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Shoulder strength, flexibility and injury profiles of high school water polo players

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SHOULDER STRENGTH, FLEXIBILITY AND INJURY PROFILES OF HIGH SCHOOL WATER POLO PLAYERS

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Table of Contents:

ABSTRACT 5

KEY WORDS: 5

ACKNOWLEDGEMENTS: 6

CHAPTER 1 - INTRODUCTION: 6

CHAPTER 2 - LITERATURE REVIEW: 8

1. Introduction 8

2. Sport of waterpolo 8

3. Anatomy of the shoulder complex 10

4. Biomechanics of throwing 12

5. Shoulder injuries 15

5.1. Prevalance of shoulder injuries 15

5.2. Strength and shoulder injuries 15

5.3. Flexibility and shoulder injuries 16

5.4.. Injuries in over-head or throwing sports 17

5.5. Adolescence in overhead sports 18

6. Testing of the shoulder complex 19

6.1. Shoulder strength testing 20

7. Adoilescence in overhead sports 21

8. Conclusion 22

CHAPTER 3 - METHODOLOGY: 22

1. Study design 22

2. Study population 22

3. Sample size and sample selection 22

4. Inclusion and exclusion criteria 23

5. Testing procedure 23

6. Ethics 27

7 Data analysis 27

CHAPTER 4 - RESULTS: 28

1. Strength 29

2. Flexibility 31

3. Correlation between flexibility and strength 32

4. Training 34

5. Positions....34
6. Injuries....35
CHAPTER 5 - DISCUSSION:....37
1. Age....37
2. Training....38
3. Flexibility....38
4. Strength....40
5. Position....41
6. Correlation between strength and flexibility....42
7. Limitations....45
8. Clinical implications....45
9. Recommendations for future research....46
CHAPTER 6 - CONCLUSION:....46
CHAPTER 7 - REFERENCE:....48
CHAPTER 8 - APPENDICES:....51
1. Appendix A: Letter St John's College....51
2. Appendix B: Letter Parktown Boys High....52
3. Appendix C: Participants Information Sheet for Minors....53
4. Appendix D: Parents Information Sheet....55
5. Appendix E: Participants Information Sheet....57
6. Appendix F: Parent/Gaurdian Consent Form....59
7. Appendix G: Minors Assent Form....60
8. Appendix H: Over 18 Consent Form....61
9. Appendix I: Data Sheet....62
10. Appendix J: Questionnaire....63
11 Appendix K: Ethical Clearance....68
12. Appendix L: Statistics....69

Table of Contents Tables, Graphs and Pictures:

GRAPHS:

- Figure 1.1. Age 28
- Figure 1.2. Training per week 34
- Figure 1.3. Position 35
- Figure 1.4. Number of Injuries 36
- Figure 1.5. Treatment 36

TABLES:

- Table 1.1. Isokinetic Shoulder Strength 60°/sec 29
- Table 1.2. Isokinetic Shoulder Strength 180°/sec 30
- Table 1.3. Isokinetic Shoulder Strength 300°/sec 31
- Table 1.4. Flexibility 32
- Table 1.5. Correlation between flexibility and strength 33

PICTURES:

- Picture 1.1. Flexibility 24
- Picture 1.2. Strength 26

Abstract:

The aim of this research was to determine the flexibility and strength of the internal and external rotators of the shoulder and injuries that occur in the shoulder in male high school water polo players. A cross sectional study was done with a convenient sample of 28 male high school water polo players. Flexibility was assessed using Myrin inclinometer and strength was assessed using the Biodex System 3 isokinetic dynamometer. The tests were done to assess the player's internal and external rotators of the shoulder. The participants were also questioned using a questionnaire to see time spent playing water polo, injuries sustained and type of injuries. The results showed increased external rotation flexibility and strength in the shoulder compared to internal rotation flexibility and strength. A strong correlation between the internal and external rotators of the same shoulder was also seen in the water polo players when looking at flexibility and strength. Even though the evidence showed that the water polo player would have adaptations in the shoulder due to the movements performed, there was very little correlation between shoulder external rotation flexibility and strength. With the different movements of the water polo player's shoulder it is shown how the different vigorous movements of water polo alter biomechanics to help in their movements during water polo. Future studies need to focus on the different adaptations during water polo and whether these adaptations cause injury or better performance.

Key Words:

Water polo;
Internal rotation;
External rotation;
Flexibility;
Strength;
Injury;
Shoulder

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Chapter 1 – Background and Introduction:

The game of water polo has many different movements that can lead to adaptations that are associated with the game. These adaptations can be seen in the greater range of motion in the throwing arm to help force production during shooting and passing. All these motions need to be achieved with the athlete in a base of support that is not solid (1). With water as the base of support during water polo there are increases of forces that are put through the shoulder during throwing and passing (1).

Due to the popularity of water polo and the participation increasing in the game of water polo there are many more young people participating. Water polo has been a team sport for the past 120 years, due to it being a replacement to soccer during the summer months (1). Research has shown that water polo players swim large distances in the pool while at the same time having to pass and shoot the ball while not having a firm base of support (1, 2). The many different movements performed during a water polo game can predispose the player to injuries. Not only do the players have to throw the ball, but sometimes in a defensive pattern need to block the ball and physically obstruct the opposite player (1). The main problem that is experience when looking at causes of injury in water polo is that there are so many different areas that need to be looked at from swimming to defensive play.

The aim of this research was to focus on the flexibility and strength of the internal and external rotators of the shoulder of high school water polo players during the game of water polo. When looking at the shoulder flexibility and

strength it was seen if due to the adaptations attained during the game, would this benefit the player? The adaptations gained in water polo are important in allowing the athlete to achieve the movements and forces in the game, but also may lead to injuries. The research looked at the shoulder strength, flexibility and injury profiles seen in high school water polo players.

Aims:

The aim of the study was to look at the strength and flexibility of the internal and external rotators of the shoulder in high school water polo players and the correlation between flexibility and strength.

Objectives of study:

1. To assess the flexibility of the internal and external shoulder rotators in male, high school water polo players.
2. To assess the internal and external shoulder rotator isokinetic muscle strength in male high school water polo players.
3. To determine the correlation between shoulder strength and flexibility
4. To describe the amount of training and different positions and the injuries sustained by high school water polo players.

Hypothesis:

It was hypothesised that the throwing arm would have greater strength than the non-throwing arm, in water polo players.

In addition, it was hypothesised that the greater range of motion in the shoulder would produce greater strength in the water polo player's shoulder.

The significance of this study was to see the relation between the shoulder external rotation and increased flexibility. This will provide unique and

beneficial information on the strength and flexibility profiles of high school water polo players in Gauteng.

Problem statement

There is very little research on high school water polo and the adaptations that occur through the rigorous movements and training done by the high school water polo players. Little research has been done looking at the adaptations of the adolescence body during water polo.

Chapter 2 - Literature Review:

1. Introduction:

During the literature review the sport of water polo will be addressed and how the different stresses the player undergoes during play can cause them to adapt to these stresses. The literature review will also show how water polo is like no other over-head throwing sport as it does not have a solid base of support when performing the different motions in water polo. The anatomy and biomechanics of the shoulder during the overhead throw will also be discussed and the importance of correct muscle activation during the overhead water polo throw. During water polo there are numerous injuries that can be sustained during the vigorous activities in the pool. The strength and flexibility of the throwing shoulder play an important role during the different movements during water polo. Testing the shoulders' internal and external strength and flexibility may address how these different factors can play a role during overhead sports.

2. Sport of Water polo:

Water polo originated in the United Kingdom in the late 1800s and had its debut in the Olympic games in Paris 1900 (3). Men's water polo was the first team sport in the Olympic Games and ever since has grown in popularity (2). Water polo is a game where the player is involved in throwing the ball without a solid

base of support (2). This is seen with no other throwing athlete having water as their base of support and this causes the transfer of more force into the shoulder stabilizers (2). The throwing motion in water polo is done by the player elevating their trunk as high as possible out of the water and maintaining this position while throwing the ball as effectively and forcefully as possible (2). The power that is generated is made up of the leg thrust, hip rotation and the trunk rotation and is limited by the fluid medium (2). This type of movement is not the only aspect that is involved in the complex game of water polo.

Water polo players are seen to continuously swim up and down the pool changing direction as the game changes. Research done by Brooks (2), has shown that during a game of water polo a player swims approximately 1000m of front crawl. The water polo swimming stroke is different due to the elevated swimming position seen by the water polo player. This elevated swimming position puts the water polo player's shoulder into abduction, elevation and internal rotation and places a large load on the shoulder joints and surrounding soft tissue structures (2). The swimming stroke also changes when the player swims with the ball causing them to swim short, high elbowed strokes to control the ball in the water (2). The reason the swimming stroke in water polo is different to normal speed swimming is due to the body position in water polo. The body position is more erect and eliminates the normal body roll that allows the easy clearance of the arm during the clearance phase of the freestyle stroke. The result of eliminating the roll causes a greater forced abduction and results in posterior impingement and early fatigue of the rotator cuff, allowing more translations (4). The discipline of water polo is a physically demanding sport and requires well-developed physical capabilities to cope with the intense nature of the sport (5).

Water polo is a complex team intermittent sport, compromising of high and low intensity efforts (5). The game of water polo is made of a combination of swimming, throwing, and water polo and is a contact sport and injuries are not uncommon (2). The increased tensile forces that are seen in the rotator cuff during throwing also results from having to throw from many different body

positions without a firm base upon which to balance (4). With water as the sole base of support causes more force to be transferred into the shoulder stabilizers (2). As there are different components to the sport of water polo, the causes of injuries to the upper extremity could be from overuse syndrome due to swimming, and traumatic shoulder injuries from contact during the throwing phase or wrestling in the pool (4).

3. Anatomy of the Shoulder Complex:

The game of water polo is an upper extremity sport that puts the shoulder complex into many different ranges during high intensity movements (4). Due to the structure of the shoulder being made of many different structures (glenoid, humerus and rotator cuff muscles) that help during static and dynamic stability of the shoulder girdle (7), it causes the shoulder complex to be under great stress when playing water polo (1). Lugo et al (7) showed how the static and dynamic stabilizers react to the forces applied through the glenohumeral joint to allow the shoulder to be stabilized through different positions during the motion arc. The static stabilizers such as the articular cartilage and humeral head have been shown to have different areas of contact during the different motions of the shoulder. This can be seen when the shoulder is in abduction, with the humeral head being more congruent with the glenoid, which increases the contact area and decreases the pressure in the shoulder (7).

Even though the bony anatomy and articulation of the glenohumeral joint are important to stability, the addition of the glenoid labrum as well as the static and dynamic stabilizers contribute to the complex interactions of the shoulder biomechanics (7). It is also important to take note of the dynamic stabilizers that attach to the labrum of the shoulder. The long head of the biceps attaches to the superior tip of the supraglenoid tubercle; the infraglenoid tubercle is the origin of the long head of triceps (7). Both of these muscles have been shown to be stabilizers of the glenohumeral joint. The biceps has shown to be an effective humeral head depressor. This allows the bicep to maintain proper ligament tension in some glenohumeral ligaments as predicted by the complementary

tightening concept of shoulder stability (7). Active stability is primarily the result of neuromuscular control between the scapulothoracic musculature and the rotator cuff muscles (7). This is seen by the shoulder joint being oriented by the functional scapulothoracic musculature to reduce instability. The neural feedback between the rotator cuff muscles and the glenohumeral ligaments help prevent pathologic translation of the glenohumeral joint (7). Large muscles that affect the glenohumeral joint stability are the latissimus dorsi, serratus anterior, pectoralis major and deltoid, due to the large torques they create around the shoulder joint (7). The muscles that attach to the scapular control the motion of the scapular during movement of the shoulder. The most important of these muscles is the serratus anterior, which prevents excessive winging of the scapular by holding the scapular against the rib cage (7). Disruption of the scapulothoracic rhythm can predispose patients to glenohumeral joint pathologies. This can be seen when weakness of the serratus anterior can disrupt the rhythm of the scapulothoracic joint and can pre dispose young overhead athletes to have rotator cuff tendinosis like symptoms (7). The four rotator cuff muscles are the Subscapularis, Supraspinatus (Internal rotators of the shoulder), Teres minor and Infraspinatus (external rotators). Infraspinutus and Teres minor control the external rotation of the humerus and will reduce anterioinferior capsuloligamentous strain (7). The rotator cuff muscles are important stabilizers as they help compress the humeral head deeper into the glenoid cavity (7). The rotator cuff muscles decrease shear forces and help centralize the humeral head on the glenoid (7).

The importance of the different segments of the shoulder complex and their contribution to the different shoulder motions allows for a smooth shoulder movement with no pain. The movement of the overhead throwing motion is accomplished through relaxed muscle activation status, and the throw velocity depends on the subjects' voluntary recruiting ability (8). The contraction of the rotator cuff muscles results in concavity compression, and asymmetric contraction acts to cause humeral head rotation during shoulder motion (7). The torques of acceleration seen in the shoulder is seen due to the ability of the rotator cuff muscles to work as force couples. This is seen with the activation of

the agonists and the deactivation of the antagonists to get a smooth shoulder motion (7). The antagonist muscles of the subject produce the stretch load in the overarm throwing motion (8). The specialized structure of the shoulder with the rotator cuff muscles and long head of biceps are ideally configured to actively compress the humeral head into the glenoid cavity (7). This is seen in the uniqueness of the shoulder as it has the ability to withstand large mechanical stresses while still maintaining large ranges of motion (9). The throwing motion causes the shoulder to move from external rotation into internal rotation and places high stress on the shoulder (10). This is when the rotator cuff muscles work as agonist and antagonists to generate the speed and control of the shoulder.

4. Biomechanics of throwing:

The biomechanics of throwing is divided into six different phases that has different aspects and muscle contractions across the shoulder. It is also important realize that the overhead throw is a sequential motion in the kinetic chain from the lower body up to the upper limbs (10). The first phase is the wind up phase when the overhead athlete develops potential energy as seen in the coiling of the spring (10). During this phase the greatest activity is seen in the upper trapezius, serratus anterior and anterior deltoids (14). During this phase the shoulder forces are low and the likelihood of injuring the shoulder during this phase is very low. The second phase is the stride phase and then followed by the cocking phase, which involves the transfer of kinetic energy generated by the foot strike from the larger lower extremity and trunk to the smaller upper extremity (14). The stride phase during water polo is when the player shifts their weight to get a strong scissor kick to get the maximum from the throw (1). During this phase the scapula upwardly rotates, elevates and retracts, the shoulder abducts, externally rotates and horizontally abducts. This motion is caused by the concentric activity of the deltoids, supraspinatus, infraspinatus, serratus anterior and upper trapezius (14). It is also important to remember the importance of the supraspinatus and how it compresses and stabilizes the

glenohumeral joint (14). This motion of overhead throwing causes the stress on the glenohumeral joint to be the greatest at the moment of direction change (10).

The cocking phase is when the arm moves into maximal shoulder abduction and external rotation. During this cocking phase, high activity of the shoulder musculature is needed to maintain the arm rotating with the rotating trunk and to control the arm when in external rotation (14). The muscles involved in this phase are the posterior cuff muscles (infraspinatus and teres minor) and latissimus dorsi that generate a posterior force to the humeral head and helps prevent anterior humeral head translation (14). During the cocking phase there are many muscles that have multiple functions. This can be seen with the pectoralis major and subscapularis contracting concentrically to horizontally adduct the shoulder and eccentrically contract to control shoulder external rotation (14). These duel functions of these muscles allows for the length-tension relationship to be maintained. This relationship allows the muscles to maintain a near constant length through this phase (14). The problem seen is when there is abnormal scapular muscle imbalances can cause abnormal scapular movement in relation to movement and position relative to the humerus. This increases the likelihood of increasing injury risks to the shoulder during throwing (14). During the cocking phase is when the highest forces are generated and there is the highest risk of injury (10).

The cocking phase is followed by the acceleration phase. The acceleration phase starts when the shoulder is in maximal external rotation. This phase is very similar to the cocking phase due to the high activity of muscles around the glenohumeral and scapular (14). In the acceleration phase the internal rotators (pectoralis major, subscapularius and latissimus dorsi) work at maximum to generate the force during the throwing motion. The subscapularis plays and important role in maintaining the humeral head in the glenoid (14). During this phase correct strengthening of the scapular musculature will prevent poor position and movement of the scapular. This incorrect movement or position can increase the risk of shoulder impingement and other related injuries. The

optimal length-tension relationship of both scapular and glenohumeral musculature will be affected (14).

The final phase is the deceleration phase and has large loads as the muscles try to decelerate the forward acceleration of the arm. The main purpose of the deceleration phase is to slow and control the arm to dissipate the kinetic energy left in the arm and minimizing the risk of shoulder injuries (14). The posterior shoulder musculature (infraspinatus, teres minor and major, posterior deltoid and latissimus dorsi) contract eccentrically to stop horizontal adduction and internal rotation of the arm, and also help resist shoulder distraction and anterior subluxation forces (14). Weak or fatigued posterior musculature can lead to injuries (14).

The shoulder complex is involved in many overhead sports, and the understanding of the shoulder biomechanics is of importance due to repetitive overhead athletes being at higher risk of shoulder injuries (15). Excessive forces or repetitive stresses can overpower the stabilizing of the shoulder and cause problems to occur (7). A force that increases the range of external rotation, extension and abduction such as during the cocking phase of throwing can lead to injury (7). Most overhead throwing sports start with the foot striking the ground, with the exception of water polo (8). The above statement shows the difference between other overhead throwing sports and water polo, with regards to the kinetic chain. Other overhead sports have a solid base of support were water polo has water as its base of support. The breaking of the kinetic chain seen in younger and older athletes in their anatomic areas of the shoulder does cause different movements to occur in the kinetic chain (10).

Webster et al (1) have shown that due to water being the base of support the forces generated during throwing are increased, and research done by Brooks (2) has also shown that the base of support in water polo causes more force to be focused into the shoulder stabilizers during throwing. During throwing in water polo the arm is placed into positions where the load is increased through the shoulder joint (1). Due to the strength needed in the shoulder region during

forceful movements of throwing causes shoulder instability and muscle imbalance between internal and external rotators of the shoulder (1). The demands of throwing in the water place the shoulder under greater stress than on land, because strength requirements come from the trunk and shoulder when throwing from an unstable base (1). The water polo throw moves from the shoulder winding up with a rotation of the trunk, followed by the strong scissors kick then followed by the cocking phase then acceleration of the water polo ball (1).

5. Shoulder Injuries:

5.1. Prevalence of shoulder injuries:

Research done by Weldon et al (11) showed that 90% of swimmers with complaints needed to seek a physician's advice about issues with their shoulder. Research has shown that the shoulder is the fourth most common site of musculoskeletal injury in the body, commonly 10% to 20% of the injuries occurred (12). As many as 50% of the athletes that present with shoulder injuries had previous shoulder injuries (12). Shoulder pain is the most common musculoskeletal complaint in water polo players (6). The glenohumeral joint is seen to be the most inherently unstable joint, but also the joint, which has the greatest freedom of movement (5). The ligaments and musculo-tendinous unit hold the stability of the shoulder together. It is important then to look at sports with repetitive overhead throwing motions that require a coordinated and synchronized shoulder muscle action (5).

5.2. Strength and Shoulder Injury:

The incidence of shoulder pain is directly correlated with the level of competition and years spent competing in the sport of water polo (6). The repetition and overuse seen in the swimming stroke is seen as a major contributor to the development of shoulder pain. Most pain in swimming is developed due to instability of the glenohumeral joint, due to the many demands the shoulder is under during the specific swimming technique. The sport specific

demands of swimming that improve performance, but at the same time reduce shoulder stability are, increased shoulder range of motion, increased internal rotation and adduction strength and prolonged fatiguing, shoulder intensive training. These adaptations can lead to reduced stability, which can contribute to subluxation of the glenohumeral joint. When all these factors are combined with repetition it leads to inflammation and pain (11).

5.3. Flexibility and Shoulder Injuries:

It is seen that many swimmers do not develop shoulder pain and that shows that there has to be a secondary insult that causers the shoulder pain (11). It is important to be aware that any variation of force, mobility, strength, stability, and flexibility within the shoulder complex will alter the function of the shoulder and put it under risk of failure and breakdown (13). It is also important to be aware that the different position and sport that is player will; alter the type of injury that will occur at the shoulder joint (10). The freedom of motion, and stabilization, seen in the shoulder work in conjunction to allow for extreme functional mobility during daily activities and when playing their sport (13). The varied and pervasive nature of shoulder pain in swimmers cannot be explained by one single cause, but shoulder pain has multiple causes (11). One of the injuries that present in shoulders of water polo players is swimmers shoulder. Swimmers shoulder is a multifactorial clinical entity of a hypermobile glenohumeral joint, which allows increased translation of the humeral head in the glenoid (6). This makes it very important for the clinician to understand the normal biomechanics of the shoulder so it will allow him/her to assess the shoulder correctly (13).

Webster et al (1) have shown that 11.5 per hundred female water polo players sustain shoulder injuries every year. The injury rate between male and females was 8.1% in females compared to 3.4% in males (1). Colville and Markman (4) showed that during a competitive season 26% of water polo players would sustain shoulder injuries. The research has also shown that there is no

significant relationship between flexibility and pain. The exact contributors to shoulder pain in water polo players are still being assessed, as there is no exact mechanism that leads to shoulder pain. There are lots of factors that are associated with shoulder pain from increased mobility of the shoulder, increased imbalance in the rotator cuff muscles and repeated throwing in the water (1).

5.4. Injuries in over-head or throwing sports:

The complex structure of the shoulder joint causes the joint to be the most mobile and one of the most unstable joints in the body. Due to the shoulder being the most mobile and unstable joint also puts it in a higher prevalence to get injured. The shoulder complex is one of the more challenging areas to ascertain complete comprehension of all the intricacies involved of its many different moving parts and the relationship that those parts have with each other (13). Any variations in the force, mobility, strength, stability and flexibility within the shoulder complex will alter the function of the shoulder, and predispose the shoulder to microtraumatic episodes. This will lead to failure and breakdown of the shoulder and its movements (13). During the late cocking phase of the water polo shot, the players shoulder is in the position of abduction and maximal external rotation, which may result in the development of internal impingement (6).

The shoulder is a very unique joint in the way it must withstand many different loads while trying to maintain stability in the overhead throw. When the shoulder has multidirectional instability (as in swimmers shoulder) this can lead to problems of impingement against the undersurface of the acromion, the coraco-acromial ligament and sometimes the coracoid process (6). The throwing shoulder is made up of the kinetic chain and the disruption of this chain can predispose the athlete to injury (10). Disruption of the critical mechanism of overhead throwing predisposes the athlete to injury (10). This disruption of the kinetic chain deserves attention as the most important biomechanical principle required to help evaluate and manage problems of the athlete's shoulder (10). Conditions such as internal impingement are unique to sports that require abduction and extremes of external rotation, such as those seen in the late cocking phase when shooting at goals or pitching (6).

5.5. Adolescence and overhead sports:

Water polo is becoming more physical than ever and this results in a number of typical acute traumatic events such as contusions, lacerations, sprains, dislocations or fractures (6). In many overhead sports there are adaptions that occur due to repetitive overhead throwing. In younger age groups it has shown that there are repetitive microtrauma and macrotrauma as the main causative factors, but with aging the aetiology of the rotator cuff lesions shifts to degenerative conditions (6). These adaptations are seen in the range of motion of the throwing arm (21). Dwelly et al (21) have shown that the increase in range of motion of the throwing arm might be an adaptive response to overhead throwing sports, but can be associated with pain, decreased performance and shoulder disorders. The movement seen in throwing sports often causes chronic changes in soft and osseous tissues in the glenohumeral joint (21). This change can be seen in an increase of the throwers external rotation in a pitching season by 11° (21). However, there were no significant changes seen in shoulder internal rotation through the season, indicating a total increase in range of motion of the throwing shoulder by 11°. This increase in external rotation range of motion is seen to be secondary to repetitive throwing and not injury. The

adaptions that will normally be seen in the shoulder will be an increase in the total range of motion increasing. (21). Therefore it is critical to monitor the range of motion of the athletes shoulder over a single season as well over multiple seasons.

Overhead injuries in adolescent athletes occur more often than in adults in the shoulder complex as there are different forces on the adolescent shoulders compared to their adult counter parts (22). Adolescent sport has increased in competitiveness and intensity and places the athlete under more pressure to perform (22). This increased need to perform has caused adolescent athletes to increase training time and duration. Ramappa, et al (22) showed that the degree of shoulder pain that the adolescent athlete feels is directly proportional to how many times they throw in a season. The stress injuries that have been seen in children involved in throwing sports are normally microtraumas; these injuries are normally due to continued repetitive throwing over a long period of time, or the amount of throws during a season (22).

Many water polo players are under risk of traumatic dislocations and subluxations of the glenohumeral and acromioclavicular joints from contact with opponent players or the ball. These injuries normally occur to the throwing arm of the water polo player during shooting or passing the ball (6). The reason this has been seen to occur is due to the shooting arm being in a position called the cocked position when throwing whilst holding the ball (6). This puts the water polo player's arm under great strain when trying to achieve maximal power and precision when passing and shooting the ball.

6. Testing of the shoulder complex:

Isokinetic testing provides objective data to determine agonist and antagonist muscular strength around the glenohumeral joint (16). The study of the shoulder muscles using isokinetics has many different problems that have to be focused on when testing the shoulder joint. The first area that needs to be looked at is the many different movement planes of the shoulder and in which plane you

want to test the shoulder to get the best results (17). The second fact is the large amount of muscles that are used in the shoulder when testing, and how will the test be reproducible. Thirdly are the anatomical landmarks that need to be lined up with the dynamometer are not as discernible as other areas on the body. This puts pressure on the tester to make sure there are no measuring mistakes when setting up the isokinetic dynamometer. Fourthly there are many different protocols in many different studies that give differing results that may not work with your results. Lastly the dominance in a normal population is different to the dominance of a sports person (17). Even with all these areas that need to be focused on, isokinetics has shown to be a good indicator of shoulder internal and external rotator strength (17).

6.1. Shoulder Strength Testing:

The isokinetic testing does provide information about antagonist-agonist muscular activity, which is important in evaluation and rehabilitation of the shoulder (16). The application of isokinetic testing and training is imperative for the upper extremity to help with the demanding work required during sport specific activities (18). The objective data about the intricate balance between the agonist-antagonist muscular strength surrounding the glenohumeral joint that is attained from the isokinetic testing is a vital resource in the rehabilitation and prevention of injuries (18). The testing of the isolated shoulder joint allows for us to indicate overuse injury or different acute shoulder injuries.

The importance of the correct set up of the isokinetic machine allows for the results of the testing to valid and reliable. Research done by Ellenbecker and Davies (18) has shown by putting the shoulder into the scapular plane it allows for enhanced bony congruity and neutral glenohumeral position. This is done by tilting the dynamometer approximately 30° from horizontal base position (18). The patient's glenohumeral joint is placed in 30° abduction and 30° of forward flexion into the plane of the scapula (18). The dynamometer head should also be at a 30° diagonal tilt from the transverse plane (18). This allows the anterior capsular ligaments to be in a midrange position and enhances the length-tension

relationship of the scapulohumeral musculature (18). This position also prevents the suprahumeral structures from being in an impinged position and is well tolerated by the patient (18).

The demand of water polo during the overhead throw needs the evaluation of the internal and external rotators of the shoulder to see if there are any deficits that may cause muscle imbalance during the overhead throw. Linther et al (10) have shown that due to the rigorous movements during throwing, shoulder injuries can occur due to a remote injury, incompletely healed or rehabilitated injury, muscle weakness or imbalance, muscle inflexibility or joint stiffness, or improper mechanics. Research has shown (16 & 19) that there is a significant difference between dominant and non-dominant arm scores. The accepted difference between dominant and non-dominant shoulder strength is 10% (20). These significant differences of the internal rotators strength of the shoulder were not only seen in athletes, but also in the control group. The only difference between the athletes and control group was seen in the athletes having a greater strength in external rotation during 60°/sec on the isokinetic machine (19).

The findings of the isokinetic testing have shown the importance of the external rotators in humeral deceleration during the overhead throwing activities. This is also important as to show the importance of the dynamic stabilization of the humeral head in the glenoid by the rotator cuffs (18). The testing is important to see the strength of the stabilizers of the shoulder as they are called into action in most movements of the upper limb (17). The isokinetic testing of the external rotators is seen as very important due to their role during the control phase in the follow through phase of throwing. In the follow through phase the external rotators have to work at high speeds to control the shoulder joint against the internal rotators (17).

6.2. Shoulder Flexibility Testing:

Testing of the glenohumeral joints flexibility is very important to assess the ability of the shoulder to move during the throwing motion. The visual

inspection technique is done by the investigator to move the shoulder into internal and external rotation and to record the measurement when the acromion starts to lift or at the capsular end feel (21). The participant starts lying supine on a treatment table/plinth with the arm that will be tested abducted to 90° (21). The investigator must secure the inclinometer to the forearm at the distal radius of the arm to be tested. The participants elbow will be flexed at 90° in neutral glenohumeral rotation and perpendicular to the floor (21). The investigator will then rotate the glenohumeral joint while still monitoring the scapular motion, end range of motion is achieved when rotation stops at capsular end feel or there is movement of the scapular (21).

8. Conclusion:

With water polo being a sport that uses the whole body to swim with, pass and throw the ball, it is important that the whole kinetic chain works correctly. With the additional issue of not having a solid base of support puts the water polo under more stress when playing water polo. Water polo players are at high risk of getting shoulder pain due to the high stressors that are put through the shoulder during the game (4). Due to the complicated anatomical structure of the shoulder and the many positions that the shoulder is put in during water polo, there is a high incidence of shoulder injury (1).

Chapter 3 - Methodology:

1. Study Design:

The study was a cross sectional descriptive study that assessed shoulder flexibility, strength and injury prevalence in high school water polo players.

2. Study Population:

The study population invited to participate were the first team water polo teams from two Gauteng high schools. Forty players were invited to participate in the study. A total of 28 (70%) first team adolescent high school water polo players

(n=28) participated in the study. The high schools that were selected were St John's College and Parktown Boys High School. Permission was granted by both of the high school headmasters (Appendix A and B).

3. Sample Selection and Sample Size:

The first team water polo squads from the selected schools were invited to participate in the study. A convenience sample of 28 participants took part from both schools. The reason these schools were specifically selected was due to geographic convenience, water polo being popular, and their ability to complete the research tests within the research time frame. An information sheet was given to all the participants that invited them to participate in the research (Appendix C). The information sheet also explained all the tests they would perform and the procedures of the study. As most of the participants were under the age of 18 years old, an information sheet was provided to the parents (Appendix D). For participants that were over 18 years old, an information sheet that explained the procedure done in the research was provided (Appendix E). The parents were required to sign a parental consent if the participant was under the age of 18 years old (Appendix F), and the participant was required to sign a child assent form (Appendix G). For the participants that were over the age of 18 years, they were required to sign an informed consent (Appendix H). The informed consent, parental consent and child assent forms informed the participant and parent that they were allowed to withdraw from the research study at any time without prejudice.

4. Inclusion and exclusion criteria:

Participants in the study were from the first team water polo players at St John's College and Parktown Boys High School.

If any participant presented with any acute shoulder injuries or an injury within the preceding 3 months of the testing they were excluded from the research study. Injury was defined as any musculoskeletal condition that would prevent them from playing their sport for any length of time. Participants were also

excluded from the research if they were on any chronic medication that could have affected the results of the research.

5. Testing Procedures:

a. Height and Weight

Height was measured using a Panamedic height measure. The participants were asked to stand against the wall with their shoes off and heels against the wall. The Panamedic height measure was lowered until it lay on the participants head and then height was be recorded in metres.

Weight was measured using on a Tanita scale. The participant was asked to remove their shoes and asked to stand on the scale until the measurement records on the scale. Measurements were also done with the participants wearing their shorts and a t-shirt. The measurement was recorded by writing it on the data sheet (Appendix I).

b. Medical and Injury history questionnaire:

The participants were required to complete an injury questionnaire (Appendix J) in order to determine any previous injuries during their sporting career. The questionnaire also included training information in terms of the amount of training the individuals undertake for their sport. The questionnaire was developed by the researcher and reviewed by other people in the field. The questionnaire was not tested for validity or reliability, and was mainly used for descriptive information, or to exclude participants from the research.

c. Shoulder Flexibility:

Flexibility testing was performed using a Myrin inclinometer on the shoulder joint to determine the degree of range of motion in the movements of internal and external shoulder rotation. The testing was done in order to isolate glenohumeral movement through a visual inspection technique.



Picture 1: Assessing shoulder Internal and External RotationFlexibility*

- Patient gave consent to be used in this photo

The participant lay supine on a plinth with their arm abducted to 90°. This position for internal and external shoulder flexibility has been reported as valid and reliable (interclass correlation values of 0.79 to 0.96). (21). An inclinometer was firmly strapped to the participants arm to measure the amount of movement in degrees. The testing of internal and external shoulder rotation flexibility was started with the arm at 90°, in a neutral glenohumeral position with the arm perpendicular to the floor. The researcher monitored scapular stabilization throughout the movement as the participant internally rotated their shoulder joint (glenohumeral joint). The participants' maximal range of motion is reached when internal rotation ceases with a firm capsular end feel or before appreciable motion of the scapular, at this point the amount of degrees of rotation will be measured and recorded (21). The participant was then instructed to rotate the arm back to neutral (90° start point and arm perpendicular to the floor). The participant was then instructed to externally rotate the shoulder joint until external rotation ceases with a firm capsular end feel or before appreciable motion of the scapular. At this point the amount of degrees was measured and recorded. The flexibility test was performed bilaterally, with each arm movement measured twice and the average of the two trials recorded.

d. Isokinetic strength test:

Isokinetic strength testing of the participants was done to determine the concentric strength of the shoulder internal and external shoulder muscles. The

testing of the shoulder was done in a modified neutral position for internal and external rotation of the shoulder. The isokinetic machine used was the Biodex System 3 dynamometer (Biodex medical, Shirley, NY, USA) . The subject was seated with trunk positioned upright and the chair back at 85^0, and the hips and knees flexed. The trunk was supported by a firm chair with a flat back up to scapular level with two straps that start just above the shoulder level and extend to the opposite pelvic side, crossing each other at sternum level. The reason for the firm chair was to keep the scapular stabilized against the chair during the testing of shoulder internal and external rotation. The straps are to hold the body against the chair to stop the participant using the incorrect muscles during the test. There is another strap that was used to stabilise the pelvis. The subject's arm was supported in the scapular plan and the elbow supported by an elbow pad connected to the Biodex throughout the test. Axis alignment is longitudinal through the head of the shaft of the humerus in a horizontal plane. The test speeds that were set on the Biodex isokinetic dynamometer were at 60^0/sec, 180^0/sec and 300^0/sec (17).Before the warm-up the participant will be given an explanation of the procedure of the testing. The participant started with three warm-up repetitions. The warm-up repetitions were 50%, 75% and 100% of their maximum before they start with the test. The participant did 5 repetitions at 60^0/sec, 10 repetitions at 180^0/sec and 15 repetitions at 300^0/sec, with a rest interval of 10 seconds between each set.



Picture 2: Testing procedure for shoulder internal and External RotationStrength*

* Patient gave consent to be used in this photo

Ellenbecker and Davies (18), reported that isokinetic testing affords the clinician objective criteria and provides reproducible data to assess and monitor a patient's internal and external shoulder strength. Isokinetic testing of shoulder internal and external strength has been demonstrated to be reliable and valid (18).

As shown in research done by Ellenbecker and Davies (18), a test-retest for reliability was conducted on isokinetic testing of internal and external rotation of the glenohumeral joint in the modified neutral position. The position of the arm was at 30^0 shoulder abduction, 30^0 shoulder flexion and 30^0 scapular retraction. The velocity testing at 60^0/sec, 180^0/sec and 300^0/sec and was performed with interclass correlation coefficients applied to determine the degree of test-retest reliability. This showed high test-retest reliability with interclass correlation coefficients ranging between 0.91 and 0.96 (18).

6. Ethics:

Ethics clearance was given by the Human Research Ethics Committee of the University of the Witwatersrand (Appendix K).

All the participants were invited to participate in the research. The participants were allowed to do the research voluntary and were allowed to withdraw from the research at any time without prejudice. All consent for the research was obtained from the participants parents/guardians. The participants had to sign ascent forms to give their permission to do the research.

All the information gathered in the research was kept confidential and the participant's information was kept in a safe place. This helped keep all the participants information anonymous. All the information was only accessible by the researcher and supervisors.

7. Data analysis:

Descriptive statistics were analysed using Microsoft Excel, whilst inferential statistical tests were done using STATISTICA version 10. A Spearman Rank correlation coefficient was used to determine the strength of the relationship, and a paired t-test was assess the differences between the left and the right internal and external rotation of the shoulders. The strength of the correlation was verbally described using the following guide:

- .0 – .19 very weak correlation
- .20 - .39 weak correlation
- .40 - .59 moderate correlation
- .60 - .79 strong correlation
- .80 – 1.0 very strong correlation

Chapter 4 - Results:

During the study 28 high school water polo player's strength and flexibility was tested. All the participants in the study were male as the study was looking at high school male water polo players. All the participants' were at the time of

testing playing in the first side water polo sides at Parktown Boys High School and St Johns College. The participants range between the ages of 14 to 18 years.

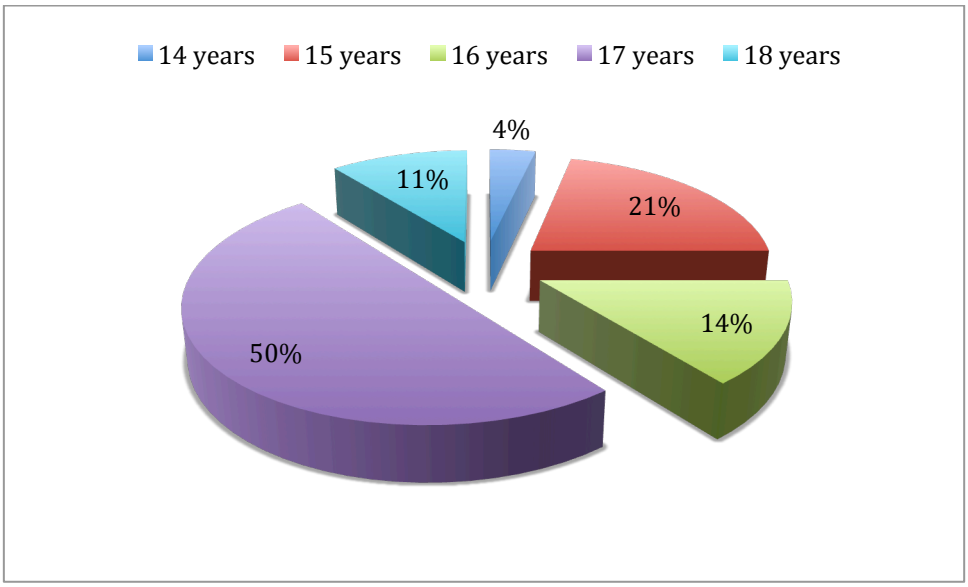


Figure 1.1 Age characteristics of the participants

When looking at the age of the participants 50% (14) where 17 years of age, 21% (6) where 15 years of age, 14% (4) where 16 years of age, 11% (3) where 18 years of age and 4% (1) was 14 years of age. The mean age of the participants was 16.4 years. All the percentage of ages and different ages of the participants can be seen in figure 1.1. Of the 28 participants in the testing there were 3 left hand dominant players and 25 right dominant players.

1. Strength:

The testing of the water polo boys showed the difference between the external rotators and internal rotators strength of the participants' shoulders. The strength was measured in newton meters (N-M) over the individual participants' body weight (BW). The results of the strength are represented as a percentage (%). The mean strength of the right external rotators (70.3%) was greater compared to the internal rotators (44.6%). The mean strength of the left external rotators (66.6%) was greater when compared to the internal rotators (46.2%). This shows that the external rotators are greater in strength compared to the internal rotators of the water polo players. The minimum external rotation on

the right (49.9%) and left (45.7%) is still higher than the minimum internal on the right (36.5%) and left (31.1%). The above shows that there is a difference between the internal and external rotation strength of the shoulder. The table below shows that the external rotation of the left and right were stronger than the internal rotation on the left and right.

Table 1.1 Isokinetic Shoulder Strength at 60°/sec

PT/BW (%)	n=	Minimum	Maximum	Mean	Standard Deviation
IR Right	28	36	55	46	±4
IR Left	28	31	54	44	±6
ER Right	28	49	89	70*	±9
ER Left	28	45	89	66	±11

(IR = Internal rotation, ER = External rotation)

(PT = Peak Torque, BW = Body Weight)

*(ER 60° right is significantly stronger than ER 60° left $p<0.05$)

When a Students T-test for the dependent variables was used on external rotation strength (at 60°/sec) of the right and left shoulder, it was shown that the right shoulder was significantly stronger than the left. When looking at the participants in the test we tested more right dominant throwers than left (25 right dominant and 3 left dominant).

Table 1.2 Isokinetic Shoulder Strength 180°/sec

PT/BW (%)	n=	Minimum	Maximum	Mean	Standard Deviation
IR Right	28	28	50	39	±5
IR Left	28	30	51	40	±5
ER Right	28	42	78	57	±10
ER Left	28	42	73	55	±9

(IR = Internal rotation, ER = External rotation)

(PT = Peak Torque, BW = Body Weight)

Table 1.3 Isokinetic Shoulder Strength 300°/sec

PT/BW (%)	n=	Minimum	Maximum	Mean	Standard Deviation
IR Right	28	30	57	42	±5
IR Left	28	35	55	42	±10
ER Right	28	28	74	50	±11
ER Left	28	30	67	49	±9

(IR = Internal rotation, ER = External rotation)

(PT = Peak Torque, BW = Body Weight)

2. Flexibility:

The water polo players showed greater external rotation flexibility compared to internal rotation flexibility. Flexibility is represented in degrees (°) of motion that the person was able to reach. The mean external rotation flexibility of the left shoulder is 103° compared to the mean internal rotation flexibility being 69°. The mean external rotation flexibility of the right shoulder was 105° compared to the mean internal rotation flexibility being 63°.

Table 1.4 Shoulder Flexibility

	n=	Minimum	Maximum	Mean	Standard Deviation
Flexibility IR Left	28	41°	86°	69°	±11
Flexibility IR Right	28	40°	102°	63°	±13
Flexibility ER Left	28	86°	135°	103°	±11
Flexibility ER Right	28	75°	126°	105°	±12

(IR = Internal rotation, ER = External rotation)

3. Correlation between flexibility and strength:

When looking at external rotators the mean right external rotation flexibility being 105° and strength being 70% compared to the right internal rotation flexibility being 63° and strength being 46%. With the mean left external rotation flexibility being 103° and strength being 66% compared to the left internal rotation flexibility being 69° and strength being 44%. This shows that the greater the range results in greater power generated by the high school water polo players.

The correlation between shoulder flexibility and shoulder strength can be seen in the Table 1.5. The greater the shoulder internal and external ranges of motion the greater the shoulder internal and external strength. This can be seen in the table 3 where the greatest mean flexibility is the right external rotation (105°). The greatest strength was seen in the right external rotators (70%) and is seen in table 1. It was shown that the majority of the participants had a greater external rotation range of motion and strength when compared to their internal rotation range of motion and strength. The mean internal strength was 44% (Left) and 46% (Right) compared to the mean external rotation strength was 66% (Left) and 70% (Right).

The table below shows the R-value that shows correlation of the right and left shoulder flexibility and strength during internal and external rotation.

Table 1.5 Correlation between Strength and Flexibility

	FLEX IR LEFT	FLEX IR RIGHT	FLEX IR LEFT	FLEX IR RIGHT	INT 60° LEFT	INT 60° RIGHT	EXT 60° LEFT
FLEX IR RIGHT	0.211						
FLEX ER LEFT	-0.172	0.142					
FLEX ER RIGHT	0.128	-0.161	0.325				

INT 60° LEFT	0.101	0.108	-0.258	0.082			
INT 60° RIGHT	0.071	0.073	-0.146	0.177	0.517*		
EXT 60° LEFT	-0.317	-0.007	-0.206	-0.016	0.527*	0.318	
EXT 60° RIGHT	-0.212	-0.129	0.053	0.163	0.311	0.508*	0.588*

(IR = Internal rotation, ER = External rotation)

*Statistically significant at p>0.05

The above table shows that there is a very weak correlation between flexibility and strength of the internal and external rotators of the shoulders.

The table also shows that there is very low correlation between the left shoulders external rotation flexibility and left shoulders external rotation strength (0.206). There is also very low correlation between right shoulders external rotation flexibility and right external rotation strength (0.163). There is a moderate correlation between internal rotation on left shoulders and internal rotation on right shoulders strength (0.517), internal rotation strength on right and left shoulders (0.517), internal and external strength on the left shoulders (0.527) and right shoulders (0.588). This showed that there was a moderate statistical significance between the internal and external rotation of the same arm. The moderate statistical significance seen is due to the changes that the shoulder goes through with the training of water polo which allows the player to attain the flexibility and strength needed to cope with the intensities of water polo.

4. Training:

The graph below shows that 76% of the players trained more than 5 times a week, 14% trained 5 times a week and 10% trained 4 times a week. This showed that the majority of the players trained greater than 5 times in a week. Each session lasted between 1 and 2 hours. The total time spent playing water

polo a week was between >5 to >10 hours. The participants also played matches between 30 minutes and an hour every week. This shows that the players where playing water polo between > 5 ½ to > 11 hours a week.

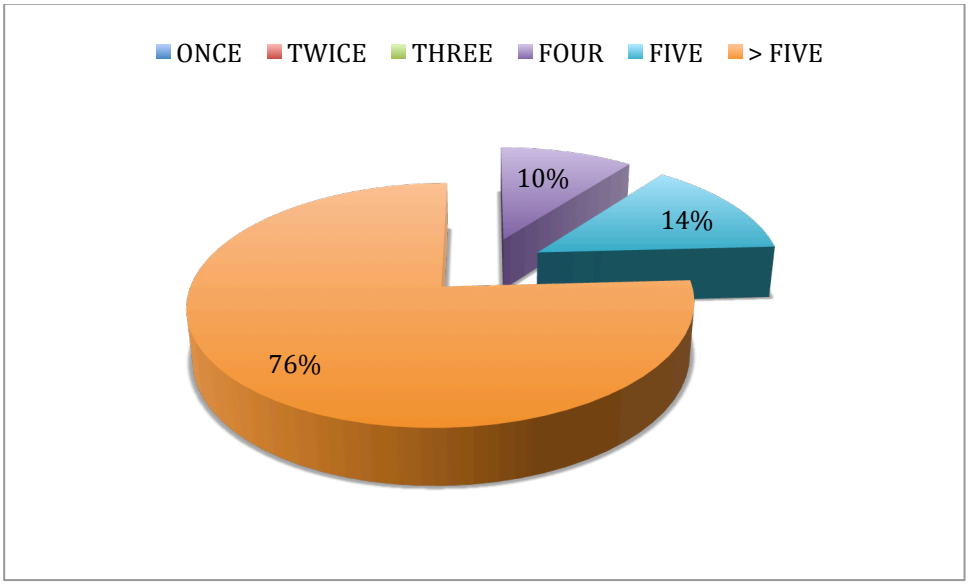


Figure 1.2. Amount of training per week

5. Positions:

The positions played by the water polo players were 13 (48%) play wing, 6 (22%) play hole marker, 4 (15%) play hole man and 4 (15%) play pivot. Of the 28 participants there was one player that play goalkeeper. Figure 1.3 shows that the majority of players played on the wing. Water polo is a sport played in water where there are a variety of physical and technical abilities that are specific of each playing position (5).

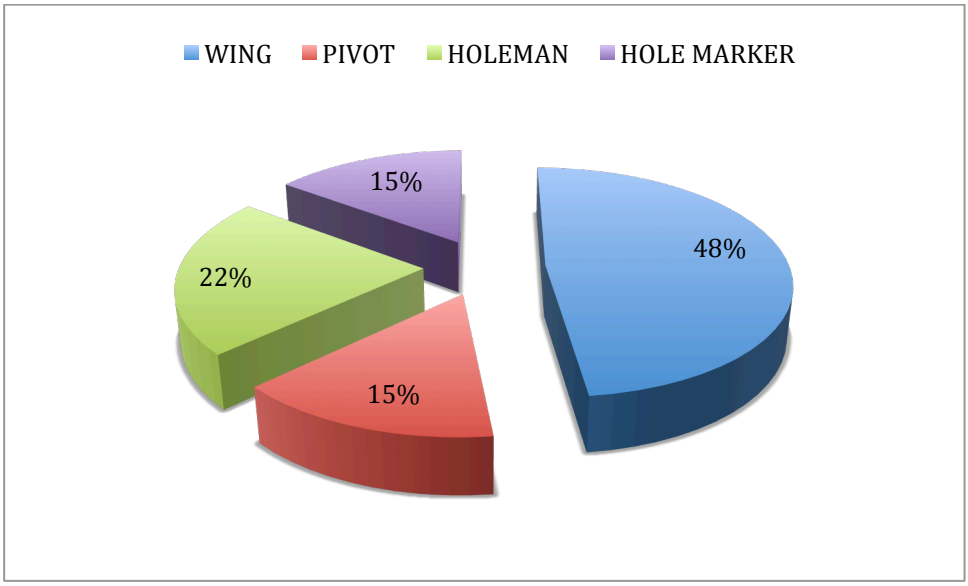


Figure 1.3. Different water polo playing positions

6. Injuries:

The number of injuries that are seen in the water polo players is 29 with some of the players presenting with more than one injury. There were 3 participants that did not have any injuries. Of the 29 injuries 8 (28%) were shoulder injuries, 7 (24%) were arm injuries, 6 (21%) were leg injuries, 5 (17%) were ankle injuries, 2 (7%) were back injuries and 1 (3%) neck injuries. The total amount of upper limb injuries was 16 (55%) of the total injuries in the participants. This shows the high incidence of upper limb injuries among high school water polo players. Figure 1.4 shows the different ratio of injuries that the participants have sustained.

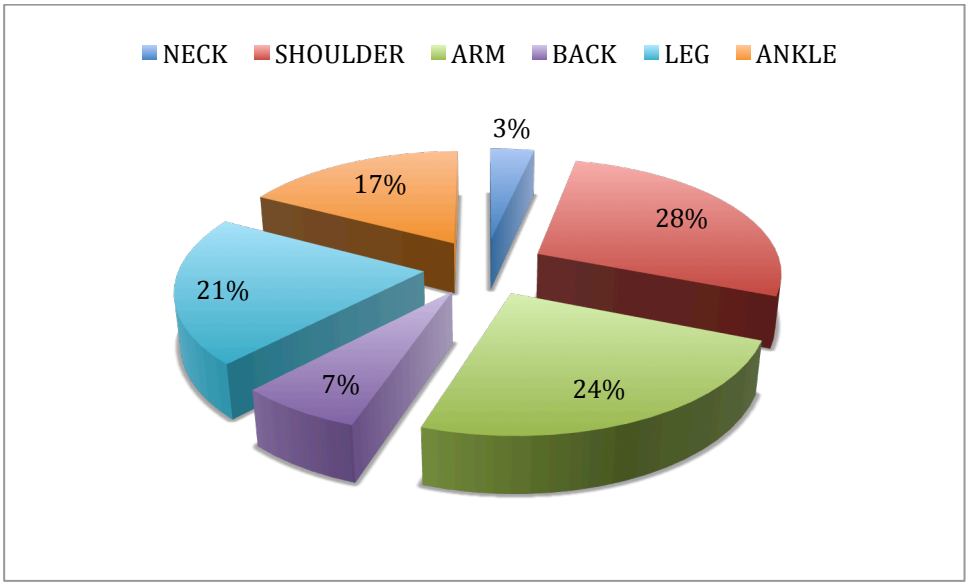


Figure 1.4. Different parts of the body injuries occur

The total number of injuries seen was 29 and they saw many different health providers. Of the 28 participants 3 had no injuries and 24 went to see a health provider for treatment with 8 (32%)getting treatment from a doctor, 10 (40%) getting treatment from a physiotherapist, 5 (20%) getting treatment from a biokineticist, 1 (4%) getting treatment from the chiropractor and 1 (4%) person not going for treatment. The number of participants that went to seek treatment is reflected below in Figure 1.5. This showed that even while injured the participant's attained treatment to help them continue their play through the water polo season.

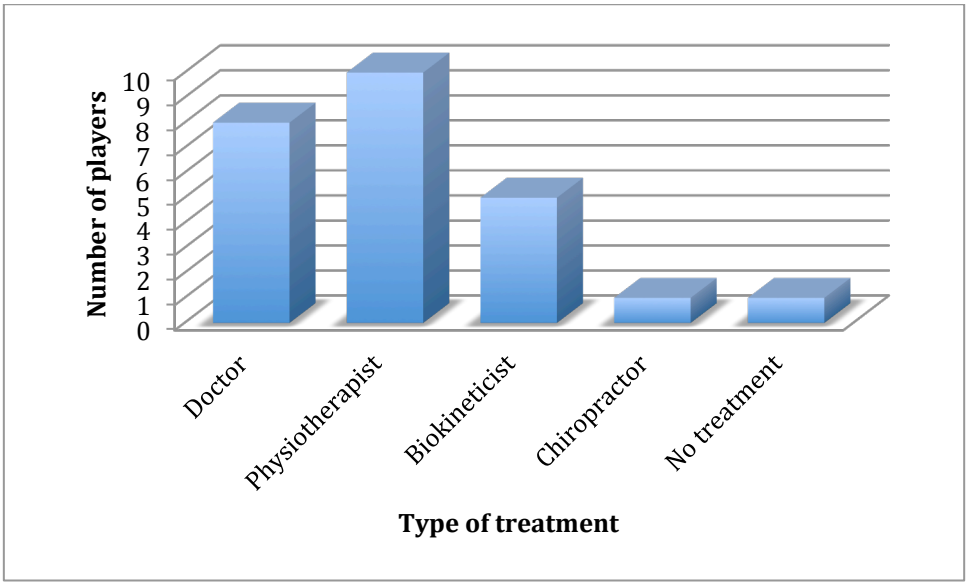


Figure 1.5. Different treatments modalities done by the water polo players

The injuries seen amongst the participants were that 7 were sustained during water polo (6 shoulder injuries and 1 elbow injury). 13 of the participant's sustained injuries outside of water polo and 8 had no history of injuries. This shows that many of the participants attained injuries outside of the game of water polo and brought injuries into their water polo season. Of the 7 participants that attained injuries during water polo they were seen to continue playing with those injuries and seek treatment from health practitioners. This shows that all injuries sustained by the participants during water polo were upper limb injuries with 6 being injuries of the shoulder joint and 1 injury to the elbow joint. The most injuries seen by water polo players were upper limb injuries followed by neck injuries. Showing the pressure put on the upper limbs and neck during the game of water polo. Also with the time-spent training in water polo causes the limbs to be under pressure constantly without rest.

Chapter 5 - Discussion:

The purpose of this study was to look at the shoulders internal and external rotators flexibility and strength of the male high school water polo players. During the research it was also to see if through water polo there was any adaptations or changes to the shoulder joint due to water polo.

1. Age:

The participants of the research varied between the ages of 14 years to 18 years. During training there are many different biological and functional adaptations that occur due to those training intensities. Varamenti et al (23) showed that there was biacromial breadth differences between junior woman water polo players compared to senior women water polo players. They stated that this was due to the higher more intense training that the senior athletes partake in. The intense training the 17 year old players are under is seen as a problem as this is when they are transitioning from buildup level to championship level. (23). This shows that many of the water polo players at the ages of the participants in the current study are starting to move from more amateur water polo to more

competitive and high-level water polo. This change of intensity of water polo training and playing will cause greater physiological changes to the shoulder.

2. Training:

This is possibly an adaptation that the shoulder undergoes with the intense training that the water polo players are under during a training season. When the internal rotation of the shoulder decreases beyond the gain of the external rotation the water polo player can present with glenohumeral internal rotation deficit (GIRD) (21). Webster et al (1) have shown that the throwing arm of a water polo player requires a large external rotation and abduction to allow the greatest possible force to throw the ball when passing or shooting. The strength requirements that are needed to allow the water polo player to throw the ball at theses velocities could be a precursor for shoulder instability and the imbalance that is seen between the internal and external rotators of the shoulder. This study showed that the majority of high school water polo players are training more than five days per week, and although strength and skill training is imperative for performance, the amount of training may predispose these adolescents to repetitive strain injuries (1).

3. Flexibility:

The flexibility of the external rotators was seen to be greater than the internal rotators, showing the increased external rotation of the participant's shoulders. The repetitive high velocities of overhead throwing cause chronic adaptations to the soft and osseous tissues in the glenohumeral joint. These adaptations are likely to lead to changes in the shoulders range of motion (21). This shows that through the repetitive motions seen in the throwing motion there will be changes in the water polo player's shoulder range of motion. This long time spent in the pool playing and training causes adaptations that will change their shoulder range of motion to help attain the best results when passing and shooting the water polo ball. The changes in range of motion are not always positive and can be due to pain and a decrease in the player's performance (21). This adaptation can be seen in the participants having a large range of motion during external rotation of the left (Mean 103°) and right (Mean 105°) shoulder.

The sum of the flexibility of the internal rotators and external rotators of the shoulder should equal between 180° and 190°. The sum of the mean internal and external rotators of the left shoulder was 172°, and the sum of the mean internal and external rotators of the right shoulder was 168°. The sum of the internal and external rotators shows to be less than the necessary 180°/190°. This therefore shows the loss in internal rotation is greater than the gain in external rotation. This showed that the water polo players present with a greater external rotation in their shoulders compared to internal rotation. With the high intensity that the participants are involved in water polo on a weekly basis they will present with physiological changes in their throwing and non-throwing arm. The vigorous training with numerous repetitions of ball throws; swimming and kicks may result in injury (6). When shooting or throwing the water polo ball the throwing arm requires a large range of external rotation and abduction to allow for the greatest amount of possible force (1). This can be seen in the results where the external rotation ranges of motion of the shoulder of the participants was greater compared to the internal rotators of the shoulder. The mean external rotators flexibility of the left shoulder was 103° and the mean external rotators flexibility of the right shoulder was 105°. It was seen that the water polo players presented with a greater external rotation in their shoulders compared to internal rotation.

It has been shown by Franic et al (6) that the incidence of shoulder pain is directly correlated with the player's level of competition and their years spent playing the sport of water polo. The problem that is seen with in many overhead-throwing athletes is an increase in external rotation and a decrease in internal rotation. This is known as glenohumeral internal rotation deficit (GIRD) (21). This can be seen in many of the participants in this study presenting with large or increased external rotation and decreased internal rotation. The large amount of training and playing water polo can lead to adaptive changes seen in the participant's shoulders. The strength requirement of the shoulder region for these different movements it requires is a precursor to shoulder instability due to imbalances seen between the internal and external rotators (1).

The mean flexibility of the internal rotators of the left shoulder was 69° and the right shoulder was 63°. The sum of the flexibility of the internal rotators and external rotators of the shoulder should equal between 180° and 190°. In the results it was shown how the internal rotation loss was greater than the gain of the shoulders external rotation. With the strong correlation between the internal and external rotators of the same shoulder shows how the shoulders need to adapt to the intensities they are under during water polo. The adaptations are an increase in external rotation of the throwing shoulder and posterior capsular tightness (22). The large flexibility limits that the shoulder is put under during water polo predispose the water polo player to upper limb injuries. Due to the high repetitive motion in water polo, the water polo player has the shoulder complex undergoing high repetitive forces. These forces are from motions in the swimming style, shooting and passing during the game (2). Of the 13 participants playing in the wing position 5 presented with shoulder injuries. The shoulder injuries that were seen in the wing position players was assessed through a questionnaire of injuries sustained by the different positions. The wing is the position in water polo where the players do the most swimming. Looking at the 7 participants that presented with upper limb injuries it was seen that 5 of those players played in the wing position, which may indicate this position is more prone to injuries.

There are a variety of injuries that can occur to the upper extremities, from overuse syndrome from repetitive swimming (4). It was shown that the greater the external range of motion of the shoulder would aid the water polo to create greater strength when throwing the ball (1). With the greater range of motion needed to generate the strength needed in water polo it may predisposes the water polo player to upper limb injuries. The incidence of shoulder pain is has been found to directly correlate to the level of competition that the water polo competes in and the years they have spent playing the sport (4), however the relationship between these factors was not assessed in this study.

4. Strength:

It was also shown that the strength of the external rotators was also stronger than the internal rotators in the participants. The shooting of the water polo ball is achieved by generating forceful abduction and external rotation of the glenohumeral joint into the cocking phase before releasing the ball in a shot or pass (4). Looking at the ability of the participants to generate better power when throwing the water polo ball depends on their ability to attain better ranges in shoulder external rotation.

5. Position:

It was shown that the wings have a greater throwing velocity compared to the other positions due to their wide variety while playing against opposition (5). The variety of positions that are played by the players puts their different limbs under different pressures that can affect their flexibility and strength. Ferragut (5) has shown that water polo is a physically demanding sport and it is evident that players require well-developed capabilities to cope with the intense nature of the discipline. It was shown by Ramappa et al (22) that successful pitchers, joint laxity and flexibility are beneficial because they enable greater degrees of arm abduction and rotation, which translates into greater forces and ball speed. Dwelly et al (21) believed that the gain in external rotation was secondary to the demands of throwing. This gain in external rotation by the participants could be due to the large amount of time they spend playing water polo in a week. These changes are due to the high demands placed on the shoulder during passing and shooting the ball. During the throwing motion the external rotators rarely fire concentrically at high speeds (19). The external rotators do fire at high speeds during the follow through phase of the throwing motion after the ball has been released in an attempt to slow down the internal rotators of the rotation arm (19). This shows the external rotators have to work at high intensities to control the shoulder during the follow through of the shoulder. Manske et al (19) have shown that the external rotators during throwing do not work in an explosive manner in overhead athletes, but work more functionally. It has even been speculated that there might be a strength carry over between eccentric to concentric strength in high velocity functional activities of the shoulder (19). The

greater strength in the external rotators of the shoulder seen in the participants compared to the internal rotators shows how through training the participant's shoulders have adapted to work better functionally. The results showed that the mean strength of the right external rotators (70.3%) was greater compared to the internal rotators (44.6%), and the mean strength of the left external rotators (66.6%) was greater when compared to the internal rotators (46.2%). Repetitive throwing at high velocities over times lead to chronic adaptations to soft and osseous tissues in the shoulder (21).

6. Correlation between strength and flexibility:

The participants had their flexibility and strength measured to attain the different values for shoulder internal and external rotation. This was done to see if there is a correlation between flexibility and strength in the water polo player's shoulder. It was shown that there was a very low correlation between the mean external rotation flexibility and strength on both shoulders. Webster et al (1) have shown that the throwing arm requires a large range of external rotation and abduction to allow the greatest possible force to throw the ball when shooting. In the results it has shown that there is a low correlation between the flexibility and strength of the external rotators of the shoulder, but past research has shown that the importance of good external rotation strength aids in generating the strength necessary in throwing and shooting the water polo ball. The results have shown that the correlation for the external rotators flexibility and strength is low, but the flexibility gained during the high intensity training in water polo is an adaptation. This adaptation allows the water polo player to generate better force during passing and shooting of the water polo ball. This adaptation is needed as water polo is one of the only overhead throwing sports that have water (unstable surface) as their base of support. Webster et al (1) have shown that due to water polo players having no base of support they have increased forces in the shoulder when throwing.

It has been shown that the intense repetitive overhead activity in water polo is a predisposing factor to shoulder pain (1). The movement of the shoulder during the game of water polo has to be able to move in a variety of ways at high

intensities to achieve the goals of water polo. The range of motion of the shoulder plays an important role in allowing the water polo player to generate the power that is needed in throwing the ball. Fu et al (9) shows that the shoulder is unique in the way it must be strengthened to withstand large mechanical stresses while maintaining a large range of motion. The large range of motion that occurs to the water polo players throwing arm is an adaptation that occurs to allow them to generate better force when passing and shooting the ball. Webster et al (1) found that due to the kinematics of throwing during water polo the players have altered kinematics. This altered kinematics can see in water polo players having to alter their throwing position due to their base of support being water.

Many young athletes have been seen to have sports related injuries due to their overhead sports that they are involved. This can be seen in young pitchers that sustain different vectors of shoulder forces compared with their adult counter parts (22). Due to the young age of the overhead athletes in water polo many of them can sustain microtrauma. Ramappa et al (22) have shown that childhood microtrauma in overhead pitchers is directly proportional to the number of pitches thrown in a season. There are many similarities between the baseball pitch and water polo throw, with the only difference being that water polo does not have a solid base of support. When looking at the results of the current study it was shown that 76% of the participants trained more than 5 times a week. With each training session lasting between 1 hour and 2 hours, the participants are training between 5 to 10 hours a week. Combined with the games played by the participants on the weekend the participants can play between 5 ½ to 11 ½ hours a week of water polo.

The overhead throwing is also seen to be an area where the shoulder is put under large pressures to attain the goal during the game. This was seen in many of the participants presenting with injuries and 7 of those injuries attained during water polo. Of the 7 injuries attained during water polo 6 were shoulder injuries and 1 was an elbow injury. It has also been seen during the throwing motion that the elbow flexion is at peak valgus stress that can cause lesser

shoulder distraction (24). This shows how during overhead throwing sports the shoulder is not the only joint that is under pressure during the throwing motion. In the results it was shown that in the total number of injuries 28% were shoulder injuries and 24% were arm injuries. This showed that 52% of the injuries of the participants were upper limb injuries showing the amount of pressure and force that is going through the upper limb during the game of water polo. It has also been shown that the incidence of shoulder pain is directly related to the level of completion of the participant (6).

The relation to shoulder range of motion and injury has been seen to be an area of importance during overhead throwing sports. Dwelly et al (21) has shown that reduction in internal rotation in overhead throwing athletes must be an area to monitor to identify any risk in the participants. The testing done on the participants have shown that the majority of the shoulder internal rotation was reduced beyond the gain of the external rotator. This reduction in internal rotation could be an adaptation to the training of the water polo players over the years until the level that they have achieved at present. Through the adaptations that the water polo players have achieved allows them to move and throw the ball at the speeds and distances that are seen in the water polo game. When the shoulders take most of the pressure during the water polo throw the players need to adapt to maintain these large ranges of motion at high intensities.

Research done on shoulder flexibility has shown that there was no relationship between shoulder flexibility and pain even when there are imbalances in flexibility during shoulder movements of throwing (1). There was also some research that shows that elite water polo players do have a greater strength of the shoulder muscles. This greater strength allows the elite water polo players to have a slight imbalance in the internal and external rotator cuff muscles (1). Also the technique of the elite water polo player during throwing will be greater than the new or non-skilled water polo player. Also the strength of the internal and external rotators with correct technique increases the velocity of the throw (23). The testing showed how the strength of the external rotators plays an important role in the throwing of the water polo ball. This showed how the adaptations

from the training have allowed the participants to play at high intensities. This adaptation can be seen in an increase in flexibility and strength of the external rotators of the throwing arm. So as to confirm with past research the adaptations the participants will gain are to assist in increasing their performance during the throwing motion. Showing the importance of correct strength, flexibility and technique when throwing the water polo ball. With correct adaptations the water polo player will be able to participate in the game with very few injuries and at maximum intensities. The adaptations seen during water polo have benefits that aid during the game of water polo. There is an increase in external rotation flexibility and strength, but these adaptations are not known to be benefits or reasons for injuries sustained during the game. The tests performed showed the gains in flexibility or strength and not the reasons for why they occurred. This is the reason why the study was not able to show if the injuries occurred due to the adaptations from water polo or the player's inability to adapt to the intensities of water polo.

7. Limitations:

The limitations that occurred during the study were the limited number of participants that could be tested. Due to the time and schedule of the high school water polo boys during their daily activities, there were certain boys that were not able to attend the testing. The isokinetic testing is the most accurate form of testing strength of the shoulder in internal and external rotation, but the testing is not done in a functional position as seen when the water polo player throws the ball. The strength of the shoulder internal and external rotators is only a small part of the strength generated by the entire body during the throwing motion. In future studies it could be recommended to test the players at the beginning of the season, middle of the season and end of the season to see the increase in strength and flexibility through the season. It would also be recommended that the researcher could provide the players with an intervention program to allow them to correct any imbalances or injuries. Video analysis of the throwing motion will also allow for the researcher to see any deficits that may be altering the throwing motion and predisposing them to injury. The video analysis will also allow for the researcher to analysis the

movement of the shoulders in internal and external rotation during throwing. In addition this was a sample of convenience and the participants were not randomized, therefore and the results cannot be generalised to all water polo players.

8. Clinical implications:

Clinical implications are that health professionals should be aware that certain adaptations in the shoulders of water polo players do exist. The external rotators of the dominant throwing arm were found to be stronger and more flexible, indicating an imbalance between the two shoulder girdle musculature. As the relationship between these adaptations and injury was not tested in this research report, it is however not clear if these adaptations are related to injury.

9. Recommendations for future research:

Further research should address the relationship between flexibility, strength and injuries, in order to understand the causal relationship. In addition, further recommendations for the research can have researchers looking at how to help prevent and treat injuries that occur during water polo. The research may allow for research to be taken on how to better simulate the technique of throwing in overhead throwing sports. This will allow for the researcher to test strength and flexibility of the internal and external rotators as seen in overhead throwing sports.

Chapter 6 - Conclusion:

Even though shoulder pain has been seen in elite and sub-elite water polo players, there are a variety of factors that could cause it such as increased mobility, muscle strength imbalance and altered throwing technique (1). Even though cause-effect was not tested in this research report, other research has shown there might be a relationship between throwing technique and shoulder strength and flexibility. The water polo players in this study showed an increase in external rotation flexibility and strength when compared to internal rotation

flexibility and strength. That shows the importance of the external rotators when throwing the water polo ball. This can be seen by research that was done by Manske et al (19) that speculated that there is a carryover of the eccentric to concentric strength during functional movements that are at high velocities. These movements are seen when the water polo player is generating the strength through the cocking phase of the throwing motion right through the whole motion till the ball is released. This shows the importance of the shoulders flexibility and strength to generate the velocity needed to throw the ball efficiently.

The research was done to look at the flexibility, strength and injury profiles of high school water polo players to identify areas of the throwing/passing motion to see adaptations to the game. What was identified in the research was that there are certain adaptations that the players will attain due to the game of water polo. These adaptations can cause the water player to generate greater velocities when throwing the ball and also can lead to injuries due to instability caused by the increased range of motion. The study has shown that there is a need for more research into adaptations caused by the game of water polo and what would be the most efficient relationship between shoulder flexibility and strength.

Chapter 7 - References:

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