one was a review. A total of four articles were given a grade II on the hierarchy of evidence scale, two articles were given a grade III and the remainder of the articles were given either grade IV or V.

4.2 **Preventative Methods**

A total of seven journals were identified overall; these included methods of preventing shoulder injuries within the study. Four were experimental studies with one of them being a pre-test, post-test design, one was a clinical trial, one was descriptive, one was a cross sectional study. One article was given a grade I, three articles were given a grade II, three articles were given a grade III and one article was given a grade V.

4.3 Summary of Results

Table 3 – Aetiological Factors

Authors	Title	Date	Study design	Participants	Groups	Procedure	Outcome	Grade
Tate, A. Turner, G N. Knab, S E. Jorgensen, C. Strittmatter, A and Michener, L A.	Risk factors associated with shoulder pain and disability across the lifespan of competitive swimmers	2012	Cross-sectional study	236 Female Aged 8-77	Ages 8 to 11 years (n = 42), 12 to 14 years (n = 43), 15 to 19 years, (n = 84) 23 to 77 years (n = 67)	Penn shoulder score and underwent testing of core endurance, range of motion, muscle force production, and pectoralis minor muscle length and the scapular dyskinesis test	21.4% swimmers aged 8 to 11 years, 18.6% swimmers aged 12 to 14 years, 22.6% aged 15-19, and (19.4%) aged 23-77 had shoulder pain and disability. Greater exposure, reduced shoulder flexion. Middle trapezius weakness and internal rotation, decreased core endurance, shorted pectorals and lattissimus dorsi	Grade II
Shana Harrington, Corinne Meisel, And Angela Tate	A cross-sectional study examining shoulder pain and disability in division i female swimmer	2014	A cross-sectional study	37 Female Aged 19.5 ± 1.19	1 group of 37	-survey including penn shoulder score -disabilities or the arm shoulder and hand (dash) outcome measure -passive range of motion	Significant difference in dominant arm resting and stretching pectoralis minor muscle length. Findings show that muscle length plays important role in contributing shoulder pain.	Grade III

Authors	Title	Date	Study design	Participants	Groups	Procedure	Outcome	Grade
L. Mckenna, L. Straker, A. Smith, J. Cunningham	Differences in scapular and humeral head position between swimmers and non-swimmer	2011	Cross-sectional comparative study	46 swimmers Aged 12-17 43 non swimmers matching age and gender	2 groups swimmers v non-swimmers	Measurements of humeral head position were taken standing up either on poolside or at schools using static superior kibler measure	Shoulder pain cumulative incidence 38.6% lower than previous reported teenage swimmers- maybe because subjects with current pain or in past 3 months were excluded. No relationship between scapular and humeral head position.	Grade III
Alisa Abgarov, Jessica Fraser-Thomas and Joseph Baker	Understanding trends and risk factors of swimming-related injuries in varsity swimmers	2012	Descriptive analysis	170 swimmers N=79, male N=92, female Mean age of 21	N= 170 1 group	10 minute questionnaire	45% of participants took time off room swimming during their career due to injury Shoulder injuries are the most common with injuries occurring from a gradual onset. Males at higher risk of acquiring injury if they specialised in swimming from a young age.	Grade V
Bryan L. Riemann, Joe Witt, and	Glenohumeral joint rotation range of motion in	2011	Experimental	144 competitive swimmers ages	Athletes, high school, us masters and us swimming	Measurements taken in supine position	Dominant shoulder – significantly more room in most tests – possibly due to	Grade II

Authors	Title	Date	Study design	Participants	Groups	Procedure	Outcome	Grade
George J. Davies	competitive swimmers			12-61	teams all participated	Hand held goniometers to assess movements of gleno humeral joint	use of dominant arm in daily activities. Sex differences – women reported higher incidence of shoulder injuries than men	
Becker, T J	Overuse shoulder injuries in swimmers	2011	Review	0	0	Discusses stroke biomechanics leading to injury	Female occurrence of shoulder injuries at different times to male Identifies causes of tendonitis, stages and symptoms and result of injury. Biceps tendon is initial contributor to shoulder pain in most strokes	Grade IV
Mya lay sein, Judie Walton, Wames Linklater, Richard Appleyard, Brent Kirkbride, Donald Kuah, George A C Murrell	Shoulder pain in elite swimmers: primarily due to swim-volume-induced supraspinatus tendinopathy	2008	Cross-sectional study	80 elite swimmers aged 13-25	1 group – all did the same testing	Questionnaire on swim training, pain and shoulder function. Laxometer used to test for inferior translation of the gleno-humeral joint 52 swimmers had an	Supraspinatus tendinopathy is a major cause of shoulder pain This is brought on by large amounts of swim training	Grade II

Authors	Title	Date	Study design	Participants	Groups	Procedure	Outcome	Grade
						mri scan on the shoulder to test for minimal thickness of the supraspinatus tendon, acromion shape, tendinopathy, acromioclavicular joint arthiritis and other conditions		
Nuno Miguel Prazeres Batalha, N M P Armando Manuel De Mendonça Raimundo, Pablo Tomas-Carus, Orlando De Jesus Semedo Mendes Fernandes, Daniel Almeida Marinho, António José Rocha Martins Da Silva.	Shoulder rotator isokinetic strength profile in young swimmer	2012	Experimental	120 participants	Swimming group- 60 n=60 male swimmers ages 14.45 ± 0.5 And control group n= 60 male non-swimmers aged 14.62 + or – 0.49	Evaluated the shoulder concentric strength and ration between torque of internal v external rotators was performed in the sitting position (90° abduction and elbow flexion) at 60° and 180°.s-1 angular speeds using an angular isokinetic dynamometer.	Swimmers showed greater muscle imbalance to non swimmers, and a greater ability to produce power with the internal rotators in comparison to the non-swimming group.	Grade II

Authors	**Title**	**Date**	**Study design**	**Participants**	**Groups**	**Procedure**	**Outcome**	**Grade**
C. Brushøj, K. Bak, H. V. Johannsen, P. Faun	Swimmers' painful shoulder arthroscopic findings and return rate to sports	2007	Retrospective analysis	18 swimmers	N= 18 participants – 1 group	Patient records reviewed and telephone interviews.	Most common finding was labral pathology, sub-acromial impingement. Treatment must be directed at underlying pathologies as surgery has a low success and return to sport rate.	Grade IV
Barghamadi Mohsen, Hoseini Seyyed Reza Attarzadeh, Behboodi Zohreh and Fathi Mehrdad	Swimming injuries and their risk factors among Iranian elite freestyle and butterfly swimmers	2012	Descriptive-explorative, historic.	89 swimmers aged 15-24	N= 89 swimmers – 1 group.	Interviews, questionnaires and test-retest reliability.	Upper limb injuries were the most significant and common injury within the swimmers. Many cases injury is related to poor technique with shoulder pain related to dropping the elbow during the recovery phase, inadequate body rotation and insufficient kick.	Grade IV
Martin Ramsi, Kathleen A. Swanik, Charles Swanik, Steve Straub and Carl Mattacola	Shoulder-rotator strength of high school swimmers over the course of a competitive season	2004	Experimental	27 participants 14 female 13 male between 14-18 years of age	N=27 participants -1 group	All participants were internal an external rotator strength was measured pre, peri and post the swimming season using a handheld	Results suggest that shoulder pain or injuries may be a result of er: ir imbalance during adolescence Er strength did slightly increase but during the last 6 weeks of the swim scheme	Grade III

Authors	Title	Date	Study design	Participants	Groups	Procedure	Outcome	Grade
						dynamometer	was no evidence on improvement. Possibly due to swimmers taking part in other sporting activities prior to the swimming season starting and developing the er muscles. Results indicate er endurance should be empahsized.	
Deb West, Gisela Sole, and S. John Sulliva	Shoulder External- and Internal-Rotation Isokinetic Strength in Master's Swimmers	2005	Cross-sectional study	13 masters swimmers 6 male 7 female	Swimming group Non swimming group of same	3 mins warm up. subjects seated adjacent isokinetic device concentric and eccentric External and internal rotator muscles movements were recorded.	No statistic differences between the two groups, however swimmers tended to be stronger across the movements measured Swimmers consistently demonstrated peak torques of 20% more than non - swimmers.	Grade III

Table 4 – Preventative Strategies

Authors	Title	Date	Study design	Participants	Groups	Procedure	Outcome	Grade
Elizabeth E. Hibberd, Sakiko Oyama, Jeffrey T. Spang, William Prentice, and Joseph B. Myers	Effect of a 6-week strengthening program on shoulder and scapular-stabilizer strength and scapular kinematics in division i collegiate swimmers	2012	Experimental-randomized control trial	44 division 1 swimmers	Intervention group and control group	Intervention carried out 3 times per week for 6 weeks Strengthing exercises with resistance tubing and stretching exercises	No significant differences between groups pre/post tests Shoulder –extension and internal rotation strength significantly increased	Grade II
Mark Kluemper, Tim Uhl, and Heath Hazelrigg	Effect of Stretching and Strengthening Shoulder Muscles on Forward Shoulder Posture in Competitive Swimmer	2006	Prospective pre-test, post-test design.	39 competitive swimmers Aged 16 ± 2 years	Exercise group (n=24) control group (n=15)	Partner stretching programme on anterior shoulder muscles and strengthening programme on posterior shoulder muscles for 6 weeks	Experiments group - shoulder posture was significantly reduced during resting position differences in shoulders was measured highlighting importance of the programme done on both shoulders.	Grade III
Antonio Frizziero, Maria G. Benedetti, Domenico Creta, Antonio Moio, Stefano Galletti and Nicola Maffull	Painful os acromiale: Conservative management in a young swimmer athlete	2012	Case report	1 competitive swimmer Aged 22	1 competitive swimmer	-Clinical and physical examination showed symmetric shoulders and absence of muscular hypotrophy/ scapular dyskinetica. -full ROM but pain associated with overhead movements	After the 2 months patient was pain free and all tests for impingement syndrome was negative. All other tests were either negative for pain or normal however digital pressure on OA site was still painful.	Grade IV

						in dominant shoulder.- Prescribed strengthening exercises to do 3 times per week for 2 months		
Annemie Van de Velde, Kristof De Mey, Annelies Maenhout, Patrick Calders and Ann M. Cools	Scapular-Muscle Performance: Two Training Programs in Adolescent Swimmers	2011	Experimental- Controlled laboratory study	18 swimmers 11 females 7 males 14.7 years ± 1.3 years	Strength training and endurance training group	12-week scapular-training programme	Identifies sport specific adaptations of scapular muscle performance. Neither group has a positive effect on scapular muscle endurance	Grade II
Jody L. Riskowski	Shoulder Stability Training And Shoulder Ailments In High School Swimmers	2010	Experimental	127 participants	Treatment group n=59, 27 male, 32 female. Control group n=68, 33 men, 35 female.	Treatment group participated in 3x20 minute weekly exercised to develop and stabilise shoulder and scapular stability.	Shoulder strengthening and stabilising exercises reduced the incidence of shoulder ailments and reduce the duration of the problem. The exercises reduced the ratio between Er: Ir muscles Females of the control group showed significant improvement.	Grade III
Jeffrey G. Williams, Kevin G. Laudner, Todd McLoda	The Acute Effects Of Two Passive Stretch Maneuvers On Pectoralis Minor	2013	Descriptive design with repeated	29 swimmers 2 male	N= 29 swimmers – 1 group, pre-post.	Tape measure to measure pectoral length, polhemus liberty electromagnetic	One of the stretches showed a significant increase in pectoralis minor	Grade II

	Length And Scapular Kinematics Among Collegiate Swimmers		measures. Pre-test, post-test.	25 female, Age 19.5±1.2 years.		tracking system to measure scapula kinematics, 2 stretches on pectoralis minor.	length (gross stretch) No significant changes in scapular upward rotation, external rotation, or posterior tilt.	
Stephanie S Lynch, Charles A Thigpen, Jason P Mihalik, William E Prentice, Darin Padua	The effects of an exercise intervention on forward head and rounded shoulder postures in elite swimmers	2009	Randomised clinical trial	28 swimmers	Exercise group n=14 Control group n=14 pre- post testing	Forward head angle was measured using a digital inclinometer, forward head translation was measured using a ruler and total scapular distance was measured using string. Peak values on strength measured using a hand held dynamometer Exercise group participated in 8 week exercise programme to correct posture.	Intervention was successful as a significant decrease in forward head angle and forward shoulder translation. Increased strength in shoulder girdle muscles.	GradeI

Chapter 5 **Discussion**

(Please note all references underlined are stated within the results section)

5.1 Opening Statement

This systematic review has identified and allowed the researcher to accept the hypothesis of this study which was "That there will be one main aetiological factor of shoulder injuries and one key preventative strategy associated with competitive swimmers". The findings will further be discussed within a review of general findings.

5.2 General Findings – Aetiological Factors

Researchers agree that the prevalence of shoulder pain amongst swimmers is relatively high, with the findings of Tate et al (2012) stating that 18.6% of swimmers aged 12-14, 22.6% of high school swimmers and 19.4% of masters swimmers having issues associated with shoulder pain. In correspondence with this, Lynch et al (2009) reported that 78% of swimmers who participated in their clinical trial reported some level of shoulder pain. Both of the above researchers suggested that shoulder pain was associated with increased exposure to swimming, and Sein et al (2008) found that increased tendon thickness was correlated with supraspinatus tendinopathy ($p<0.01$) and 69% of the 52 participants had evidence of this ailment. It was also found that athletes participating at a higher level were more likely to see this problem occurring ($rs=0.36$, $p<0.01$) as there was a strong correlation between swimmers training 15+ hours a week and supraspinatus tendinopathy. However, Weldon and Richardson (2001) suggest that although greater exposure to swimming is an influencing factor of shoulder pain, other contributing factors such as flexibility, joint laxity, posture and muscle strength may play a role in ailments of the shoulder.

The findings of Harrington et al (2014) suggested that pectoral muscle length is a contributing factor towards shoulder pain and disability in female Division One swimmers. Of all the swimmers who participated in the study, only the ones who experienced shoulder pain were associated with a shorter pectoralis minor muscle length in both the resting and stretching position. In addition to this, the pectoral muscles have been shown to become shorter due to the anterior muscle imbalance which also protracts the shoulders (Kluemper et al, 2006). In connection to this, Solem-Bertoft et al (1993) implied that the protraction of the shoulder decreases sub-acromial space. In addition, other studies (Borstad and Ludewig, 2005) have also suggested that the shortening of the pectoralis minor muscle is associated with improper scapular kinematics which results in a change in the resting position of the scapular, and a decrease in sub-acromial space. These researchers also reiterated that athletes with a shortened pectoralis minor are at a higher risk of shoulder impingement due to an increased exposure to elevation, force, and repetition. All of these studies reiterate and support the finding of Harrington et al (2014) as the shortening of the pectoral muscle leads to a protraction of the shoulders and a decrease in sub-acromial space, resulting in irritation of the shoulder and associated ailments.

The findings of Ramsi et al (2004) show in their study conducted over a 12 week swimming season, the strength of the internal rotator muscles increased continually throughout the 12 weeks. Whereas the strength of the external rotators increased in the first six weeks of the study, but not within the last six weeks of study, which leaves the shoulder vulnerable to potential issues during the second half of the swim season. The authors state that the swimmers taking part in other sporting activities may influence the strength of the external rotator muscles. This puts forward considerations to introduce other sporting activities to help develop or maintain the strength of the external rotators throughout the swim season. In association with the findings of Ramsi et al (2004), Miguel et Al (2012) found in their study of 120 participants, where 60 were swimmers and 60 were non swimmers, within the swimming group, muscle imbalances of the internal rotators and external rotator muscles were present. Significant differences were found between groups for the values of the internal rotator and internal/external rotator ratio. Both Warner et al (1990) and Leroux et al (1994) endorse these results in relation to shoulder injuries, as they reiterate that a decrease in the concentric strength of the external rotators, along with an increase in the strength of the internal rotators such as the finding presented in the study of Miguel et al (2012) are characteristics leading to instability of the glenohumeral joint resulting in the increase in risk of an injury of this joint.

Reimann et al (2011) examined the range of motion of the glenohumeral joint in competitive swimmers. The findings suggested the range of motion in the dominant vs non-dominant shoulder was that the non-dominant shoulder had a greater internal rotation range of motion in comparison to the dominant shoulder. The dominant shoulder had a greater external rotation range of motion. However, demographic factors need to be taken into consideration such as age, gender, other sporting activities and work life. This is due to the 144 participants who took place in the study ranging from 12-61 years of age, and this age range within the study needs to be considered, because although the results are specific within age categories, the study was not focused on one age group, which may have been more beneficial due to the most shoulder injuries occurring in swimming during high school and early adult hood years. Tate et al (2012)

It was established in the findings of McKenna et al (2011) in a study of 46 junior elite and 43 physically active non-swimmers that the position of the scapular was more symmetrical than that of the non swimmers, this could be due to the bi-lateral actions of all swimming strokes which develops the symmetry of the scapular. The finding of this study concluded no differences in scapula and humeral head position between the two groups P=0.438 for the superior kibler and P=0.439 for the inferior kibler. However, as this study tested the participants when the individuals were not fatigued it may have had an impact on the significance of the results. Had the swimmers been fatigued prior to the measurements been taken, the posture of the swimmer may have been different leading to a difference in the results which were measured. The significance of this study may have been affected, the validity of this study is increased due to the large number of participants involved in comparison to other studies involving swimmers. If there was a abnormal result within the data, it would have had less of an impact on the rest of the results, this makes the results more reliability had there been a retest of this study.

Abgarov et al (2012) exposed in their study of 170 varsity-level swimmers, that a higher proportion of swimmers obtained shoulder injuries during the swimming season rather than prior to it, which highlights that increased swim volume within the swim season is a key factor relating to shoulder injuries with other studies (Mcmaster and Troup, 1993) supporting these findings. Additionally, it was found that swimmers who take time off from training due to injury place unrealistic demands on themselves on return to training as they try to return to their previous fitness state, this results in a higher chance of a recurring injury as (Driska et al, 2012) informs us that elite swimmers push themselves more intensely than other swimmers possibly resulting in injury. Expanding on the return rates to the sport, Brushøj et al (2007) discovered that after surgery, in a study of 18 swimmers who all had surgery on their shoulder, only 56% of them returned to the sport post-surgery, this implies the success and rate of return after surgery to the sport is low in association with swimming; this suggests that for competitive athletes, alternative methods would be more beneficially adhered to as mentioned within the general findings of the preventative strategies.

The study by Mohsen et al (2012) emphasised swimmers shoulder (common terminology used for multiple shoulder ailments in swimmers), is a result of poor technique. This article was graded IV, therefore leaving it slightly less significant to some other articles reviewed, and the article also does not support nor it is supported by any other articles used within this review. This could be due to the nationality of the participants included within the study (Iranian) possibly suggesting that middle-eastern countries have different factors which affect the prevalence of shoulder injuries due to possible lifestyle aspects or coaching techniques.

Becker (2011) identified that the most effective method for reducing the risk of shoulder injuries is through good technique and stroke mechanics. However, the validity of this study is questionable as there was no experimental design or participants taking place as it was an article providing information on shoulder injuries in swimming relating to stroke biomechanics, signs and symptoms of injury. Although the information may be useful for an inexperienced reader, due to the lack of experimental design and proof behind statements it leaves the study insignificant and ineffective for validity within this review.

5.3 General Findings – Preventative Strategies

It is agreed upon by researchers and has been concluded in many studies that there is a strategy which is utilised to prevent the onset of a shoulder injury in competitive swimmers. Most articles agree that in order to prevent pain or injury of the shoulder in swimmers, strengthening of the external rotator cuff muscles, strengthening the scapular, and stretching the anterior shoulder and pectoral muscles will help decrease the onset of this problem arising.

Lynch et al (2009) focused on the effects of an eight week training programme on the forward head and rounded shoulder posture of swimmers, and found that strengthening exercises of the scapular muscle, stretching the pectoralis muscle group and cervical neck muscles produces significant results in terms of posture and the reduction of muscle tightness. They found a decrease in the forward head angle and the rounded shoulder posture of the participants due to the intervention used within the study. These result reiterate the findings of Williams et al (2013) as these researchers found that stretching techniques particularly on the pectoralis minor lengthens the pectoral muscles. It is necessary to do this to ensure the kinematics of the scapular are correct, and to enhance the recovery of an athlete with shoulder injuries associated with muscle tightness. Similarly, Kluemper et al (2006) found that the participants of the exercise group within their study, who performed partner stretching exercises on the anterior shoulder muscles, compared to the control group showed a reduction in the distance measured from the wall to the acromion. These findings are comparable to the findings of Williams et al (2013), who also found that stretching is an appropriate intervention to reduce the forward head and rounded shoulder posture of swimmers. Conversely, Hibberd (2012) found that a six-week programme primarily focusing on strengthening the scapular and rotator muscles, and stretches to improve the flexibility of the pectoralis minor, and the range of motion of internal-rotation, that no significant changes took place and was not effective in altering the strength of the scapular or improving scapular kinematics. These findings interlink with the findings of McMaster and Troup (1993) who identified that some of the factors which interfere with shoulder pain in swimmers are weight training, stretching, and various resistance activities, all of which were used in the intervention set out by Hibberd et al (2012), this suggests a posssible explanation for the lack of success of this intervention; however this does not explain the success of other articles who did use these methods within the study and found that it produces positive results.

In association with muscle imbalances, the strength imbalance of the shoulder internal and external rotator muscles has been identified by West et al, 2005 as a cause of glenohumeral instability in swimmers, resulting in impingement and shoulder pain. The researchers of this study carried out peak torque tests on two groups, a swimming and a control group, and measured the differences in concentric and eccentric muscle contractions of the internal and external rotator muscles. They also found that concentric contraction strength of the internal to external rotator ratio was larger for the swimmers than it was for the control group. However, only 13 participants were used within the study, all of which were master's swimmers, therefore the diversity of the results are limited as they do not research into shoulder injuries in swimmers who are not masters swimmers. Additionally, more time and money may need to be invested into experimental studies of younger participants as these are the swimmers more likely to compete at an elite level when they reach an older age. It is important that research is targeted at these swimmers. Research carried out by Riskowski (2010) focused on improving shoulder stability, and scapula strength within 58 high school swimmers by performing 3x20 minute shoulder stability exercises per week. The results concluded that for both men and women, the amount of time off throughout the season was lower for the intervention group than the control group who sustained more injuries throughout the season, and an increase in swim performance, especially for the female swimmers. They also found that shoulder stabilizing exercises can significantly reduce the ER: IR strength ratio in both men and women.

Van de Velde et al (2011) found from their study of 18 swimmers all of similar age (adolescents) and ability that a 12-week scapular training programme with one group performing scapular strengthening and the other group performing scapular endurance exercises, that both programmes improved the ability of all swimmers to retract the scapular further back, as when re-tested post the 12-week programme this was the case. Compared to healthy adults who do not participate in sport, the muscle ratio of the shoulder protractors: retractors are roughly 1 : 1. Cools et al (2007) found in a similar study of adolescent gymnasts that the strength ratio of the shoulder protractors: retractors was 1.24 : 1.35 suggesting that these higher values do not reflect adaptations made by participating in sport, but may be age related characteristics. It is important to consider the muscle ratios within sports and not to compare to the non-sporting adult ratios of 1 : 1, and the issue relating to muscle balance within different sports are adaptations only, or whether or not they propose a possible risk to shoulder injury.

Frizziero et al (2012) carried out a case study on a 22 year old male swimmer who had ongoing shoulder pain for several years. A physical examination found scapular dyskinetica and pain associated with overhead movements. In addition to this, the Jobe Test which is used to detect anterior shoulder instability, and Palm Up which tests for long head of the biceps, were both positive in the right shoulder. To resolve this issue the participant refrained from swimming and was given local anti-inflammatory drugs. Applied an ice pack for twenty minutes three times per day, did exercises to strengthen the internal and external rotator cuff muscles, serratus anterior muscle, scapular stabilizing exercises and exercises to lower the position of the humeral head. The result of managing the rehabilitation of this athlete was that he became pain free, and all associated tests regarding shoulder pain and instability were negative. After the 2 month treatment period, the athlete returned to swimming and participated in the rehabilitation exercises three times per week to prevent the onset of another shoulder injury. In addition to this, a follow up of this athlete was issued one year later and there were still no symptoms of any shoulder ailments. Although the treatment for this swimmer was beneficial and resulted in him returning to the sport, the treatment required no participation in swimming whilst carrying out the programme, which may not be the most effective methods for an elite competitive swimmer to take, therefore the importance of preventative methods is essential in ensuring swimmers do not take extended amounts of training off as a result of an injury which could have been prevented. However, it must be considered that although the results of this case study were positive, a grade IV was given to this study so it therefore lacks in significance due to there being only one participant taking part, and that it was not an experimental study.

Chapter 6 **Considerations and Recommendations**

Swimmers usually start serious training before the onset of puberty and achieve international competitive level at a relatively early age in comparison to other sports. Due to this and from the findings of this current research, it may be beneficial to conduct research on the prevention of injuries in pre-pubertal adolescents.

It may also be of interest for future researchers to focus on when, during the swim season a study is carried out as Ramsi et al (2004) found differences in results during different stages of the swim season.

It is important to consider additional factors other than swimming which affects the presence of shoulder ailments such as and gender differences, job role and age. More in-depth research could be beneficial to help fill this gap in the literature. In addition to this, research focussing on, how age and the age at which swimmers begin to train for swimming competitively has an impact on the prevalence of shoulder injuries, and how age related differences may affect the strength of a swimmer.

It is a final recommendation that further experimental studies are carried out with competitive swimmers, and research is needed to explore other possible interventions looking into strength and muscle balance parameters and their impact and importance in injury prevention.

Chapter 7 **Conclusion**

The shoulder is relatively unstable, when taking into consideration the training distances, propulsive demands, and inherent shoulder laxity, the risk of injury to the shoulder is understandably at high risk. Pink and Tibone (2000). This research can conclude that from current published literature, most studies agree that there is one main aetiological factor which initiates shoulder issues within competitive swimmers. The findings suggest that across the board, this is due to a muscle imbalance of the internal to external rotator muscles, due to the mainly adduction movements of the humerus during many phases of the swimming stroke. Additionally, the forward head and rounded shoulder posture of swimmers has implications, as this posture is emphasized and worsened by tight pectoral muscles which draw the shoulders forward, a weak scapular and weak external rotator shoulder muscles. However, there are various sources which agree that increased swim volume is primary cause of shoulder injuries, but this increase in yardage results in the greater muscle imbalances as mentioned above. The research may also confirm that there is one main preventative strategy which was be used throughout many studies to reduce the risk and onset of an injury occurring which was to stretch the pectoral muscles and to strengthen and stabilize the external rotator muscles and scapular.

Ultimately, it is understandable that time and cost is an issue which effects how dependable research in this area actually is. This review has exposed the lack of research and experimental designs within studies relating to this field, and has revealed that case studies and reviews are common articles found relating to this issue, leading to the lack of applicable results and findings. Finally conclusions can be drawn, and it can be said that prevention assumes a fundamental performance-influencing role and findings of this review suggests and restates the expression that prevention of shoulder injuries in competitive swimming is most certainly better than the cure.

References

Abgarov A, Fraser-Thomas J, Baker J. (2012) Understanding trends and risk factors of swimming-related injuries in varsity swimmers. *Clinical Kinesiology* **66** (2)

Aspenes S T and Karlsen T (2012) Exercise-Training Intervention Studies in Competitive Swimming. *Sports Medicine.* **42** (6) pp.527-543 [2/3/14]

ASA (2013*), Clubs and Members*. British Swimming [online] www.swimming.org [3-11-2013]

Avalos M, Hellard P, Chatard J C. (2003) Modeling the training performance relationship using a mixed model in elite swimmers. Med Science Sports Exercise **35** (5) pp. 838-46

Bak, K. & Magnusson, D.P. (1997). Shoulder strength and range of motion in symptomatic and pain free elite swimmers. *American Journal of Sports Medicine*. **25**. pp.454-459.

Batalha N M P, Raimundo A M, Tomas-Carus P, Fernandes O S M, Marinho D A, Silva A J R M (2012) Shoulder rotator isokinetic strength profile in young swimmers. *Brazilian Journal of Kineanthropometry.* **14**(5) pp. 545-553

Brushøj C, Bak K, Johannsen H V, Faunø P (2007) Swimmers' painful shoulder arthroscopic findings and return rate to sports. *Scandinavian Journal of Medicine & Science in Sports* **17** pp. 373–377

Becker T J, (2011) Overuse Shoulder Injuries In Swimmers. *Journal of Swimming Research*. **18** [19.2.14]

Borstad J D, Ludewig P M. (2005) The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. *Journal of Orthopaedic Sports Physical Therapy*. **35**(4):227–238.

British Swimming and ASA (2013) *News.* [Online] available from: http://www.swimming.org/asa/news/swimming/sport-england-active-people-survey-shows-upward-participation-trend-in-swim/19163 [2/3/14]

Cools A M, Geerooms E, Van den Berghe D F, Cambier D C, Witvrouw E E. (2007) Isokinetic scapular muscle performance in young elite gymnasts. Journal of Athletic Training. **42**(4):458–463.

Fox, A J S. Wanivenhaus, F. Chaudhury, S. Rodeo,S A. (2012) Epidemiology of Injuries and Prevention Strategies in Competitive Swimmers*. Sports Health* 4 (**3**) pp 246–251 [online] available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3435931/ [7/11/2013]

Frizziero A, Benedetti M G, Creta D, Moio A, Galletti S, Maffulli N. (2012) Painful os acromiale: Conservative management in a young swimmer athlete Journal of Sports Science and Medicine. **11** pp. 352-356

Harrington S, Meisel C, Tate A (2014) A Cross-Sectional Study Examining Shoulder Pain and Disability in Division I Female Swimmers. *Journal of Sport Rehabilitation,* 23 pp.65-75

Hibberd E E, Oyama S, Spang J T, Prentice W and Myers J B. (2012*)* Effect of a 6-Week Strengthening Program on Shoulder and Scapular-Stabilizer Strength and Scapular Kinematics in Division I Collegiate Swimmers*. Journal of Sport Rehabilitation*. **21**, pp. 253-265. [Online] available from: http://web.a.ebscohost.com.ezp.don.ac.uk:8081/ehost/pdfviewer/pdfviewer?sid=9ee4d7d4-dc55-4535-ac88-ae560aecab64%40sessionmgr4001&vid=17&hid=4214 [18.2.2014]

Hyde T E and Gengenbach M S (2006) *Conservative Management of Sports Injuries.* London: Jones and Bartlett*.*

Jeffrey E. Johnson, M D. (1987) Musculoskeletal Injuries in Competitive Swimmers. *Mayo Clinic Proceedings* **62** (4) pp.289–304 [online] available from: http://www.sciencedirect.com/science/article/pii/S0025619612619065?np=y [25.2.14]

Jobe F.W. & Pink M. (1993). Classification and treatment of shoulder dysfunction in the overhead athlete. *Journal of Orthopaedic & Sports Physical Therapy.* **18** pp.427-432.

Jorgić B, Puletić M, Okičić T, Meškovska N (2011) Importance Of Maximal Oxygen Consumption During Swimming*. Physical Education and Sport.* **9** (2) pp. 183 - 191

Kluemper, M. Uhl, T. Hazelrigg H (2006) Effect of Stretching and Strengthening Shoulder Muscles on Forward Shoulder Posture in Competitive Swimmers, *Journal of Sport Rehabilitation*. **15**. pp. 58-70 [23.2.14]

Leroux JL, Codine P, Thomas E, Pocholle M, Mailhe D, Blotman F (1994) Isokinetic evaluation of rotational strength in normal shoulders and shoulders with impingement syndrome. *Clinical Orthopaedics Related Research* 304 pp.108-15.

Manocchia P (2011) *Anatomy of Exercise*. Heatherton Victoria: Hinkler

L. McKenna, L. Straker, A. Smith, J. Cunningham (2011) Differences in scapular and humeral head position between swimmers and non-swimmers. *Scandinavian Journal of Medicine & Science in Sports* **21** pp.206–214

Mcleod I (2010) *Swimming Anatomy*. Leeds: Human Kinetics.

McMaster W C, Troup J (1993) A survey of interfering shoulder pain in United States competitive swimmers. *American Journal of Sports Medicine*. 21 pp.67-70

McMaster W C (1999) Shoulder injuries in competitive swimmers. *Clinical journal of Sports Med*icine **18** pp. 349-359.

Mohsen B, Attarzadeh H S R, Zohreh B, Mehrdad F (2012) Swimming Injuries And Their Risk Factors Among Iranian Elite Freestyle And Butterfly Swimmers. International Journal of Sports Sciences and Fitness, **2** (2) pp.231-238

Page P (2011) Shoulder Muscle Imbalance and Subacromial Impingement Syndrome in Overhead Athletes. *International Journal of Sports Physical Therapy* **6** (1) pp.51-58

Pink, M M. Tibone, J E (2000) The painful shoulder in the swimming athlete. *Orthopedic clinics of North America.* **31** (2) pp.247-261 [22.2.14]

Ramsl M, Swanik KA. Swanik CB, Straub S, Maltacola C (2004) Shoulder-rotator strength of high school swimmers over the course of a competitive season. Journal of Sports *Rehabilitation.* **13** pp.9-18

Riemann B L,Witt J, Davies G J. (2011) Glenohumeral joint rotation range of motion in competitive swimmers. Journal of Sports Sciences. **29** (11) pp.1191–1199

Riskowski J L (2010) Shoulder Stability Training And Shoulder Ailments In High School Swimmers International Symposium On Biomechanics In Sports **28** pp.1

Ristolainen L, Heinonen A, Turunen H, Mannstro H, Waller B, Kettunen J A, Kujala U M. (2010) Type of sport is related to injury profile: A study on cross country skiers, swimmers, long-distance runners and soccer players. A retrospective 12-month study. *Scandinavian Journal of Medicine & Science in Sports.* **20**. pp. 384–393

Ristolainen L, Kettunen J A, Kujala U M, Heinonen A (2012) Sport injuries as the main cause of sport career termination among Finnish top-level athletes. *European Journal of Sport Science.* **12** (3) pp. 274-282 [2/3/14]

Rupp S, Berninger K, Hopf T (1995*)* Shoulder problems in high level swimmers*. International Journal of Sports Medicine* **16** 557–562. [11.2.2014]

Sein ML, Walton J, Linklater J, Appleyard R, Kirkbride B, Kuah D, Murrell G A C. (2008) Shoulder pain in elite swimmers: primarily due to swim-volume-induced supraspinatus tendinopathy. *British Journal Sports Medicine.* **44**(2) pp.105-113.

Solem-Bertoft E, Thuomas K A, Westerberg C E. (1993) The influence of scapular retraction and protraction on the width of the subacromial space, an MRI study. *Clinical Orthopaedics and Related Research*. 296 pp. 99-103.

Soares S, Silva R., Aleixo I., Machado L., Fernandes R.J, Maia J, Vilas-Boas J P (2010) Evaluation of Force Production and Fatigue using an Anaerobic Test Performed by Differently Matured Swimmers. *International Symposium for Biomechanics & Medicine in Swimming [online] available from: http://web.a.ebscohost.com.ezp.don.ac.uk:8081/ehost/pdfviewer/pdfviewer?sid=a2f7fbbf-7d77-403a-95e6-4d97974cf2ac%40sessionmgr4003&vid=35&hid=4104 [2/3/14]*

Sport Scotland (2013) *Extended investment in children's swimming programme* [online] available from: http://www.sportscotland.org.uk/news/sportscotland/2013/extended_investment_in_childrens_swimming_programme/ [2/1/14]

Swanik K A, C. Swanik, C B. lephart, S M. Huxel K. (2002) The Effect of Functional Training on the Incidence of Shoulder Pain and Strength in Intercollegiate Swimmers. *Journal of Sport Rehabilitation* **11** pp.140-154 [7/3/14]

Tovin, B J (2006) Prevention and Treatment of Swimmer's Shoulder. *North American Journal of Sports Physical Therapy*. **1**(4) pp.166–175 [7.11.13]

Tate, A. Turner, G N. Knab, S E.Jorgensen, C. Strittmatter, A. Michener, L A (2012) Risk Factors Associated With Shoulder Pain and Disability Across the Lifespan of Competitive swimmers. *Journal of Athletic Training* **47** (2) pp.148-158 [8/11/13]

Van de Velde A, De Mey K, Maenhout A, Calders P, Cools A M. (2011) Scapular-Muscle Performance: Two Training Programs in Adolescent Swimmers. *Journal of Athletic Training* **46**(2) pp.160–167

Warner JJ, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R (1990). Patterns of flexibility, laxity, and strength in normal shoulders and shoulders with instability and impingement. *American Journal Sports Medicine* **18** (4) pp. 366-75.

Weldon E J III, Richardson A B (2001) Upper extremity overuse injuries in swimming: a discussion of swimmer’s shoulder. *Clinical Sports Medicine*. 20 pp.423-438.

Welsh Government (2012) *Free Swimming*. [Online] available from: http://wales.gov.uk/topics/cultureandsport/sportandactiverecreation/freeswimming/?lang=en [2/3/14]

Wenger H A, Bell G J (1986) The interactions of intensity, frequency and duration of exercise training in altering cardiorespiratory fitness. *Sports Medicine*. 3 (5) pp.346-56

West D, Sole G, Sullivan S J. (2005) Shoulder external- and internal-rotation isokinetic strength in master’s swimmers. Journal of Sport Rehabilitation. **14** pp.12-19

Williams J G, Laudner K G, McLoda T (2013) The Acute Effects Of Two Passive Stretch Maneuvers On Pectoralis Minor Length and Scapular Kinematics Among Collegiate Swimmers. *The International Journal of Sports Physical Therapy* **8** (1) pp.25