Risk factors associated with non-specific shoulder pain in male adolescent water polo players

by

PAULA LAUREN TULLY

TLLPAU001

SUBMITTED TO THE UNIVERSITY OF CAPE TOWN

In partial fulfilment of the requirements for the degree

MSc Exercise and Sports Physiotherapy

Faculty of Health Sciences

UNIVERSITY OF CAPE TOWN

21 October 2022

Supervisors: Associate Professor Janine Gray

Professor Steven Roche

Division of Physiotherapy

Department of Health & Rehabilitation Science

Acknowledgements

I would like to express my sincerest gratitude to the following people for their invaluable support, expertise and assistance, without whom the completion of this study would have been inconceivable:

1. Assoc Prof Janine Gray, my supervisor, for her vast knowledge, unwavering support and patience, and for giving me the greatest pep talks when I needed them.
2. Prof Steven Roche, my co-supervisor, for his expertise and vital input.
3. Prof Mike Lambert, for his assistance with statistical analysis and continuous support.
4. The University of Cape Town's Division of Exercise Science and Sports Medicine (ESSM) for the use of their equipment for my data collection.
5. All the participants who took part in this study with such enthusiasm, and their coaches whose willingness to help and organisation made it all possible.
6. Team Tully, my supportive and loving family, who helped in more ways than they realise. Special thanks to my Mum for her assistance with data collection that ensured we got it all done in time.
7. Amy Mathew and Philippa Brebner, my extraordinary friends, whose support and advice I relied on too many times to count.

Plagiarism Declaration

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

I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

Signature: Signed by candidate

Date: 21/10/2022

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AC	Acromioclavicular
AHD	Acromiohumeral distance
BMI	Body mass index
CI	Confidence interval
cm	Centimetre
CKCUEST	Closed kinetic chain upper extremity stability test
ER	External rotation
ERG	External rotation gain
FINA	Federation Internationale de Natation
GH	Glenohumeral
GIRD	Glenohumeral internal rotation deficit
HHD	Hand-held dynamometer
ICC	Intraclass correlation
IR	Internal rotation
IR:ER	Internal rotation: external rotation ratio
Kg	Kilogram
KJOC	Kerlan-Jobe Orthopaedic Clinic
LT	Lower trapezius
NPRS	Numeric pain rating scale
PBW	Percentage body weight
PM	Pectoralis minor
PML	Pectoralis minor length
PMI	Pectoralis minor index
PHV	Peak height velocity
PST	Posterior shoulder tightness
RC	Rotator cuff

ROM	Range of motion
SA	Serratus anterior
SD	Standard deviation
SLAP	Superior labrum anterior to posterior
TROM	Total range of motion
UCT	University of Cape Town
UT	Upper trapezius

Glossary of Terms

Adolescent	Any person between 10 – 19 years of age [1, 2]
Dominance	The preference for using one hand or foot over the other for functional tasks [3]
External rotation gain	An increase in the dominant shoulder external rotation range of motion compared to the non-dominant side due to a functional adaptation [4]
Extrinsic risk factor	External/environmental characteristics that affect an athlete while they participate in sport [5-7]
Flexibility	The quality of a muscle to bend or lengthen without breaking, allowing for increased range of motion at a joint [8]
Glenohumeral internal rotation deficit	The loss of internal rotation range (in degrees) in the dominant compared to the non-dominant shoulder [4, 9]
Injury	A physical complaint sustained during training or match play the requires medical attention, activity modification, or loss of training or competition time [5-7, 10, 11]
Intrinsic risk factor	Internal biological, physical or psychological characteristics that affect an athlete while they participate in sport [5, 12-14]
Maturation	The process of physical development during childhood [15]
Modifiable risk factor	Any variables that influence the potential for pain or injury, that can be altered [5-7, 11]
Non-modifiable risk factor	Any variables that influence the potential for pain or injury, that are unable to be altered [5-7, 11]
Overload	Training volumes that exceed normal volumes [5, 16, 17]

Preseason	The training period before the start of the season of sport [5, 16, 17]
Peak height velocity	The point of maximum growth during the adolescent growth spurt [15, 18, 19]
Risk factor	Any variable that influences the potential for pain or injury [5-7, 11]
Rotator cuff	The four shoulder muscles that provide stability to the shoulder joint, and produce glenohumeral elevation and rotation of the shoulder [20]
Scapular dyskinesis	Abnormal control, positioning and movement of the scapula during shoulder movement [21-24]
Strength	The ability of a muscle to withstand load [25]

Thesis Abstract

Water polo is a fast-growing aquatic sport that combines swimming, overhead throwing, defending and grappling. There are great demands placed on the shoulder to complete these activities and shoulder pain is the most common musculoskeletal complaint among water polo players. The aetiology of shoulder injury amongst water polo players is not well understood and there is limited research investigating the adolescent water polo population. The aim of this thesis was to identify the incidence of shoulder pain over a 12-week period and determine the contribution of intrinsic and extrinsic risk factors in the development of non-specific shoulder pain in male adolescent water polo players.

An overview of the literature (Chapter 2) includes the biomechanics of throwing and swimming; the epidemiology of shoulder injury in water polo players; and the current understanding of risk factors for shoulder injuries and the screening thereof. Risk factors for shoulder injury in swimming have been identified as weakness of the glenohumeral (GH) internal rotator muscles, altered GH range of motion (ROM), GH joint laxity, high training loads, pectoralis minor tightness and altered scapular control. In other overhead throwing sports the risk factors include altered GH ROM and glenohumeral internal rotation deficit (GIRD), shoulder muscles weakness, altered scapular control, pitching velocity, age, height, early sport specialisation, throwing with arm fatigue and a heavy workload. A few studies have proposed potential risk factors for shoulder injury in water polo players but significant associations have not been found and little is known about the musculoskeletal risk factors. However, water polo players are susceptible to shoulder pain due to repetitive overheard throwing at high velocities, the repetitive swimming stroke as well as the unique upright swimming style.

Chapter 3 presents the research findings. This study recruited male adolescent water polo players between the ages of 14-18 who were not currently experiencing shoulder pain. Participants underwent a pre-season screening session followed by a period of in-season monitoring for 12 weeks. The pre-season screening included a demographic questionnaire, the Kerlan-Jobe Orthopaedic Clinic (KJOC) Shoulder and Elbow Score, anthropometry and maturation testing as well as shoulder specific tests to assess for shoulder pain, shoulder range of movement, shoulder strength, shoulder flexibility and shoulder stability. The experience of shoulder pain and participant training load was then monitored using a self-report questionnaire. Participants were categorised into two groups (shoulder pain and no shoulder pain) based on their report of pain, irrespective of a medical diagnosis.

The shoulder musculoskeletal profile of the water polo players, the incidence of shoulder pain and the player's training loads are presented (Chapter 3). Shoulder pain was reported by 52% of the participants at least once during the 12-week monitoring period, with pain in both the shoulders simultaneously (56%) or the dominant shoulder only (42%) commonly reported. The onset of activity was reported most commonly as swimming (55%) followed by throwing (38%). Participants with shoulder pain had mean KJOC scores lower than 90, and were significantly older (p = 0.003), heavier (p = 0.050) and the predicted years from peak height velocity (PHV) was greater (p = 0.029) than those without shoulder pain. An interaction was found between pain/no pain and dominant/non-dominant side for isometric internal rotation (IR) strength (p = 0.049), with stronger IR muscles in the dominant shoulder of the group with shoulder pain. Significant shoulder asymmetries were identified, however there was no association between the variables and the development of shoulder pain. In general, the participants presented with greater external rotation (ER) ROM and total range of motion (TROM) in the dominant shoulder, greater isometric strength of the IR muscles, serratus anterior (SA), upper trapezius (UT) and lower trapezius (LT) muscles, as well as reduced pectoralis minor length (PML) and a lower pectoralis minor index (PMI) on the dominant side. There was a significant difference between pain/no pain and the hours of water polo matches in weeks 3-4, with a higher work load in the shoulder pain group compared to the no shoulder pain group (p = 0.008). Participants with shoulder pain reported significantly lower self-perceived strength scores for passing, shooting, swimming, defending and gym training compared to those without shoulder pain.

In conclusion (Chapter 4), there is a high incidence of shoulder pain among male adolescent water polo players, which is in line with the findings from other studies. The players who developed shoulder pain were significantly older, heavier and had a higher predicated age from PHV than those without shoulder pain. This may suggest a trend towards cumulative overloading and it's likely that the key players of water polo teams may be at greater risk of developing shoulder pain. Greater IR strength was observed in the dominant shoulder of those players with shoulder pain, indicating that the more powerful throwers are developing shoulder pain. The relative weakness of the ER muscles suggests that players are unable to effectively control through deceleration of the throwing motion. This cohort presented with significant asymmetries in GH ROM, rotator and scapular muscle strength, and shoulder flexibility; however, these variables were not associated with shoulder pain. Asymmetries have been associated with pain in previous studies, so these variables should not be ruled out as risk factors for injury. Participants of this study reported the activity most commonly associated with shoulder pain was swimming, not throwing, and bilateral shoulder pain was commonly reported. This would suggest that the musculoskeletal profile of the non-dominant side is indeed important and that the implications of significant asymmetries should be evaluated further in a larger population. KJOC scores seem to be in line with those for baseball players and a score below 90 may indicate an at-risk athlete. An increase in competitive match play was associated with an increase in shoulder pain. This should inform coaches to structure training and recovery appropriately during tournaments or weeks with a high load of matches.

This study provides a basis for further investigation into shoulder injuries among adolescent water polo players, as well as the prevention and management thereof. It is advised that coaches and medical staff endeavour to identify at-risk players. Rehabilitation programs should be implemented to target the modifiable risk factors identified in this study, in order to reduce the incidence and prevalence of shoulder pain.

Chapter 1: Introduction and Scope

1.1 Introduction

Water polo is a well-established aquatic team sport that is growing rapidly in population and participation around the world. [26] It is played in many different age categories, by both males and females, and is considered to be a very physically and psychologically challenging sport. [26-28]

It is a high-intensity contact sport that requires players to tread water, swim in short and fast bursts, throw overhead, shoot at goal, and defend. [28-31] It is a non-weightbearing sport and therefore has less contribution from the lower limbs in throwing activities than field-based sports. [32-34] As a result, there are greater demands placed upon the upper limbs for force distribution [28, 34, 35] and a higher incidence of upper limb injuries is observed. [32, 36, 37] Water polo has the highest prevalence of injury than any other aquatic sport and shoulder pain is the most common musculoskeletal complaint. [36-40] The biomechanical requirements of the sport place a large demand on the players' upper limbs, particularly the shoulder and it is proposed this contributes to the high prevalence of shoulder injuries among water polo players, particularly the adolescent population. [27, 28, 38, 41, 42]

It has been proposed that identifying a high incidence of injury in an athletic population is the crucial first step before risk factors can be explored and injury prevention programs can be implemented. [13] Recent studies have identified a high incidence of shoulder injuries among South African male adolescent water polo players [41-43] and this warrants further investigation. Furthermore, it is unclear if the risk factors associated with shoulder pain in other overhead sports and swimming are the same as the risk factors for shoulder pain in water polo. [27, 28, 44] Therefore, further research is necessary to identify specific risk factors associated with shoulder pain in this population. Accordingly, the aims and objectives were designed to give insight into this topic. A prospective, quantitative study was used to assess the incidence of shoulder pain and explore the risk factors for shoulder pain among male adolescent water polo players.

1.2 Aims and Objectives

1.2.1 Aim of the study

The aim of this study is to determine the association of intrinsic and extrinsic risk factors in the development of non-specific shoulder pain in male adolescent water polo players.

1.2.2 Specific objectives

- To determine the incidence of shoulder pain in male adolescent water polo players over a 12-week season
- To describe the population of male adolescent water polo players with respect to intrinsic shoulder variables
- To determine the relationship between intrinsic/extrinsic shoulder variables and shoulder pain over a 12-week period
- To assess the training load of male adolescent water polo players and the relationship to shoulder pain over a 12-week period

1.3 Significance of this Study

The purpose of this study is to gain insight into the risk factors that predispose water polo players to shoulder pain. This study will provide further understanding of the overall shoulder health of male adolescent water polo players, current training loads and the incidence of shoulder injury in this population over a season. It is hoped that the results of this study may inform future training practices and conditioning programs in order to minimise injuries.

1.4 Plan of Development

In preparation for this dissertation, a broad review of the literature is presented in Chapter 2. It includes an overview of water polo as a sport and more specifically the biomechanics of the shoulder, a review of shoulder injuries in water polo, swimming and other overhead throwing sports, known and proposed risk factors for shoulder injuries, and current testing methods of these musculoskeletal risk factors. This is followed by a prospective study designed to investigate the intrinsic and extrinsic risk factors that contribute to shoulder injuries in male adolescent water polo players (Chapter 3). The results of this study are presented, interpreted and discussed. Limitations of the study and recommendations for future research are also detailed in Chapter 3. A thesis summary and conclusion are included in Chapter 4.

Chapter 2: Literature Review

2.1 Introduction

Water polo is an Olympic aquatic team sport that has been in existence for over 120 years. The sport is physically demanding and players need to be well-trained swimmers, proficient throwers and tacticians. [10, 29] The incidence of injury in water polo is higher than any other aquatic sport. [36] Injuries to the head/face are most common due to the nature of the contact sport. [27, 36, 44, 45] Shoulder injuries are the most common musculoskeletal complaint among water polo players, likely due to the repetitive swimming stroke, overhead throwing and defensive tackling. [27, 38, 44, 46]

The biomechanical demands of water polo places immense strain on the upper limbs and this is suggested to be an important factor in the high prevalence of shoulder pain, particularly of adolescent players. [41, 42] Adolescents are a vulnerable population and are at high risk for musculoskeletal injuries due to their immature skeletons and general joint laxity. [47]

Historically, water polo has been dominated by European teams, but water polo's popularity has grown over the last decade and it is now played in many countries around the world, including America, Australia, Canada and South Africa. [29, 44] In South Africa, water polo is played at school level, nationally and internationally. [42] Despite the popularity of the sport in South Africa, there are only a few published studies documenting the high prevalence of shoulder pain among South African adolescent water polo players, [41, 42] and there is limited evidence regarding the causation of these injuries.

Shoulder pain has been well researched in swimmers [10, 48-50] and other overhead sports, [51-55] particularly baseball. [56-60] It is unclear whether or not these findings can be extrapolated to water polo players as there is limited information on the aetiology of shoulder injuries specifically among water polo players. [43, 61] The aim of this literature review is to explore the current research on shoulder pain and injury among water polo players, supported by literature on swimming and other overhead sports.

The scientific and medical literature was searched using databases and online search engines including EBSCO, PubMed, and Google Scholar. The following keywords were used: *Water polo, swimming, throwing, overhead throwing, baseball, handball, shoulder, shoulder pain, injuries, sports injury, youth, adolescent, biomechanics, risk factors, intrinsic, extrinsic, training load, screening, musculoskeletal screening, shoulder test, shoulder assessment, maturation. Only English, full text access studies were included and priority was given to reviews and* *randomised controlled trials. Handsearching in select key journals was also done to ensure that important studies were not missed.*

2.2 Water Polo as a Sport

Water polo originated in England and Scotland in the late 1800s. [62] In 1900, men's water polo was the first aquatic team sport to participate in the Olympic Games. [29, 62] The game has evolved significantly since 'water football' was first invented with many changes to the rules. [26] Water polo teams consist of a maximum of thirteen players, comprising eleven field players and two goalkeepers. [63] Seven players are in the pool at one time, including one goalkeeper. The size of the pool is typically between 20 – 30m long for men's matches and 20-25m long for women's matches, with a width of between 10 – 20m. [45, 63] Games consist of four periods of eight minutes of play, with short intervals between each period. [63] The aim is to score goals by forcing the water polo ball into the opponent's net. [45] Players, with the exception of the goalkeeper, are only allowed one hand on the ball at any time. [45] It is an intermittent sport and players are required to perform in short bursts of intense activity followed by periods of slow swimming or treading water. [29]

2.2.1 Biomechanics of Water Polo

Water polo is physically demanding and it uniquely combines endurance and sprint swimming, overhead throwing and blocking, an egg-beater kicking style and physical contact with other players. [44] The combination of overhead throwing loads and high-frequency swimming strokes may put water polo players at an increased risk for injury in their dominant arm. [46]

2.2.1.1 Swimming

Competitive swimmers repeat their stroke continuously during training or competition, while water polo players constantly change their swimming speed, direction and style of stroke. [46, 64]

The phases of traditional front crawl are:

(1) Entry and catch
The fingers enters the water and the hand begins to pull backwards. [65] The arm is fully extended, with the shoulder fully elevated and externally rotated to achieve maximum forward reach. [48, 66] The UT and rhomboid muscles are active to elevate and retract the scapula respectively. [67] The SA protracts and upwardly rotates the scapula, and is active from the initial catch through the pull phase. [67]

(2) Pull through

The hand pulls backwards in a straight line to the hip. [67] The shoulder adducts and internally rotates to achieve a straight pull through. [66] The pectoralis major muscle activates to adduct and extend the shoulder. [67] The latissimus dorsi and subscapularis muscles activate simultaneously from the mid pull and the external rotator muscle, teres minor, activates to balance the GH IR. [67]

This phase is sometimes described in the literature as two separate phases, where the hand pulls backwards to in line with the vertical plane of the shoulder for the "pull phase" and the "push phase" is where the hand pushes back until it's released form the water. [65]

(3) Recovery

The time from when the hand is released from the water until it enters the water. [65] The deltoid and supraspinatus muscles are most active in this phase, abducting and externally rotating the shoulder. [66, 67]

Three different swimming strokes have been identified and analysed among water polo players: front crawl with head under water, front crawl with head above water, and front crawl when leading the ball. [64, 68] The three styles all have slight kinematic differences and specific player position or play objectives may necessitate the use of one style over another. [64]

When swimming front crawl leading the ball and head above water, the trunk is in a more upright position compared to the traditional crawl stroke, which reduces body roll and leads to increased shoulder abduction and internal rotation. [28, 69] Greater stroke frequency and shorter stroke length is observed in front crawl when leading the ball compared to the other two styles, while a shorter kick stroke frequency is seen in front crawl with head under water than the other two styles. [64] It has be found that water polo players are less economical during front crawl with head under water swimming when compared to competitive swimmers, [29] however water polo players can still achieve high speeds for short bursts, and are well adapted to swim with their head out of the water. [64]

Swimming is predominantly driven by the shoulder joint complex and swimmers are at risk of injury due to overuse and fatigue. [70] The highly repetitive overhead movements of water polo swimming styles with the head above the water and the trunk elevated may place great strain on the players shoulders. [64]

2.2.1.2 Throwing

Throwing has been well researched and described for other overhead sports such as baseball, [58, 59, 71, 72] cricket [55, 73] and handball. [74] On land, the throwing motion is initiated and energy is created in the legs and trunk, and then transferred via the kinetic chain to the shoulder, elbow, hand and finally to the ball. [71, 75] The six phases of an overhead throw on land are the windup, stride, cocking, arm acceleration, arm deceleration and follow-through. [59, 71] The shoulder moves rapidly from a position of abduction and maximal external rotation into maximal internal rotation, which places large forces and torques on the shoulder joint at high angular velocities. [59, 76]

There are differences in technique between overhead sports. The handball throw is characterised by large GH ER followed by rapid IR and minimal changes in flexion and abduction. [74] A scoping review reported that proximal-to-distal sequencing is not seen in handball players, as the elbow achieves its maximal velocity before the shoulder. [74] Cricketers exhibit a reduced GH ER ROM and reduced thoracolumbar flexion in comparison to baseball players, and throw with a more sidearm position. [55] The musculoskeletal profile of the cricketer's shoulder has been reported as different to the classic 'thrower's shoulder' described in baseball research, [55] thus highlighting the need to explore the unique throwing style in water polo players.

There are also differences between the demands of throwing in different overhead sports, for example the time pressure for cricketers to throw quickly from the boundary to the wicket in comparison to baseball pitchers who are not under time constraints. [73] In water polo there are time constraints to pass and shoot due to defensive pressure from the opposition.

Water polo is the only overhead throwing sport in which players consistently throw from an unstable base of support. [45] The windup and stride phases of throwing are minimised in the water. [28] As players cannot make use of hip and trunk rotation off a fixed point, they utilise an egg-beater style kicking action to lift their torso high out of the water, and a greater proportion of energy is required from the shoulder stabilisers. [44, 45] Water polo is also unique in that players will frequently throw, shoot or catch the ball with their non-dominant arm, depending on their body positioning at the time. [44] As a result of bony and soft tissue adaptations, water polo players show a gain in shoulder ER ROM which may be an advantage in generating high throwing velocities. [77, 78]

Overhead throwing can also be separated into passing (lower velocity) and shooting (high velocity, high accuracy needed) and these are two separate skills that can be trained. [44] The different types of throws in water polo are described below.

2.2.1.2.1 Overhead Shot

The overhead throw/shot is most commonly used in water polo. [79, 80] It has the greatest velocity and highest accuracy of all water polo shots, which may be attributed to the kinetic link principle. [81] The ball is lifted out of the water into the top of the backswing with the ball above and behind the player's head, elbow and hand high, chest out of the water, and hips and torso rotated back. [80-82] The shoulder goes into horizontal abduction in the cocking phase, before accelerating into shoulder IR, forward swing where the ball is moves along proximal-to-distal chain to increase speed, release and follow through. [80, 81, 83] The non-throwing arm sculls underwater to provide stability, keep the torso upright and turn the body left or right. [82, 84] The torque rotation of the shoulder muscles has been identified as an important parameter for the performance of the overhead shot. [85]

2.2.1.2.2 Penalty Shot

Players will use the overhead shot as previously described, or the sweep technique, in which the ball is swept horizontally across the water surface using primarily horizontal adduction. [86] Studies of international water polo matches found a high penalty shot success rate of 80.1% [87] and 77% [88] respectively. Penalties only affected the outcome in 20% of games analysed, thus the impact of the penalty shot is modest. [87, 88]

2.2.1.2.3 Push Shot

Accuracy of the push shot is 50%. [89] The ball is picked up in the front crawl position, pulled backwards towards the body and then pushed forwards to release the ball. [81] The push shot requires a high amplitude of anterior deltoid muscle activation. [81] The middle deltoid and triceps brachii muscles have a longer duration of activation during the push shot compared to the overhead shot. [81]

2.2.1.2.4 Backhand Shot

The starting position is with the ball in front of the body, hand on top of the ball. [81] The cocking phase begins with IR of the shoulder and a lateral side bend of the trunk away from the ball; the ball is lifted sideways as the shoulder abducts. [81] Forceful horizontal abduction is used to accelerate through the shot. The wrist flexors have a high amplitude of activation compared to other shots. [81] Backhand shots only have 27.2% accuracy. [89]

In summary, the biomechanics of swimming and throwing in water polo differ to that of swimmers and overhead throwers in traditional land-based sports.

2.3 **Injuries in Water Polo**

In the literature, injury is most commonly defined as any musculoskeletal complaint or concussion that occurs in competition or training and requires medical attention, regardless of consequences or time-loss. [36, 39, 90] Injuries occur either due to a traumatic event, such as player contact or getting hit by the ball, or may occur due to repetitive overuse. [90]

A study of the 2009 Federation Internationale de Natation (FINA) World Championships found water polo to have the highest incidence of injury among all aquatic sports. [36] Of the total number of injuries in the tournament, 37% were reported by water polo players and of that 19% affected the head/neck region and 12,5% affected the shoulder. [36] A more recent study analysing over 8000 water polo matches from the 2004-2016 Olympic Games and 2009 – 2017 FINA World Championships found an average incidence of 14.1 injuries per 100 players (95% CI ± 1.42), and an average incidence of match injuries was 56.2 injuries per 1000 match hours (95% CI ± 6.74) with no significant differences between men or women. [90]

Shoulder pain is widely reported to be the most common musculoskeletal complaint among water polo players. [27, 36-40, 44] A systematic review found a high incidence of shoulder pain among water polo players, ranging between 24% – 80%, [38] while other studies reported incidence of shoulder pain of 11.3% [90] and 11.5%. [91] A study of male adolescent water polo players in Kwa-Zulu Natal, South Africa, found a high prevalence of shoulder (51.04%), knee (23.95%) and vertebral musculoskeletal pain (17.71%). [42] Another study of male water polo players in Johannesburg, South Africa, found shoulder injuries to be the predominating injury, with a 25% incidence of previous injury and 8.3% incidence of recent injury. [41]

The following subsections will discuss the specific shoulder injuries that arise in water polo, as well as specific considerations in the adolescent population.

2.3.1 Types of Shoulder Injuries in Water Polo

Overuse injuries of the shoulder in water polo include swimmer's shoulder, rotator cuff (RC) pathologies and superior labrum anterior to posterior (SLAP) lesions. [27, 92] Swimmer's shoulder is a syndrome characterised by shoulder pain, GH joint instability and impingement. [70] The forceful and repetitive nature of swimming and overhead throwing in water polo can cause microtrauma in the RC muscles. [38] This may lead to RC impingement, tendinopathy or RC muscle tears. [92] Supraspinatus tendinopathy is a common RC pathology found in swimmers and overhead throwers. [38, 70] Partial or full thickness supraspinatus tears due to overuse can cause narrowing of the subacromial space and lead to subacromial impingement. [93] SLAP lesions are found in overhead throwing athletes and water polo players as the superior labrum is placed under high distractive forces during the cocking and acceleration phase of throwing when the shoulder is abducted and externally rotated. [92] This may lead to impingement of the labrum between the head of the humerus and the glenoid rim. [92] GIRD is common in the dominant arm of water polo players due to the large distractive forces on the shoulder during the follow-through phase of overhead throwing. [92]

Water polo players are also at risk for traumatic shoulder injuries caused by contact with another player while throwing the ball, or while blocking the ball. [27] These include subluxations and dislocations of the acromioclavicular (AC) joint and GH joint. [27, 44]

2.3.2 Shoulder Injuries Among Adolescents

The number of adolescents participating in organised sports is increasing all over the world and injury surveillance of these athletes is important. [94] While organised sports have many benefits for child and adolescent health, there has been an increase in both acute and overuse injuries over the past 20-30 years. [95] Adolescents are at high risk for musculoskeletal injuries due to their immature skeleton, decreased muscular development, general joint laxity, and rapid periods of growth during puberty. [47] Overuse injuries often occur when there is a rapid increase in training load, for example during training camps, and in athletes training at consistently high levels. [95]

There is large variability in height, weight, strength, speed and endurance in adolescents of the same chronological age, and these differences are accentuated during the adolescent growth spurt. [15] For this reason it has been proposed that matching adolescent sports groups using biological age instead of chronological age could help to equalise competition, enhance adolescents chance of success and potentially reduce the incidence of injury. [15]

It has been observed that the incidence of RC tears is lower in the general adolescent population than in adults, due to the degenerative changes that predispose RC pathology. [47, 96] Less than 1% of RC tears occur in individuals younger than 20 years of age. [96] The incidence of RC tendinopathy is also generally lower in adolescents than adults, as the apophysis (site of tendon attachment to the bone) is weaker than the tendon itself. [95] However, RC tendinopathies are commonly observed in adolescent overhead throwers and swimmers. [95] Apophysitis resulting from chronic traction of the tendon insertion can results in microavulsions. [95]

A study of adolescent water polo players found a presence of GIRD in 14 – 62% (depending on the definition of GIRD) and this high prevalence is similar to other adolescent and elite adult overhead throwing athletes. [97] Posterior capsule thickening has been observed in the dominant arm of adolescent overhead throwers. [98]

Research into shoulder injuries among adolescent water polo players is limited, however the high incidence of injury warrants further investigation into the underlying mechanisms. Additional research into this at-risk population will help develop protocols to reduce injuries.

2.4 **Risk Factors for Shoulder Pain**

There is limited knowledge of the exact contributing factors for shoulder pain among water polo players, however the causation appears to be multifactorial. [38, 44, 99] Understanding the mechanism of injury and identifying risk factors is considered a prerequisite for injury prevention strategies. [12, 100, 101] A model for injury prevention outlines the importance of considering the internal and external risk factors, as well as the dynamic interaction of those risk factors in repeated cycles of participation. [12] Due to the complex interaction of factors, it is suggested that we move towards recognising risk patterns. [101]

The following subsections will cover the literature on intrinsic and extrinsic risk factors for shoulder injury among water polo players.

2.4.1 Intrinsic Risk Factors

Every athlete has their own unique set of internal characteristics that may predispose them to injury. [12, 13] This section will highlight the known and potential intrinsic risk factors for shoulder pain in water polo, as well as in swimming and other overhead sports.

2.4.1.1 Previous History of Injury

A recent cohort study of male water polo players found that a previous shoulder injury was the most predictive factor of new injury. [99] Players with a prior injury were 6.5 times (95% CI = 1.6, 26.4) more likely to develop a new injury. [99] This is also demonstrated in baseball [102] and swimming. [103] In a one-year follow-up of youth baseball players, a history of shoulder pain was the strongest risk factor for the development of subsequent shoulder pain. [102] Similarly, swimmers with a history of shoulder pain were found to be between 4.1 (95% CI = 1.3, 13.3) and 11.3 (95% CI = 2.6, 48.4) times more likely to sustain a new shoulder injury, for ‘interfering shoulder pain’ and a ‘significant shoulder injury’ (lasting more than 2 weeks) respectively. [103]

2.4.1.2 Anthropometric Characteristics

A systematic review found that age and height were risk factors for injury among adolescent baseball pitchers. [104] There is a correlation between the anthropometric variables of body mass [105], height [105], body mass index (BMI) [105] and ball-throwing speed among young and adult water polo players. [25, 105] It has not been shown whether or not this is linked to shoulder pain, however pitching velocity is a risk factor for shoulder pain among adolescents in baseball which appears to insinuate a level of connection. [104, 106]

2.4.1.3 Muscle Weakness and Imbalances

Weakness of the RC muscles can lead to excessive superior translation of the humeral head and cause a decrease in subacromial space. [93] During overhead throwing, there is great demand on the eccentric capacity of the ER muscles in the deceleration phase [54] and weakness of the ER muscles has been associated with a risk of shoulder injury in baseball [56, 57, 76], cricket [55], handball [53] and tennis. [54] In water polo studies, deficits in ER and IR strength as a percentage of body weight was found to be an indicator of shoulder injury. [107, 108] Further, RC strength deficits have been correlated with GIRD and loss of TROM in baseball. [109] It has been found that overhead throwers, including water polo players, exhibit greater strength of the internal rotator muscles compared to the external rotators [51, 107, 110, 111] and these muscle imbalances have been linked to shoulder injury and time loss from sport. The weaker external rotators are not able to effectively decelerate the arm during the overhead throw. [111] Among elite water polo players, a ratio of ER to IR muscle strength of 0.6 – 0.7:1 [107, 111] has been observed, however significant difference between injured/uninjured groups was not established. [107] This ratio is lower than the ER:IR strength ratios reported in baseball (0.83 – 0.99:1) [56, 57] and cricket (0.83:1). [55] Adolescent swimmers with an ER:IR strength ratio of below 0.68:1 had increased risk of injury during the season. [112] Among swimmers, there is some evidence of an association between IR muscle weakness and shoulder pain [10, 113, 114], however a systematic review found the evidence insufficient to conclude IR or ER is a risk factor for shoulder pain in swimmers. [6] Among female adolescent volleyball players, RC strength was not predictive of shoulder injury. [115] In adolescent water polo players, significant asymmetries have been found for isometric IR and ER strength, but there was no association with shoulder pain. [43] Further, IR:ER ratios were evaluated and players had an average of 0.79 – 0.84:1, with no significant asymmetries of associations to shoulder pain. [43]

The scapular stabilisers play an important role in providing stability to the base of the GH joint, and decreased stabilisation may lead to altered scapular position and movement. [93] Weakness of the scapular muscles has been linked to shoulder injury in swimmers. [10, 93] Weaker SA and UT force production observed in swimmers after a session may be due to fatigue. [50] Furthermore, altered scapular kinematics and SA weakness have been observed in swimmers following an intense bout of swimming. [116] A study of cricketers found consistently weaker SA in the population compared to baseball pitchers. [55] Weakness and lengthening of the LT muscle has been linked to pectoralis minor muscle shortening and a downwardly rotated scapular positioning in normal individuals. [117] Significant asymmetrical strength of the LT muscles and a non-significant difference for SA was found for LT in a study of adolescent water polo players. [43]

2.4.1.4 Glenohumeral Range of Motion

A reduction in IR ROM and TROM are risk factors associated with shoulder pain in overhead sports such a baseball [109, 118-120], cricket [55], and handball. [53, 121] A study of male water polo players found that reduced IR ROM was significantly associated with shoulder pain. [99]

GIRD is the loss of IR range (in degrees) in the dominant compared to the non-dominant throwing shoulder. [4, 9] It is understood to be an adaptive change commonly seen in overhead throwers due to the repetitive load placed on the shoulder, leading to an increased risk of pathology in the dominant shoulder. [4] A study found that baseball pitchers with a TROM deficit > 5° compared to the non-dominant shoulder were 2.5 (95% CI = 1.1, 5.3) times more likely to have shoulder injuries. [120] An IR deficiency of > 20° to 25° compared to the non-dominant shoulder is considered to be clinically important, [122] however, reduced IR ROM of > 13° was found to be a risk factor for shoulder injury among adolescent baseball pitchers. [119] Reduced IR ROM may negatively impact the deceleration phase of overhead throwing, thereby placing the RC muscles under more mechanical stress, [99] potentially leading to pathologies of the posterior-superior GHJ. [46, 99] It is also suggested that the loss of IR ROM also reduces the efficiency of the pull-through phase of swimming. [99]

A common biomechanical adaptation seen in overhead throwers is humeral retroversion, where the humeral head is orientated in a more posteromedial direction. [123, 124] The overhead throwing motion creates stress on the GH joint and can alter the bony or soft tissue anatomy, causing a shift towards ER and thus an increase in ER ROM, or ER gain (ERG), and decrease in IR ROM (with no change to TROM). [98, 123, 125] It is proposed that this is a protective adaptation to prevent soft tissue injury, however there is also evidence suggesting shoulder or elbow injury may result from either excessive humeral torsion. [123] Humeral retroversion is seen commonly in baseball pitchers. [98, 126-128] The loss of IR ROM and gain of ER ROM is also seen in male and female sub-elite water polo players. [107] Interestingly, cricketers demonstrate a loss in IR but not the compensatory gain in ER ROM. [55] There is variation in the shoulders of athletes from different overhead sports and it is therefore necessary to study the throwing shoulders of water polo players before extrapolating the findings of other overhead sports to water polo players.

2.4.1.5 Posterior Shoulder Tightness

Posterior shoulder tightness (PST) is another factor that is associated with shoulder injury [8, 9, 129] and is common in the dominant arm of baseball pitchers, [8, 9, 129, 130] cricketers, [55] tennis players. [131] Furthermore, it is associated with GIRD and scapular changes in baseball. [130] A recent study of adolescent water polo players did not find any significant associations between PST and shoulder pain. [43] However, it is proposed that the forces on the shoulder during overhead throwing cause a contracture of the posteroinferior shoulder capsule which leads to a posterosuperior shift of the humeral head and a reduction in IR ROM. [92, 93] The exact structures contributing to PST have not been identified, [131] possibly due to the difficulty in isolating the posterior capsule from the RC muscles and deltoid muscle when testing. [93]

2.4.1.6 Upward Scapular Rotation

Throwing requires a complex and coordinated movement pattern that includes upward rotation and posterior tilt of the scapula. [21, 122] Furthermore, adequate positioning and movement of the scapula in necessary to create a stable base for maintaining humeral head position and force production during shoulder activity. [122, 132] Altered scapular kinematics are associated with shoulder impingement, RC tears, GH instability and shoulder stiffness. [22]

It has been found that overhead throwers have increased upward rotation of the scapula in their dominant arm, which suggest that this is an adaptation to enhance subacromial clearance during throwing. [21] Among baseball players a loss of upward scapular rotation (USR) is associated with an increased risk of shoulder injury, in particular subacromial impingement [21, 93] and a positive relationship between posterior capsule thickness and USR has been identified. [130] In a study of elite water polo players, injured players demonstrated altered scapular kinematics when they were fatigued after an intense training session [133]. This has also been observed in swimmers. [50, 134] Further, scapular dyskinesis has been observed in the dominant shoulder of handball players. [53] Downwardly rotated scapulae have been observed in cricketers [55, 135] and may predispose elite young players to shoulder pain due to increased load on the RC muscles during throwing. [135] An unpublished study of adolescent water polo players identified a significant association between increased USR at 90° abduction of the dominant shoulder and the development of shoulder pain. [43] Furthermore, weakness of the SA and LT muscles on the dominant side was identified and linked to altered scapular kinematics of those players with shoulder pain. [43]

2.4.1.7 Pectoralis Minor Length

Optimal scapular function in healthy individuals requires the pectoralis minor muscle to lengthen as the arm elevates. [136, 137] Shortened pectoralis minor length has been associated altered scapular kinematics, reduced scapular posterior tilt and increased GH internal rotation with shoulder elevation. [23, 117, 136] This may potentially reduce the subacromial space and lead to impingement of the RC. [10] A study of competitive female swimmers found reduced pectoralis minor muscle length to be associated with shoulder pain in 15-year-olds, but not in other age categories. [10] A systematic review stated that the evidence of pectoralis minor length as a risk factor for shoulder pain among swimmers is inconsistent. [6] In elite male sportsmen, longer pectoralis minor muscle length has a moderate relationship with greater acromiohumeral distance (AHD). [138] Reduced PML has been observed in the dominant shoulder of adolescent water polo players, however this was not associated with the development of shoulder pain. [43]

2.4.1.8 Acromiohumeral Distance

AHD is a measurement from the acromion to the humeral head used to quantify the subacromial space. [139, 140] There are conflicting results in the literature with regards to AHD and shoulder pain. A reduction in the subacromial space (i.e., reduced AHD) has been associated with reduced RC muscle function, superior translation of the humeral head, morphological changes to the acromion and altered posture, and can lead to RC tendinopathy and subacromial bursitis, particularly in overhead athletes. [93, 139] Reduced AHD has been found in junior elite tennis players with scapular dyskinesis, [141] while cricketers have normal AHD [55] and an increase in AHD has been seen in baseball [142] and volleyball. [140] The supraspinatus tendon runs through the subacromial space and is affected by pathological changes. [139] Thickened supraspinatus tendons have been observed among cricketers, [55] swimmers [70, 143] and volleyball players [140] and this hypertrophy may be due to the high loading demands of the overhead action.

2.4.1.9 Proprioception

Shoulder proprioception, the ability to sense joint position and movement, has been associated with a risk of injury and performance among throwers. [144-146] Furthermore, an association has been found between proprioception acuity and the level of play. [28, 147] Reduced joint position sense and limited ER ROM has been seen in female softball players. [148] Among elite male water polo players, a negative correlation has been found between proprioception and ER muscle strength at 30°. [149] It is suggested that poor proprioception could lead to delayed neuromuscular protective reflexes and failure to protect the joint from excessive movement due to ineffective RC muscle contraction and stabilisation. [149] Proprioception has also been linked to throwing performance in water polo players and poor proprioception is a proposed risk factor for shoulder injury in this population. [77] Shoulder stability was not linked to the development of shoulder pain in a study of adolescent water polo players, but players in the injured group has slightly lower pre-season scores in the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) than the uninjured group [43] and this warrants further investigation.

2.4.2 Extrinsic Risk Factors

The risk factors external to the player may include exposure to the sport and training load. Other extrinsic risk factors such as training methods, level of coaching, and psychosocial factors are beyond the scope of this review.

In a study of risk factors associated with shoulder pain and disability in competitive swimmers over a lifespan, it was found that adolescent high school swimmers were the most symptomatic group and also had the highest training load, with an average of 16 hours per week [10]. A positive correlation was found between increased swimming volume and shoulder pain, dissatisfaction and disability. [10] While water polo players swim as part of training, they also utilise a head above water style of swimming during match play [64] and practice water polo techniques of throwing and shooting. [44, 45, 81] Little is known about the combined workload of swimming and water polo training and the risk of shoulder pain. The monitoring and prescription of adolescent water polo training load is therefore an important factor to consider in order to prevent overuse shoulder injuries and dissatisfaction.

A study of male adolescent water polo players collected data using a validated questionnaire, and reported that all training sessions were 120 minutes, players averaged 5.05 (± 2.46) sessions per week and 88% of the participants attributed their musculoskeletal pain to over training. [42] Another study of male adolescent water polo players reported that 58% of participants participate in more than 10 hours of water polo specific training per week. [41] This is higher than Croatian male adolescent water polo players that reported total training of 10 – 15 hours per week, with water polo-specific training comprising 30 – 50%. [150] It is clear there is great variability in the weekly training loads of adolescent water polo players and optimal training loads have not been determined.

Among baseball pitchers, an increased number of pitches per game has been associated with an increased risk for shoulder pain. [106, 151] Pitching with arm fatigue is also a risk for shoulder injury. [106] There is limited literature on the effects of throwing or shooting load in water polo. A study monitoring elite female water polo players during squad selection and game-based training camps found a significant interaction between shooting at goal and shoulder soreness. [152] A greater number of shots during a training session (p = 0.005) and less rest time in between shots at goal (p = 0.032) was associated with increased shoulder soreness. [152] These findings underscore the importance of monitoring shooting loads; however, more research is needed in this area.

While training load does seem to play a role in the development of shoulder pain in water polo players, further studies monitoring training and match load throughout a season must be conducted to provide more empirical data in this area.

2.5 **Screening for Risk Factors**

The purpose of musculoskeletal screening within a specific population is to detect physical changes or deficits in individuals without signs or symptoms of a disorder, with the aim to identify intrinsic risk factors and pathological conditions early on or even prevent the injury itself. [153, 154] This may lead to earlier intervention and treatment which may prevent or reduce the severity of musculoskeletal injury. While screening for risk factors has been debated in the literature, [100, 153] the benefit of screening an at-risk population can highlight areas for concern within individuals and populations and allow for appropriate intervention to minimise the risk of injury. [13] Screening tools need a strong relationship between the marker and injury risk, and the tests properties need to be examined in specific and relevant populations, using appropriate statistical tools. The properties of a number of relevant screening tests for overhead athletes were investigated for reliability and validity.

2.5.1 Shoulder Specific Screening Tests

2.5.1.1 Upper Limb Function and Performance

There are many questionnaires used to assess patient upper limb function. The Oxford Shoulder Score is a shoulder-specific questionnaire used to assess pain perception and quality of life. [155] While it is valid and reliable, it is mainly used in an orthopaedic setting and does not have any questions relating to sports performance. The Simple Shoulder Test is a self-assessment tool with 12 questions that assess general shoulder function. [156] It is quick to administer but there are not questions relating to sports performance. The Constant-Murley Score is a shoulder-specific, clinician-based assessment tool. [157] The assessment of shoulder pain or injury on function is limited, and the emphasis is placed on assessing shoulder ROM and muscle strength. The Disabilitites of the Arm, Shoulder and Hand (DASH) is a self-administered questionnaire with answers given on a 5-point Likert scale. [158] There is an optional module with an extra 4 questions relating to sports function. This questionnaire is comprehensive, but is best suited for patients with multiple upper limb joint problems.

The KJOC Score is a self-report questionnaire that assesses both the elbow and shoulder. [159] It is divided into three sections including function and athletic performance, symptoms related to the upper limb and interpersonal relationships related to performance. [159] This tool is easy to administer and the questions are specific for shoulder function in an active population. The KJOC Score has been found to be a reliable (ICC = 0.88) and valid (r = 0.84-0.86) measure of shoulder and elbow function in overhead athletes. [159] KJOC scores have been established in baseball, [160-162] collegiate swimming, [163] and female adolescent softball. [164]

2.5.1.2 Pain Provocation Tests

Orthopaedic special tests (OSTs) are widely used in clinical testing to identify shoulder pathology. [165] It is advised that a cluster of high-quality tests be used to make a diagnosis. [165] Two pain provocation tests that are used in both the research and clinical setting to assess for shoulder pain and impingement have been identified, namely the Hawkins-Kennedy Test and Jobe's Test. [166, 167] A positive Hawkins-Kennedy test indicates subacromial impingement. [166] The test has a sensitivity of 79% and a specificity of 59%. [168] The Jobe's test is conducted in both shoulder GH IR (Empty Can position) and ER (Full Can position). [166] Pain in both testing positions indicates the presence of a RC pathology, however if the Empty Can is positive and the Full Can is negative, then it is likely that the shoulder impingement is not caused by RC pathology. [166] This test must be interpreted in combination with the other impingement tests as there is limited evidence for the sensitivity, specificity and accuracy of this test. [168]

2.5.1.3 Glenohumeral and Scapular Range of Motion

GH internal and external rotation ROM is measured using a hand-held goniometer. The intrarater reliability for the goniometric measurements of shoulder ROM is high (ICC = 0.94-0.99), however the position of testing (supine or sitting) should be consistent and recorded. [169] Both shoulders should be measured twice and the average recorded. A high intratester reliability (ICC= 0.93-0.99) has been found for these ROM tests. [170]

USR can be measured in all GH abduction ranges in the coronal plane by use of an inclinometer. [171] Multiple measures of the test are performed and an average of two measurements recorded at 45°, 90° and 135° of GH shoulder abduction. [171, 172] This method of assessing scapula upward rotation has demonstrated good to excellent intrarater reliability (ICC = 0.89 – 0.96) and good validity. [172]

2.5.1.4 Muscle Strength

In a clinical setting, manual muscle testing is the most common method for examining muscular strength, however it is acknowledged that the testing procedure can be subjective, and rely heavily on the experience, judgement and strength of the examiner. [173, 174] A study that compared the reliability of three different methods for assessing muscle strength found that the use of a hand-held dynamometer (HHD) or a spring-scale dynamometer had superior reliability to manual muscle tests. [174] HHD is demonstrated to be the most reliable and valid method for testing isometric muscle strength of the RC muscles, [174-176] with the intrarater reliability to be good for IR (ICC = 0.64 – 0.96) and excellent for ER (ICC = 0.78 – 0.98). [174] In a study describing the profile of scapulothoracic position, strength and flexibility in adolescent tennis players, a HHD was effectively used to assess the muscle strength of the serratus anterior, upper trapezius and lower trapezius muscles. [177] It has been found that the intrarater reliability of HHD for all shoulder movements is excellent (ICC = 0.79 – 0.96). [178]

2.5.1.5 Muscle Length

The measurement of PML using palpation of relevant landmarks and a caliper or tape measure has been validated and is reliable (ICC = 0.96). [179] The protocol has since adapted into a supine position and used to evaluate adolescent tennis players. [177]

2.5.1.6 Posterior Shoulder Tightness

The test for PST can be conducted with the subject in either side-lying or a supine position. A study comparing the accuracy, reliability, precision and validity of PST assessment in overhead athletes found that the supine position was most effective and had good intrasession reliability (ICC = 0.91), good intersession reliability (ICC = 0.75), good intertester reliability (ICC = 0.94) and good construct validity. [131] The test is conducted using an inclinometer to measure the passive GH horizontal adduction before scapular movement, and an average of three measurements is recorded for PST. [131]

2.5.1.7 Dynamic Upper Limb Stability

A systematic review found that passive joint position sense testing is the most reliable method for evaluating joint position sense, and threshold to detect passive motion testing is reliable for kinesthesia. [180] However, position-matching protocols may give a better indication of joint function than passive-protocols. [180] Dynamic tests are useful for assessing deficits in muscle strength, as well as evaluating proprioception and motor control. The CKCUEST is used to test the dynamic stability of the upper limb and can give insight into functional performance of a subject. [181] The CKCUEST has been studied in adolescent overhead athletes and has intersession reliability of the average touches score, normalised score, and power score of 0.68, 0.68 and 0.87 respectively. [182] Currently, the CKCUEST is the only dynamic stability test for shoulders that has been shown to be reliable and valid in a clinical setting.

2.5.2 Anthropometry and Maturation

Chronological age is used to classify adolescents for sport and research purposes, however it has limited use in the assessment of growth and maturation. [15, 183] Around the adolescent growth spurt, there is a large range of variability between individuals of the same chronological age in somatic and biological growth. [15, 184-186] Therefore, studies of adolescents need to attempt to control for the confounding effects of maturation.

Skeletal age assessment is considered to be the best index of maturation, however despite its efficacy it requires specialised equipment, it is expensive and there are concerns about the use of radiation. [15] The assessment of secondary sex characteristics is limited to clinical settings, is considered to be invasive for adolescents and cannot reflect the timing of growth. [15]

PHV is the velocity of maximum growth during the adolescent growth spurt and age of PHV is considered an indicator of maturity. [15, 18, 19] A longitudinal study on 113 boys and 115 girls found that the practical technique of predicting PHV using four anthropometric variables is a reliable measure of biological maturity and is non-invasive. [15] Chronological age, standing height, sitting height and body mass are measured and an equation is used to predict PHV, and the correlation coefficient between skeletal age and PHV maturity offset from chronological age is 0.83. [15]

2.5.3 Training Load

Monitoring training load can provide explanations for changes in athletic performance, which may then be used to help plan future training loads. [187, 188] It may also help to reduce the risk of injury, illness, non-functional overreaching in individuals and teams. [187]

The use of external training load (ETL) parameters, such as duration of specific exercise, type of swimming or technical activity, or swimming distance, are described in water polo teams to monitor load. [189] Monitoring ETL can also be done by use of global positioning system (GPS) tracking. [187] Although this is becoming a popular choice for team sports, the reliability of the tracking is reduced with high velocity movements, so this may not be a practical measure for water polo players as this limits the ability to count passes and shooting. [187, 190]

Monitoring the rate of perceived exertion (RPE) may be a useful for identifying training load for overhead athletes. [190] A study of male adolescent water polo players demonstrated that recording session rate of RPE is effective in monitoring internal training load (ITL). [189] Session RPE (RPE score multiplied by training time in minutes) was shown to be just as effective as monitoring heart rate during training sessions. [189] This measure does not require any equipment and may be a practical way for coaches to monitor ITL. Session RPE has been demonstrated to be valid and reliable compared to summated heart rate zones (ICC = 0.75 – 0.90). [191]

A study of training load in young female water polo players found a high incidence of upper respiratory tract infections and blood damage markers (indicating muscle damage) in the first 6 weeks of a season. [192] These findings were attributed to a lowered immune system and lower levels of physical fitness respectively when players return from a period of rest, and are associated with a negative influence on performance. [192]

Monitoring training load and RPE may provide some insight into the duration and intensity of training, help to identify players who are overtraining and may be at risk of injury, or identify a time within the season at which players may be more at risk for injury. In addition, information on training load may provide insight into the effect of spikes in training load or numbers of matches played within a season. Monitoring can also be useful help coaches with the planning of their periodised training schedules. [188]

2.6 **Summary**

There is a high incidence of shoulder pain among adult and adolescent water polo players, with both traumatic and overuse injuries reported. [38, 41, 42] Adolescents are at high risk for musculoskeletal injuries due to their immature skeleton, decreased muscular development, general joint laxity, and rapid periods of growth during puberty. [47] The global increase in adolescent participation in sport, growing popularity of water polo around the world and in South Africa, combined with the increase in adolescent sporting injuries highlights the necessity of research in this field that may help to reduce injury rates.

There are a number of risk factors identified among overhead athletes and swimmers that may be relevant to water polo players: shoulder muscle weakness, [10, 53, 56, 113] altered GH ROM and GIRD, [10, 49, 52, 53, 103, 119, 122, 193-195] GH joint laxity, [10, 193, 196] pectoralis minor tightness, [10] altered scapular control, [21, 50, 53, 93, 197-199] age, [104, 200, 201] height, [104, 106, 200, 201] pitching velocity, [104, 106, 200] early sport specialisation, [106, 202] throwing with arm fatigue, [106, 203, 204] and heavy training load. [10, 70, 103, 177, 190, 201, 205, 206] A limited number of risk factors for shoulder pain among water polo players have been identified: previous shoulder injury, [99] overtraining, [42] shoulder muscle strength deficits, [28, 107, 108, 110, 196] altered GH ROM, [78, 107] reduced PML, [207] increased USR [43] and reduced proprioception. [149] However, the causation is not fully understood. [38] The high prevalence of injuries in male adolescent water polo players warrants further investigation into this population in other parts of South Africa, as well as an examination of the risk factors for shoulder injury.

Chapter 3: Screening for risk factors associated with non-specific shoulder pain in male adolescent water polo players

3.1 Introduction

Participation in water polo is commonly associated with musculoskeletal injury, with the shoulder identified as the most vulnerable site of injury. [38, 41, 42, 44, 69, 91, 208] Water polo is a unique combination of swimming, overhead throwing, and physical contact and the causation of shoulder injuries appears to be multifactorial. [44, 45, 61, 208] The incidence of shoulder injuries among water polo players is reported to be between 24%-80%. [38] Adolescents have an increased risk of musculoskeletal injuries. [47] Among adolescent water polo players in South Africa, the prevalence of shoulder pain is 51.04%. [42]

Numerous risk factors for shoulder injuries in swimming have been identified: high training loads, [10, 70, 103, 177, 206, 209] weakness of the GH internal rotator muscles, [10, 113] altered GH ROM, [10, 49, 103, 193] GH joint laxity, [10, 193, 196] pectoralis minor tightness [10] and altered scapular control. [50, 93] Poor shoulder abduction and ER endurance is also linked to swimmers with shoulder pain, however, it is unclear whether this is a cause or effect. [49]

Overhead throwing sports such as baseball, cricket, and handball have been studied extensively. The risk factors for shoulder injury among throwers include: altered GH ROM and GIRD, [52, 53, 119, 122, 194, 195] shoulder muscle weakness, [53, 56] altered scapular control, [21, 53, 197-199] age, [104, 200, 201] height, [104, 106, 200, 201] pitching velocity, [104, 106, 200] early sport specialisation, [106, 202] throwing with arm fatigue, [106, 203, 204] and a heavy workload. [190, 201, 205]

Current research in water polo proposes that previous shoulder injury, [99] overtraining, [42] shoulder muscle strength deficits, [28, 107, 108, 110, 196] altered GH ROM, [78, 107] reduced PML, [207] increased USR [43] and reduced proprioception [149] may contribute to shoulder pain. Clinicians speculate that the repetitive nature of swimming and overhead throwing motion predispose water polo players to shoulder injuries. [28, 61, 78] Identifying and confirming the specific risk factors that lead to shoulder pain and injury may be the first step in reducing the incidence of injury in the adolescent population. Therefore, the aim of this study was to investigate the intrinsic and extrinsic risk factors that are associated with non-specific shoulder pain and injury among male adolescent water polo players. More specifically the study aimed to evaluate musculoskeletal and training load risk factors associated with injury.

3.2 **Methods**

3.2.1 Research Design

This study has a quantitative, prospective longitudinal cohort design.

3.2.2 Participants

3.2.2.1 Recruitment

Water polo playing schools in the Western Cape were contacted via email and telephone and asked to participate in the study. The purpose and aims of the study, as well as the risks and benefits to participants were explained to the schools, the players and their legal guardians. A sample of 34 male adolescent water polo players were recruited from three schools. Participation in the study was completely voluntary.

3.2.2.2 Sample Size Determination

Data from previous studies that measured the effect of shoulder pain on variables such as USR, [21, 210] GH IR and ER ROM, [135] SA, UT and LT strength [177] as well as GH IR and ER strength [177] was used to determine a sample size with sufficient statistical power. GH IR and ER strength required the greatest sample size to achieve statistical power, hence this measurement was used to calculate the sample size. The sample size was calculated using a small meaningful difference of 2 units and a standard deviation of 3 units (effect size d = 0.7). Statistical significance was accepted as $p < 0.05$, therefore a sample size of 29 participants would provide 80% statistical power for GH IR and ER strength.

3.2.2.3 Inclusion Criteria

Male high school water polo player between the age of 14 and 18 years of age were eligible to participate in the study. Participants were required to play in the 'A' or 'B' team in their age group (under 15) or play in the school's 1st, or 2nd team and train at least twice (net) per week in the pool. Assent forms and informed consent forms needed to be signed prior to participation in this study.

3.2.2.4 Exclusion Criteria

Participants were excluded from the study if they had a current shoulder injury or any pre-existing injuries to the cervical spine, thoracic spine, or elbow that might interfere with the physical testing. Participation in another overhead throwing sport during the study period also resulted in exclusion from the study.

3.2.3 Study Procedure

The research proposal was submitted for ethical approval to the Human Research Ethics Committee (HREC REF NO: 404/2019) of the Faculty of Health Sciences, University of Cape Town (UCT) (Appendix I). Once ethical approval was granted, the proposal was submitted to the Western Cape Education Department for approval (Appendix II).

Water polo players were then recruited to participate in the study. Participants aged 14-17 were required to sign an assent form (Appendix III), and their parent/legal guardian was required to sign an informed consent form (Appendix IV). Participants aged 18 and over were required to sign an informed consent form. An Information Sheet with pictures and explanations of the physical tests was given to the participants and their parents/guardians prior to the testing (Appendix V). All forms and questionnaires were coded, and participants were assured that privacy and confidentiality of all information would be strictly maintained.

The pre-season screening was conducted over a one-week period in September 2019 at the respective schools (Figure 1). The participants were then monitored for a period of 12 weeks to track shoulder pain and training load.

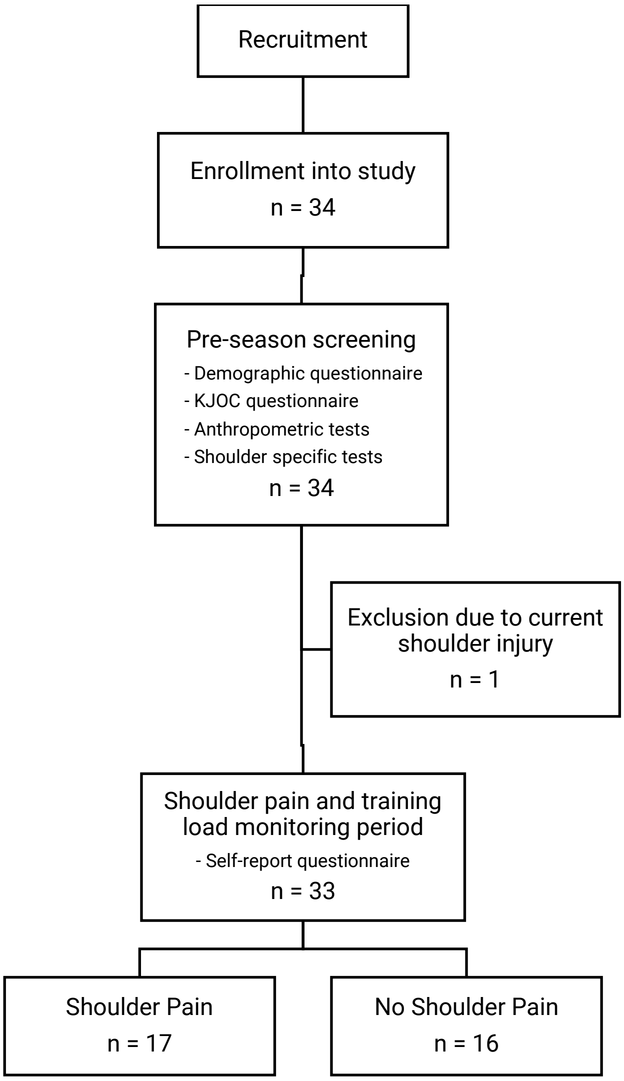


Figure 1: Graphic representation of the study procedure

3.2.3.1 Pre-season screening

All participants completed three sections of screening – questionnaires, anthropometry and maturation tests, and shoulder specific tests.

3.2.3.1.1 Questionnaires

The participants filled out a questionnaire to obtain their demographic information (Appendix VI). The questionnaire also gathered information relating to medical history, past and current injury, level of competition and training load.

Participants completed the KJOC Score (Appendix VII). This questionnaire was used to gather information about participants current shoulder function and athletic performance, symptoms related to the upper limb and interpersonal relationships related to performance. The KJOC Score has been found to be both a reliable (ICC = 0.88) and valid (r = 0.84 – 0.86) measure of shoulder and elbow function in overhead athletes. [159]

3.2.3.1.2 *Anthropometry and Maturation Testing*

All participants had their anthropometric measurements taken. Body mass was measured to the nearest 0.1 kilogram (kg) with participants standing barefoot on a calibrated scale. Standing height in centimetres (cm) was recorded with participants standing barefoot with their heels flat on the floor and level against the wall. A line was drawn on the wall to mark the participants height with a ruler placed on top of their head. Sitting height (cm) was measured from the crown of the head to sitting surface, with participants sitting on a bench.

Chronological age was recorded in years. PHV and predicted years from PHV were then calculated using 4 variables (chronological age, standing height, sitting height and body mass) to find the maturity offset as described by Mirwald *et al.* [15]

3.2.3.1.3 *Shoulder Specific Testing*

The physical screening tests for the shoulder included assessments for shoulder pain, shoulder ROM, shoulder strength, shoulder flexibility and shoulder stability. A summary of the tests, instrumentation used, intra-rater reliability and reference protocols is provided in Table 1. The tests were performed by the same examiners (J. G and P. T) who were familiarised with the protocols.

Table 1: Shoulder Specific Tests

Measure	Test Performed	Testing Position	Instrumentation	Intra-rater Reliability	Protocol Reference
Pain Provocation	Hawkins-Kennedy	Sitting; arm is draped over examiner's arm and positioned in 90° GH abduction and 90° GH flexion. Examiner stabilises the scapula by applying a gentle downward pressure and performs passive GH IR.	N/A	κ = 1.0 [211]	[166]
	Jobe Test	Sitting; both arms positioned in 90° GH elevation, in the scapula plane and full GH IR. The examiner applies downward force to both of the participant's arms simultaneously.	N/A	κ = 1.0 [211]	[166]
	Full Can	As for Jobe's Test, but both arms are positioned in 90° GH ER.	N/A	Interpreted in conjunction with Hawkins-Kennedy & Jobe Test [168]	[166]
Range of Motion	GH Internal Rotation	Supine; arm positioned in 90° GH abduction, 90° elbow flexion, neutral forearm rotation and neutral wrist. A towel is placed under the upper arm to maintain a horizontal position. Examiner passively takes the arm into maximum GH IR.	Inclinometer (Digi-Pas DWL80E)	ICC = 0.89 – 0.99 [176] ICC = 0.94 – 0.99 [169]	[212]
	GH External Rotation	Supine; arm positioned in 90° GH abduction, 90° elbow flexion, neutral forearm rotation and neutral wrist. A rolled-up towel is placed under the upper arm to maintain a horizontal position. Examiner passively takes the arm into maximum GH IR.	Inclinometer (Digi-Pas DWL80E)	ICC = 0.89 – 0.99 [176] ICC = 0.94 – 0.99 [169]	[212]
	Upward Scapular Rotation	Standing with inclinometer placed on the scapular spine; upward scapular rotation measured in the scapular plane with the arm at rest (0°), 45°, 90° and 135° GH abduction.	Inclinometer (Digi-Pas DWL80E)	ICC = 0.89 – 0.96 [172]	[172] modified by [171]

Isometric Strength	GH Internal Rotators	Sitting; arm positioned in 90° of GH abduction, 90° (or end of range if less than 90°) of GH external rotation and 90° elbow flexion resting on a table. Examiner stabilises the lateral aspect of the distal humerus with the non-testing hand, and the HHD centred on the volar aspect of the distal forearm.	HHD (MicroFET 2)	ICC = 0.64 – 0.96 [174]	[174]
	GH External Rotators	Sitting; arm positioned in 90° of GH abduction, 90° of GH external rotation and 90° elbow flexion resting on a table. Examiner stabilises the medial aspect of the distal humerus with the non-testing hand, and the HHD centred on the dorsal aspect of the distal forearm.	HHD (MicroFET 2)	ICC = 0.78 – 0.98 [174]	[174]
	Serratus Anterior	Supine; arm positioned in 90° GH flexion and elbow fully extended. The HHD is placed in the participant's palm of the arm being tested. Examiner will apply a downward force to the participant's palm, while the participant performs scapular protraction.	HHD (MicroFET 2)	ICC = 0.81 – 0.95 [213]	[57]
	Upper Trapezius	Sitting, arm at side in neutral GH rotation. Examiner stands behind the participant and the HHD is placed over the superior aspect of the scapula. Examiner applies a downward force to the HHD, while the participant lifts the shoulder upward.	HHD (MicroFET 2)	ICC = 08.1 – 0.95 [213]	[214]
	Lower Trapezius	Prone, 145° GH abduction and full external rotation. Participants instructed to lift their arm up, while the examiner applies a downward force to the HHD.	HHD (MicroFET 2)	ICC = 0.89 [57]	[57]
Muscle Length/Flexibility	Pectoralis Minor Length	Supine; arms at side in neutral GH rotation and full elbow extension. Measurement taken from medial-inferior angle	Calliper (Mastercraft Vernier Calliper)	ICC = 0.83 – 0.87 [179]	[179] modified by [177]

		of the coracoid process to the lateral aspect of the sternocostal joint of the inferior aspect of the fourth rib.			
	Posterior Shoulder Tightness	Supine; arm positioned in 90° GH abduction, and 90° elbow flexion. Examiner stabilises scapula in retraction with one hand and with the other hand moves the participant's arm into horizontal adduction.	Inclinometer (Digi-Pas DWL80E)	ICC = 0.93 [197]	[197]
Stability	Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST)	Push up position, back flat, hands 36-inches apart on marked lines. Participants must reach one hand over to tap the other hand and then return to the starting position, alternating taps as quickly as possible. The test is performed for 15 seconds with a 45 second rest in between the 3 trials.	Stopwatch	Average touches and Normalised Score ICC = 0.68 [182] Power Score ICC = 0.87 [182]	[215]

GH = Glenohumeral; IR = Internal Rotation; ER = External Rotation; ICC = Intraclass Correlation

3.2.3.2 Shoulder Pain and Training Load Monitoring

The participants were monitored for a 12-week period at the start of the 2019/2020 water polo season and they recorded shoulder pain and training load via a Google Forms self-report questionnaire (Appendix VIII). A link to the online questionnaire was sent bi-monthly to the participants via smart phone communication. The participants were sent ad hoc reminders to complete the questionnaire.

For the purposes of this study, shoulder pain was defined as a physical complaint or manifestation of pain for one day (24 hours) or longer, sustained during competition and/or training, irrespective of the need for medical attention or loss of time to training and/or competition due to the pain. Participants were required to report if they had experienced shoulder pain, and if so, to report which shoulder was affected (dominant, non-dominant, or both), rate their shoulder pain on a 0-10 numeric pain rating scale (NPRS) and report the activity of onset of pain (throwing, swimming, defending, gym, other). Participants were also required to rate their perceived shoulder strength from 0-10 for various shoulder-related activities (passing, shooting, swimming, defending and gym) over the 12-week season.

Participants were required to record their weekly training load for different types of training (swimming training, water polo training, water polo matches) on a bi-monthly basis for the monitoring period. Data was collected for weeks 1-2, weeks 3-4, weeks 7-8 and weeks 11-12. The load was reported as both the number of training sessions per week and the total time per week for each type of training. Training intensity was not included as load was recorded bi-monthly and this may have introduced recall bias.

3.2.4 Statistical Analysis

The data collected from the pre-season screening were analysed using IBM SPSS Statistics for Windows version 27.0 [216]. All variables were screened for normality using the Shapiro Wilk Test. Descriptive statistics were calculated for all variables. Independent t-tests were performed to determine group differences for shoulder pain sustained during the season for those data that were normally distributed. For the data not normally distributed, the Mann-Whitney U test was used. A Chi-Square test was used to determine differences in the ordinal variables between the shoulder pain and no shoulder pain groups.

Statistical significance for the two main effects of shoulder pain and shoulder dominance, and the interaction (pain x dominance) of GH internal and external rotation ROM; upward scapula rotation at rest, 45°, 90° and 135°; isometric muscle strength of GH internal and external rotator muscles, serratus anterior muscles, and upper and lower trapezius muscles; pectoralis minor muscle length; pectoralis minor index; and posterior shoulder tightness were assessed using a two-way analysis of variance (ANOVA) with repeated measures. Effect sizes were categorised as large (d = 0.8), medium (d = 0.5) and small (d = 0.2).

Statistical significance was set at $p < 0.05$. Data are presented as mean ± standard deviation, unless otherwise stated.

3.3 **Results**

3.3.1 Study Sample

Thirty-four water polo players were recruited for the study and one participant was excluded during the pre-season screening as he presented with a current shoulder injury. There were no further drop-outs during the study. Thus, 33 water polo players (15.5 ± 1.4 years) completed the pre-season screening and 12-week monitoring period.

3.3.2 Shoulder Pain

Shoulder pain was reported by 52% (n = 17) of the participants at least once during the 12-week monitoring period and 36% (n = 12) reported shoulder pain at the end of the 12 weeks. There were no injuries that resulted in time off from play. Over the 12-week period shoulder pain was most frequently reported in both shoulders simultaneously (n = 23), or the dominant shoulder only (n = 17). Participants most frequently reported swimming to be the activity of onset of their shoulder pain (n = 22), followed by throwing (n = 16). Pain scores ranged from 2-10 on the NPRS (Table 2). Participant's individual pain ratings are illustrated in Figure 2.

Table 2: Self-reported shoulder pain over the 12-week period. Data are expressed as whole numbers, or as mean ± standard deviation.

Variable		**Week 1-2**	**Week 3-4**	**Week 7-8**	**Week 11-12**
Shoulder Pain	Yes	7	11	11	12
	No	26	22	22	21
Side of Pain	Dominant Shoulder Only	3	4	5	5
	Non-dominant Shoulder Only	0	0	0	1
	Both Shoulders	4	7	6	6
	None	26	22	22	21
Activity of Onset	Throwing	2	4	5	5
	Swimming	5	6	5	7
	Defending	0	0	0	0
	Gym	0	1	1	1
	None	26	22	22	20
Mean NPRS Rating		4.3 ± 1.5	5.2 ± 2.1	3.2 ± 1.4	3.6 ± 1.4

NPRS = Numeric Pain Rating Scale

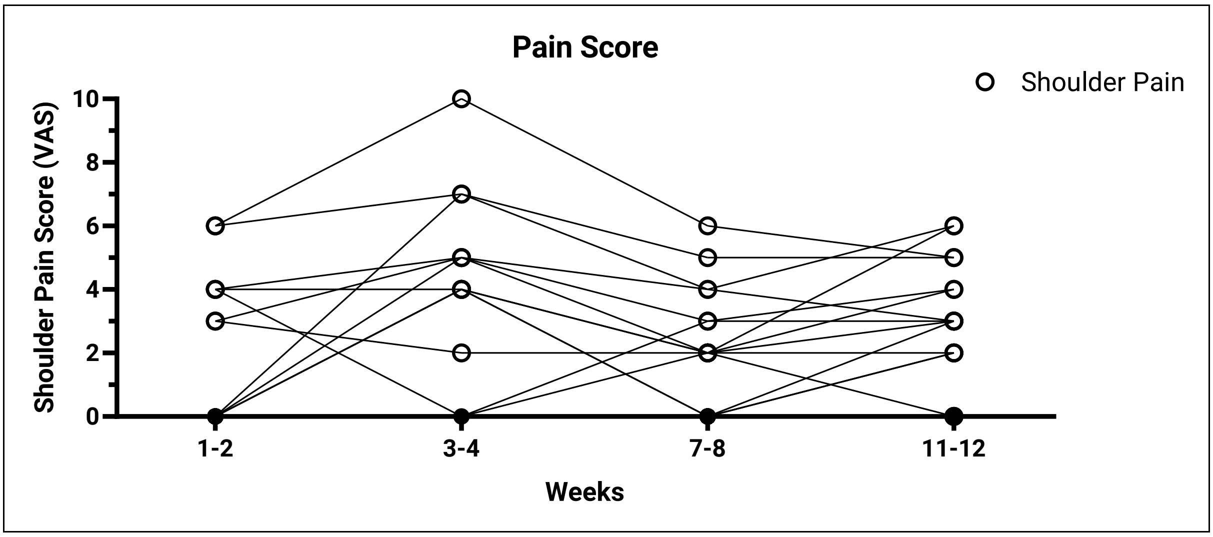


Figure 2: Individual shoulder pain scores rated on a numeric pain rating scale (NPRS) reported for weeks 1-2, 3-4, 7-8, and 11-12.

3.3.3 Descriptive Characteristics

The nominal descriptive characteristics for the participants are shown in Table 3 and the ordinal descriptive characteristics are shown in Table 4.

This study found a difference in age between those participants who developed shoulder pain (16.0 years ± 1.6) and those who did not (14.9 years ± 0.9) ($t_{26.3}$ = 2.5; p = 0.003). Participants who developed shoulder pain during the season had a higher body mass (74.1kg ± 13.1kg) than those players who did not develop shoulder pain during the season (66.3kg ± 8.3kg) ($t_{27.3}$ = 2.1; p = 0.050). A strong, positive correlation was found between participant age and mass (r = 0.800, n = 33, p = 0.0001). After covarying for age, the adjusted body mass was not different between groups (70.6kg vs 70.1kg).

The mean predicted age of PHV was 14.1 ± 0.6. Only two of the 33 participants had not yet reached their predicted age of PHV, thus the sample is largely homogenous. There was a difference in the predicted years from PHV between the participants who developed shoulder pain (1.9 ± 1.5) and those who did not (0.9 ± 0.8) ($t_{25.2}$ = 2.3; p = 0.029).

Table 3: Nominal descriptive characteristics of all participants (n = 33), participants who developed shoulder pain (n = 17) and participants who did not develop shoulder pain (n = 16). Data are expressed as mean ± standard deviation.

Variable	All (n = 33)	Shoulder Pain (n = 17)	No Shoulder Pain (n = 16)	t	df	*p*
Age	15.5 ± 1.4	16.0 ± 1.6	14.9 ± 0.9	2.5	26.3	0.003*
Years Playing	6.1 ± 1.7	6.8 ± 1.8	5.3 ± 1.3	2.7	31	0.054
Body Mass (kg)	70.3 ± 11.6	74.1 ± 13.1	66.3 ± 8.3	2.1	27.3	0.050*
Standing Height (cm)	178.1 ± 8.8	180.3 ± 8.4	175.8 ± 8.9	1.5	31	0.140
BMI	22.01 ± 2.3	22.7 ± 2.7	21.4 ± 1.6	1.6	26.4	0.116
Predicted age of PHV	14.1 ± 0.6	14.2 ± 0.4	14.1 ± 0.7	0.5	31	0.602
Predicted years from PHV	1.4 ± 1.3	1.9 ± 1.5	0.9 ± 0.8	2.3	25.2	0.029*

BMI = Body Mass Index; kg = kilograms; cm = centimetres; PHV = Peak Height Velocity

* Significant difference

Table 4: Ordinal descriptive characteristics of all participants (n = 33), participants who developed shoulder pain (n = 17) and participants who did not develop shoulder pain (n = 16).

Variable		All (n = 33)	Shoulder Pain (n = 17)	No Shoulder Pain (n = 16)
Dominant Shoulder	Left	5	3	2
	Right	28	14	14
Position	Goalkeeper	3	2	1
	Defensive specialist	5	3	2
	Driver	18	10	8
	Two-metre specialist	6	2	5
History of Shoulder Injury	Yes	13	9	4
	No	20	8	12

Of the participants who had a previous history of shoulder injury (including, but not limited to, shoulder muscle tear, thrower's shoulder or impingement) 69% (n = 9) experienced shoulder pain during the season. However, there was not an association between previous history of shoulder injury and the development of shoulder pain $X^2(1, n = 33) = 0.1$, $p = 0.101$.

There was no significant association between shoulder dominance and shoulder pain, or between player position and shoulder pain.

3.3.4 Pre-season Testing

3.3.4.1 Pain Provocation Tests

This study found no significant associations between a positive pain provocation test and the development of shoulder pain (Table 5).

Table 5: Pre-season pain provocation test results for all participants (n = 33), in the shoulder pain (n = 17) and no shoulder pain (n = 16) groups respectively.

Test	Shoulder	All (n = 33)	Shoulder Pain (n = 17)	No Shoulder Pain (n = 16)
Symptoms on Hawkins- Kennedy Test	Dominant	12	8	4
	Non-dominant	10	4	6
Symptoms on Jobe Test	Dominant	5	3	2
	Non-dominant	3	3	0
Symptoms on Full Can Test	Dominant	1	1	0
	Non-dominant	0	0	0

3.3.4.2 Kerlan-Jobe Orthopaedic Clinic Elbow and Shoulder Score

KJOC scores ranged from 42.4 – 100 with a mean score of 90.3 ± 13.1 (Table 6 & 7). There was no difference between KJOC scores and the pain groups. A total of 11 participants (shoulder pain group n = 7; no shoulder pain group n = 4) had a mean score of < 90.

There was a positive association between participants with a history of shoulder injury and a lower KJOC score X^2 (1, n = 33) = 0.4, p = 0.013.

There was not a significant association found between the mean KJOC score and the number of years of playing (r = -0.327, n = 33, p = 0.063).

Table 6: Pre-season test results of the KJOC for all participants (n = 33), in the shoulder pain (n = 17) and no shoulder pain (n = 16) groups respectively, and compared to the known normative values. Data are expressed as mean ± standard deviation.

Test	All (n = 33)	Shoulder Pain (n = 17)	No Shoulder Pain (n = 16)	Reference Data
KJOC Mean Score	90.3 ± 13.1	87.6 ± 15.6	93.1 ± 9.6	90 [162] +

KJOC = Kerlan-Jobe Orthopaedic Clinic Elbow and Shoulder Score

+ Based on healthy baseball pitchers

3.3.4.3 Musculoskeletal Testing

There were no main effects for pain for shoulder ROM, shoulder strength and shoulder flexibility (Table 8).

Table 7: Pre-season test results of the individual questions from the KJOC for all participants (n = 33).

Question	Score of 0	Score of 10	Mean ± SD	Range
1. How difficult is it for you to get loose or warm before competition or practice?	Never feel loose during games or practice	Normal warm-up time	8.3 ± 2.4	0 – 10
.. 2. How much pain do you experience in your shoulder?	Pain at rest	No pain with competition	8.7 ± 19.	3.8 – 10
3. How much weakness and/or fatigue (I.e., loss of strength) do you experience in your shoulder?	Weakness/fatigue preventing any competition	No weakness, normal competition fatigue	8.5 ± 2.2	2.2 – 10
4. How unstable does your shoulder feel during competition?	"Popping out" routinely	No instability	9.1 ± 2.0	2.7 – 10
5. How much have arm problems affected your relationship with your coaches, 6. management, and agents?	Left team, traded or waived, lost contract or scholarship	Not at all	9.9 ± 0.4	8.2 – 10
7. How much have you had to change your stroke due to your arm?	Completely changes, don't perform motion anymore	No change in motion	9.0 ± 1.7	4.5 – 10
8. How much has your velocity and/or power suffered due to your arm?	Lost all power, became finesse or distance athlete	No change in velocity	9.4 ± 1.4	3.8 – 10
9. What limitation do you have in endurance in competition due to your arm?	Significant limitation	No endurance limitation	8.9 ± 2.0	1.9 – 10
10. How much has your control suffered due to your arm?	Unpredictable control on all pitches, serves, strokes etc.	No loss of control	9.3 ± 2.0	1.6 – 10
11. How much do you feel your arm affects your current level of competition (I.e., is your arm holding you back from being at your full potential)?	Cannot compete, had to switch sports	Desired level of competition	9.2 ± 1.8	2.4 – 10

KJOC = Kerlan-Jobe Orthopaedic Clinic Elbow and Shoulder Score

Table 8: Pre-season musculoskeletal tests for participants in the shoulder pain (n = 17) and no shoulder pain (n = 16) groups respectively, the main effects and interactions between the groups, and compared to the known normative values. Data are expressed as mean ± standard deviation.

	Shoulder Pain (n = 17)			No Shoulder Pain (n = 16)			Main Effects		Interaction	Reference Data	
Variable	**Dominant**	**Non-dominant**	**Average**	**Dominant**	**Non-dominant**	**Average**	**Side**	**Pain/No Pain**	**Side x Pain/No Pain**	**Dominant**	**Non-dominant**
GH IR ROM (°)	57 ± 11	60 ± 9	58 ± 8	60 ± 11	61 ± 8	60 ± 8	$F_{1,31}$ = 0.45 p = 0.51	$F_{1,31}$ = 0.49 p = 0.49	$F_{1,31}$ = 0.21 p = 0.65	40.4 ± 11.1 [61 +]	52 ± 11.4 [61 +]
GH ER ROM (°)	100 ± 11	93 ± 8	96 ± 8	106 ± 11	97 ± 18	101 ± 12	$F_{1,31}$ = 14.2 p = 0.001*	$F_{1,31}$ = 1.93 p = 0.18	$F_{1,31}$ = 0.10 p = 0.76	103.9 ± 12.1 [61 +]	96.6 ± 13.1 [61 +]
Total GH ROM (°)	157 ± 15	152 ± 11	155 ± 11	166 ±13	158 ± 18	162 ± 12	$F_{1,31}$ = 5.1 p= 0.031*	$F_{1,31}$ = 3.1 p = 0.09	$F_{1,31}$ = 0.26 p = 0.61	144.3 ± 16.9 [61 +]	148.6 ± 16.8 [61 +]
USR at rest (°)	-3 ± 5	-3 ± 4	-3 ± 4	-5 ± 4	-5 ± 3	-5 ± 3	$F_{1,31}$ = 0.01 p = 0.94	$F_{1,31}$ = 1.27 p = 0.27	$F_{1,31}$ = 0.01 p = 0.91	5.2 ± 4 [177 ++]	3.5 ± 2.6 [177 ++]
USR at 45° GH Abd (°)	3 ± 5	2 ± 3	3 ± 4	2 ± 4	2 ± 3	2 ± 3	$F_{1,31}$ = 0.11 p = 0.74	$F_{1,31}$ = 0.40 p = 0.53	$F_{1,31}$ = 0.22 p = 0.65	13.2 ±11.1 [171 Δ]	
USR at 90° GH Abd (°)	12 ± 5	13 ± 4	13 ± 4	12 ± 5	11 ± 4	11 ± 4	$F_{1,31}$ = 0.26 p = 0.61	$F_{1,31}$ = 0.84 p = 0.37	$F_{1,31}$ = 3.50 p = 0.07	29.2 ± 10.4 [177 ++]	24.2 ± 6.2 [177 ++]
USR at 135° GH Abd (°)	23 ± 7	26 ± 5	25 ± 5	24 ± 7	25 ± 5	25 ± 5	$F_{1,31}$ = 1.93 p = 0.18	$F_{1,31}$ = 0.01 p = 0.92	$F_{1,31}$ = 1.02 p = 0.32	41.6 ± 5 [171 Δ]	
Isometric GH IR (Nm)	189 ± 64	165 ± 57	177 ± 60	151 ± 34	145 ± 49	148 ± 40	$F_{1,31}$ = 12.19 p = 0.001*	$F_{1,31}$ = 2.59 p = 0.12	$F_{1,31}$ = 4.22 p = 0.049*	181.9 ± 49.2 [217 ×]	150.7 ± 39.6 [217 ×]
Isometric GH ER (Nm)	94 ± 16	94 ± 18	94 ± 14	89 ± 17	90 ± 23	89 ± 18	$F_{1,31}$ = 0.02 p = 0.90	$F_{1,31}$ = 0.76 p = 0.39	$F_{1,31}$ = 0.07 p = 0.80	106.2 ± 18.5 [217 ×]	102.0 ± 24.0 [217 ×]
Isometric ER:IR	0.54 ± 0.15	0.60 ± 0.11	0.58 ± 0.15	0.62 ± 0.11	0.64 ± 0.18	0.62 ± 0.10	$F_{1,31}$ = 5.6 p = 0.024*	$F_{1,31}$ = 0.73 p = 0.4	$F_{1,31}$ = 0.62 p = 0.44	0.68 ± 0.09 [218 ◊]	0.68 ± 0.11 [218 ◊]
Isometric GH IR as PBW (kgf)	25.6 ± 6.0	22.4 ± 5.4	24.0 ± 5.5	23.4 ± 4.8	22.3 ± 6.1	22.8 ± 5.2	$F_{1,31}$ = 12.5 p = 0.001*	$F_{1,31}$ = 0.42 p = 0.52	$F_{1,31}$ = 2.94 p = 0.096	25.11 ± 3.81 [107 ∞]	23.81 ± 3.85 [107 ∞]

Isometric GH ER as PBW (kgf)	13.3 ± 2.6	13.2 ± 2.9	13.2 ± 2.4	13.7 ± 2.5	13.9 ± 3.1	13.8 ± 2.5	$F_{1,31}$ = 0.002 p = 0.96	$F_{1,31}$ = 0.48 p = 0.5	$F_{1,31}$ = 0.06 p = 0.81	16.25 ± 2.71[107 ∞]	15.99 ± 2.69 [107 ∞]
Isometric SA (Nm)	209 ± 54	189 ± 53	199 ± 53	194 ± 31	180 ± 37	187 ± 32	$F_{1,31}$ = 20.99 p = 0.0001*	$F_{1,31}$ = 0.67 p = 0.42	$F_{1,31}$ = 0.65 p = 0.43	154.8 ± 61.9 [177 ++]	136.8 ± 44.8 [177 ++]
Isometric UT (Nm)	160 ± 48	154 ± 43	157 ± 45	146 ± 33	141 ± 28	144 ± 30	$F_{1,31}$ = 4.89 p = 0.035*	$F_{1,31}$ = 1.03 p = 0.32	$F_{1,31}$ = 0.05 p = 0.82	158.6 ± 47.7 [177 ++]	148.4 ± 49.6 [177 ++]
Isometric LT (Nm)	64 ± 15	58 ± 9	61 ± 11	60 ± 13	53 ± 10	57 ± 11	$F_{1,31}$ = 14.71 p = 0.001*	$F_{1,31}$ = 1.28 p = 0.27	$F_{1,31}$ = 0.02 p = 0.89	31.2 ± 10.7 [177 ++]	29.2 ± 9.2 [177 ++]
PML (cm)	13.6 ± 0.7	14.0 ± 1.3	13.8 ± 0.9	13.5 ± 1.4	14.0 ± 1.3	13.8 ± 1.3	$F_{1,31}$ = 7.36 p = 0.011*	$F_{1,31}$ = 0.01 p = 0.92	$F_{1,31}$ = 0.06 p = 0.81	11.7 ± 1.2 [177 ++]	12.9 ± 1.3 [177 ++]
PMI	7.5 ± 0.4	7.8 ± 0.6	7.7 ± 0.5	7.7 ± 0.7	8.0 ± 0.5	7.8 ± 0.5	$F_{1,31}$ = 7.17 p = 0.012*	$F_{1,31}$ = 0.96 p = 0.33	$F_{1,31}$ = 0.08 p = 0.78	7.1 ± 0.4 [177 ++]	7.9 ± 0.4 [177 ++]
PST (cm)	114.9 ± 8.8	113.6 ± 8.2	114.3 ± 7.3	116.4 ± 5.7	113.6 ± 4.0	115.0 ± 3.8	$F_{1,31}$ = 2.35 p = 0.14	$F_{1,31}$ = 0.15 p = 0.70	$F_{1,31}$ = 0.35 p = 0.56	105.9 ± 5.9 [131 ‡]	114.1 ± 9.2 [131 ‡]

GH = Glenohumeral; IR = Internal Rotation; ER = External Rotation; ROM = Range of Movement; USR = Upward Scapular Rotation; Abd = Abduction; SA = Serratus Anterior; Nm = Newton-metres; PBW = Percentage of Body Weight; kgf = kilograms force; UT = Upper Trapezius; LT = Lower Trapezius; PML = Pectoralis Minor Length; cm = centimetres; PMI = Pectoralis Minor Index; PST = Posterior Shoulder Tightness

* Significant difference

[+] Based on sub-elite water polo players aged 19.8 ± 3.2; [++] Based on adolescent elite tennis players aged 13.6 ± 1.4; [∆] Based on patients with shoulder pathology aged 29 ± 2.5; [×] Based on overhead athletes aged 18-25; [◊] Based on elite male swimmers aged 19.9 ± 3.2; [∞] Based on sub-elite male water polo players aged 19.8 ± 3.2; [‡] Based on male intercollegiate baseball pitchers aged 20-25

3.3.4.4 Glenohumeral Range of Motion

There was a main effect for the side of GH ER ROM ($F_{1, 31}$ = 14.2, p = 0.001), with greater mean ER ROM in the dominant shoulder (103° ± 11°) compared to the non-dominant (95° ± 13°) shoulder. There were no significant effects for ERG. Mean scores were similar in the pain (8° ± 10°) and no pain (9° ± 15°) groups ($t_{25.6}$ = -0.3; p = 0.517).

There was a main effect for the side of GH TROM ($F_{1, 31}$ = 5.1, p = 0.031), with greater mean TROM in the dominant shoulder (162° ± 14°) compared to the non-dominant shoulder (155° ± 15°). There were no significant effects for TROM difference. TROM difference mean scores in the pain group (5° ± 14°) was slightly lower than the no pain group (9° ± 20°) ($t_{26.9}$ = -0.5; p = 0.838).

There were no significant effects for IR ROM. Participants had greater GH IR ROM on both the dominant (59° ± 7°) and non-dominant shoulder (60° ± 9°) compared to the normative values for dominant (40° ± 11°) and non-dominant shoulders (52° ± 11°).

There were no effects for GIRD. There with a slightly greater mean GIRD in the pain group (2° ± 12°) compared to the no pain group (0.4° ± 11°) but these were not significantly different ($t_{30.8}$ = 0.5; p = 0.413). Seven participants (21%) had an IR loss of >13° and of those 5 (71%) developed shoulder pain. Only 1 participant (3%) had an IR loss of between 20° – 25° and none of the participants had an IR loss >25°.

3.3.4.5 Upward Scapular Rotation

There were no significant findings for USR. Participants presented with downwardly rotated scapulae at rest, and consistently less USR at 45°, 90° and 135° compared to the normative values across both groups and both sides.

3.3.4.6 Isometric Shoulder Strength

An interaction was found between pain/no pain and dominant/non-dominant side for isometric IR strength ($F_{1, 31}$ = 4.22, p = 0.049) with stronger IR muscles in the dominant shoulder of the group with shoulder pain. There was a main effect for the side of isometric IR strength ($F_{1, 31}$ = 12.2, p = 0.001) with greater mean strength in the dominant shoulder (171 ± 55) compared to the non-dominant shoulder (155 ± 54). A difference was found for the main effect for the side of isometric IR as a PBW ($F_{1, 31}$ = 12.5, p = 0.001) with greater mean strength as a PBW in the dominant shoulder (24.5 ± 5.5) compared to the non-dominant shoulder (22.3 ± 5.7).

There were no significant findings for isometric ER strength. Participants had weaker mean isometric ER strength in both the dominant (92 ± 18) and non-dominant shoulder (92 ± 21), compared to the normative values for dominant (106 ± 19) and non-dominant shoulders (102 ± 24).

There was a main effect for side of the isometric strength ratio (ER:IR) ($F_{1, 31}$ = 5.6, p = 0.024), with a lower mean ratio in the dominant shoulder (0.57 ± 0.13) compared to the non-dominant shoulder (0.63 ± 0.15).

There was a main effect for side of isometric SA strength ($F_{1, 31}$ = 20.99, p = 0.0001), isometric UT strength ($F_{1, 31}$ = 20.99, p = 0.0001), and isometric LT strength ($F_{1, 31}$ = 20.99, p = 0.0001), with greater mean strength in the dominant shoulder compared to the non-dominant shoulder.

3.3.4.7 Shoulder Flexibility

A main effect for the side of PML was found ($F_{1, 31}$ = 12.2, p = 0.001), with shorter muscle length on the dominant shoulder (13.5cm ± 1.1cm) compared to the non- dominant shoulder (14.0cm ± 1.3cm).

There was a main effect for the side of PMI ($F_{1, 31}$ = 20.99, p = 0.0001), with a lower PMI in the dominant shoulder (7.6 ± 0.5) compared to the non-dominant shoulder (7.9 ± 0.6).

There were no findings for PST between the pain groups or dominant/non-dominant sides.

3.3.4.8 Shoulder Stability – Closed Kinetic Chain Upper Limb Stability Test

There were no differences found between the pain groups and the CKCUEST scores (Table 9). The Average Score and Normalised Score were aligned with the normative values tested among adolescents. The mean CKCUEST Power Score in this cohort of water polo players (82.8 ± 21.1) was higher than the normative values among physically active adolescents (69.1 ± 18.0).

Table 9: Pre-season test results of the CKCUEST for all participants (n = 33), in the shoulder pain (n = 17) and no shoulder pain (n = 16) groups respectively, and compared to the known normative values. Data are expressed as mean ± standard deviation.

Test	All (n = 33)	Shoulder Pain (n = 17)	No Shoulder Pain (n = 16)	Reference Data

CKCUEST Average Score	25.8 ± 3.9	26.2 ± 4.1	25.4 ± 2.4	25.6 ± 3.8 [182 +]
CKCUEST Normalised Score	14.5 ± 1.9	14.5 ± 2.3	14.5 ± 1.6	14.8 ± 16.2 [182 +]
CKCUEST Power Score	82.8 ± 21.1	89.0 ± 25.7	76.3 ± 12.3	69.1 ± 18.0 [182 +]

CKCUEST = Closed Kinetic Chain Upper Extremity Stability Test

[+] Based on healthy, physically active male and female adolescents aged 16.9 ± 1.4

3.3.4.9 Effect Sizes

There were no *large* mean effect sizes for any of the variables (Figure 3). However, there were *medium* positive mean effect sizes for GH ER ROM (shoulder pain = 0.73 and no shoulder pain = 0.60) and PST (no shoulder pain = 0.57). There was a *medium* negative mean effect sizes for PMI (shoulder pain = -0.59).

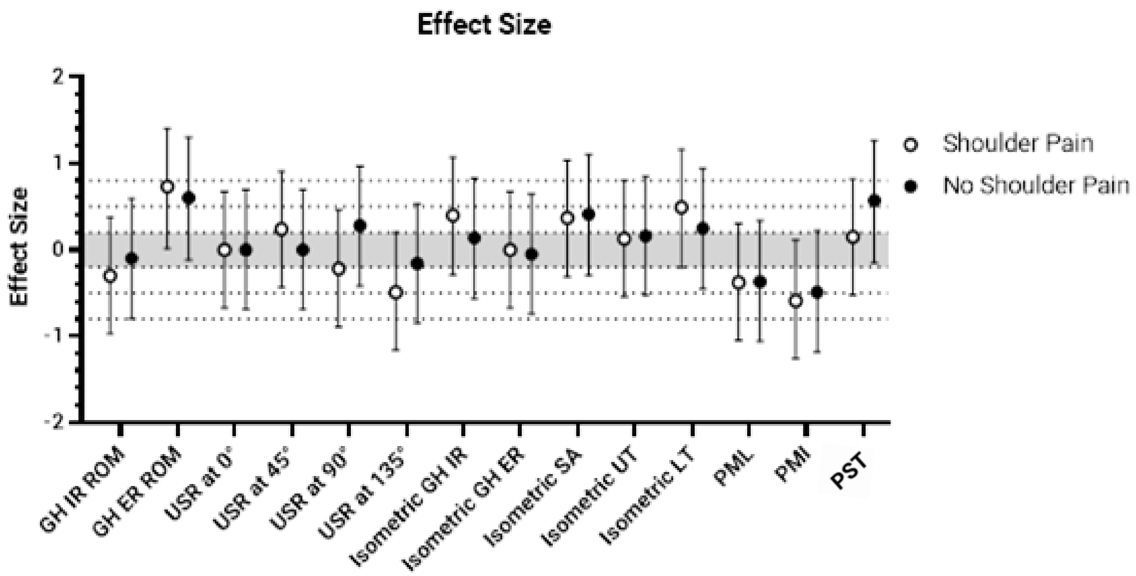


Figure 3: Effect size of different shoulder tests

3.3.5 Training Load

There was a significant difference between shoulder pain/no shoulder pain and the hours of water polo matches in weeks 3-4, with a higher work load in the shoulder pain group (4.1 ± 2.3) compared to the no shoulder pain group (2.0 ± 1.6) (U = 53.5, p = 0.008) (Figure 4 & 5; Table 10).

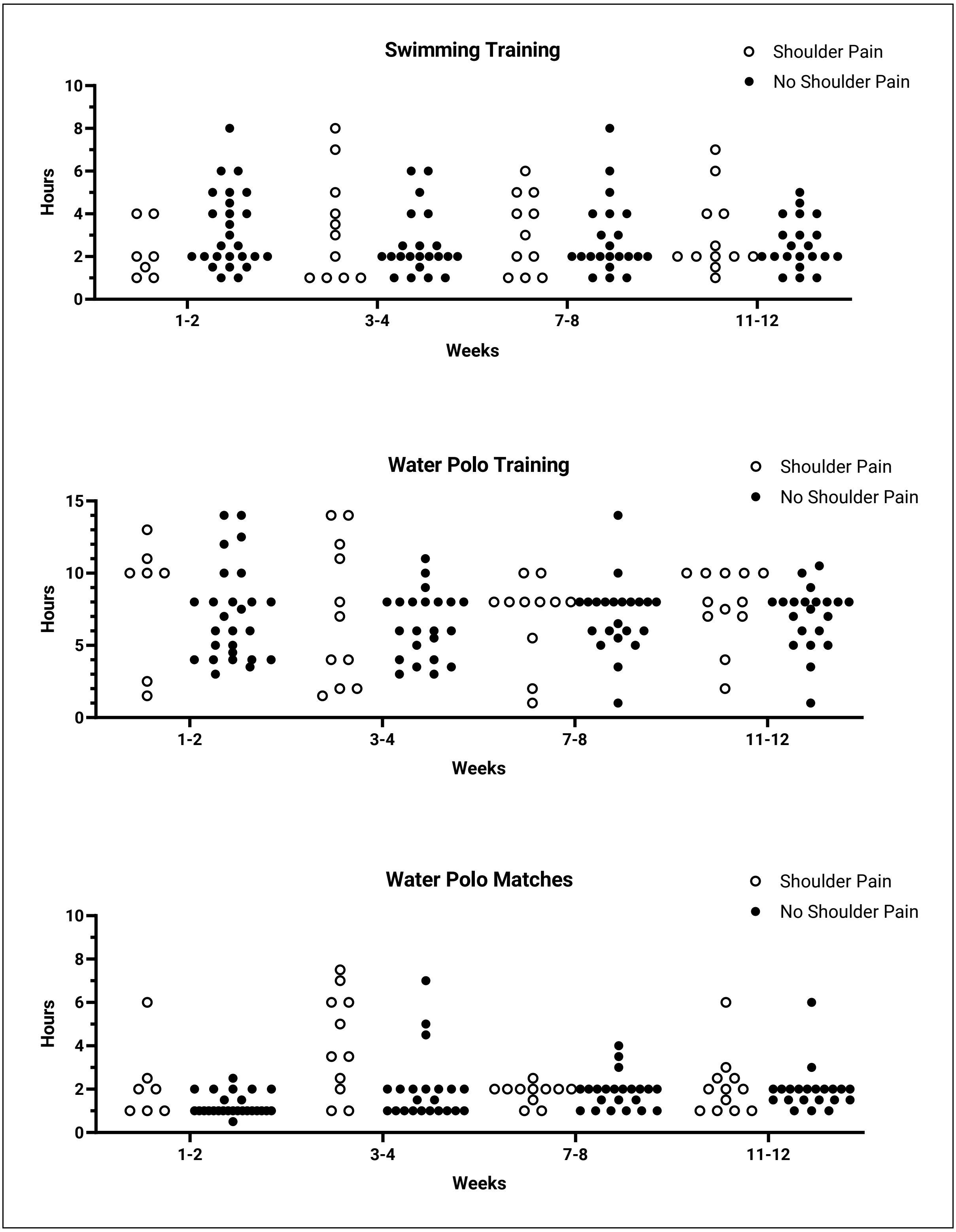


Figure 4: Individual self-reported training load (hours) of the shoulder pain and no shoulder pain groups for swimming training, water polo training and water polo matches, reported for weeks 1-2, 3-4, 7-8, and 11-12.

Table 10: Mean training hours (swimming training, water polo training, water polo matches) of the shoulder pain and no shoulder pain groups respectively, reported for weeks 1-2, weeks 3-4, weeks 7-8, and week 11-12.

	Weeks 1-2			Weeks 3-4			Weeks 7-8			Weeks 11-12		
Variable	**All (n = 33)**	**Shoulder Pain (n = 7)**	**No Shoulder Pain (n = 26)**	**All (n = 33)**	**Shoulder Pain (n = 11)**	**No Shoulder Pain (n = 22)**	**All (n = 33)**	**Shoulder Pain (n = 11)**	**No Shoulder Pain (n = 22)**	**All (n = 33)**	**Shoulder Pain (n = 12)**	**No Shoulder Pain (n = 21)**
Swimming Training	3.0 ± 1.7	2.2 ± 1.3	3.2 ± 1.8	2.8 ± 1.9	3.3 ± 2.5	2.6 ± 1.5	2.9 ± 1.7	3.1 ± 1.8	2.8 ± 1.7	2.7 ± 1.4	3.0 ± 1.9	2.6 ± 1.2
Water Polo Training	7.4 ± 3.5	8.3 ± 4.4	7.2 ± 3.3	6.7 ± 3.3	7.2 ± 4.9	6.4 ± 2.3	7.0 ± 2.6	7.0 ± 3.0	7.0 ± 2.6	7.3 ± 2.3	7.8 ± 2.6	7.0 ± 2.2
Water Polo Matches	1.8 ± 2.1	3.6 ± 4.1	1.3 ± 0.5	2.7 ± 2.1	4.1 ± 2.3	2.0 ± 1.6	1.9 ± 0.7	1.8 ± 0.5	1.9 ± 0.9	2.0 ± 1.2	2.3 ± 1.4	2.0 ± 1.0

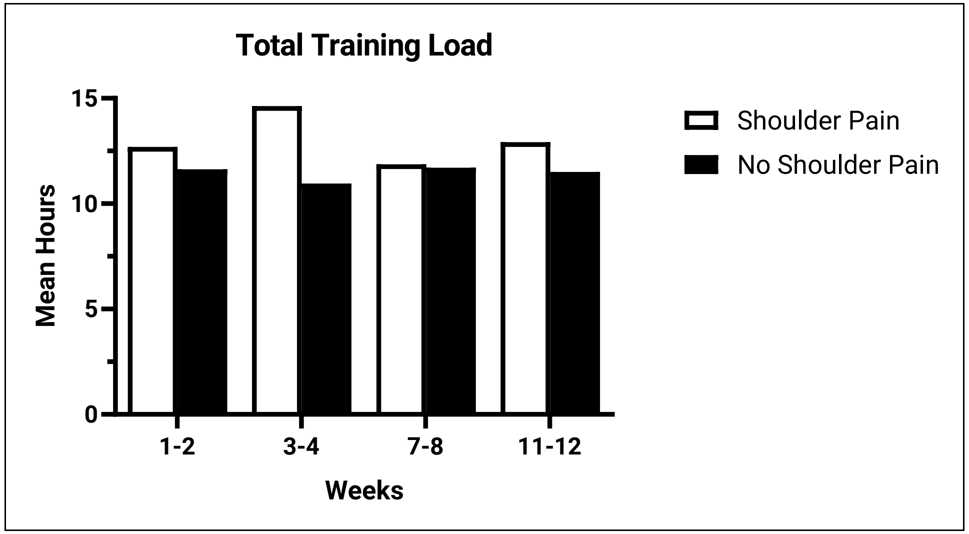


Figure 5: Total training load (mean hours of swimming, water polo training and water polo matches) for the shoulder pain (n = 17) and no shoulder pain (n = 16) groups for weeks 1-2, 3-4, 7-8, and 11-12.

3.3.6 Strength Rating

There were significant differences between shoulder pain and mean strength rating scores (Figure 6.1 & 6.2; Table 11), with lower mean scores in the shoulder pain group, compared to the no shoulder pain group for the following variables:

- **Passing** – weeks 1-2 (U = 29.5, p = 0.005), weeks 3-4 (U = 53.5, p = 0.008), weeks 7-8 (U = 24.5, p = 0.0001), and weeks 11-12 (U = 35, p = 0.0001)
- **Shooting** – weeks 1-2 (U = 35, p = 0.010), weeks 3-4 (U = 45.5, p = 0.003), weeks 7-8 (U = 18, p = 0.0001), and weeks 11-12 (U = 32, p = 0.0001)
- **Swimming** – weeks 1-2 (U = 32, p = 0.008), weeks 3-4 (U = 45, p = 0.003), weeks 7-8 (U = 39.5, p = 0.001), and weeks 11-12 (U = 66, p = 0.021)
- **Defending** – weeks 11-12 (U = 71, p = 0.032)
- **Gym training** – weeks 1-2 (U = 56.5, p = 0.048), weeks 3-4 (U = 52, p=0.007), weeks 7-8 (U = 47.5, p = 0.004), and weeks 11-12 (U = 64, p = 0.017)

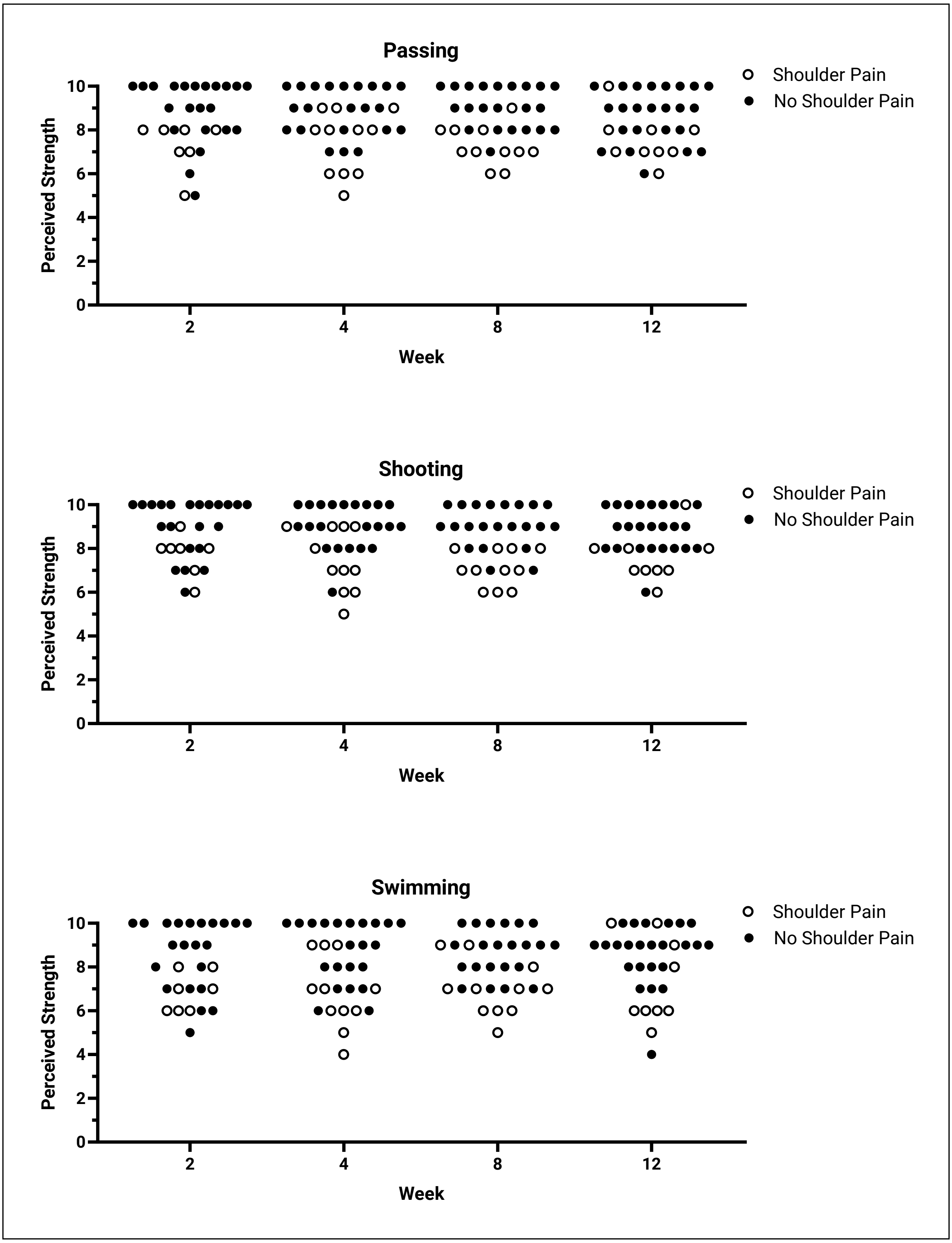


Figure 6.1: Individual perceived strength rating of the shoulder pain and no shoulder pain groups for passing, shooting and swimming for weeks 1-2, 3-4, 7-8, and 11-12.

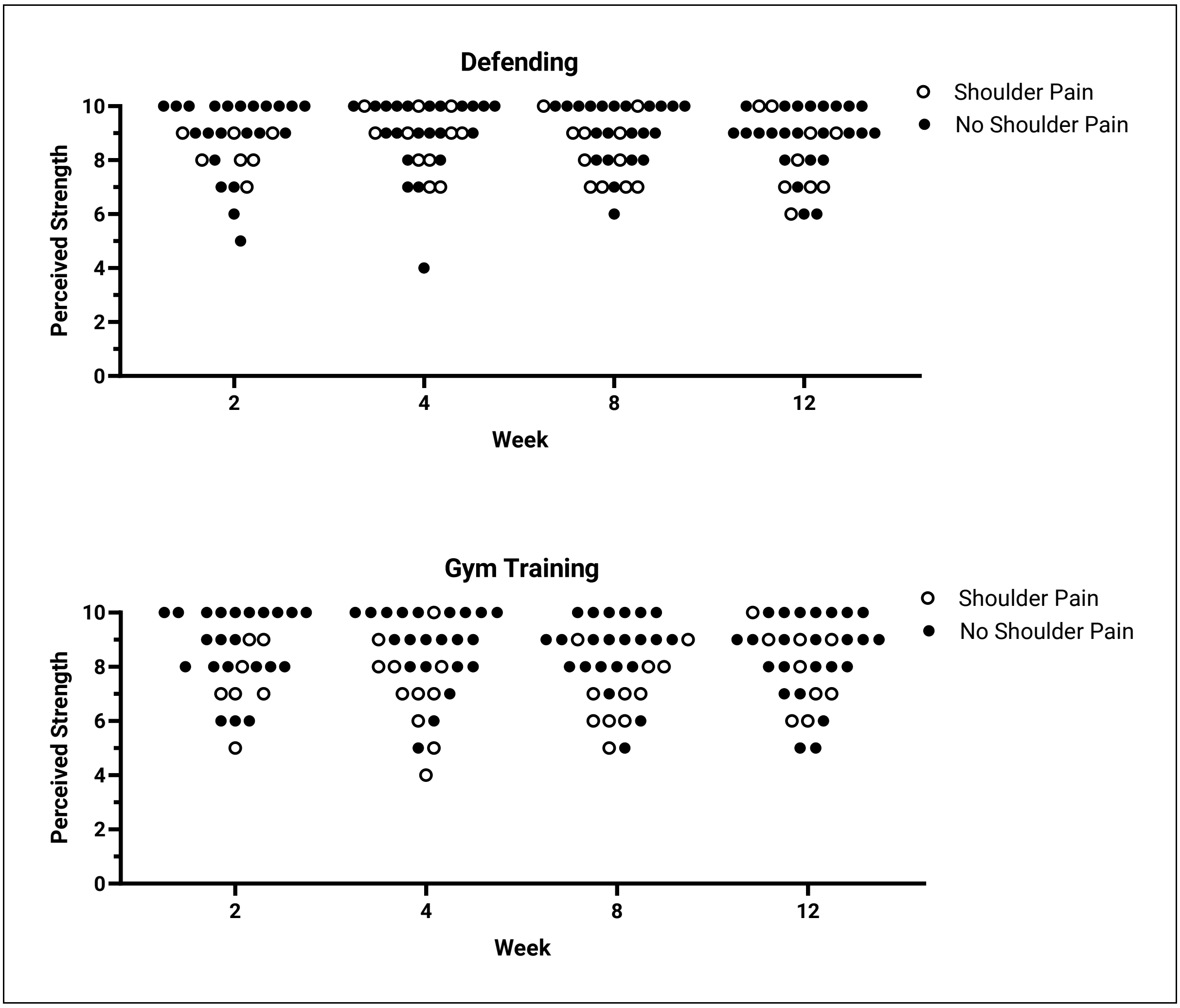


Figure 6.2: Individual perceived strength rating of the shoulder pain and no shoulder pain groups for defending and gym training for weeks 1-2, 3-4, 7-8, and 11-12.

Table 11: Mean strength rating on a scale of 0-10 (0 = no strength; 10 = maximal strength) for different shoulder activities (passing, shooting, swimming, defending and gym training) for all participants (n = 33), the shoulder pain and no shoulder pain

	Weeks 1-2			Weeks 3-4			Weeks 7-8			Weeks 11-12		
Variable	**All (n=33)**	**Shoulder Pain (n=7)**	**No Shoulder Pain (n=26)**	**All (n=33)**	**Shoulder Pain (n=11)**	**No Shoulder Pain (n=22)**	**All (n=33)**	**Shoulder Pain (n=11)**	**No Shoulder Pain (n=22)**	**All (n=33)**	**Shoulder Pain (n=12)**	**No Shoulder Pain (n=21)**
Passing	8.6 ± 1.5	7.3 ± 1.1	8.9 ± 1.4	8.4 ± 1.4	7.5 ± 1.4	8.9 ± 1.1	8.5 ± 1.3	7.5 ± 0.9	9.1 ± 1.0	8.4 ± 1.3	7.3 ± 1.1	9.0 ± 1.0
Shooting	8.8 ± 1.3	7.7 ± 1.0	9.0 ± 1.2	8.5 ± 1.3	7.5 ± 1.4	9.1 ± 1.1	8.4 ± 1.3	7.3 ± 1.0	9.1 ± 1.0	8.2 ± 1.6	7.3 ± 1.1	9.1 ± 0.8
Swimming	8.2 ± 1.6	6.7 ± 0.9	8.6 ± 1.5	8.1 ± 1.7	6.8 ± 1.7	8.7 ± 1.4	8.1 ± 1.4	7.3 ± 0.9	9.1 ± 1.0	8.3 ± 1.6	7.3 ± 2.0	8.9 ± 1.0
Defending	8.7 ± 1.5	8.3 ± 0.8	8.8 ± 1.6	8.9 ± 1.4	8.7 ± 1.1	9.0 ± 1.5	8.8 ± 1.2	7.3 ± 0.9	9.1 ± 1.0	8.7 ± 1.3	8.0 ± 1.4	9.1 ± 1.1
Gym Training	8.4 ± 1.5	7.4 ± 1.4	8.7 ± 1.4	8.3 ± 1.7	7.2 ± 1.7	8.8 ± 1.4	8.1 ± 1.5	7.3 ± 0.9	9.1 ± 0.9	8.3 ± 1.5	7.4 ± 1.7	8.8 ± 1.2

3.3.7 Compliance

Participants were fully compliant with the pre-season screening. Compliance to the self-report questionnaire was good for weeks 1-2 (94%) and 3-4 (73%) and poor compliance was initially achieved for weeks 7-8 (15%) and 11-12 (9%). However, with regular ad hoc reminders sent to participants to complete the questionnaire, 100% compliance was achieved for all assessment periods.

3.4 Discussion

The results from the current study builds on the limited research regarding shoulder injuries among adolescent water polo players. This study found that 52% of participants experienced shoulder pain during the 12-week monitoring period. This figure is in line with the findings from two other studies of male adolescent water polo players in South Africa, where it was reported that 51.04% of athletes sustained shoulder injuries within a 12-month period [42] and 49% developed shoulder pain within a 3-month period. [43] This is higher than the findings in the study by Gradidge *et al.*[41] where 8.3% of adolescent water polo players reported a recent shoulder injury (within 1 month). This disparity may be partially explained by differences in the definition of “shoulder injury” used in different studies.

The main finding of this study was a significant interaction between pain groups and dominance for isometric IR strength; those with shoulder pain had significantly stronger isometric IR on the dominant side. Participants with shoulder pain were also significantly older and heavier than those without shoulder pain, with a higher predicated age from PHV in the pain group. A difference in training load was found between pain groups for the number of hours of water polo matches played at weeks 3-4, with a significantly higher training load in shoulder pain group over those 2 weeks. A number of significant musculoskeletal asymmetries were also observed; however, these were not associated with pain.

3.4.1 Descriptive Characteristics

The participants who developed shoulder pain were on average significantly older, heavier and their predicted age from PHV was higher compared to the participants without shoulder pain. These results are consistent with a systematic review on various sports (including baseball, basketball, football and soccer among others) that found the risk of injury in young athletes consistently increases with age, with those >13 years of age at greater risk than younger athletes. [11] The study also reported that taller and heavier athletes were more susceptible to injury due to greater forces placed on the joints and soft tissues structures. [11]

Participants of this study reported the activity most commonly associated with shoulder pain was swimming, not throwing, and bilateral shoulder pain was commonly reported. This would suggest that the musculoskeletal profile of the non-dominant side is indeed important and that the implications of significant asymmetries observed in this study should be investigated further in a larger study population. The pain rating results showed that participants mean pain scores are mild to moderate and ranged from 2-10 on the NPRS. Pain intensity has not been reported in studies evaluating water polo players. The findings indicate that these adolescent players are playing through their mild-moderate shoulder pain. It has been reported that competitive adolescent swimmers believe a mild to moderate amount of amount of shoulder pain is considered normal in swimming. [219] The clinical implication of a finding of this nature is that players may delay seeking medical attention for their shoulder pain which would increase the chronicity of injuries and may impact the response to treatment.

The results suggest that the group with shoulder pain may be the more experienced, key players on their respective teams, with a higher acute and chronic playing load and who potentially generate greater forces during throwing. These players appear to be more vulnerable to shoulder pain and it is clear that specific interventions to reduce the high incidence of shoulder pain are needed.

3.4.2 KJOC Score

The KJOC score is an effective questionnaire for the functional assessment of overhead athletes. [159, 162] Lower KJOC scores were not significantly associated with shoulder pain, however the mean KJOC score for the shoulder pain group was less than 90 (87.6 ± 15.6) which is below the recommended baseline score for healthy overhead athletes, based on a study among baseball pitchers. [162] These findings are similar to another study of male adolescent water polo players in which the pre-season mean KJOC score in the shoulder injury group (77.1 ± 14.5) was significantly lower than the uninjured group (91.3 ± 5.9) ($U = 98.0$; $p = 0.01$). [43]

In a study of male collegiate level swimmers, the baseline KJOC scores were much lower (81.9 ± 15.6) than expected. [163] Swimmers competing for more than 11 years had lower baseline KJOC scores than those competing for less than 10 years, which the authors argue is due to a cumulative effect of swimming. [163] This study did not find any significant association between the number of years playing and a lower KJOC score, however in the shoulder pain group the mean years of playing was higher (6.8 ± 1.8) than those without pain (5.3 ± 1.3), which, combined with the lower KJOC scores in the pain group, may indicate a trend towards a cumulative loading effect.

In this study a history of previous shoulder pain was correlated to a lower KJOC score. Although the current study did not find a significant association between previous shoulder injury and current shoulder pain, it has been reported in the literature as a risk factor for injury among swimmers, [103] throwers [102] and water polo players. [99]

Question 1 of the KJOC questionnaire with the lowest mean score (8.3 ± 2.4) was related to feeling warmed up before practice/games (i.e., it takes players longer than normal warm up time to feel loose). This may have practical implications for coaches and trainers. Longer or more efficient warm ups are necessary for players to feel more confident in their shoulder function prior to training and match play.

These results provide a baseline KJOC score for adolescent male water polo players, which seem to be in line with the baseline scores for baseball pitchers, [162] rather than the baseline scores for swimmers. [163] Administering the KJOC questionnaire pre-season may aid coaches and clinicians to identify players who are potentially at risk for shoulder injury in the season and can provide insight into players perceptions of their shoulder health and function.

3.4.3 Pain Provocation Tests

Orthopaedic special tests are used as part of the shoulder assessment to help diagnose shoulder pathologies. [165, 168, 220] In this study there were no significant findings between a positive result on any of the pain provocation tests and the development of shoulder pain. This differs to the findings of a recent study that found 65.4% of players with pain on one or more pain provocation test in the pre-season went on to develop shoulder pain during the season. [43]

It has been suggested that the Hawkins-Kennedy special test is most useful in ruling out subacromial impingement when the test is negative, [221] however there is debate in the literature about the usefulness of the diagnosis of subacromial impingement [221, 222] due to the broad range of pathologies it may encompass. [223] While there may be some benefit to using these pain provocation tests in conjunction with other shoulder special tests and physical examination of the shoulder, there is limited use for them individually [165, 168, 221] and it is advised that clusters of tests be used to improve diagnostic accuracy of shoulder pathologies. [165]

Our findings do not support the inclusion of pain provocation tests in the screening for shoulder injuries of water polo players, however a cluster of special tests may be useful in the assessment of shoulder injuries for water polo players.

3.4.4 Glenohumeral Range of Motion

The participants in this study had significant asymmetries in shoulder ROM, with greater ER ROM and greater TROM demonstrated in the dominant shoulder. The IR, ER and TROM results are consistent with those of a previous study on male adolescent water polo players who identified significant side asymmetries in GH rotation [43] and together these provide a good reference for male adolescent water polo players GH ROM.

The findings are consistent with the results of a previous study of college-level water polo players. [78] The authors postulate that the repetitive ER motion elongates the inferior GH ligament, and that IR ROM is preserved due to the demands of swimming. [78] Increases in ER ROM and TROM have also been observed in previous studies of other overhead throwers, and this has been associated with improved throwing performance. [4, 53] This may be due to longer wind-up, longer available acceleration distance and the potential for a greater throwing velocity at the end of release. [17, 31, 224, 225] The ERG observed in overhead athletes, especially at a young age, has been attributed to the demands of throwing. [226] The current study found no association between ER ROM and shoulder pain, which is similar to other studies. [51, 107 43]

In the current study, TROM was greater on the dominant shoulder but still not approaching 180°. Previous studies have found a TROM difference of > 5° [120] in baseball pitchers to be a risk factor for injury, and > 7.5° [107] in water polo players to be predictive of subsequent injury. While the mean TROM difference was > 5° in this study, there was large variability among individuals. This study did not find any association between TROM and shoulder pain or TROM difference and shoulder pain.

Swimmers tend to have a bilateral increase in shoulder ROM, [78] however most studies have not found significant associations between GH ROM and shoulder pain. [49, 227] One study found that swimmers with either high (≥ 100) or low (< 93) ER ROM had an increased risk of developing shoulder pain, but there was no association between IR ROM and shoulder pain in the current study. [103] In contrast, a study by Tate *et al.* found that reduced IR ROM was linked to shoulder pain. [10] Water polo players do not present with the same shoulder profiles as swimmers, likely due to the asymmetrical nature of the sport and repetitive throwing.

GIRD has been investigated in baseball players [109, 120, 228, 229] and elite water polo players. [107, 230] A study of adolescent water polo players identified GIRD in 14% – 62% of participants, depending on the definition of GIRD used. [97] The authors could not identify the cause of GIRD, however an increase in pre-season training hours was approaching a correlation with GIRD, indicating a potential causal relationship. [97] Among baseball pitchers, a significant association has been found between TROM, strength and GIRD. [109] In this study there was no statically significant findings for GIRD and only 1 participant had a score ≥ 20° which is considered clinically relevant. However, 21% of participants in this study had an IR loss of > 13° which is considered a risk for injury among adolescent baseball pitchers. [119] The mean GIRD scores are slightly lower another study of adolescent water polo players (5.1° ± 12.4°) [43] and much lower than the results of other overhead athletes, which range from 10° to 25°. [97, 107, 119, 120, 228, 231]

3.4.5 Upward Scapular Rotation

Overhead throwers exhibit changes in scapular positioning compared to non-throwers. [21] Scapular dyskinesis has previously been identified as a risk factor for shoulder injury in baseball, [21, 199] cricket, [55, 135] handball [53] and water polo, [43] A study of adolescent water polo players identified a significant association between increased USR at 90° abduction of the dominant shoulder and the development of shoulder pain. [43] The current study however, did not find any associations between USR and shoulder pain. Previous studies of symptomatic and asymptomatic throwing athletes have identified reduced USR at full GH elevation in the dominant shoulder compared to the non-dominant shoulder is predictive of shoulder injury, [122, 166, 232, 233] but although the scapula appeared more downwardly rotated throughout the movement in this group it was not a risk factor for shoulder pain.

Although this study did not find any significant associations between USR and shoulder pain, the results can inform clinicians about the presentation of the shoulder among this population and may provide a basis for future comparison.

3.4.6 Isometric Strength

The main finding in this study was the significant interaction between shoulder pain/no shoulder pain and dominance for isometric IR strength. The dominant throwing arm is significantly stronger in the shoulder pain group, which indicates that the potentially more powerful throwers are experiencing more shoulder pain. IR muscle strength is required for defending, swimming and throwing in water polo. Previous studies have identified greater strength of the IR muscles in overhead throwers and water polo players compared to ER muscles. [23, 51, 107, 110, 111, 231] [43] A relationship between IR strength and shoulder pain has not previously been identified among other overhead sports, [53, 56] however both IR and ER strength deficits have been associated with shoulder injury among adult water polo players. [107, 108] In the current study, shoulder pain may be more related to chronic workload which may impact key players with strong throwing arms.

In order to decelerate the arm and reduce forces on the shoulder joint during throwing, water polo players need to have adequate ER muscle strength to balance the IR muscles. [56, 111] Weakness of the ER muscles has been associated with subsequent shoulder injury among other overhead throwers. [53, 56, 231, 234] Evaluating ER strength in relation to IR strength is considered an important part of injury prevention and rehabilitation. [194, 231, 235] The relative weakness of the shoulder ER muscles in the dominant shoulder in this study, as reflected by the reduced ER:IR strength ratios, may hinder the athlete's ability to eccentrically control the deceleration of their throw. ER muscle weakness has also been identified in a study of female water polo players, with lower peak torque values for concentric and eccentric ER muscles in comparison to the IR muscles. [236] The ER:IR strength ratios in the current study were lower than those recommended for healthy shoulders [237] as well as adolescent water polo players, [43] swimmers [218] and overhead athletes. [53, 55-57] The mean isometric IR strength values were similar to tennis, volleyball and handball athletes, [217] yet the ER strength values were lower which indicates this population of water polo players may be over-strengthening their IR muscles due to throwing/playing load or gym training, and/or neglecting to strengthen their ER muscles. A systematic review reported a wide range in strength ratios among water polo players, [28] and the optimum ratio for adolescents has not been established.

A study of sub-elite water polo players identified reduced IR and ER strength as a percentage of body weight (PBW) as predictors of in-season shoulder injury among sub-elite water polo players. [107] Cut-off values of IR strength ≤ 16.8% of PBW and ER strength ≤ 12.5% were identified as increasing the likelihood of shoulder injury. The study found IR strength to be the strongest discriminator of predicting shoulder injury and the authors attribute this to the demands of repetitive overhead throwing, swimming and defending. [107]The current study did not find a significant association between reduced strength as PBW and shoulder pain, however there was a significant difference between dominant and non-dominant shoulders for isometric IR as PBW. Interestingly none of the participants fell below the cut-off value for isometric IR as PBW in the dominant shoulder but 39% were below the cut-off value for isometric ER as PBW in the dominant shoulder, further highlighting the relative weakness of the ER muscles in this population. Cut-off values for reduced isometric strength as PBW may need to be adjusted for this younger population of water polo players.

The scapular muscles are important for USR and control through GH elevation. [22, 238] In this study isometric strength of the scapular muscles was not associated with shoulder pain, however significant asymmetries were identified. The scapular muscles in the dominant shoulder were significantly stronger than the non-dominant. A previous study of adolescent water polo players found significant asymmetrical strength of the LT muscles, a non-significant difference for SA, and symmetrical side strength for UT muscles. [43] In contrast to the current study, weakness of the SA and LT muscles on the dominant side was identified and was linked to altered scapular kinematics in the dominant shoulder of those with shoulder pain. [43] Previous studies of scapular muscles in other overhead athletes have found conflicting results. [50, 231, 239] It has been suggested that stronger SA and UT muscles in the dominant shoulder may lead to muscle imbalances, and therefore an increased risk of injury. [177] Strengthening the SA, [22] middle trapezius [177] and LT [22, 177] [43] muscles may be beneficial in reducing injury risk in overhead athletes.

Identifying and applying an intervention to players with strong dominant shoulder IR muscles and relatively weak ER muscles, may help to reduce injury among this population. As a number of participants in this study presented with bilateral shoulder pain, the asymmetry of the scapular muscle strength may be an important consideration and warrants further investigation within this population.

3.4.7 Shoulder Flexibility

Participants had significantly shorter PML and lower PMI in the dominant shoulder, however there was no relationship between these variables and shoulder pain. Reduced PML is observed bilaterally in swimmers, [10, 16] however the findings from this study seem to be in line with other studies of tennis players [177] and water polo players [43] where a shortened pectoralis minor has been identified in the dominant shoulder only. Furthermore, a smaller PMI has been observed in the dominant shoulder of overhead athletes. [117, 177] Shorter PML has been linked to altered scapular kinematics and an increased risk for shoulder impingement during the overhead motion. [23, 117, 136] The participants in this study did not have significantly altered scapular rotation on the dominant side, despite the significant difference in PML and PMI although it is acknowledged that the measurement of upward scapula rotation is a relatively static assessment of scapula positioning. The strong SA muscle in the dominant shoulder may offer resistance to the shortened pectoralis muscle to prevent altered scapular positioning, as proposed by Habechian *et al.* [240] for competitive swimmers. Furthermore it has been suggested that optimal PML is influenced by the inner strength of the lower trapezius. [117]

Previous research has found tightness of the posterior shoulder complex among overhead throwers [8, 9, 55, 129, 130] and swimmers. [219] This study did not identify any significant differences in PST between participants who developed shoulder pain and those who did not, nor any significant asymmetries between sides. The findings are in similar to studies of adolescent [43] and college-level [78] water polo players. This suggests that water polo players may not present with a typical throwers shoulder, nor the same adaptive changes to the shoulder seen in swimmers.

3.4.8 Shoulder Stability

The CKCUEST is a functional test that may identify deficits in muscle strength, motor control issues and proprioception. [182] [215] The current study did not identify a significant association between the CKCUEST scores and shoulder pain. Results from this study are similar to the reference values that have been established for healthy, physically active adolescents. Only one study has assessed the CKCUEST among adolescent water polo players and there were no significant associations between lowers scores and shoulder pain, however the group that developed shoulder injury had lower average and power pre-season scores compared to the uninjured group. [43] A study of American football players found that players with an average score of less than 21 were more likely to sustain shoulder injuries during the season. [241] In the current study only 2 participants scored less than 21 and they did not go on to develop shoulder pain during the monitoring period of this study. Therefore, the cut-off value of 21 for the average CKCUEST score may not indicate injury risk among male adolescent water polo players.

The CKCUEST is particularly useful among football players as it mimics the upper limb position commonly used and can assess a players ability to transfer weight through the shoulder. [241] As water polo players do not adopt this closed-chain position during play, there may be limited use for the test among this population. However, closed chain activities are prescribed for early stage rehabilitation of upper extremity injuries [194], and this is an easy to administer test that may serve as a useful baseline or assessment tool. This test may also be useful as a way to motivate players to improve their strength and speed.

3.4.9 Training Load

Participants with shoulder pain reported a significantly higher number of hours playing water polo matches (4.1 ± 2.3) than those without pain at weeks 3-4 (2.0 ± 1.6) ($U = 53.5$, $p = 0.008$). These findings indicate that an increase in competitive match play, likely around tournaments, is a risk factor for injury among adolescent water polo players. This is consistent with two systematic reviews that identified an increased risk of injury during tournament play compared to training for adolescent athletes [11] and overhead athletes. [5] As the players with shoulder pain in this study were on average older, it may also indicate a trend towards a cumulative over-loading.

While the role of throwing load injury was beyond the scope of this study, a previous study of female water polo players found that higher volumes of shooting were associated with increased shoulder soreness. [152] High volumes of throwing without adequate short- and long-term recovery periods may lead to arm pain and injury in overhead athletes. [201] Monitoring the throwing and/or shooting load of water polo players may help identify at-risk athletes.

In this study swimming was commonly reported to be a mechanism of onset of pain. While it has been reported that repetitive overhead arm movements during swimming training and the high intensity of swimming can contribute to the development of shoulder pain among swimmers, [70] a systematic review reported that it is unclear if a high swimming load, intensity and volume directly contribute to shoulder pain among swimmers as results from studies are inconsistent. [6] Among elite swimmers, training mileage of > 35km per week is associated with an increased likelihood of supraspinatus tendinopathy and furthermore intense training led to increased tendon thickness, a sign associated with tendinopathies. [70] It was beyond the scope of this study to track swimming mileage or measure of supraspinatus tendon thickness; however, it would be useful to identify the swimming mileage among water polo players in order to find the optimal loading, and compare tendon changes in this population. There may be a different relationship between swimming volume and shoulder pain in water polo players, who swim for fitness, utilise a different swimming stroke, and also throw and use their shoulders defensively.

These results provide a reference for the training load of this population. The participants trained on average for 12 hours per week, including match play. While there was a wide range in the training hours observed in this study, the results are comparable to male adolescent water polo players in Croatia that train 10 – 15 hours per week, with 30 – 50% swimming training, 30 – 50% water polo-specific training, and 12 – 25% dry land training. [150] Tracking training loads across a full season of water polo may help to further identify periods of increased risk.

3.4.10 Self-reported Strength Ratings

Participants in the shoulder pain group had significantly lower self-reported strength scores for passing, shooting, swimming, defending and gym training than the no-pain group. This is an interesting finding as the participants in the pain group presented on average with stronger shoulders. The presence of shoulder pain was associated with feelings of reduced strength, which could have an impact on performance.

3.4.11 Limitations of this Study and Recommendations for Future Research

Studies investigating injury, muscle strength, throwing performance, posture and shoulder ROM among water polo players had total sample sizes varying between 10 – 100 participants. [41, 42, 61, 77, 107, 108, 242] This study had a sample of 33 male water polo players and although this sample was large enough to provide statistical power, it is recognised that a larger sample would have provided a better representation of the effect of the risk factors for shoulder injury among water polo players. Furthermore, the results may be limited by selection bias and cannot be generalised to children as this study only included adolescents >14 years of age and most participants were older than their PHV age. Most of the participants were older than their PHV, indicating the group was largely homogenous. The small effect sizes may also limit the generalisability of the results.

The definition of shoulder pain in this study may be a limitation. In a study of water polo players, a higher incidence of shoulder injuries was found when examining athlete self-reported data compared to physiotherapist-reported data. [61] It is therefore important to note that the participants in this study reported their shoulder pain independent of diagnosis of injury by a health professional and time-off from sport was not considered part of the definition of pain or injury. This may have led to the inclusion of participants with acute, mild symptoms in the shoulder pain group. There may also be recall bias as not all the participants completed the bi-monthly questionnaire timeously.

It was beyond the scope of this study to assess the intensity of each training session or match. This is an area that could be examined to better understand the effects of overtraining on shoulder pain among water polo players. Future studies should investigate throwing repetition, throwing velocity and accuracy, swimming intensity, and look at comparisons between match play versus practice.

This study made use of a HHD for isometric muscle strength testing as it is a valid, reliable, cost-effective and accessible tool. [243] Inclusion of eccentric testing for shoulder ER in future studies might provide a better insight into the deceleration component of throwing and build on the knowledge of rotator strength ratios and risk of injury.

It has been reported that asymmetries change during the season as a result of accumulative fatigue. [108, 244] The results from this study are only representative of pre-season asymmetries.

3.5 Conclusion

In conclusion, this population of male adolescent water polo players had a high incidence of non-specific shoulder pain. Pain was commonly reported bilaterally or on the dominant shoulder only. The shoulder pain group had significantly stronger isometric IR strength on the dominant shoulder and they were taller, heavier and had a higher predicted age from PHV than the group without pain. Pain was associated with a higher number of hours of match pain at weeks 3 – 4. The participants presented with asymmetries in shoulder and scapular strength, ROM and flexibility, and further research is needed to evaluate the efficacy of an intervention aimed at asymmetry. The pain group also had KJOC scores below 90, and a previous history of shoulder injury was correlated to a lower KJOC score. This study adds to the current body of literature on water polo players and pain. It will be beneficial to address modifiable musculoskeletal variables in future studies.

Chapter 4: Summary and Conclusion

4.1 Summary

Water polo is a fast-growing sport with a high incidence of shoulder injury. While the term injury prevention is commonly used to describe strategies to reduce the incidence and prevalence, it is acknowledged that 100% prevention is unlikely due to the complex nature of injury aetiology. It is proposed that understanding the risk factors may result in a reduction of injury in this overhead throwing population. The aim of this study was to assess the incidence of shoulder pain in male adolescent water polo players and to determine the contribution of intrinsic and extrinsic risk factors in the development of non-specific shoulder pain. The literature identified risk factors for shoulder injury in overhead sports and swimming, including age, height, shoulder and scapular muscle weakness, altered GH ROM and GIRD, pectoralis minor tightness, altered scapular control, high training loads and throwing with a fatigued arm. Among water polo players, a high incidence of shoulder injury was found in the adolescent population. While there is growing evidence for risk factors for injury in other overhead sports such as overtraining, shoulder muscle weakness, altered GH ROM, reduced pectoralis minor length, altered scapular control and reduced proprioception, there are a limited number of studies that have evaluated these among adolescent water polo players. The literature review highlighted significant gaps in our understanding of the mechanism of shoulder pain in water polo player, especially for younger players.

The first specific objective of this study was to determine the incidence of shoulder pain in male adolescent water polo players over a three-month season. This study identified a high incidence (52%) of shoulder pain in this population over a 12-week period. The second objective was to describe the population of male adolescent water polo players with respect to intrinsic shoulder variables. This objective was met and the population was described in terms of history of injury, anthropometric characteristics, muscle weakness and imbalances, GH ROM, PST, USR, PML, AHD and proprioception. The third objective was to determine the relationship between intrinsic/extrinsic shoulder variables and shoulder pain over a 12-week period. Participants with shoulder pain were significantly older, heavier and had higher predicated age from PHV than those without shoulder pain. Greater isometric IR strength in the dominant arm was significantly associated with shoulder pain, indicating that the more powerful throwers are developing shoulder pain. There were significant side asymmetries in this population: decreased GH ER ROM and TROM in the dominant arm, greater isometric IR, UT, SA, and LT strength in the dominant arm, as well and reduced PML and PMI in the dominant arm compared to the non-dominant arm. However, these variables were not associated with shoulder pain.

Participants who developed shoulder pain had a KJOC score below the recommended score for healthy overhead athletes, and a lower score was correlated to a previous history of injury. Those with shoulder pain also reported lower perceived strength scores for passing, shooting, swimming, defending and gym training.

The final specific objective of this study was to assess the training load of this population. Participants trained on average for 12 hours per week, including swimming training, water polo training and water polo matches, comparable to other adolescents. A greater number of hours of match play at weeks 3 – 4 was associated with shoulder pain, suggesting that an increase in competitive match play, typically associated with tournaments, increases the risk of players experiencing shoulder pain.

In conclusion, the findings of this study suggest that age, weight, greater isometric IR strength in the dominant arm and an increase in competitive match play are associated with shoulder pain in this population of male adolescent water polo players. Addressing the modifiable musculoskeletal risk factors for shoulder pain may help to reduce the prevalence and it is hoped this study could provide a basis for further investigation into shoulder pain among water polo players in the adolescent population.

4.2 Clinical Implications

The high prevalence of shoulder pain is a concern for this population. This study simply identified shoulder pain and did not define an injury by missed participation in practice/matches or the need for medical attention. However, the high incidence of pain in a 12-week season is similar to trends observed in adult water polo and is a reason for concern for vulnerable adolescent athletes.

Greater isometric IR strength in the players who experienced shoulder pain is not an altogether surprising finding, as both swimming and throwing require strong IR to propel the ball and ball. It appears to suggest that the stronger water polo players are more vulnerable for shoulder pain. This finding was strongly linked to age and it is likely that the older, more experienced players are key players in their respective teams, with greater acute (more pool time during matches) and chronic workloads (years playing water polo). Further studies that investigate the role acute and chronic workloads on these young, developing athletes, would add value.

It is advised that players strengthen the relatively weak ER muscles in order to more effectively counteract the strong IR muscles, and control through the deceleration phase of throwing. Shoulder asymmetries in scapular muscle strength, ROM and flexibility should also be addressed to reduce shoulder pain. As pain was often experienced in both shoulders simultaneously and swimming was frequently reported to be the activity of onset, it is clear that throwing is not the only mechanism of injury. Therefore, addressing asymmetries may reduce shoulder pain in those with non-dominant shoulder pain. Table 12 provides some evidence-based exercises to address the deficit in external rotation strength and asymmetries in flexibility and scapular strength. Future studies could investigate the efficacy of effectiveness of a shoulder conditioning program which utilises exercises of this nature.

Preseason testing should be implemented where possible to identify at-risk athletes. The KJOC score is easy to administer, cost effective, and can help to identify athletes who are vulnerable. This may also assist coaches to identify players who have not recovered from shoulder pain or injury in the previous season, and may inform their training programs. It is recommended that physical testing include isometric strength testing of the shoulder rotator and scapular muscles, and measurement of height, weight, GH ROM and PML if possible.

Finally, it is advised that coaches structure training programs appropriately to reduce the risk of shoulder pain during periods of high loads of competitive match play, particularly around tournaments. At- risk players should be closely monitored and adequate recovery time should be allocated for all players.

Table 12: Exercises for prevention of shoulder pain in water polo players

Exercise	Purpose	Reference
Prone row into ER	Strengthens the ER muscles in a functional 90°/90° position. This position is important for throwing in water polo.	194
Push up plus (standard position)	Strengthens the SA muscle and improves scapular control.	245
Y to T	Strengthens the scapular muscles through full shoulder elevation and improves scapular control. These muscles play an important role in mobilising and stabilising the scapular throughout shoulder elevation in throwing and swimming.	246
Doorway pectoral stretch	Maintains shoulder flexibility by stretching the pectoralis minor muscle. This may assist with control of USR during shoulder elevation, and reduce stress on the shoulder during overhead throwing and swimming.	247
Sleeper stretch	Maintains shoulder flexibility by stretching the posterior shoulder complex. This helps to maintain GH ROM.	247

ER = External Rotation; SA = Serratus Anterior; USR = Upward Scapular Rotation; GH = Glenohumeral; ROM = Range of Motion

The aetiology of shoulder pain in adolescent water polo players is a complex, multifactorial problem. It is hoped the findings from this study add some insight into the issue and may provide evidence to assist coaches, trainers and the medical staff of adolescent water polo players to make more informed decisions when dealing with these athletes, with the goal of reducing shoulder pain in this population.

References

1. Stracciolini, A, Casciano, R, Levey Friedman, H, Meehan, WP, 3rd, Micheli, LJ. *Pediatric sports injuries: An age comparison of children versus adolescents*. American Journal of Sports Medicine. 2013;41(8): 1922-1929.
2. Räisänen, AM, Kokko, S, Pasanen, K, Leppänen, M, Rimpelä, A, Villberg, J, et al. *Prevalence of adolescent physical activity-related injuries in sports, leisure time, and school: The national physical activity behaviour study for children and adolescents*. BMC Musculoskeletal Disorders. 2018;19(1): 58.
3. Scharoun, S, Bryden, P. *Hand preference, performance abilities, and hand selection in children*. Frontiers in Psychology. 2014;5.
4. Keller, RA, De Giacomo, AF, Neumann, JA, Limpisvasti, O, Tibone, JE. *Glenohumeral internal rotation deficit and risk of upper extremity injury in overhead athletes: A meta-analysis and systematic review*. Sports Health. 2018;10(2): 125-132.
5. Asker, M, Brooke, HL, Waldén, M, Tranaeus, U, Johansson, F, Skillgate, E, et al. *Risk factors for, and prevention of, shoulder injuries in overhead sports: A systematic review with best-evidence synthesis*. British Journal of Sports Medicine. 2018;52(20): 1312-1319.
6. Hill, L, Collins, M, Posthumus, M. *Risk factors for shoulder pain and injury in swimmers: A critical systematic review*. The Physician and Sportsmedicine. 2015;43(4): 412-420.
7. Tyler, TF, Mullaney, MJ, Mirabella, MR, Nicholas, SJ, McHugh, MP. *Risk factors for shoulder and elbow injuries in high school baseball pitchers: The role of preseason strength and range of motion*. The American Journal of Sports Medicine. 2014;42(8): 1993-1999.
8. Cools, AM, Johansson, FR, Borms, D, Maenhout, A. *Prevention of shoulder injuries in overhead athletes: A science-based approach*. Brazilian Journal of Physical Therapy. 2015;19: 331-339.

9. Burkhart, SS, Morgan, CD, Kibler, WB. *The disabled throwing shoulder: Spectrum of pathology part i: Pathoanatomy and biomechanics*. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2003;19(4): 404-420.
10. Tate, A, Turner, GN, Knab, SE, Jorgensen, C, Strittmatter, A, Michener, LA. *Risk factors associated with shoulder pain and disability across the lifespan of competitive swimmers*. Journal of Athletic Training. 2012;47(2): 149-158.
11. Emery, CA. *Risk factors for injury in child and adolescent sport: A systematic review of the literature*. Clinical Journal of Sports Medicine. 2003;13(4): 256-268.
12. Meeuwisse, WH, Tyreman, H, Hagel, B, Emery, C. *A dynamic model of etiology in sport injury: The recursive nature of risk and causation*. Clinical Journal of Sports Medicine. 2007;17(3): 215-219.
13. van Mechelen, W, Hlobil, H, Kemper, HC. *Incidence, severity, aetiology and prevention of sports injuries. A review of concepts*. Sports Medicine. 1992;14(2): 82-99.
14. Caine, D, Maffulli, N, Caine, C. *Epidemiology of injury in child and adolescent sports: Injury rates, risk factors, and prevention*. Clinics in Sports Medicine. 2008;27(1): 19-50.
15. Mirwald, R, Baxter-Jones, A, Bailey, D, P Beunen, G. *An assessment of maturity from anthropometric measurements*. Medicine & Science in Sports & Exercise. 2002;34(4): 689-694.
16. Higson, E, Herrington, L, Butler, C, Horsley, I. *The short-term effect of swimming training load on shoulder rotational range of motion, shoulder joint position sense and pectoralis minor length*. Shoulder Elbow. 2018;10(4): 285-291.
17. Marques, MC, Liberal, SM, Costa, AM, van den Tillaar, R, Sánchez-Medina, L, Martins, JC, et al. *Effects of two different training programs with same workload on throwing velocity by experienced water polo players*. Perceptual and Motor Skills. 2012;115(3): 895-902.
18. Sanders, JO, Qiu, X, Lu, X, Duren, DL, Liu, RW, Dang, D, et al. *The uniform pattern of growth and skeletal maturation during the human adolescent growth spurt*. Scientific Reports. 2017;7(1): 16705.
19. Sanders, JO, Karbach, LE, Cai, X, Gao, S, Liu, RW, Cooperman, DR. *Height and extremity-length prediction for healthy children using age-based versus peak height velocity timing-based multipliers*. The Journal of Bone and Joint Surgery American volume. 2021;103(4): 335-342.
20. Palastanga, N, Soames, R. *Anatomy and human movement structure and function*. Churchill Livingstone Elsevier; 2012.

21. Myers, JB, Laudner, KG, Pasquale, MR, Bradley, JP, Lephart, SM. *Scapular position and orientation in throwing athletes*. The American Journal of Sports Medicine. 2005;33(2): 263-271.
22. Ludewig, PM, Reynolds, JF. *The association of scapular kinematics and glenohumeral joint pathologies*. Journal of Orthopaedic & Sports Physical Therapy. 2009;39(2): 90-104.
23. Kibler, WB, Wilkes, T, Sciascia, A. *Mechanics and pathomechanics in the overhead athlete*. Clinics in Sports Medicine. 2013;32(4): 637-651.
24. Kibler, WB. *The role of the scapula in athletic shoulder function*. American Journal of Sports Medicine. 1998;26(2): 325-337.
25. Bloomfield, J, Blanksby, BA, Ackland, TR, Allison, GT. *The influence of strength training on overhead throwing velocity of elite water polo players*. Australian Journal of Science and Medicine in Sport. 1990;22(3): 63-67.
26. Donev, Y, Aleksandrovic, M. *History of rule changes in water polo*. 2008. p.116-122.
27. Franić, M, Ivković, A, Rudić, R. *Injuries in water polo*. Croatian medical journal. 2007;48(3): 281-288.
28. Miller, AH, Evans, K, Adams, R, Waddington, G, Witchalls, J. *Shoulder injury in water polo: A systematic review of incidence and intrinsic risk factors*. Journal of Science and Medicine in Sport. 2018;21(4): 368-377.
29. Smith, H. *Applied physiology of water polo*. 1998. p.317-334.
30. Tan, F, Polglaze, T, Dawson, B. *Activity profiles and physical demands of elite women's water polo match play*. Journal of Sports Sciences. 2009;27(10): 1095-1104.
31. Melchiorri, G, Padua, E, Padulo, J, D'Ottavio, S, Campagna, S, Bonifazi, M. *Throwing velocity and kinematics in elite male water polo players*. Journal of Sports Medicine and Physical Fitness. 2011;51(4): 541-546.
32. Prien, A, Mountjoy, M, Miller, J, Boyd, K, van den Hoogenband, C, Gerrard, D, et al. *Injury and illness in aquatic sport: How high is the risk? A comparison of results from three fina world championships*. British Journal of Sports Medicine. 2017;51(4): 277.
33. Cohen, RCZ, Cleary, PW, Mason, BR, Pease, DL. *Forces during front crawl swimming at different stroke rates*. Sports Engineering. 2018;21(1): 63-73.
34. Heinlein, SA, Cosgarea, AJ. *Biomechanical considerations in the competitive swimmer's shoulder*. Sports Health. 2010;2(6): 519-525.
35. Cools, AM, Witvrouw, EE, Declercq, GA, Vanderstraeten, GG, Cambier, DC. *Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms*. British Journal of Sports Medicine. 2004;38(1): 64-68.

36. Mountjoy, M, Junge, A, Alonso, JM, Engebretsen, L, Dragan, I, Gerrard, D, et al. *Sports injuries and illnesses in the 2009 fina world championships (aquatics)*. British Journal of Sports Medicine. 2010;44(7): 522.
37. Mountjoy, M, Junge, A, Benjamen, S, Boyd, K, Diop, M, Gerrard, D, et al. *Competing with injuries: Injuries prior to and during the 15th fina world championships 2013 (aquatics)*. British Journal of Sports Medicine. 2015;49(1): 37.
38. Webster, MJ, Morris, ME, Galna, B. *Shoulder pain in water polo: A systematic review of the literature*. Journal of Science and Medicine in Sport. 2009;12(1): 3-11.
39. Soligard, T, Steffen, K, Palmer, D, Alonso, JM, Bahr, R, Lopes, AD, et al. *Sports injury and illness incidence in the rio de janeiro 2016 olympic summer games: A prospective study of 11274 athletes from 207 countries*. British Journal of Sports Medicine. 2017;51(17): 1265.
40. Engebretsen, L, Soligard, T, Steffen, K, Alonso, JM, Aubry, M, Budgett, R, et al. *Sports injuries and illnesses during the london summer olympic games 2012*. British Journal of Sports Medicine. 2013;47(7): 407-414.
41. Gradidge, P, Neophytou, N, Benjamin, N, Ko, F, E, K, Constantinou, D. *The injury and posture profiles of male high school of male high school water polo players in johannesburg, south africa*. 2014. p.179-188.
42. Ellapen, T, Stow, C, Macrae, N, Milne, J, van Heerden, J. *Prevalence of musculoskeletal pain among competitive high school male water polo players in kwa zulu natal, south africa*. 2012.
43. Jameson, Y, Gray, J, Roche, S. Identifying risk factors contributing to the development of shoulder pain and injury in male, adolescent water polo players. Cape Town: University of Cape Town; 2020.
44. Spittler, J, Keeling, J. *Water polo injuries and training methods*. Current Sports Medicine Reports. 2016;15(6): 410-416.
45. Stromberg, JD. *Care of water polo players*. Current Sports Medicine Reports. 2017;16(5): 363-369.
46. Klein, M, Tarantino, I, Warschkow, R, Berger, CJ, Zdravkovic, V, Jost, B, et al. *Specific shoulder pathoanatomy in semiprofessional water polo players: A magnetic resonance imaging study*. Orthopaedic Journal of Sports Medicine. 2014;2(5): 2325967114531213.
47. Dashe, J, Roocroft, JH, Bastrom, TP, Edmonds, EW. *Spectrum of shoulder injuries in skeletally immature patients*. Orthopedic Clinics of North America. 2013;44(4): 541-551.
48. Bak, K, Faunø, P. *Clinical findings in competitive swimmers with shoulder pain*. American Journal of Sports Medicine. 1997;25(2): 254-260.

49. Struyf, F, Tate, A, Kuppens, K, Feijen, S, Michener, LA. *Musculoskeletal dysfunctions associated with swimmers' shoulder*. British Journal of Sports Medicine. 2017;51(10): 775.
50. Su, KP, Johnson, MP, Gracely, EJ, Karduna, AR. *Scapular rotation in swimmers with and without impingement syndrome: Practice effects*. Medicine & Science in Sports & Exercise. 2004;36(7): 1117-1123.
51. Kibler, WB, Kuhn, JE, Wilk, K, Sciascia, A, Moore, S, Laudner, K, et al. *The disabled throwing shoulder: Spectrum of pathology—10-year update*. Arthroscopy. 2013;29(1): 141-161.e126.
52. Andersson, SH, Bahr, R, Clarsen, B, Myklebust, G. *Risk factors for overuse shoulder injuries in a mixed-sex cohort of 329 elite handball players: Previous findings could not be confirmed*. British Journal of Sports Medicine. 2018;52(18): 1191.
53. Clarsen, B, Bahr, R, Andersson, SH, Munk, R, Myklebust, G. *Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: A prospective cohort study*. British Journal of Sports Medicine. 2014;48(17): 1327.
54. Cools, AM, Palmans, T, Johansson, FR. *Age-related, sport-specific adaptions of the shoulder girdle in elite adolescent tennis players*. Journal of Athletic Training. 2014;49(5): 647-653.
55. Dutton, M, Tam, N, Brown, JC, Gray, J. *The cricketer's shoulder: Not a classic throwing shoulder*. Physical Therapy in Sport. 2019;37: 120-127.
56. Byram, IR, Bushnell, BD, Dugger, K, Charron, K, Harrell, FE, Noonan, TJ. *Preseason shoulder strength measurements in professional baseball pitchers: Identifying players at risk for injury*. The American Journal of Sports Medicine. 2010;38(7): 1375-1382.
57. Donatelli, R, Ellenbecker, TS, Ekedahl, SR, Wilkes, JS, Kocher, K, Adam, J. *Assessment of shoulder strength in professional baseball pitchers*. Journal of Orthopaedic & Sports Physical Therapy. 2000;30(9): 544-551.
58. Hirashima, M, Kadota, H, Sakurai, S, Kudo, K, Ohtsuki, T. *Sequential muscle activity and its functional role in the upper extremity and trunk during overarm throwing*. Journal of Sports Sciences. 2002;20(4): 301-310.
59. Weber, A, Kontaxis, A, O'Brien, S, Bedi, A. *The biomechanics of throwing: Simplified and cogent*. Sports Medicine and Arthroscopy Review. 2014;22(2): 72-79.
60. Reinold, MM, Wilk, KE, Macrina, LC, Sheheane, C, Dun, S, Fleisig, GS, et al. *Changes in shoulder and elbow passive range of motion after pitching in professional baseball players*. The American Journal of Sports Medicine. 2007;36(3): 523-527.

61. Hams, A, Evans, K, Adams, R, Waddington, G, Witchalls, J. *Epidemiology of shoulder injury in sub-elite level water polo players*. Physical Therapy in Sport. 2019;35: 127-132.
62. Smith, JR. *The world encyclopedia of water polo*. Los Olivos (CA): Olive Press; 1989.
63. Natation, FId. Fina water polo rules 2017 - 2021. 2017.
64. De Jesus, K, Figueiredo, P, Jesus, K, Pereira, F, Vilas-Boas, JP, Machado, L, et al. *Kinematic analysis of three water polo front crawl styles*. Journal of Sports Sciences. 2012;30(4): 715-723.
65. Chollet, D, Chalies, S, Chatard, JC. *A new index of coordination for the crawl: Description and usefulness*. Internation Journal of Sports Medicine. 2000;21(1): 54-59.
66. Yanai, T, Hay, JG. *Shoulder impingement in front-crawl swimming: Ii. Analysis of stroking technique*. Medicine & Science in Sports & Exercise. 2000;32(1): 30-40.
67. Johnson, JN, Gauvin, J, Fredericson, M. *Swimming biomechanics and injury prevention: New stroke techniques and medical considerations*. The Physician and Sportsmedicine. 2003;31(1): 41-46.
68. Dopsaj, M. *The assessment of the acquisition of various crawl styles modes in water polo players with respect to age and competitive levels*. Physical Education and Sport. 2007;5(2): 109-120.
69. Colville, JM, Markman, BS. *Competitive water polo: Upper extremity injuries*. Clinics in Sports Medicine. 1999;18(2): 305-312.
70. Sein, ML, Walton, J, Linklater, J, Appleyard, R, Kirkbride, B, Kuah, D, et al. *Shoulder pain in elite swimmers: Primarily due to swim-volume-induced supraspinatus tendinopathy*. British Journal of Sports Medicine. 2010;44(2): 105.
71. Chu, S, Jayabalan, P, Kibler, B, W, Press, J. *The kinetic chain revisited: New concepts on throwing mechanics and injury*. PM&R. 2016;8: S69-S77.
72. Cohn, RM, Jazrawi, LM. *The throwing shoulder: The orthopedist perspective*. Magnetic Resonance Imaging Clinics of North America. 2012;20(2): 261-275.
73. Cook, DP, Strike, SC. *Throwing in cricket*. Journal of Sports Sciences. 2000;18(12): 965-973.
74. Skejø, SD, Møller, M, Bencke, J, Sørensen, H. *Shoulder kinematics and kinetics of team handball throwing: A scoping review*. Human Movement Science. 2019;64: 203-212.
75. Anderson, MW, Alford, BA. *Overhead throwing injuries of the shoulder and elbow*. Radiologic Clinics of North America. 2010;48(6): 1137-1154.
76. Wilk, KE, Obma, P, Simpson, CD, Cain, EL, Dugas, JR, Andrews, JR. *Shoulder injuries in the overhead athlete*. Journal of Orthopaedic & Sports Physical Therapy. 2009;39(2): 38-54.

77. Hams, AH, Evans, K, Adams, R, Waddington, G, Witchalls, J. *Throwing performance in water polo is related to in-water shoulder proprioception*. Journal of Sports Sciences. 2019;37(22): 2588-2595.
78. Witwer, A, Sauers, E. *Clinical measures of shoulder mobility in college water-polo players*. Journal of Sport Rehabilitation. 2006;15(1): 45.
79. Escalante, Y, Saavedra, JM, Tella, V, Mansilla, M, García-Hermoso, A, Domínguez, AM. *Differences and discriminatory power of water polo game-related statistics in men in international championships and their relationship with the phase of the competition*. Journal of Strength and Conditioning Research. 2013;27(4): 893-901.
80. Yaghoubi, M, Mahdi Esfehani, M, Hosseini, H, Alikhajeh, Y, Shultz, S. *Comparative electromyography analysis of the upper extremity between inexperienced and elite water polo players during an overhead shot*. Journal of applied biomechanics. 2014;31: 79-87.
81. Yaghoubi, M, Moghadam, A, Khalilzadeh, MA, Shultz, SP. *Electromyographic analysis of the upper extremity in water polo players during water polo shots*. International Biomechanics. 2014;1(1): 15-20.
82. Solum, J. *The fundamentals of the water polo shot*. Available from: http://www.waterpoloplanet.com/HTML_Jim_pages/js01_shot_doctor_jim.html. [Accessed 15/12/2021].
83. Elliott, BC, Armour, J. *The penalty throw in water polo: A cinematographic analysis*. Journal of Sports Sciences. 1988;6(2): 103-114.
84. Armour, J, Elliot, B. *Three-dimensional cinematographic analysis of throwing.* 7 International Symposium on Biomechanics in Sports. ISBS - Conference Proceedings Archive; 1989.
85. Platanou, T, Varamenti, E. *Relationships between anthropometric and physiological characteristics with throwing velocity and on water jump of female water polo players*. Journal of Sports Medicine and Physical Fitness. 2011;51(2): 185.
86. Feltner, ME, Taylor, G. *Three-dimensional kinetics of the shoulder, elbow, and wrist during a penalty throw in water polo*. Journal of applied biomechanics. 1997;13(3): 347-372.
87. Smith, HK. *Penalty shot importance, success and game context in international water polo*. J Sci Med Sport. 2004;7(2): 221-225.
88. Smith, KH. *Penalty shots in international water polo: Regular opportunities with robust success despite a greater impact on the game under current rules*. International Journal of Performance Analysis in Sport. 2011;11(2): 335-343.
89. Clarys, J, Lewillie, L. *The description of wrist and shoulder motion of different waterpolo shots using a simple light-trace technique*. First International Symposium on

"Biomechanics and Swimming, Waterpolo and Diving", 14-16 September 1970 Proceedings. 1971: 249-256.

90. Mountjoy, M, Miller, J, Junge, A. *Analysis of water polo injuries during 8904 player matches at fina world championships and olympic games to make the sport safer*. British Journal of Sports Medicine. 2019;53(1): 25-31.

91. Sallis, R, Jones, K, Sunshine, S, Smith, G, Simon, L. *Comparing sports injuries in men and women*. Internation Journal of Sports Medicine. 2001;22(6): 420-423.

92. Seroyer, ST, Nho, SJ, Bach, BR, Bush-Joseph, CA, Nicholson, GP, Romeo, AA. *Shoulder pain in the overhead throwing athlete*. Sports Health. 2009;1(2): 108-120.

93. Michener, L, McClure, P, R Karduna, A. *Anatomical and biomechanical mechanisms of subacromial impingement syndrome*. Clinical Biomechanics. 2003;18(5): 369-379.

94. Goldberg, AS, Moroz, L, Smith, A, Ganley, T. *Injury surveillance in young athletes: A clinician's guide to sports injury literature*. Sports Medicine. 2007;37(3): 265-278.

95. Soprano, J. *Musculoskeletal injuries in the pediatric and adolescent athlete*. Current Sports Medicine Reports. 2014;4: 329-334.

96. Tarkin, IS, Morganti, CM, Zillmer, DA, McFarland, EG, Giangarra, CE. *Rotator cuff tears in adolescent athletes*. The American Journal of Sports Medicine. 2005;33(4): 596-601.

97. Suszter, M, Vardiabasis, N, Smith, M, Schlechter, J. *Glenohumeral internal rotation deficit in adolescent water polo players*. Journal of Orthopedic Research and Physiotherapy. 2015;1: 1-4.

98. Astolfi, MM, Struminger, AH, Royer, TD, Kaminski, TW, Swanik, CB. *Adaptations of the shoulder to overhead throwing in youth athletes*. Journal of Athletic Training. 2015;50(7): 726-732.

99. Croteau, F, Paradelo, D, Pearsall, D, Robbins, S. *Risk factors for shoulder injuries in water polo: A cohort study*. Int J Sports Phys Ther. 2021;16(4): 1135-1144.

100. Bahr, R, Krosshaug, T. *Understanding injury mechanisms: A key component of preventing injuries in sport*. British Journal of Sports Medicine. 2005;39(6): 324.

101. Bittencourt, NFN, Meeuwisse, WH, Mendonça, LD, Nettel-Aguirre, A, Ocarino, JM, Fonseca, ST. *Complex systems approach for sports injuries: Moving from risk factor identification to injury pattern recognition—narrative review and new concept*. British Journal of Sports Medicine. 2016;50(21): 1309.

102. Matsuura, T, Iwame, T, Suzue, N, Arisawa, K, Sairyo, K. *Risk factors for shoulder and elbow pain in youth baseball players*. The Physician and Sportsmedicine. 2017;45(2): 140-144.

103. Walker, H, Gabbe, B, Wajswelner, H, Blanch, P, Bennell, K. *Shoulder pain in swimmers: A 12-month prospective cohort study of incidence and risk factors*. Physical Therapy in Sport. 2012;13(4): 243-249.
104. Norton, R, Honstad, C, Joshi, R, Silvis, M, Chinchilli, V, Dhawan, A. *Risk factors for elbow and shoulder injuries in adolescent baseball players: A systematic review*. American Journal of Sports Medicine. 2019;47(4): 982-990.
105. De Siati, F, Laffaye, G, Gatta, G, Dello Iacono, A, Ardigò, LP, Padulo, J. *Neuromuscular and technical abilities related to age in water-polo players*. Journal of Sports Sciences. 2016;34(15): 1466-1472.
106. Olsen, SJ, Fleisig, GS, Dun, S, Loftice, J, Andrews, JR. *Risk factors for shoulder and elbow injuries in adolescent baseball pitchers*. The American Journal of Sports Medicine. 2006;34(6): 905-912.
107. Hams, A, Evans, K, Adams, R, Waddington, G, Witchalls, J. *Reduced shoulder strength and change in range of motion are risk factors for shoulder injury in water polo players*. Physical Therapy in Sport. 2019;40: 231-237.
108. Hams, AH, Evans, K, Adams, R, Waddington, G, Witchalls, J. *Shoulder internal and external rotation strength and prediction of subsequent injury in water-polo players*. Scandanavian Journal of Medicine and Science in Sport. 2019;29(9): 1414-1420.
109. Amin, NH, Ryan, J, Fening, SD, Soloff, L, Schickendantz, MS, Jones, M. *The relationship between glenohumeral internal rotational deficits, total range of motion, and shoulder strength in professional baseball pitchers*. Journal of the American Academy of Orthopaedic Surgeons. 2015;23(12): 789-796.
110. Tsekouras, Y, Kavouras, S, Campagna, A, Kotsis, Y, S Syntosi, S, Papazoglou, K, et al. *The anthropometrical and physiological characteristics of water polo players*. European Journal of Applied Physiology. 2005;95: 35-41.
111. McMaster, WC, Long, SC, Caiozzo, VJ. *Isokinetic torque imbalances in the rotator cuff of the elite water polo player*. The American Journal of Sports Medicine. 1991;19(1): 72-75.
112. Drigny, J, Gauthier, A, Reboursière, E, Guermont, H, Gremeaux, V, Edouard, P. *Shoulder muscle imbalance as a risk for shoulder injury in elite adolescent swimmers: A prospective study*. Journal of Human Kinetics. 2020;75(1): 103-113.
113. Swanik, KA, Lephart, SM, Swanik, CB, Lephart, SP, Stone, DA, Fu, FH. *The effects of shoulder plyometric training on proprioception and selected muscle performance characteristics*. Journal of Shoulder and Elbow Surgery. 2002;11(6): 579-586.

114. Liaghat, B, Juul-Kristensen, B, Frydendal, T, Marie Larsen, C, Søgaard, K, Ilkka Tapio Salo, A. *Competitive swimmers with hypermobility have strength and fatigue deficits in shoulder medial rotation*. Journal of Electromyography and Kinesiology. 2018;39: 1-7.
115. Stickley, CD, Hetzler, RK, Freemyer, BG, Kimura, IF. *Isokinetic peak torque ratios and shoulder injury history in adolescent female volleyball athletes*. Journal of Athletic Training. 2008;43(6): 571-577.
116. Serenza, FS, Oliveira, AS, Bedo, BLS, Mariano, FP, Aquino, R, Warner, M, et al. *Biomechanical analysis of the shoulder of swimmers after a maximal effort test*. Physical Therapy in Sport. 2018;30: 14-21.
117. Komati, MA, Korkie, FE, Becker, P. *Pectoralis minor length measurements in three different scapula positions*. South African Journal of Physiotherapy. 2020;76(1): a1487.
118. Ruotolo, C, Price, E, Panchal, A. *Loss of total arc of motion in collegiate baseball players*. Journal of Shoulder and Elbow Surgery. 2006;15(1): 67-71.
119. Shanley, E, Kissenberth, MJ, Thigpen, CA, Bailey, LB, Hawkins, RJ, Michener, LA, et al. *Preseason shoulder range of motion screening as a predictor of injury among youth and adolescent baseball pitchers*. Journal of Shoulder and Elbow Surgery. 2015;24(7): 1005-1013.
120. Wilk, KE, Macrina, LC, Fleisig, GS, Porterfield, R, Simpson, CD, 2nd, Harker, P, et al. *Correlation of glenohumeral internal rotation deficit and total rotational motion to shoulder injuries in professional baseball pitchers*. American Journal of Sports Medicine. 2011;39(2): 329-335.
121. Almeida, GP, Silveira, PF, Rosseto, NP, Barbosa, G, Ejnisman, B, Cohen, M. *Glenohumeral range of motion in handball players with and without throwing-related shoulder pain*. Journal of Shoulder and Elbow Surgery. 2013;22(5): 602-607.
122. Burkhart, SS, Morgan, CD, Kibler, WB. *The disabled throwing shoulder: Spectrum of pathology part iii: The sick scapula, scapular dyskinesis, the kinetic chain, and rehabilitation*. Arthroscopy. 2003;19(6): 641-661.
123. Greenberg, EM, Fernandez-Fernandez, A, Lawrence, JTR, McClure, P. *The development of humeral retrotorsion and its relationship to throwing sports*. Sports Health. 2015;7(6): 489-496.
124. Davis, J, Limpisvasti, O, Fluhme, D, Mohr, K, Yocum, L, Elattrache, N, et al. *The effect of pitching biomechanics on the upper extremity in youth and adolescent baseball pitchers*. American Journal of Sports Medicine. 2009;37(8): 1484-1491.

125. Whiteley, R, Oceguera, M. *Gird, trrom, and humeral torsion-based classification of shoulder risk in throwing athletes are not in agreement and should not be used interchangeably*. Journal of Science and Medicine in Sport. 2016;19(10): 816-819.
126. Reagan, KM, Meister, K, Horodyski, MB, Werner, DW, Carruthers, C, Wilk, K. *Humeral retroversion and its relationship to glenohumeral rotation in the shoulder of college baseball players*. American Journal of Sports Medicine. 2002;30(3): 354-360.
127. Chant, CB, Litchfield, R, Griffin, S, Thain, LM. *Humeral head retroversion in competitive baseball players and its relationship to glenohumeral rotation range of motion*. The Journal of Orthopaedic Sports Physical Therapy. 2007;37(9): 514-520.
128. Myers, J, Oyama, S, Rucinski, T, Creighton, R. *Humeral retrotorsion in collegiate baseball pitchers with throwing-related upper extremity injury history*. Sports Health. 2011;3: 383-389.
129. Tyler, TF, Nicholas, SJ, Roy, T, Gleim, GW. *Quantification of posterior capsule tightness and motion loss in patients with shoulder impingement*. American Journal of Sports Medicine. 2000;28(5): 668-673.
130. Thomas, SJ, Swanik, CB, Higginson, JS, Kaminski, TW, Swanik, KA, Bartolozzi, AR, et al. *A bilateral comparison of posterior capsule thickness and its correlation with glenohumeral range of motion and scapular upward rotation in collegiate baseball players*. Journal of Shoulder and Elbow Surgery. 2011;20(5): 708-716.
131. Myers, JB, Oyama, S, Wassinger, CA, Ricci, RD, Abt, JP, Conley, KM, et al. *Reliability, precision, accuracy, and validity of posterior shoulder tightness assessment in overhead athletes*. The American Journal of Sports Medicine. 2007;35(11): 1922-1930.
132. Struyf, F, Cagnie, B, Cools, A, Baert, I, Brempt, JV, Struyf, P, et al. *Scapulothoracic muscle activity and recruitment timing in patients with shoulder impingement symptoms and glenohumeral instability*. Journal of Electromyography and Kinesiology. 2014;24(2): 277-284.
133. Mukhtyar, FR, Mitra, M, Kaur, AP. *The effects of intense practice sessions on the scapular kinematics of elite water polo players with and without impingement syndrome*. Indian Journal of Physiotherapy and Occupational Therapy An International Journal. 2014;8: 189-193.
134. Madsen, PH, Bak, K, Jensen, S, Welter, U. *Training induces scapular dyskinesis in pain-free competitive swimmers: A reliability and observational study*. Clinical Journal of Sports Medicine. 2011;21(2): 109-113.

135. Green, RA, Taylor, NF, Watson, L, Ardern, C. *Altered scapula position in elite young cricketers with shoulder problems*. Journal of Science and Medicine in Sport. 2013;16(1): 22-27.
136. Borstad, JD, Ludewig, PM. *The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals*. Journal of Orthopaedic & Sports Physical Therapy. 2005;35(4): 227-238.
137. McClure, PW, Michener, LA, Sennett, BJ, Karduna, AR. *Direct 3-dimensional measurement of scapular kinematics during dynamic movements in vivo*. Journal of Shoulder and Elbow Surgery. 2001;10(3): 269-277.
138. Mackenzie, TA, Herrington, L, Funk, L, Horsley, I, Cools, A. *Relationship between extrinsic factors and the acromio-humeral distance*. Manual Therapy. 2016;23: 1-8.
139. McCreesh, KM, Crotty, JM, Lewis, JS. *Acromiohumeral distance measurement in rotator cuff tendinopathy: Is there a reliable, clinically applicable method? A systematic review*. British Journal of Sports Medicine. 2015;49(5): 298.
140. Leong, H-TT, Sammi ; Ying, Michael ; Leung Vivian Yee-fong and Siu N. Fu. *Ultrasound measurements on acromio-humeral distance and supraspinatus tendon thickness: Test–retest reliability and correlations with shoulder rotational strengths*. Journal of Science and Medicine in Sport. 2012;15(4): 284-291.
141. Silva, RT, Hartmann, LG, Laurino, CF, Biló, JP. *Clinical and ultrasonographic correlation between scapular dyskinesia and subacromial space measurement among junior elite tennis players*. British Journal of Sports Medicine. 2010;44(6): 407-410.
142. Wang, HK, Lin, JJ, Pan, SL, Wang, TG. *Sonographic evaluations in elite college baseball athletes*. Scandanavian Journal of Med and Science in Sports. 2005;15(1): 29-35.
143. Porter, KN, Blanch, PD, Walker, HM, Shield, AJ. *The effect of previous shoulder pain on supraspinatus tendon thickness changes following swimming practice*. Scandanavian Journal of Medicine and Science in Sports. 2020;30(8): 1442-1448.
144. Salles, JI, Velasques, B, Cossich, V, Nicoliche, E, Ribeiro, P, Amaral, MV, et al. *Strength training and shoulder proprioception*. Journal of Athletic Training. 2015;50(3): 277-280.
145. Myers, JB, Lephart, SM. *The role of the sensorimotor system in the athletic shoulder*. Journal of Athletic Training. 2000;35(3): 351-363.
146. Tripp, BL, Yochem, EM, Uhl, TL. *Functional fatigue and upper extremity sensorimotor system acuity in baseball athletes*. Journal of Athletic Training. 2007;42(1): 90-98.
147. Han, J, Waddington, G, Anson, J, Adams, R. *Level of competitive success achieved by elite athletes and multi-joint proprioceptive ability*. Journal of Science and Medicine in Sport. 2015;18(1): 77-81.

148. Dover, GC, Kaminski, TW, Meister, K, Powers, ME, Horodyski, M. *Assessment of shoulder proprioception in the female softball athlete*. The American Journal of Sports Medicine. 2003;31(3): 431-437.
149. Mota, N, Ribeiro, F. *Association between shoulder proprioception and muscle strength in water polo players*. Isokinetics and Exercise Science. 2012;20: 17-21.
150. Uljevic, O, Esco, MR, Sekulic, D. *Reliability, validity, and applicability of isolated and combined sport-specific tests of conditioning capacities in top-level junior water polo athletes*. The Journal of Strength & Conditioning Research. 2014;28(6): 1595-1605.
151. Lyman, S, Fleisig, GS, Andrews, JR, Osinski, ED. *Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers*. The American Journal of Sports Medicine. 2002;30(4): 463-468.
152. Wheeler, KK, Tamara; Mosler, Andrea; Lebedew, Alexis and Lyons, Keith. *The volume of goal shooting during training can predict shoulder soreness in elite female water polo players*. Journal of Science and Medicine in Sport. 2013;16(3): 255-258.
153. Bahr, R. *Why screening tests to predict injury do not work—and probably never will…: A critical review*. British Journal of Sports Medicine. 2016;50: 776-780.
154. Evershed, J, Burkett, B, Mellifont, R. *Musculoskeletal screening to detect asymmetry in swimming*. Physical Therapy in Sport. 2014;15(1): 33-38.
155. Dawson, J, Fitzpatrick, R, Carr, A. *Questionnaire on the perceptions of patients about shoulder surgery*. The Journal of Bone and Joint Surgery British volume. 1996;78-B(4): 593-600.
156. Lippitt, SB, Harryman, DT, Matsen, FA, Lippitt, S, Lippit, S. *A practical tool for evaluating function: The simple shoulder test*. The shoulder: A balance of mobility and stability. 1993; 501-518.
157. Constant, CR, Murley, AH. *A clinical method of functional assessment of the shoulder*. Clinical Orthopaedics & Related Research. 1987(214): 160-164.
158. Hudak, PL, Amadio, PC, Bombardier, C. *Development of an upper extremity outcome measure: The dash (disabilities of the arm, shoulder and hand)*. American Journal of Industrial Medicine. 1996;29(6): 602-608.
159. Alberta, FG, ElAttrache, NS, Bissell, S, Mohr, K, Browdy, J, Yocum, L, et al. *The development and validation of a functional assessment tool for the upper extremity in the overhead athlete*. The American Journal of Sports Medicine. 2010;38(5): 903-911.
160. Fronek, J, Yang, JG, Osbahr, DC, Pollack, KM, ElAttrache, NS, Noonan, TJ, et al. *Shoulder functional performance status of minor league professional baseball pitchers*. Journal of Shoulder and Elbow Surgery. 2015;24(1): 17-23.

161. Franz, JO, McCulloch, PC, Kneip, CJ, Noble, PC, Lintner, DM. *The utility of the kjoc score in professional baseball in the united states*. American Journal of Sports Medicine. 2013;41(9): 2167-2173.
162. Kraeutler, MJ, Ciccotti, MG, Dodson, CC, Frederick, RW, Cammarota, B, Cohen, SB. *Kerlan-jobe orthopaedic clinic overhead athlete scores in asymptomatic professional baseball pitchers*. Journal of Shoulder and Elbow Surgery. 2013;22(3): 329-332.
163. Wymore, L, Fronek, J. *Shoulder functional performance status of national collegiate athletic association swimmers: Baseline kerlan-jobe orthopedic clinic scores*. American Journal of Sports Medicine. 2015;43(6): 1513-1517.
164. Holtz, KA, O'Connor, RJ. *Upper extremity functional status of female youth softball pitchers using the kerlan-jobe orthopaedic clinic questionnaire*. Orthopaedic Journal of Sports Medicine. 2018;6(1): 2325967117748599-2325967117748599.
165. Hegedus, EJ, Cook, C, Lewis, J, Wright, A, Park, JY. *Combining orthopedic special tests to improve diagnosis of shoulder pathology*. Physical Therapy in Sport. 2015;16(2): 87-92.
166. Cools, AM, Cambier, D, Witvrouw, EE. *Screening the athlete's shoulder for impingement symptoms: A clinical reasoning algorithm for early detection of shoulder pathology*. British Journal of Sports Medicine. 2008;42(8): 628.
167. Tennent, TD, Beach, WR, Meyers, JF. *A review of the special tests associated with shoulder examination: Part i: The rotator cuff tests*. The American Journal of Sports Medicine. 2003;31(1): 154-160.
168. Hegedus, EJ, Goode, A, Campbell, S, Morin, A, Tamaddoni, M, Moorman, CT, et al. *Physical examination tests of the shoulder: A systematic review with meta-analysis of individual tests*. British Journal of Sports Medicine. 2008;42(2): 80.
169. Sabari, JS, Maltzev, I, Lubarsky, D, Liszkay, E, Homel, P. *Goniometric assessment of shoulder range of motion: Comparison of testing in supine and sitting positions*. Archives of Physical Medicine and Rehabilitation. 1998;79(6): 647-651.
170. Wang, S, Trudelle-Jackson, E. *Comparison of customized versus standard exercises in rehabilitation of shoulder disorders*. Clinical Rehabilitation. 2006;20(8): 675-685.
171. Watson, L, Balster, SM, Finch, C, Dalziel, R. *Measurement of scapula upward rotation: A reliable clinical procedure*. British Journal of Sports Medicine. 2005;39(9): 599.
172. Johnson, M, McClure, P, Karduna, A. *New method to assess scapular upward rotation in subjects with shoulder pathology*. The Journal of Orthopaedic and Sports Physical Therapy. 2001;31(2): 81-89.

173. Nicholas, JA, Sapega, A, Kraus, H, Webb, JN. *Factors influencing manual muscle tests in physical therapy*. The Journal of Bone and Joint Surgery American volume. 1978;60(2): 186-190.

174. Hayes, K, Walton, JR, Szomor, ZL, Murrell, GAC. *Reliability of 3 methods for assessing shoulder strength*. Journal of Shoulder and Elbow Surgery. 2002;11(1): 33-39.

175. Roy, J-S, MacDermid, JC, Orton, B, Tran, T, Faber, KJ, Drosdowech, D, et al. *The concurrent validity of a hand-held versus a stationary dynamometer in testing isometric shoulder strength*. Journal of Hand Therapy. 2009;22(4): 320-327.

176. Cools, AM, De Wilde, L, Van Tongel, A, Ceyssens, C, Ryckewaert, R, Cambier, DC. *Measuring shoulder external and internal rotation strength and range of motion: Comprehensive intra-rater and inter-rater reliability study of several testing protocols*. Journal of Shoulder and Elbow Surgery. 2014;23(10): 1454-1461.

177. Cools, AM, Johansson, FR, Cambier, DC, Velde, AV, Palmans, T, Witvrouw, EE. *Descriptive profile of scapulothoracic position, strength and flexibility variables in adolescent elite tennis players*. British Journal of Sports Medicine. 2010;44(9): 678.

178. Tyler, TF, Nahow, RC, Nicholas, SJ, McHugh, MP. *Quantifying shoulder rotation weakness in patients with shoulder impingement*. Journal of Shoulder and Elbow Surgery. 2005;14(6): 570-574.

179. Borstad, JD. *Measurement of pectoralis minor muscle length: Validation and clinical application*. Journal of Orthopaedic & Sports Physical Therapy. 2008;38(4): 169-174.

180. Ager, AL, Roy, JS, Roos, M, Belley, AF, Cools, A, Hébert, LJ. *Shoulder proprioception: How is it measured and is it reliable? A systematic review*. Journal of Hand Therapy. 2017;30(2): 221-231.

181. Goldbeck, T, Davies, G. *Test-retest reliability of the closed kinetic chain upper extremity stability test: A clinical field test*. Journal of Sport Rehabilitation. 2000;9(1): 35-45.

182. de Oliveira, VMA, Pitangui, ACR, Nascimento, VYS, da Silva, HA, dos Passos, MHP, de Araújo, RC. *Test-retest reliability of the closed kinetic chain upper extremity stability test (ckcuest) in adolescents: Reliability of ckcuest in adolescents*. International Journal of Sports Physical Therapy. 2017;12(1): 125-132.

183. Malina, R. Growth and maturation: Do regular physical activity and training for sport have a significant influence? In: Armstrong N, van Mechelen W, editors. *Paediatric exercise science and medicine*. Oxford: Oxford University Press; 2000. p. 95-106.

184. Tanner, J. *Foetus into man: Physical growth from conception to maturity*. London: Open Books; 1978.

185. Iuliano-Burns, S, Mirwald, RL, Bailey, DA. *Timing and magnitude of peak height velocity and peak tissue velocities for early, average, and late maturing boys and girls*. American Journal of Human Biology. 2001;13(1): 1-8.
186. Marshall, WA, Tanner, JM. *Variations in the pattern of pubertal changes in boys*. Archives of disease in childhood. 1970;45(239): 13-23.
187. Halson, SL. *Monitoring training load to understand fatigue in athletes*. Sports Medicine. 2014;44(2): 139-147.
188. Marrin, K, Bampouras, T. *Anthropometric and physiological changes of elite female water polo players during a training year*. Serbian Journal of Sports Sciences. 2008;2: 75-83.
189. Lupo, C, Capranica, L, Tessitore, A. *The validity of the session-rpe method for quantifying training load in water polo*. International Journal of Sports Physiology and Performance. 2014;9(4): 656-660.
190. Black, GM, Gabbett, TJ, Cole, MH, Naughton, G. *Monitoring workload in throwing-dominant sports: A systematic review*. Sports Medicine. 2016;46(10): 1503-1516.
191. Foster, C. *Monitoring training in athletes with reference to overtraining syndrome*. Medicine and Science in Sports and Exercise. 1998;30(7): 1164-1168.
192. Brisola, GMP, Claus, GM, Dutra, YM, Malta, ES, de Poli, RAB, Esco, MR, et al. *Effects of seasonal training load on performance and illness symptoms in water polo*. Journal of Strength and Conditioning Research. 2020;34(2): 406-413.
193. Bansal, S, Sinha, AG, Sandhu, J. *Shoulder impingement syndrome among competitive swimmers in india - prevalence, evaluation and risk factors*. Journal of Exercise Science and Fitness. 2007;5: 102-108.
194. Wilk, KE, Meister, K, Andrews, JR. *Current concepts in the rehabilitation of the overhead throwing athlete*. American Journal of Sports Medicine. 2002;30(1): 136-151.
195. Burkhart, SS, Morgan, CD, Kibler, WB. *The disabled throwing shoulder: Spectrum of pathology part ii: Evaluation and treatment of slap lesions in throwers*. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2003;19(5): 531-539.
196. McMaster, WC, Roberts, A, Stoddard, T. *A correlation between shoulder laxity and interfering pain in competitive swimmers*. The American Journal of Sports Medicine. 1998;26(1): 83-86.
197. Laudner, KG, Stanek, JM, Meister, K. *Assessing posterior shoulder contracture: The reliability and validity of measuring glenohumeral joint horizontal adduction*. Journal of Athletic Training. 2006;41(4): 375-380.

198. Struyf, F, Nijs, J, Meeus, M, Roussel, NA, Mottram, S, Truijen, S, et al. *Does scapular positioning predict shoulder pain in recreational overhead athletes?* Internation Journal of Sports Medicine. 2014;35(1): 75-82.
199. Myers, JB, Oyama, S, Hibberd, EE. *Scapular dysfunction in high school baseball players sustaining throwing-related upper extremity injury: A prospective study*. Journal of Shoulder and Elbow Surgery. 2013;22(9): 1154-1159.
200. Harada, M, Takahara, M, Mura, N, Sasaki, J, Ito, T, Ogino, T. *Risk factors for elbow injuries among young baseball players*. Journal of Shoulder and Elbow Surgery. 2010;19(4): 502-507.
201. Zaremski, JL, Zeppieri, G, Jr., Tripp, BL. *Sport specialization and overuse injuries in adolescent throwing athletes: A narrative review*. Journal of Athletic Training. 2019;54(10): 1030-1039.
202. Jayanthi, NA, LaBella, CR, Fischer, D, Pasulka, J, Dugas, LR. *Sports-specialized intensive training and the risk of injury in young athletes: A clinical case-control study*. The American Journal of Sports Medicine. 2015;43(4): 794-801.
203. Yang, J, Mann, BJ, Guettler, JH, Dugas, JR, Irrgang, JJ, Fleisig, GS, et al. *Risk-prone pitching activities and injuries in youth baseball: Findings from a national sample*. The American Journal of Sports Medicine. 2014;42(6): 1456-1463.
204. Register-Mihalik, J, Oyama, S, Marshall, S, Mueller, F. *Pitching practices and self-reported injuries among youth baseball pitchers: A descriptive study*. Athletic Training & Sports Health Care. 2012;4: 11-20.
205. Møller, M, Nielsen, RO, Attermann, J, Wedderkopp, N, Lind, M, Sørensen, H, et al. *Handball load and shoulder injury rate: A 31-week cohort study of 679 elite youth handball players*. British Journal of Sports Medicine. 2017;51(4): 231-237.
206. Kruger, PE, Dressler, A, Botha, M. *Incidence of shoulder injuries and related risk factors among master swimmers in south africa*. African Journal for Physical Health Education, Recreation and Dance. 2012;18(sup-1): 57-76.
207. Tate, AR, McClure, P, Kareha, S, Irwin, D, Barbe, MF. *A clinical method for identifying scapular dyskinesis, part 2: Validity*. Journal of Athletic Training. 2009;44(2): 165-173.
208. Girdwood, M, Webster, M. *High rates of shoulder and hip pain in water polo players across elite, sub-elite and recreational levels*. Journal of Science and Medicine in Sport. 2017;20: 17.
209. Struyf, F, Meeus, M, Fransen, E, Roussel, N, Jansen, N, Truijen, S, et al. *Interrater and intrarater reliability of the pectoralis minor muscle length measurement in subjects with and without shoulder impingement symptoms*. Manual Therapy. 2014;19(4): 294-298.

210. Giles, K, Musa, I. *A survey of glenohumeral joint rotational range and non-specific shoulder pain in elite cricketers*. Physical Therapy in Sport. 2008;9(3): 109-116.
211. Johansson, K, Ivarson, S. *Intra- and interexaminer reliability of four manual shoulder maneuvers used to identify subacromial pain*. Manual Therapy. 2009;14(2): 231-239.
212. Kolber, M, Fuller, C, Marshall, J, Wright, A, Hanney, W. *The reliability and concurrent validity of scapular plane shoulder elevation measurements using a digital inclinometer and goniometer*. Physiotherapy Theory and Practice. 2012;28(2): 161-168.
213. Gillet, B, Begon, M, Sevrez, V, Berger-Vachon, C, Rogowski, I. *Adaptive alterations in shoulder range of motion and strength in young tennis players*. Journal of Athletic Training. 2017;52(2): 137-144.
214. Hislop, H, Montgomery, J. *Daniels and worthingham's muscle testing: Techniques of manual examination 6th edition*. Elsevier Science Health Science Division, USA; 1995.
215. Tucci, HT, Martins, J, Sposito, GdC, Camarini, PMF, de Oliveira, AS. *Closed kinetic chain upper extremity stability test (ckcues test): A reliability study in persons with and without shoulder impingement syndrome*. BMC Musculoskeletal Disorders. 2014;15(1): 1.
216. Corp, I. Released 2020. Ibm spss statistics for windows, Version 27.0. Armonk, NY: IBM Corp.
217. Cools, AM, Vanderstukken, F, Vereecken, F, Duprez, M, Heyman, K, Goethals, N, et al. *Eccentric and isometric shoulder rotator cuff strength testing using a hand-held dynamometer: Reference values for overhead athletes*. Knee Surg Sports Traumatol Arthrosc. 2016;24(12): 3838-3847.
218. Boettcher, C, Halaki, M, Holt, K, Ginn, K. *Is the normal shoulder rotation strength ratio altered in elite swimmers?* Medicine and Science in Sports and Exercise. 2020;52(3): 680-684.
219. Hibberd, EE, Myers, JB. *Practice habits and attitudes and behaviors concerning shoulder pain in high school competitive club swimmers*. Clinical Journal of Sport Medicine. 2013;23(6): 450-455.
220. Jain, NB, Luz, J, Higgins, LD, Dong, Y, Warner, JJ, Matzkin, E, et al. *The diagnostic accuracy of special tests for rotator cuff tear: The row cohort study*. American Journal of Physical Medicine and Rehabilitation. 2017;96(3): 176-183.
221. Hegedus, EJ, Goode, AP, Cook, CE, Michener, L, Myer, CA, Myer, DM, et al. *Which physical examination tests provide clinicians with the most value when examining the shoulder? Update of a systematic review with meta-analysis of individual tests*. British Journal of Sports Medicine. 2012;46(14): 964-978.

222. Neer, C. *Impingement lesions*. Clinical Orthopaedics and Related Research. 1983;173: 70-77.
223. Harrison, AK, Flatow, EL. *Subacromial impingement syndrome*. JAAOS - Journal of the American Academy of Orthopaedic Surgeons. 2011;19(11): 701-708.
224. Whiteley, R, Adams, R, Ginn, K, Nicholson, L. *Playing level achieved, throwing history, and humeral torsion in masters baseball players*. Journal of Sports Sciences. 2010;28(11): 1223-1232.
225. Ferragut, C, Vila, H, Abraldes, JA, Argudo, F, Rodriguez, N, Alcaraz, P. *Relationship among maximal grip, throwing velocity and anthropometric parameters in elite water polo players*. The Journal of sports medicine and physical fitness. 2011;51 1: 26-32.
226. Whiteley, R, Oceguera, MV, Valencia, EB, Mitchell, T. *Adaptations at the shoulder of the throwing athlete and implications for the clinician*. Techniques in Shoulder & Elbow Surgery. 2012;13: 36-44.
227. Elliott, J. *Shoulder pain and flexibility in élite water polo players*. Physiotherapy. 1993;79(10): 693-697.
228. Nakamizo, H, Nakamura, Y, Nobuhara, K, Yamamoto, T. *Loss of glenohumeral internal rotation in little league pitchers: A biomechanical study*. Journal of Shoulder and Elbow Surgery. 2008;17(5): 795-801.
229. Meister, K, Day, T, Horodyski, M, Kaminski, TW, Wasik, MP, Tillman, S. *Rotational motion changes in the glenohumeral joint of the adolescent/little league baseball player*. The American Journal of Sports Medicine. 2005;33(5): 693-698.
230. Giombini, A, Rossi, F, Pettrone, FA, Dragoni, S. *Posterosuperior glenoid rim impingement as a cause of shoulder pain in top level waterpolo players*. Journal of Sports Medicine and Physical Fitness. 1997;37(4): 273-278.
231. Trakis, JE, McHugh, MP, Caracciolo, PA, Busciacco, L, Mullaney, M, Nicholas, SJ. *Muscle strength and range of motion in adolescent pitchers with throwing-related pain: Implications for injury prevention*. The American Journal of Sports Medicine. 2008;36(11): 2173-2178.
232. Struyf, F, Nijs, J, Baeyens, JP, Mottram, S, Meeusen, R. *Scapular positioning and movement in unimpaired shoulders, shoulder impingement syndrome, and glenohumeral instability*. Scandanavian Journal of Medicine and Science in Sports. 2011;21(3): 352-358.
233. Hickey, D, Solvig, V, Cavalheri, V, Harrold, M, McKenna, L. *Scapular dyskinesis increases the risk of future shoulder pain by 43% in asymptomatic athletes: A systematic review and meta-analysis*. British Journal of Sports Medicine. 2018;52(2): 102.

234. Edouard, P, Degache, F, Oullion, R, Plessis, JY, Gleizes-Cervera, S, Calmels, P. *Shoulder strength imbalances as injury risk in handball*. International Journal of Sports Medicine. 2013;34(7): 654-660.
235. Noffal, GJ. *Isokinetic eccentric-to-concentric strength ratios of the shoulder rotator muscles in throwers and nonthrowers*. The American Journal of Sports Medicine. 2003;31(4): 537-541.
236. Aginsky, KD, Tracey, C, Neophytou, N. *Posture and isokinetic shoulder strength in female water polo players*. South African Journal of Sports Medicine. 2016;28: 64+.
237. Ellenbecker, T, Davies, G. *The application of isokinetics in testing and rehabilitation of the shoulder complex*. Journal of Athletic Training. 2000;35(3): 338-350.
238. Ludewig, PM, Braman, JP. *Shoulder impingement: Biomechanical considerations in rehabilitation*. Manual Therapy. 2011;16(1): 33-39.
239. Cools, AM, Geerooms, E, Van den Berghe, DFM, Cambier, DC, Witvrouw, EE. *Isokinetic scapular muscle performance in young elite gymnasts*. Journal of Athletic Training. 2007;42(4): 458-463.
240. Habechian, FAP, Lozana, AL, Cools, AM, Camargo, PR. *Swimming practice and scapular kinematics, scapulothoracic muscle activity, and the pressure-pain threshold in young swimmers*. Journal of Athletic Training. 2018;53(11): 1056-1062.
241. Pontillo, M, Spinelli, BA, Sennett, BJ. *Prediction of in-season shoulder injury from preseason testing in division i collegiate football players*. Sports Health. 2014;6(6): 497-503.
242. Freeston, J, Rooney, K, Smith, S, O'Meara, D. *Throwing performance and test-retest reliability in olympic female water polo players*. Journal of Strength and Conditioning Research. 2014;28(8): 2359-2365.
243. Stark, T, Walker, B, Phillips, JK, Fejer, R, Beck, R. *Hand-held dynamometry correlation with the gold standard isokinetic dynamometry: A systematic review*. PM & R. 2011;3(5): 472-479.
244. Wang, HK, Cochrane, T. *Mobility impairment, muscle imbalance, muscle weakness, scapular asymmetry and shoulder injury in elite volleyball athletes*. Journal of Sports Medicine and Physical Fitness. 2001;41(3): 403-410.
245. Ludewig, PM, Hoff, MS, Osowski, EE, Meschke, SA, Rundquist, PJ. *Relative balance of serratus anterior and upper trapezius muscle activity during push-up exercises*. The American Journal of Sports Medicine. 2004;32(2): 484-493.

246. Lynch, SS, Thigpen, CA, Mihalik, JP, Prentice, WE, Padua, D. *The effects of an exercise intervention on forward head and rounded shoulder postures in elite swimmers*. British Journal of Sports Medicine. 2010;44(5): 376.
247. McClure, PW, Bialker, J, Neff, N, Williams, G, Karduna, A. *Shoulder function and 3-dimensional kinematics in people with shoulder impingement syndrome before and after a 6-week exercise program*. Physical Therapy. 2004;84(9): 832-848.

Appendices

6.1 Appendix I – HREC Approval

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E53-46 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6626
Email: shuretta.thomas@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

08 August 2019

HREC REF NO: 404/2019

Dr Janine Gray
Sport Science Institute
Human Biology

Dear Dr Gray

PROJECT TITLE: ***SCREENING FOR RISK FACTORS ASSOCIATED WITH SHOULDER PAIN IN MALE ADOLESCENT WATER POLO PLAYERS BASED IN THE SOUTHERN SUBURBS OF CAPE TOWN (MSC CANDIDATE: MS P TULLY)***

Thank you for submitting your response to the Faculty of Health Sciences Human Research Ethics Committee.

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

Approval is granted for one year until the 30 August 2020.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please quote the HREC REF in all your correspondence.

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

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

The HREC acknowledge that the student, Paula Tully will also be involved in this study.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.

Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI), and Declaration of Helsinki (2013) guidelines. 5
The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

6.2 Appendix II – WCED Approval

Western Cape Government
Education

Directorate: Research

Fax: 0865902282
Private Bag x9114, Cape Town, 8000
wced.wcape.gov.za

REFERENCE: 20190814-7873
ENQUIRIES: Dr A T Wyngaard

Ms Paula Tully
3D Avenue Massif
Devils Peak Estate
Cape Town
8001

Dear Ms Paula Tully

RESEARCH PROPOSAL: SCREENING FOR RISK FACTORS ASSOCIATED WITH SHOULDER PAIN IN MALE ADOLESCENT WATER POLO PLAYERS BASED IN THE SOUTHERN SUBURBS OF CAPE TOWN

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **20 August 2019 till 20 September 2019**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

    The Director: Research Services
    Western Cape Education Department
    Private Bag X9114
    CAPE TOWN
    8000

We wish you success in your research.

Kind regards.
Signed: Dr Audrey T Wyngaard
Directorate: Research
DATE: 16 August 2019

Lower Parliament Street, Cape Town, 8001
tel: +27 21 467 9272 fax: 0865902282
Safe Schools: 0800 45 46 47

Private Bag X9114, Cape Town, 8000
Employment and salary enquiries: 0861 92 33 22
www.westerncape.gov.za

6.3 Appendix III – Assent Form

Department of Health and Rehabilitation Sciences

Faculty of Health Sciences

Division of Physiotherapy

F45 Old Main Building, Groote Schuur Hospital

ASSENT TO PARTICIPATE IN A RESEARCH STUDY

Screening for risk factors associated with shoulder pain in male adolescent water polo players based in the southern suburbs of Cape Town

Dear Participant

I am a master's student in the Division of Physiotherapy at the University of Cape Town. I will be conducting a study with my supervisor, Dr Janine Gray, to determine the risk factors that lead to shoulder pain and injury in male adolescent water polo players.

Before you decide if you want to be in this study, it is important for you to understand why we are doing the research and what is involved.

Please read this form carefully. You can discuss it with your parents or anyone else. If you have questions about this research, just ask me.

Why are we doing this study?

Among water polo players, shoulder pain is the most common complaint relating to the muscles and skeleton. Adolescents water polo players have a high chance of developing shoulder pain and/or injury. The risk factors that predispose you to shoulder pain and injury are unclear. We are doing this study to find out more information about these risk factors. We want to determine if pre-season screening can tell us whether or not a player is likely to develop shoulder pain during the season. This study is not part of your school water polo program, and does not count towards team selection.

Why are we talking to you about this study?

We are asking male adolescent water polo players between the ages of 14-18 years to participate in this study. We are inviting you to take part because you play water polo at one of the schools that have been selected to be part of the study in the Western Cape.

How many people will take part in this study?

We are hoping to get a sample of 60 participants.

What will happen if you are in this study?

If you agree to be in the study and your parents/guardian give permission, you will be asked to attend one testing session at a convenient time at your school. To minimise your travelling, this will take place either before water polo training (you will not be reimbursed for travel costs). It will take

30-45 minutes. We will ask you to complete a questionnaire and then a series of physical tests will be done. You will be familiarised with the tests by way of explanation and in some cases some practise repetitions. Injury surveillance will then take place for 3 months.

Any questions and/or concerns will be answered and addressed appropriately. Your participation is completely voluntary. The decision to participate will remain confidential; will not be disclosed to the respective coaching and/or management staff; and will not affect your selection for your school water polo team in any way or form. The testing will be done by qualified physiotherapists.

The testing protocol to be utilised during this study, is described in points 1-5 below:

1. **Anthropometrical Information**
   - Weight – a scale will be used to measure your weight in kilograms
   - Height – measured with a tape measure
   - Body fat percentage – callipers will be used to perform a skinfold test. Your skin will be gently squeezed at seven areas on your body – two on the upper arm, just below the shoulder blade, on your upper back, on your calf, your abdomen and above the hip. This test is painless.

   This section will take 5-10minutes.

2. **Questionnaire (Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow Score)**

This is a two-page questionnaire relating to arm and shoulder function and performance. There are 19 questions and it will take approximately five minutes to complete the questionnaire. You will be asked to fill this out at the beginning and end of the study period.

3. **Shoulder Specific Tests:**

The following tests will be performed on your shoulders (in a variety of positions such as standing, sitting or lying on his back) and this will take 20-25 minutes:

- Pain Provocation Tests (used to assess the presence of shoulder pain by a yes/no answer)
- Measurement of passive range of shoulder joint rotation
- Measurement of range of motion of the shoulder blade
- Muscle strength of the muscles that rotate the shoulders
- Muscle strength of the muscles that stabilise the shoulder blade
- Muscle length of the pectoralis minor muscle (deep chest muscle)
- Flexibility of the posterior shoulder complex (back of the shoulder)
- Stability of the shoulder (Closed kinetic chain upper extremity stability test)

4. **Ultrasonographic Measurement of your Shoulder:**

Ultrasound is not painful in anyway and does not use radiation. The following measurements will be performed using an ultrasound machine with you sitting in a chair and will take 5-10 minutes:

- Measurement of the distance between the acromion (a bony process from the shoulder blade) and the head of the humerus (upper arm bone)

- Measurement of the thickness of the supraspinatus tendon (one of the rotator cuff tendons).

5. Injury Monitoring:

The beginning of the season is when most shoulder injuries are reported. Therefore, any shoulder pain or injury sustained during the first 3 months of the 2019/2020 water polo season will be tracked. Every two weeks you will be reminded telephonically to answer a short, self-reported questionnaire to monitor shoulder pain/injury and training load. This will take about 5 minutes to complete. The information will be filled in on an online form and will be collected electronically.

Are there any benefits to being in the study?

There are no immediate benefits to you. There will not be refreshments available during testing. You will learn about your overall shoulder 'health', and may also learn about any potential risks for shoulder pain and/or injury. If you develop shoulder pain and/or injury during the duration of the study, we will refer you to a medical professional in the area. You will be sent the overall results of the study. We hope that the results of the research will eventually help to reduce the number of shoulder injuries sustained by adolescent water polo players.

Are there any risks or discomforts to being in the study?

- You may experience an increase in current shoulder pain for a short time after the testing. However, every effort will be made to minimise the extent of pain during testing. All tests used are accepted clinical tests used to assess pain in a joint, and strength and length of shoulder muscles. Testing will be stopped if your shoulder pain increases and is sustained during any of the procedures.
- You may develop post-exercise soreness or stiffness to the back and shoulder. This soreness or stiffness is a normal occurrence after performing exercise you have not done in a while, and will usually disappear within three to four days.
- A possible risk for any research is that people outside the study might get hold of confidential study information. We will do everything we can to make sure that doesn't happen.

Who will know about your study participation?

Besides you and your parents, the researchers are the only ones who will know the details of your study participation. If we publish reports or give talks about this research, we will only discuss group results. We will not use your name or any other personal information that would identify you.

To help protect confidentiality, we will give your study data a code number, and keep it in a locked cupboard or in a file with a password that only the researchers know.

Will you get paid for being in the study?

You will not be paid for taking part in this study.

Do you have to be in the study?

No, you don't. Research is something you do only if you want to.

Do you have any questions?

You can contact us if you have questions about the study, or if you decide you don't want to be in the study any more. You can talk to me, or your parents, or someone else at any time during the study.

Contact details:

Student Investigator: **Paula Tully**

Physical Address: 3D Avenue Massif
Devil's Peak Estate
Cape Town
8001
Tel number: 082 829 6785
E-mail: paula@tullyphysio.co.za

Principal Investigator: Janine Gray

Physical Address: Division of Exercise Science and Sports Medicine,
Department of Human Biology

University of Cape Town
Sports Science Institute of South Africa
Boundary Road
Newlands
7700
Tel number: (021) 650 4557
Fax number: (021) 650 1796
E-mail: janineg@cricket.co.za

Professor Marc Blockman

Chairperson, Faculty of Health Sciences Research Ethics Committee
Physical address: E52 – 23 Old Main
Building
Groote Schuur Hospital
Observatory
7925
Tel number: (021) 406 6492
Fax number: (021) 406 6411

The UCT's Faculty of Health Sciences Human Research Ethics Committee can be contacted on 021 406 6338 in case you have any ethical concerns or questions about your rights or welfare as a participant on this research study.

****

ASSENT OF ADOLESCENT (13–17 years old)

If you decide to participate, and your parents agree, we will give you a copy of this form to keep for future reference.

If you would like to be in this research study, please sign your name on the line below.

____ _______________

Child's Name/Signature Date

____ _______________

Signature of Investigator Date

6.4 Appendix IV – Informed Consent Form

Department of Health and Rehabilitation Sciences

Faculty of Health Sciences

Division of Physiotherapy

F45 Old Main Building, Groote Schuur Hospital

INFORMED CONSENT

Screening for risk factors associated with shoulder pain in male adolescent water polo players based in the southern suburbs of Cape Town

Dear Parent/Legal guardian

I am a masters' student in the Division of Physiotherapy at the University of Cape Town. I will be conducting a study with my supervisor, Dr Janine Gray, to determine the risk factors that lead to shoulder pain and injury in male adolescent water polo players.

Information obtained from the study will be used to complete my mini-dissertation for the MSc Sports and Exercise Physiotherapy programme. This study has been given ethical approval by the Human Research Ethics Committee, Faculty of Health Sciences, University of Cape Town (HREC REF to be inserted).

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

Prior to your son's inclusion in this study, you will be expected to complete and sign this consent form.

Why is this study being done?

Among water polo players, shoulder pain is the most common complaint relating to the muscles and the skeleton. Adolescents who participate in water polo have a high chance of developing shoulder pain and/or injury. The risk factors that predispose adolescent water polo players to shoulder pain and injury are unclear. We are doing this study to find out more information about these risk factors. We want to determine if pre-season screening (i.e. testing) can tell us whether or not a player is likely to develop shoulder pain during the season. This study is not part of the school water polo program, and does not count towards team selection.

Why is your son being asked to take part in this study?

Your son is being asked to participate in this study because he is between the ages of 14-18 years and plays water polo for one of the schools selected to participate in this study. Adolescents are being asked to participate in this study due to the high risk of developing a musculoskeletal injury of the shoulder.

How many people will take part in this study?

We are hoping to get a sample of 60 participants.

How long will the study last?

Data for this study will be collected during the 2019/2020 water polo season.

What will happen if your child takes part in the study?

Your son will be asked to attend one testing session at a convenient time at your child's school. To minimise on travelling, this will take place either before water polo training (you will not be reimbursed for travel costs). It will take 30-45 minutes. They will be asked to complete a questionnaire and they will undergo physical tests, including height and weight measurements, a series of physical tests for the shoulder (flexibility, strength and function) and an ultrasonographic measurement of the shoulder. Your son will be familiarised with the testing procedure utilised within this study, by way of explanation and for some tests a warm-up sequence of testing. Injury surveillance will then take place for 3 months after the initial testing. Every two weeks your son will be asked to complete a short questionnaire to report on shoulder pain/injury and training load. Any questions and/or concerns will be answered and addressed appropriately. Participation is completely voluntary. The decision to participate will remain confidential; will not be disclosed to the respective coaching and/or management staff; and will not compromise your child's selection for their school water polo team in any way or form. The tests will be conducted by qualified physiotherapists.

The testing protocol to be utilised during this study, is described in points 1-5 below.

1. Anthropometrical Information

- Weight – a scale will be used to measure your weight in kilograms
- Height – measured with a tape measure
- Body fat percentage – callipers will be used to perform a skinfold test. Your skin will be gently squeezed at seven areas on your body – two on the upper arm, just below the shoulder blade, on your upper back, on your calf, your abdomen and above the hip. This test is painless.

This section will take 5-10minutes.

2. Questionnaire (Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow Score)

This is a two-page questionnaire relating to arm and shoulder function and performance. There are 19 questions and it will take approximately five minutes to complete the questionnaire. Your son will be asked to fill this out at the beginning and end of the study period.

3. Shoulder Specific Tests:

The following tests will be performed on your son's shoulders (in a variety of positions such as standing, sitting or lying on his back) and this will take 20-25 minutes:

- Pain Provocation Tests (used to assess the presence of shoulder pain by a yes/no answer)
- Measurement of passive range of shoulder joint rotation
- Measurement of range of motion of the shoulder blade
- Muscle strength of the muscles that rotate the shoulders
- Muscle strength of the muscles that stabilise the shoulder blade
- Muscle length of the pectoralis minor muscle (deep chest muscle)

- Flexibility of the posterior shoulder complex (back of the shoulder)
- Stability of the shoulder (Closed kinetic chain upper extremity stability test)

4. Ultrasonographic Measurement of the Shoulder:

Ultrasound is not painful in anyway and does not use radiation. The following measurements will be performed using an ultrasound machine with your child sitting in a chair and will take 5-10 minutes:

- Measurement of the distance between the acromion (a bony process from the shoulder blade) to the head of the humerus (upper arm bone)

- Measurement of the thickness of the supraspinatus tendon (one of the rotator cuff tendons).

5. Injury Monitoring:

The beginning of the season is when most shoulder injuries are reported. Therefore, any shoulder pain or injury sustained during the first 3 months of the 2019/2020 water polo season will be tracked. Every two weeks your son will be reminded telephonically to answer a short, self-reported questionnaire to monitor shoulder pain/injury and training load. This will take about 3 minutes to complete. The information will be filled in on an online form and will be collected electronically.

Are there any benefits to being in the study?

There are no immediate benefits to your son. There will not be refreshments available during testing. However, your son will learn about their overall shoulder 'health', and may also learn about any potential risks for shoulder pain and/or injury. He will be sent the overall results of the study. If your son develops shoulder pain and/or injury during the duration of the study, we will refer him to a medical professional in the area if required. The costs for the treatment will be for the cost of the individuals' parents/guardian. We hope that the results of the research will eventually help to reduce the number of shoulder injuries sustained by adolescent water polo players by informing coaching staff of potential risk factors to developing shoulder pain and developing intervention programmes aimed at addressing risk factors.

Are there any risks or discomforts to being in the study?

There are minimal to no-risks for participating in this study.

- Your son may experience temporary shoulder pain during the physical testing, as some of the testing protocols utilised may provoke shoulder pain. However, every effort will be made to minimise the extent of pain during testing. All tests used are accepted clinical tests used to assess pain in a joint, and strength and length of shoulder muscles. Testing will be discontinued if any sustained increase in your son's shoulder pain occurs during any of the testing procedures.
- Your child may develop post-exercise soreness or stiffness to the back and shoulder. This soreness or stiffness is a normal occurrence after performing exercise you have not done in a while, and will usually disappear within three to four days.
- A possible risk for any research is that people outside the study might get hold of confidential study information. We will do everything we can to make sure that doesn't happen. This will

be done by replacing your son's name with a participant code. All information is only available to the research team and is stored in locked cupboards and/or password protected files.

Will your son get paid for being in the study?

Your son will not be paid for taking part in this study.

Questions/Concerns

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

Please note that no physiotherapy treatment or any medical management will be given to your son should he develop shoulder pain and/or a shoulder injury during the course of the study. We will, however offer advice, or refer him to an appropriate medical professional if requested.

If at any time you have any questions about the study, please feel free to contact any of the individuals listed below. You are assured that all inquiries will remain confidential.

Student Investigator: **Paula Tully**

Physical Address: 3D Avenue Massif

Devil's Peak Estate
Cape Town
8001
Tel number: 082 829 6785
Email: paula@tullyphysio.co.za

Principal Investigator: **Dr Janine Gray**
Physical Address: Division of Exercise Science and Sports Medicine,
Department of Human Biology
University of Cape Town
Sports Science Institute of South Africa
Boundary Road
Newlands
7700
Tel number: (021) 650 4557

Fax number:	(021) 650 1796
E-mail:	janineg@cricket.co.za

Professor Marc Blockman

Chairperson, Faculty of Health Sciences Research Ethics Committee

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

The UCT's Faculty of Health Sciences Human Research Ethics Committee can be contacted on 021 406 6338 in case you have any ethical concerns or questions about your rights or welfare as a participant on this research study.

By placing your signature below, it serves as confirmation that you have had adequate time to read through the study information, that you have understood the consent form and that your son is willing to participate in this study.

Your son has the right to withdraw at any time and may ask questions at any time during the study.

All information recorded during this study will remain confidential, and no participants will be identified in the event of future publication. Data will be used for scientific purposes only.

Your signature is further confirmation that you are aware of the possible risks involved in this study.

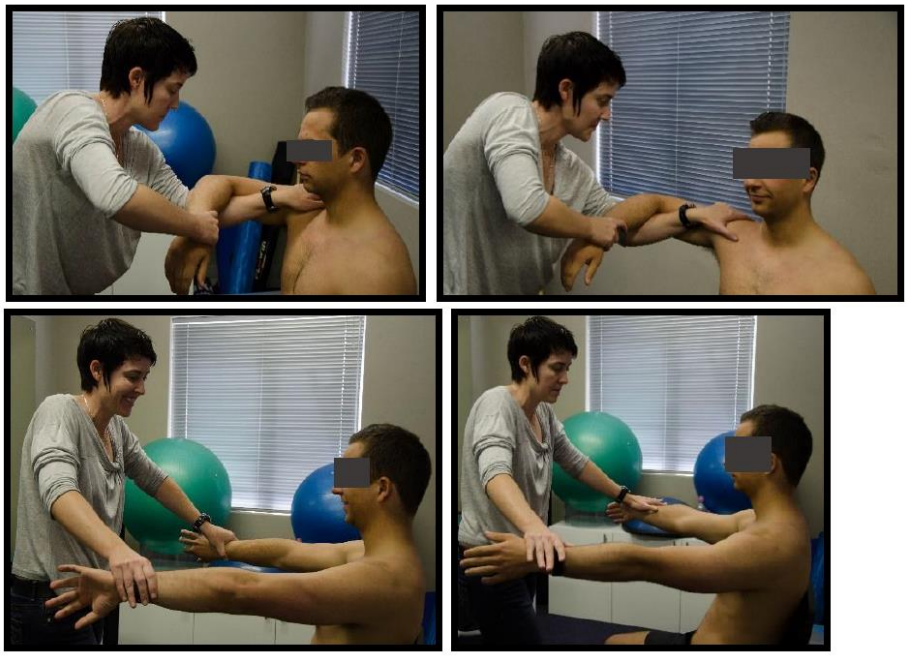
______________________	______________________	________
Signature of Legal guardian	Full Name (please print)	Date
______________________	______________________	________
Signature of Investigator	Full Name (please print)	Date

6.5 **Appendix V – Shoulder Test Information Sheet**

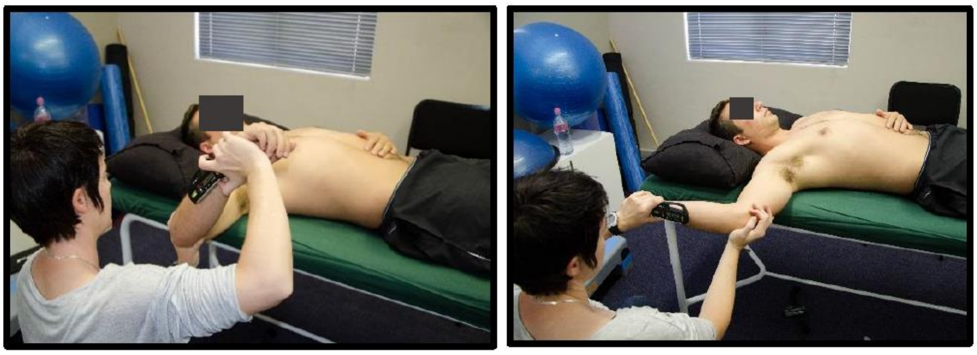
The following physical tests (that you may not be familiar with) will be done on you/your son during the pre-season screening:

1. **Skinfold Test:** (Image from topendsports.com)

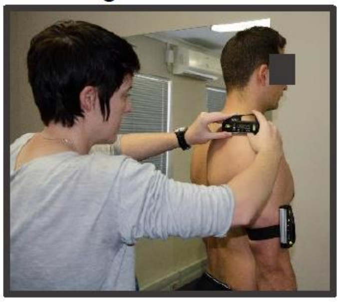
2. **Shoulder Specific Tests:**
   - Pain Provocation tests

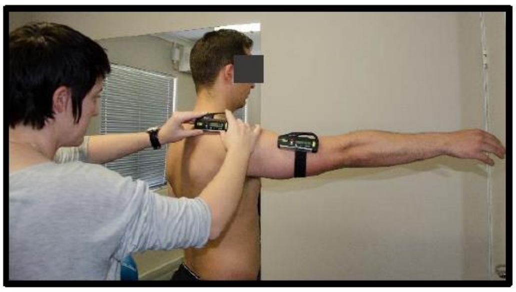


   - Measurement of passive range of shoulder joint rotation

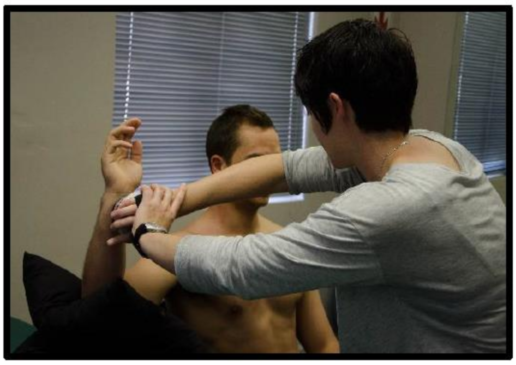


- Measurement of range of motion of the shoulder blade

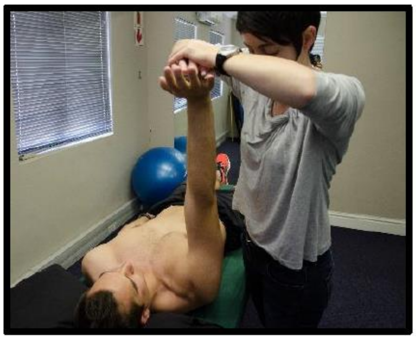




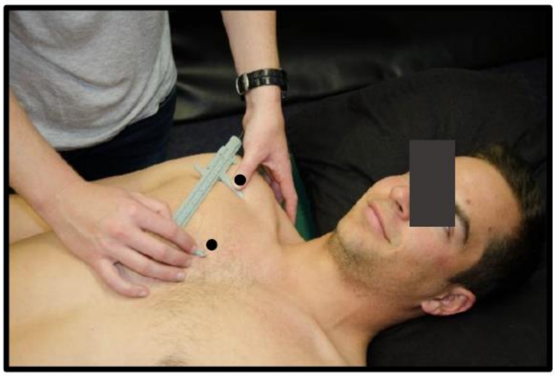

- Muscle strength of the muscles that rotate the shoulders

- Muscle strength of the muscles that stabilise the shoulder blade

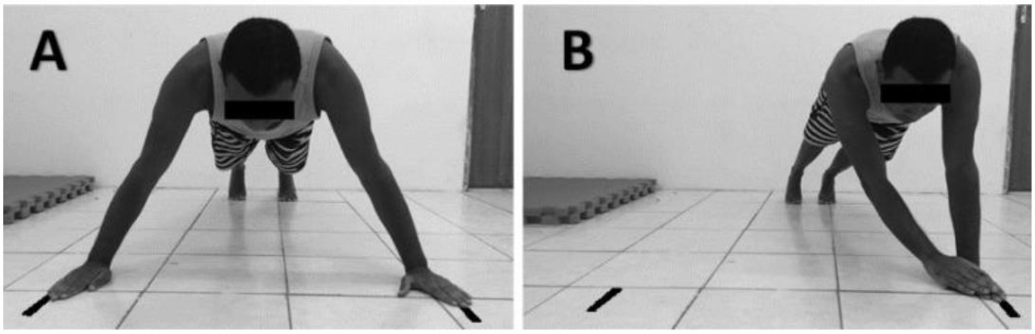


- Muscle length of the pectoralis minor muscle (deep chest muscle)



- Flexibility of the posterior shoulder complex (back of the shoulder)

- Stability of the shoulder (Closed kinetic chain upper extremity stability test)



3. Ultrasonographic Measurements:

6.6 Appendix VI – Demographic Information

Demographic Information

Participant Code: ____________ Date: ___________________

1. PERSONAL INFORMATION

Please complete the table below: (circle where appropriate)

Name			**Surname**	
Date of Birth			**Age**	
School & Team				
Years playing water polo				
Dominant Hand	Left		Right	
Position	Goalkeeper	Defensive specialist	Driver	Two-meter specialist

2. CONTACT DETAILS

This information is needed to provide feedback at the end of this study. Please complete the table below:

Contact Number	
E-mail Address	

3. WATER POLO SPECIFIC DATA

Please show how much time you train during the week on average. (mark with an "x")

Hours	0–30min	30min–1 hr.	1–2 hrs.	2–3 hrs.	3-4 hrs.	4-5 hrs.	5-6 hrs.	6-7 hrs.	> 7hrs
Swimming									
Water polo specific									
Upper body strength/ gym									

4. OTHER SPORTS TRAINING

Please show how much time you train other sports during the week on average (mark with an "x" where appropriate)

Hours	0–30min	30min–1 hr.	1–2 hrs.	2–3 hrs.	3-4 hrs.	4-5 hrs.	5-6 hrs.	6-7 hrs.	> 7hrs
Sport 1 (specify)									

Sport 2 (specify)									

5. GENERAL HEALTH STATUS

Do you have any of the following? If yes, please indicate the frequency (i.e. once a week) and the medication you use for the condition.

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

6. HISTORY OF INJURY

Please show whether you have picked up any of the following injuries (mark with an "x"). If you answer yes then please complete the rest of the columns.

Injury	Yes	No	Which side (if applicable)?		Date of injury	Do you still have the injury?	
			Left	Right		Yes	No
Headache							
Whiplash							
Shoulder muscle tear							
Neck Injury							
Pain down either or both arms							
"Tennis Elbow"							
Thrower's Shoulder/Impingement							

Injury	Yes	No	Which side (if applicable)?		Date of injury	Do you still have the injury?	
			Left	Right		Yes	No
Upper arm muscle tear							
Upper back pain							
Lower back pain							

6.7 Appendix VII – KJOC Questionnaire

Kerlan-Jobe Orthopaedic Clinic Shoulder & Elbow Score

Name_______________________ Age______ Sex_________ Dominant Hand (R) _____ (L) ____ (Ambidextrous) _____________ Date of Examination_____________________ Sport ________ Position ________ Years Played ________

Please answer the following questions related to your history of injuries to **YOUR ARM ONLY:**

	YES	**NO**
1. Is your arm currently injured?	☐	☐
2. Are you currently active in your sport?	☐	☐
3. Have you missed game or practice time in the last year due to an injury to your shoulder or elbow?	☐	☐
4. Have you been diagnosed with an injury to your shoulder or elbow other than a strain or sprain?	☐	☐
If yes, what was the diagnosis? ___________	☐	☐
5. Have you received treatment for an injury to your shoulder or elbow?	☐	☐
If yes, what was the treatment? (Check all that apply)	☐	☐

☐ Rest ☐ Therapy ☐ Surgery (please describe): ______________

Please describe your level of competition in your current sport:
(Use Professional Major League, Professional Minor League, Intercollegiate, High School as the choices)

6. What is the highest level of competition you've participated at?__________

7. What is your current level of competition? ______________________

8. If your current level of competition is not the same as your highest level, do you feel it is due to an injury to your arm?	☐	☐

Please check the ***ONE category only*** that best describes your current status:
☐ Playing without any arm trouble ☐ Playing, but with arm trouble
☐ Not playing due to arm trouble

Instructions to athletes:
The following questions concern your physical functioning during game and practice conditions. Unless otherwise specified, all questions relate to your **shoulder or elbow**. Please answer with an **X** along the horizontal line that corresponds to your current level.

1. How difficult is it for you to get loose or warm prior to competition or practice?

Never feel loose during games or practice —————————— Normal warm-up time

2. How much pain do you experience in your shoulder or elbow?

Pain at rest —————————— No pain with competition

3. How much weakness and/or fatigue (ie, loss of strength) do you experience in your shoulder or elbow?

Weakness or fatigue preventing any competition —————————— No weakness, normal competition fatigue

4. How unstable does your shoulder or elbow feel during competition?

"Popping out" routinely —————————— No instability

5. How much have arm problems affected your relationship with your coaches, management, and agents?

Left team, traded or waived, lost contract or scholarship — Not at all

The following questions refer to your level of competition in your sport. Please answer with an **X** along the horizontal line that corresponds to your current level.

6. How much have you had to change your throwing motion, serve, stroke, etc, due to your arm?

Completely changed, don't perform motion anymore — No change in motion

7. How much has your velocity and/or power suffered due to your arm?

Lost all power, became finesse or distance athlete — No change in velocity/power

8. What limitation do you have in endurance in competition due to your arm?

Significant limitation (became relief pitcher, switched to short races for example) — No endurance limitation in competition

9. How much has your control (of pitches, serves, strokes, etc.) suffered due to your arm?

Unpredictable control on all pitches, serves, strokes, etc. — No loss of control

10. How much do you feel your arm affects your current level of competition in your sport (ie, is your arm holding you back from being at your full potential)?

Cannot compete, had to switch sports — Desired level of competition

6.8 Appendix VIII – Shoulder Pain and Training Load Questionnaire

Injury Monitoring Questionnaire

Thank you for taking part in this study about shoulder injuries in water polo players!
Please take a few minutes to complete this questionnaire as accurately as possible.
Please note that none of this information will be shared with your coach.

* Required

Name & Surname *

Your answer

Participant Code *

Your answer

Next

Page 1 of 6

Injury Monitoring Questionnaire

* Required

Training Load

These questions are regarding your training over the last week. It includes any school, provincial or national level training.

1.1 How many sessions of swimming training have you had in the last 2 weeks? *

Choose

1.2 How many hours of swimming training have you had in the last 2 weeks? *

Choose

1.3 How many sessions of water polo training have you had in the last 2 weeks? *

Choose

1.4 How many hours of water polo training have you had in the last 2 weeks? *

Choose

1.5 How many water polo matches have you had in the last 2 weeks? *

Choose

1.6 How many hours have you spent playing water polo matches in the last 2 weeks? *

Choose

Back Next

Page 2 of 6

Injury Monitoring Questionnaire

* Required

Shoulder Pain

For this section, shoulder pain is defined as 'a physical complaint or presentation of pain for one or more days, sustained during competition and/or training, regardless of the need for medical management or a loss of training time and/or competition because of the pain'.

2.1 Have you had any shoulder pain in the last 2 weeks? *

If your answer is YES, please answer questions 2.2 - 2.5

- Yes
- No

Back Next

Page 3 of 6

Injury Monitoring Questionnaire

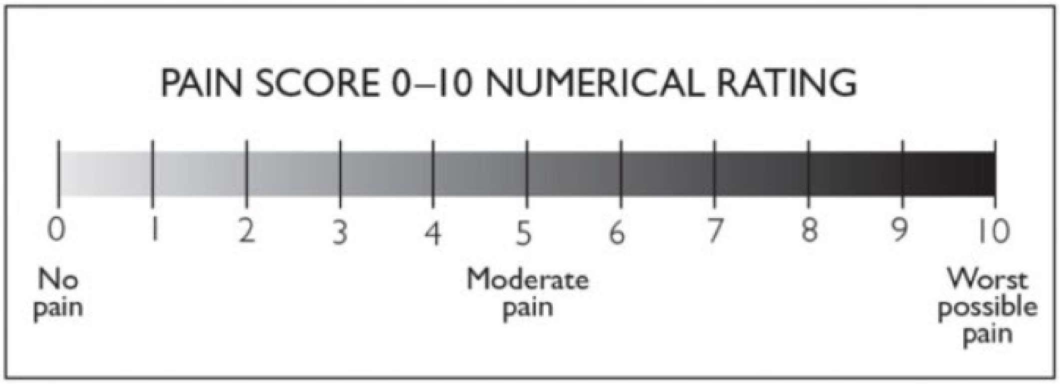
* Required

Shoulder Pain

2.2 Which shoulder is painful? *

- ◯ Dominant arm
- ◯ Non-dominant arm
- ◯ Both

2.3 How severe is your shoulder pain? *



Choose ▾

2.4 During which activity did you first feel your shoulder pain? *

- ◯ Throwing
- ◯ Swimming
- ◯ Defending
- ◯ Gym
- ◯ Other

2.5 Would you like advice on how to manage your pain? *

- ◯ Yes
- ◯ No

Back Next Page 4 of 6

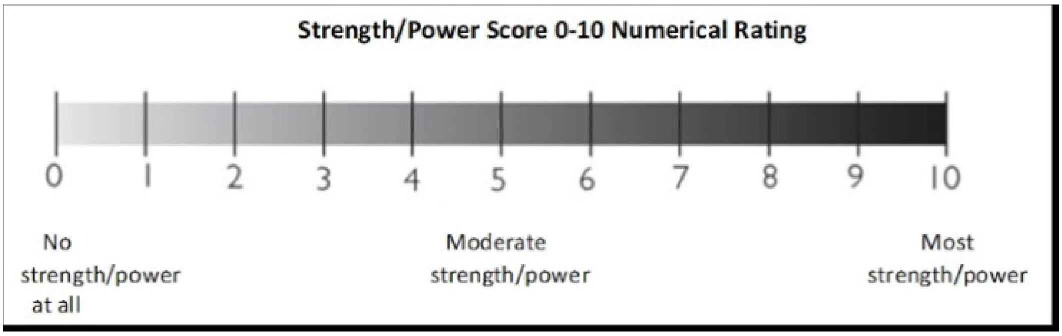
Injury Monitoring Questionnaire

* Required

Shoulder Strength/Power

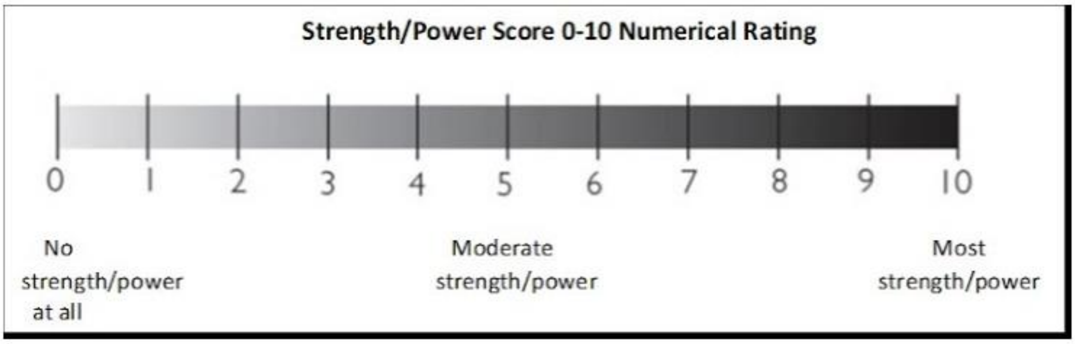
For this section, strength/power is defined as 'the ability of the body to perform an activity.

3.1 Please rate your average strength/power with PASSING in the last 2 weeks. *



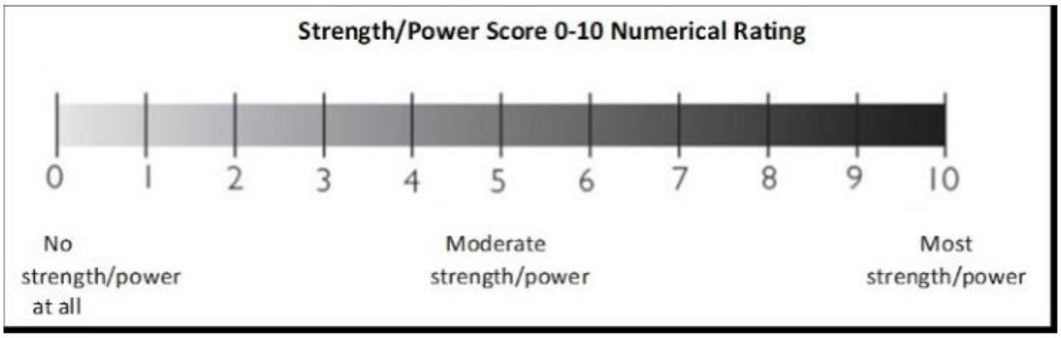
Choose

3.2 Please rate your average strength/power with SHOOTING in the last 2 weeks.
*



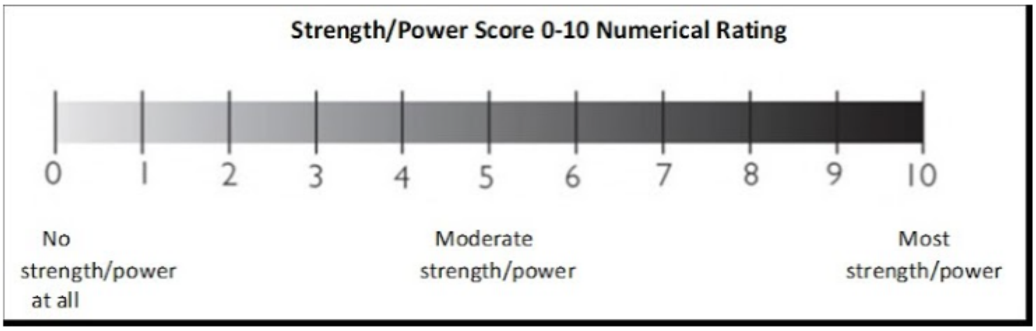
Choose

3.3 Please rate your average strength/power with SWIMMING in the last 2 weeks.
*



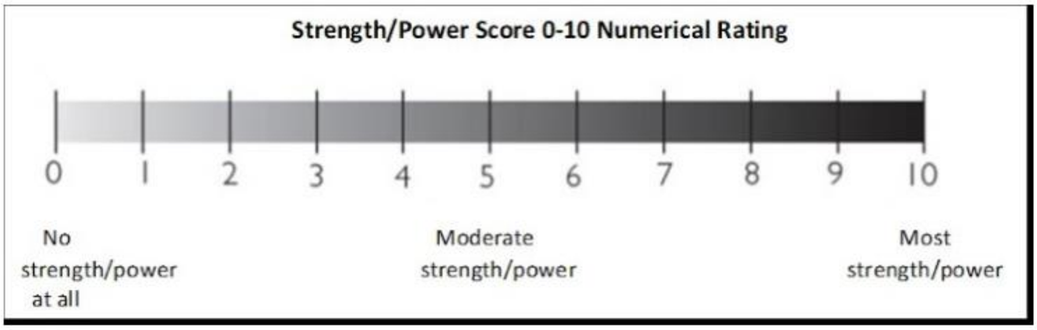
Choose

3.4 Please rate your average strength/power with DEFENDING in the last 2 weeks. *



Choose

3.5 Please rate your average strength/power with GYM in the last 2 weeks.



Choose

Back Next Page 5 of 6

Injury Monitoring Questionnaire

Thank you for taking the time to complete this questionnaire!

Please contact Paula on 083 411 4214 or paula@tullyphysio.co.za if you have any questions or concerns.

Back Submit Page 6 of 6

Never submit passwords through Google Forms.