Shoulder injury in cricketers: The role of shoulder rotation range of movement, throwing arc range of movement and pectoralis minor muscle length

Bhakti Lala

This research report is presented to the University of the Witwatersrand in partial fulfilment of the requirements for the degree of Master of Science in Physiotherapy

Johannesburg, 2017

Declaration

I, Bhakti Lala, present this research report which contains my own work. I have submitted it to the University of the Witwatersrand. I have not submitted it to any other university for a degree.

Signature: ____________________________

Date: ____________________________

Acknowledgements

I would like to thank my supervisors, Associate Professor Benita Olivier and Miss Nadia Gillion, for all of their, support and patience in completing this research.

Thank you to Gauteng Cricket Board, Marks Park Cricket club for their participation in this study.

Thanks to the South African Society of Physiotherapy for their support by funding this research.

Thank you to The Lord, my family and friends for always standing by me.

Conflicts of interest

There were no conflicts of interest

Abstract

BACKGROUND:

The game of cricket requires the repetitive use of the upper limbs in batting, bowling and fielding. Shoulder injuries are prevalent in cricket players with the most common activities causing injury being fielding and bowling. There is no research on pectoralis minor muscle length in cricketers or the role that the throwing arc range of movement (ROM) plays in shoulder injuries, in a male only cricket population older than 18 years of age.

OBJECTIVE:

The objective of this study was to determine if there is an association between shoulder rotation ROM, throwing arc ROM, pectoralis minor muscle length, and incidence of shoulder injury, as monitored in the first three months of a cricket season

METHOD:

This was a prospective, observational cohort study. Thirty six male, provincial and club cricket players, with and without shoulder pain, were recruited. Shoulder internal rotation ROM, external rotation ROM and pectoralis minor muscle length test distance were measured at the beginning of a cricket season and during the first three weeks of the in-season. Glenohumeral internal rotation deficit (GIRD), external rotation gain (ERG) and throwing arc ROM were calculated from these measurements. The incidence of injury was monitored for three months. Comparisons were made between the injured and uninjured groups. Parametric data were analysed using independent t-tests and paired t-tests. Non-parametric data were analysed with the Mann-Whitney U tests, chi-squared tests and Sign tests. A logistic regression model was used to determine the relationship between variables.

RESULTS:

Thirty six participants were recruited and underwent the baseline testing procedure, although only thirty two participants' data were analysed. During the study, four participants were not exposed to the typical cricket training and match workloads and were therefore excluded from the study. The mean age of participants was 23.56 (SD

± 4.27) years. Nine participants (28%) sustained dominant shoulder injuries and twenty-three (72%) remained uninjured. The presence of initial shoulder pain at rest, during or after training ($p = 0.007$) at the beginning of the season occurred in six participants who sustained shoulder injuries during the season.

There were no statistically significant differences between the injured and uninjured group in any of the other variables. All pre-season measurements in the entire group were significantly different between the dominant and non-dominant upper limb. The external rotation ROM ($p = 0.0037$) was increased on the dominant side and the internal rotation ROM ($p < 0.0001$), throwing arc ROM ($p = 0.016$) and pectoralis minor muscle length ($p = 0.0001$) (decreased pectoralis minor length test distance) was increased on the non-dominant side. In the injured group, there was no significant difference between dominant and non-dominant measurements. The uninjured group had a smaller dominant internal rotation ROM ($p = 0.0001$), throwing arc ROM ($p = 0.005$) and pectoralis minor muscle length ($p = 0.0002$) (larger pectoralis minor length test distance) which was statistically significantly different to the non-dominant shoulder. A logistic regression analysis found no association between the variables and injury.

CONCLUSION:

Shoulder pain at the beginning of the season may be a precursor to shoulder injuries in cricket players. The presence of pain should be questioned during the pre-season screening, so that preventative programmes may be put into place to prevent shoulder injuries which result in time out of play. Asymmetries were found in the uninjured group with internal rotation ROM, throwing arc ROM and pectoralis minor muscle length although, no asymmetries existed in the injured group. These asymmetries may have a protective role in injury prevention whereas, non-asymmetries (as seen in the injured participants) may precipitate dominant shoulder injuries.

Table of contents

Tables

Figures

Abbreviations

ROM : Range of movement

GIRD : Glenohumeral internal rotation deficit

ERG : External rotation gain

SLAP : Superior labrum tear from anterior to posterior

IRs : Internal rotators

ERs : External rotators

IRD : Internal rotation difference

ERD : External rotation difference

ICC : Intraclass correlation coefficient

IQR : Interquartile range

CHAPTER 1: Background and Need

1.1 Introduction

Cricket is a demanding sport that requires the use of the upper limbs in batting, bowling and fielding (Dhillon et al. 2012). Upper limb injuries account for 19.8 - 26.3% of the total number of injuries sustained, where 21.7% of these injuries are sustained at the glenohumeral joint (Stretch 2003). The most common activities causing shoulder injury are fielding and bowling (Stretch 2003).

The glenohumeral joint is a ball and socket joint that derives its stability from its static and dynamic stabilisers (Farrar et al. 2013). The static stabilisers are composed of the glenohumeral ligaments, labrum and joint capsule (Farrar et al. 2013). The dynamic stabilisers are the rotator cuff muscles (Farrar et al. 2013) and the scapula stabilising muscles (Murray et al. 2013). The static and dynamic constraints are required to provide stability and control of movement especially with overhead movements in athletes (Murray et al. 2013).

Glenohumeral joint injuries in overhead athletes occur mostly during the late cocking (Mihata et al. 2015) and the follow-through phase of throwing (Kinsella et al. 2014). The cocking phase of throwing consists of shoulder abduction, horizontal extension and maximal external rotation (Mihata et al. 2015). In this phase, the scapula retracts causing the acromion to elevate above the rotator cuff muscles (Brukner & Khan 2012; Seroyer et al. 2010). In the late cocking phase, the anterior inferior glenohumeral ligament prevents anterior humeral translation, but with repetitive throwing it stretches resulting in an increase in external rotation range of movement (ROM) and an anterior capsule instability (Mihata et al. 2015; Murray et al. 2013).

The deceleration and follow-through phase occurs from ball release with deceleration of the shoulder into full shoulder internal rotation (Seroyer et al. 2010). The posterior shoulder muscles work eccentrically to control the deceleration of the shoulder, however, these excessive distracting forces can cause tearing of the posterior joint capsule (Dashottar & Borstad 2012). The tearing heals but with repetitive throwing the tissues lose elasticity in the posterior capsule resulting in a decrease in internal rotation ROM (Dashottar & Borstad 2012). The anterior instability and posterior tightness affect the stability of the glenohumeral joint, which alters the normal throwing biomechanics and increases the risk of injury (Fessa et al. 2015).

Glenohumeral internal rotation deficit (GIRD) is associated with a decrease in internal rotation ROM (Fessa et al. 2015). GIRD may be anatomical or pathological. Pathological GIRD consists of GIRD greater than 18° – 20° with an associated loss of total arc ROM between the shoulders (Manske et al. 2013b). GIRD causes the humerus to rotate into a more posterior superior position (Burkhart, Morgan & Kibler 2003). The change in the humeral rotation in the late cocking phase increases the tension in the biceps tendon (Fessa et al. 2015). The biceps tendon inserts onto the superior labrum, therefore the tensional forces causes a peeling back of the labrum resulting in shoulder pain (Fessa et al. 2015).

Normal scapula function is required for throwing to be injury free. The scapula moves in coordination with the humerus during overhead activities, to elevate the acromion and allow safe movement of the rotator cuff muscles (Brukner & Khan 2012). Shoulder pain has been associated with changes in muscle activation and scapula kinematics (Phadke, Camargo & Ludewig 2009). Kinsella et al. (2014) proposed abnormal scapula movement such as increased internal rotation as a cause of a decrease in the subacromial space. Tightness of the pectoralis minor muscle has been associated with scapula internal rotation and it orientates the glenoid fossa closer to the humeral head (Kinsella et al. 2014). During the late cocking phase, the scapula malposition impinges the rotator cuff muscles between the humeral head and the labrum resulting in pathology (Kinsella et al. 2014).

GIRD and external rotation gain (ERG) on shoulder pain has been investigated in various overhead sports (Fessa et al. 2015). The problems being: a tight posterior capsule, the peel back mechanisms causing superior labrum tear from anterior to posterior (SLAP), hyperexternal rotation due to anterior capsule laxity (Fessa et al. 2015) and scapular malposition (Kinsella et al. 2014). Therefore the aim of this study is to establish if there is an association between shoulder rotational ROM, throwing arc ROM, pectoralis minor muscle length, and shoulder injuries, as monitored in the first three months of a cricket season.

1.2 Research Problem

GIRD and ERG have been identified in overhead athletes (Almeida et al. 2013) and cricketers (Giles & Musa 2008) to contribute to shoulder injuries, however, the contribution of pectoralis minor muscle length in cricketers has not been researched. Throwing arc ROM and its association with shoulder injury has been researched in an elite female population (Steulcken, Ginn & Sinclair 2008), and in a mixed female and male population which included both adolescent and adult elite cricketers (Giles & Musa 2008). Throwing arc ROM has not been researched in a male only population of cricketers older than 18. During the pre-season training, the players undergo an intensive three month training schedule. Players return to the pre-season training from a two month holiday, a season of playing club cricket in England or it is their first time playing at a high performance level. After the pre-season training, they participate in fitness and skills sessions, they play three or four T20 games per week in the evenings, a three day test match and a 50 over game. The first three months of the cricket season, is the part of the season with the highest load of training and match sessions for the included teams.This results in training overload, fatigue and injuries. This study will be monitoring shoulder rotation ROM, throwing arc ROM and pectoralis minor muscle length over a three month period, when all formats of the games are played, to determine their association with shoulder injury.

1.3 Research Question

Is there an association between shoulder rotation ROM, throwing arc ROM, pectoralis minor muscle length, and the dominant shoulder injury, in the first three months of a cricket season?

1.4 Aim of the study

The aim of the study is to determine if there is an association between the shoulder rotational ROM, throwing arc ROM, pectoralis minor muscle length, and the dominant shoulder injury, in the first three months of a cricket season.

1.4.1 Research Objectives

The objectives of the study are:

- To determine baseline shoulder rotation ROM, throwing arc ROM and pectoralis minor muscle length during the last week of the pre-season and first three weeks of the in-season.
- To determine the dominant shoulder injury incidence as monitored in the first three months of a cricket season.
- To determine if there is an association between shoulder rotation ROM, throwing arc ROM, pectoralis minor muscle length, and dominant shoulder injury.

1.5 Significance of the study

If shoulder rotation ROM, throwing arc ROM and pectoralis muscle length are found to be associated with the dominant shoulder injury in cricketers, then these measurements can be included into the shoulder injury screening tools. Conducting these measurements during the pre-season will contribute to the early identification of risk to injury. High risk cricketers can be given a secondary injury prevention program to prevent an injury and reduce time off from sports. This study may provide the basis for future studies in both the prevention and rehabilitation programmes of shoulder injuries in cricket.

CHAPTER 2: Literature Review

2.1 Introduction

Cricket is a team sport that requires the use of the upper limbs in all aspects of the game including batting, bowling and fielding (Dhillon et al. 2012). The cricketer uses these skills repetitively throughout the game which lasts from one up to three or more days consecutively (Orchard et al. 2005). This repetitive use results in players sustaining upper limb injuries which affect their training availability and game selection (Dhillon et al. 2012).

To gain more insight into the topic of this research report, the literature review will address the current literature regarding shoulder injuries in cricket. It will discuss the epidemiology of cricket related upper limb injuries by reviewing the implication of the skills (batting, bowling, fielding and wicket keeping) demands on the glenohumeral joint and the effect that shoulder pain has on the cricketer's ability to play. It will include the importance of stability of the glenohumeral joint, while analysing the biomechanics of the joint during bowling, throwing and normal elevation. Literature will be explored to find the association between the pathology causing shoulder injury and the following variables: shoulder rotational ROM, GIRD, ERG, throwing arc ROM, pectoralis minor muscle length in the development of a shoulder injury in cricket. Lastly, it will explore measurement tools involving the goniometer, manual inclinometer, caliper and the right angle ruler in measuring glenohumeral rotational ROM and pectoralis minor muscle length.

2.2 Definition of a cricket injury

The epidemiology of cricket related upper limb injuries depends upon the injury definition used within the study. A significant injury as stated within a cricket injury consensus statement is described as "any injury or other medical condition that either prevents a player from being fully available for selection for a major match or during a match causes a player to be unable to bat, bowl or keep wicket when required" (Orchard et al. 2016). This internationally accepted definition does not cover elite sportsmen playing with an existing injury (Ranson & Gregory 2008), therefore most injuries are not recorded. An injury definition that covered non-significant injuries was defined as: a musculoskeletal pathology that caused a cessation of cricket activity days or terminated a bowler's activity to gain medical care (Olivier et al. 2015). The injury definition according to the consensus statement was updated in 2016 to include general time loss injuries which is defined as "any injury (or illness) that results in a player being considered unavailable for match-play, irrespective of whether a match or training was actually scheduled" (Orchard et al. 2016).

This definition will capture the broad spectrum of injuries sustained in future cricket related studies. The injuries were previously described as contact or non-contact, however, in the 2016 consensus statement, the modes of onset of injuries are classified as: sudden-onset non-contact injury, impact/traumatic injury, gradual onset, insidious or medical illness (Orchard et al. 2016). Prior to the updated consensus statement, a combination of significant and non-significant injury definitions could capture the true amount of shoulder injuries sustained. Therefore an injury was defined as dominant shoulder pain that presented during or after the various skills (batting, bowling, fielding and wicket keeping), on training or game days that required a limitation or termination of that activity.

2.3 Epidemiology of upper limb injuries in cricket

The prevalence of shoulder injury in cricket players ranges between 0.1 – 1.7% (Orchard et al. 2010; Ranson & Gregory 2008; Ranson et al. 2013) and it represents the percentage of players unavailable for selection for a match due to injury (Orchard et al. 2016). Club cricket players based in England and Wales rated the highest at 1.7% of injury prevalence during the 2005 season including both match and training injuries (Ranson & Gregory 2008). The shoulder injuries contained both contact and non-contact injuries (Ranson & Gregory 2008). Prevalence of shoulder tendon injuries between 0.1% – 1.4% were based on the Australian national and the state teams, over 11 seasons (1998 – 2009), with the prevalence based only on missed matches and not missed training (Orchard et al. 2010). An injury prevalence of 0.1% was reported by national squads during the International Cricket Council World Cup, based on missed tournament days during the 50 day tournament (Ranson et al. 2013). The shoulder injuries may have been traumatic in nature as activities that caused injury during fielding were recorded as catching and diving, however, the exact mechanism related to the shoulder prevalence was not stated (Ranson et al. 2013). The different prevalence rates reported in the literature may be attributed to the type of study populations, the time period of the injury surveillance and the injury definition used, therefore injury surveillance is required on a regular basis to keep up with the current trends in prevalence rates.

The occurrence of upper limb and, more specifically, shoulder injuries represents a moderate percentage of injuries which are not reflected by the low prevalence rate. In younger cricket groups, such as adolescents, upper limb injuries account for 33.3% (Das et al. 2013) and 24% (Stretch & Trella 2012) of the total number of injuries sustained. Similar percentages were reported on u19 players at a 27 match international tournament (Das et al. 2013) and the elite schoolboy cricket players over three seasons (Stretch & Trella 2012). Shoulder injury statistics in the adult population was described as 23% of participants in the English and Wales club teams during their 2005 season (Ranson & Gregory 2008). These statistics illustrate that upper limb and shoulder injuries affect adolescents through to adulthood with a steady, moderate injury percentage within this upper limb region.

2.4 Cricket skills and shoulder pain

2.4.1 Batting

The role of the batsman in cricket is to score the maximal amount of runs during the game by hitting the ball and running across the crease on the opposite side of the pitch (Tennant 2009). Alternatively, after the ball is hit, if it reaches the boundary with or without bouncing, then four or six runs are scored (Tennant 2009). The skill of batting in cricket involves a variety of different shots that can be played, as a batsman has a range of 360° in which he can strike the ball (Portus & Farrow 2011). The ball is struck with a long bat that can weigh up 1.5kg (Ranson & Gregory 2008). The upper limb plays an important role in batting with regards to the batsman hitting the ball.

There is a small percentage of cricket players complaining of batting related shoulder pain. In club cricket, players' perception of pain was as follow: 8.6% of batsmen always felt pain and 17.1% sometimes felt pain while batting (Ranson & Gregory 2008). A study by Ranson & Gregory (2008) reported that shoulder pain affected batting performance as 2.9% of their batsmen changing a shot, 2.9% avoiding a shot, 5.7% reducing the power of a shot and 5.7% incorrectly placing a shot due to pain. Shoulder pain has a minor influence in affecting the batsmen's batting ability.

Batting is also an activity which forms part of baseball. In baseball players, rehabilitation by strengthening the internal rotators (IRs) and external rotators muscles (ERs) to a lower IRs:ERs torque ratio of 62.31% (at 60°/sec) produced a decrease in shoulder pain and a decrease in internal rotator muscle fatigue (Cha et al. 2014). In cricket players, batsmen with large isokinetic internal rotator peak torques 46.20Nm and average internal rotator power torques of 84.38Nm in the dominant shoulder at high speeds (240°/sec), are more successful batsmen (Nunes & Coetzee 2007). These uninjured batsmen had ERs:IRs torque ratio of 64.41Nm suggesting that the internal rotators muscles require a large torque however, a larger torque is required from the external rotator muscles for the batsmen to remain injury free (Nunes & Coetzee 2007). Therefore the rate of shoulder pain felt with batting may be prevented with the correct muscle balance ratio.

2.4.2 Bowling

In cricket, the bowlers' requirement is to bowl a ball with a straight arm, which causes the ball to bounce on the pitch before reaching the batsman (Orchard et al. 2005). There are two types of bowlers, fast bowlers and spin bowlers (Orchard et al. 2005). Fast bowlers use a long run up to deliver the ball to the batsman at an increased speed (Dhillon et al. 2012; Orchard et al. 2010) whereas spin bowlers make use of a short run up and cause the ball to rotate so that it deviates once it hits the ground (Gregory, Batt & Wallace 2002; Orchard et al. 2010). Both types of bowlers make use of the upper limb to deliver the ball while bowling.

The development of shoulder injuries in bowlers is evident as the pain experienced influence the bowlers' capabilities. In English and Welsh cricket clubs, 60% of players continue playing cricket with a shoulder injury (Ranson & Gregory 2008). Fifteen percent of these players reported that they always feel shoulder pain while bowling (Ranson & Gregory 2008). Shoulder pain affects the bowlers' bowling performance, as 50% decrease the number of balls bowled during training and 35% decrease the number of overs bowled during a match, when they have pain (Ranson & Gregory 2008). The shoulder joint plays a crucial role during bowling with pain having a relative effect on bowling performance.

Spin bowlers are said to develop more shoulder injuries than fast bowlers (Gregory, Batt & Wallace 2002). This may be related to spin bowlers having a significantly larger external rotation ROM (150.15°) compared to fast bowlers (144.49°) in elite cricketers (Sundaram, Bhargava & Karuppannan 2012). However, in county cricket clubs, more fast bowlers are at risk of developing shoulder injuries (Ranson & Gregory 2008). Ranson & Gregory (2008) noticed that in this population, 45% of the fast bowlers and 15% of the spin bowlers found that their speed and spin was affected while bowling, due to shoulder pain. These studies used different injury definitions, with the club teams capturing more injuries that affect match participation; training and activities of daily living (Ranson & Gregory 2008). Spin bowlers and fast bowlers are affected by shoulder injuries, however, more research should be conducted to observe definitive injury trends.

The acceleration phase of bowling is associated with shoulder injuries. During this phase large internal rotation torques occur. Internal rotation toques of 65.2 Nm/kg as compared to 45.91Nm/kg in uninjured bowlers' shoulders (at 180°/sec) were obtained using isokinetic shoulder testing (Aginsky, Lategan & Stretch 2004). In this study, bowlers had a lower ERs:IRs torque in the injured group (72.13Nm) as compared to the uninjured group (78.58Nm), suggesting a rotator cuff muscle imbalance which predisposed the risk for impingement (Aginsky, Lategan & Stretch 2004). Therefore it has been proposed that a bowler's external rotators muscles should be 60 - 100% of his internal rotator muscle strength to prevent injury (Aginsky, Lategan & Stretch 2004).

The follow-through phase of bowling is implicated with injury during the quick decelerating of the arm after ball release (Glazier & Wheat 2014). Maximal shoulder distraction forces occur during follow-through at 27° past the vertical, and after ball release which is at 15° past the vertical (Steulcken et al. 2010). The repetitive distraction forces result in adaptations of the tissue of the posterior capsule which alters the shoulder joint mechanics thus leading to injury (Dashottar & Borstad 2012). These results are based on elite female fast bowlers suggesting that large distraction forces while bowling are risk factors for developing a shoulder injury (Steulcken et al. 2010).

2.4.3 Fielding

Effective fielding is a requirement for all cricket players (Tennant 2009). Whether a cricketer is a specialist batsman or bowler, all cricket players are still obligated to field. A cricket field is made up of an infield and outfield (Lockie, Callaghan & Jeffriess 2014). The infield consists of two semicircles that form an oval around the pitch and stumps, and an outfield which is the area from the outer part of the infield to the boundary (Lockie, Callaghan & Jeffriess 2014; Tennant 2009). Different fielding positions require different skills, such as quick reactions in the infield and a strong throwing arm in the outfield (Lockie, Callaghan & Jeffriess 2014). The fielder irrespective of their fielding position, needs to sprint over short distances to dismiss or restrict the amount of runs scored by the batsman (Lockie, Callaghan & Jeffriess 2014). They achieve this by catching the ball, stopping the ball to minimise the amount of runs scored, or by throwing the ball to the bowler, wicket keeper or stumps for a run out (Lockie, Callaghan & Jeffriess 2014; Tennant 2009).

Fielding causes the most shoulder pain as compared to bowling and batting (Das et al. 2014; Dhillon et al. 2012; Ranson & Gregory 2008; Stretch & Trella 2012). Fielders with shoulder pain experience a decrease in throwing power and expect to feel pain with powerful throws, therefore they field closer to the infield to avoid powerful throws from the boundary (Ranson & Gregory 2008). Ranson & Gregory (2008) found that in club cricketers: 60% avoided fielding positions, 57% moved into the infield from the outfield, 94% felt decreased throwing power when throwing from the outfield and 65% always or often felt shoulder pain while throwing. However, in 83% of the fielders who had shoulder injuries, the injury did not influence them to miss or drop a ball (Ranson & Gregory 2008). Therefore catching was not associated with non-contact shoulder injuries (Ranson & Gregory 2008), but contact upper limb injuries are common in younger cricket players as they lack experience in fielding skills (Das et al. 2014).

Fielding is a common source of shoulder injury which causes players to adapt their fielding position and fielding ability.

Throwing workload has been associated with shoulder injuries. In elite Australian cricket players, injury risk occurred with more than 40 throws/day or more than 100 throws/week (Saw et al. 2011). Saw et al. (2011) observed that injuries were related to more throwing days and fewer rest days. They suggested that throwing injuries may occur slowly over time, however, throwing overload that occurred a week prior to the injury, was enough to trigger the injury. Throwing guidelines for cricketers should be drawn up to prevent throwing related injuries (Saw et al. 2011).

2.4.4 Wicket keeping

The wicket keeper is a cricketer who stands behind the stumps on the batsman's side of the pitch (Tennant 2009). Tennant (2009) indicated that the role of the wicket keeper is to catch the ball that passes the batsman. The wicket keeper can dismiss a batsman by catching the ball after it is flicked off the bat, stump the batsman by throwing the ball at the stumps after catching the ball, or run out the batsman by catching a ball from a fielder and throwing it towards the stumps (Tennant 2009). The batsman will be dismissed from stumping or run out only if the batsman is out of his crease (Tennant 2009).

There is minimal literature regarding shoulder injuries in wicket keepers. A study by Ranson & Gregory (2008) observed no shoulder injuries sustained by the 16 wicket keepers in their study, although Giles & Musa (2008) reported one contact shoulder injury in their study, which included 18 wicket keepers. According to the available research, wicket keepers sustain the least number of shoulder injuries compared to the other activities which form part of the game.

2.5 Upper limb stability, biomechanics and pathology

2.5.1 Stability of the glenohumeral joint

The glenohumeral joint is an unstable joint that gains its stability from the static and dynamic stabilisers (Farrar et al. 2013). Farrar et al. (2013) identified the static stabilisers to include the glenoid labrum, the glenoid cavity of the scapula, the head of the humerus, the articular cartilage, the glenohumeral joint capsule, the glenohumeral ligaments and the negative intra-articular pressure. They explained that a large ROM exists at the glenohumeral joint and the static stabilisers provide support at the end ROM of this joint. The structures that are tensioned depend on the position of the head of the humerus at the end ROM (Farrar et al. 2013).

The dynamic joint stabilisers include the following muscles: the rotator cuff muscles (supraspinatus, infraspinatus, teres minor, subscapularis), long head of biceps brachii (Farrar et al. 2013; Murray et al. 2013) and scapular stabilising muscles (trapezius, rhomboids, serratus anterior) (Moezy, Sepehrifar & Dodaran 2014; Murray et al. 2013). The function of the dynamic stabilisers is to hold the head of the humerus in the centre of the glenoid cavity, by means of muscle contraction, to achieve stability (Farrar et al. 2013).

2.5.2 Biomechanics of throwing and muscle action involvement

In cricket, there are three types of throwing techniques: the underarm throw, the overarm throw and throw on the run (Tennant 2009). The overhead throwing technique is made up of the following phases: the wind up, stride phase, arm cocking phase, arm acceleration, arm deceleration phase and follow-through (Sachlikidis & Salter 2007).

The first phase is the wind up, which is when maximal non-dominant hip flexion with knee flexion takes place (Sachlikidis & Salter 2007). More hip flexion occurs when throwing with speed, than the amount of hip flexion that occurs with throwing for accuracy (Sachlikidis & Salter 2007).

The stride phase comprises the non-dominant hip moving laterally until the non-dominant foot makes contact with the ground, with larger strides occurring with faster throws (Sachlikidis & Salter 2007). The dominant arm externally rotates and the elbow flexes (Sachlikidis & Salter 2007).

The cocking phase involves elbow flexion, scapula retraction, and shoulder abduction until maximal external rotation (Sachlikidis & Salter 2007; Seroyer et al. 2010). The deltoid muscle maintains 90° of shoulder abduction while the rotator cuff muscles stabilise the glenohumeral joint. Subsequently, the infraspinatus, teres minor and latissimus dorsi muscles resist the anterior translation of the humeral head with a posterior force (Escamilla & Andrews 2009). The authors indicated that the shoulder internal rotators muscles in effect (pectoralis major, subscapularis, and latissimus dorsi) eccentrically control the amount of external rotational ROM.

The acceleration phase occurs from maximal shoulder external rotation until ball release (Sachlikidis & Salter 2007; Seroyer et al. 2010). The energy that is developed in the lower limbs (Laxmi, Prosenjit & Shahid 2015), is transferred along the kinetic chain to the upper limb (Seroyer et al. 2010), with coordinated muscle activity, until the energy transmits from the hand to the ball at ball release (Laxmi, Prosenjit & Shahid 2015). The scapula protracts and the humerus horizontally adducts and internally rotates (Seroyer et al. 2010). The deltoid muscle contracts to maintain shoulder abduction while maximum contraction of the internal rotators muscles (subscapularis, latissimus dorsi, pectoralis major) occur for acceleration of the arm (Escamilla & Andrews 2009). Simultaneously they found that contraction of the subscapularis, teres minor and infraspinatus muscles centre the head of humerus in the glenoid cavity.

The final deceleration phase includes ball release to maximum internal rotation and full elbow extension (Sachlikidis & Salter 2007; Seroyer et al. 2010). The muscles resist the distraction forces and the anterior subluxation of the joint (Escamilla & Andrews 2009). Escamilla & Andrews (2009) suggest that high eccentric activity occurs in the infraspinatus, teres major and minor, latissimus dorsi and post deltoid muscles to decelerate the arm into internal rotation and adduction. The concentric contraction of the lower trapezius muscle creates depression, retraction and downwardly rotates the scapula (Escamilla & Andrews 2009). The follow-through is the movement of the body and arm until they come to a stop (Seroyer et al. 2010).

2.5.3 Biomechanics of bowling

The biomechanics of the upper limb during the different phases of bowling has been described in the literature. There are two types of bowlers, namely fast and spin bowlers, and three types of bowling techniques: side-on, front-on and a mixed technique (Bartlett et al. 1996). These bowling techniques differ with body positioning while bowling (Bartlett et al. 1996). Bowling consists of the following phases: the run up, pre-delivery stride, delivery stride, and follow-through (Olivier et al. 2016a). There are three types of bowling techniques: side-on, front-on and a mixed technique (Bartlett et al. 1996). These bowling techniques differ with body positioning while bowling (Bartlett et al. 1996).

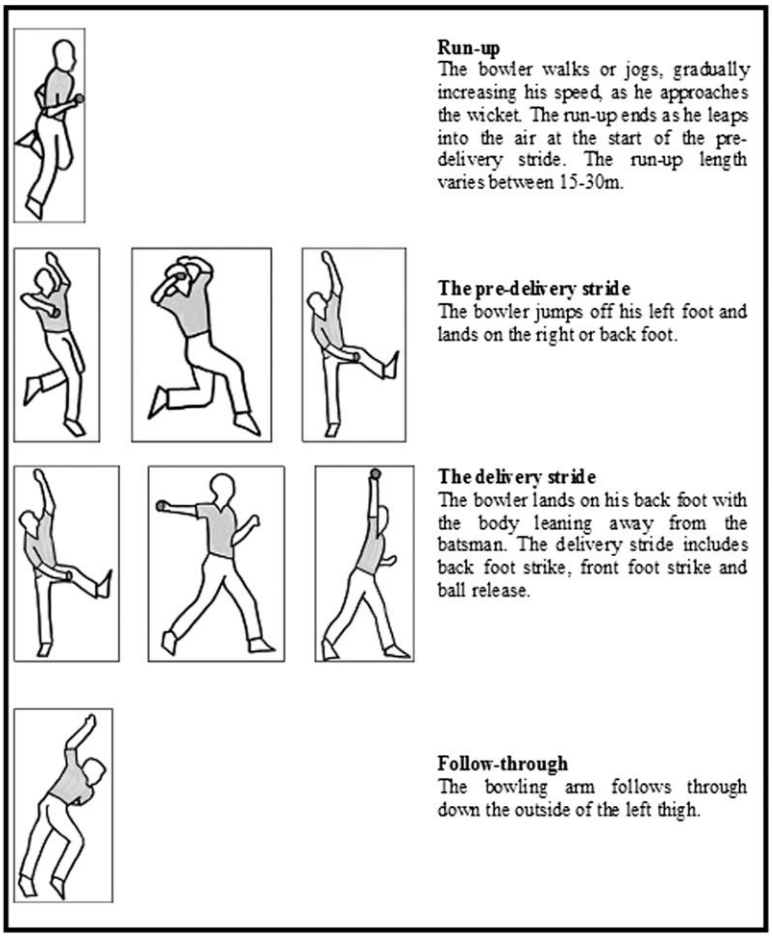

Figure 1 A schematic presentation of the cricket fast bowling action (Olivier et al. 2016a)

The run up involves walking or jogging 15 – 30m towards the batsman. The speed of the run increases steadily until the jump, which takes place before the pre-delivery stride (Bartlett et al. 1996; Olivier et al. 2016a).

The pre-delivery stride includes the jump and back foot impact (Olivier et al. 2016a). During the jump, the body begins to rotate and the arms remain close to the body until the back foot makes contact with the ground (Glazier & Wheat 2014; Tennant 2009). The shoulder alignment angle, between the shoulders and the wickets, varies from 180° to greater than 180°, depending on the bowling technique used (Bartlett et al. 1996).

The delivery stride involves the back foot impact, the front foot landing on the ground and ball release (Glazier & Wheat 2014). The front leg lands with either a fully extended or slightly flexed knee and it provides stability for the shoulder rotation to occur (Bartlett et al. 1996; Steulcken et al. 2010; Tennant 2009) and shock absorption from ground reaction forces (Bartlett et al. 1996). The bowling shoulder joint circumducts towards the batsman, with the elbow extended (Steulcken et al. 2010; Tennant 2009) and it rotates towards the batsman after the ipsilateral hip rotation has taken place in the same direction (Bartlett et al. 1996). The non-bowling arm begins from an upright position in front of the body, it then adducts and extends gradually into the follow-through phase (Bartlett et al. 1996). As a result of these movements, the momentum and the energy is transferred up the kinetic chain to the upper limb, towards the ball (Glazier & Wheat 2014). The release phase consists of the bowling arm circumduction and ends when the ball is released from the bowling hand (Tennant 2009).

Follow-through then takes place from the point of ball release until the arm moves downwards and across the body while the body continues to move in a forward direction (Bartlett et al. 1996; Tennant 2009). Research on the muscle action involved during bowling could not be sourced.

2.5.4 Scapulohumeral rhythm

The biomechanics of the scapula and humerus in arm elevation is called scapulohumeral rhythm (Scibek & Carcia 2012). In non-athletes, it is similar in the dominant and non-dominant upper limb (Hosseinimehr et al. 2015) where 1° degree of scapula rotation occurs with 2.34° of humeral elevation (Scibek & Carcia 2012).

However, in athletes performing overhead movements, the dominant scapula has increased in downward rotation at rest and increased in upward rotation at 90° and 135° of humeral abduction (Hosseinimehr et al. 2015). The scapula and humerus move in coordination during arm elevation, however, their movement pattern is different in the dominant shoulder joint of athletes performing overhead movements.

2.5.5 Humeral retroversion

In young athletes that perform repetitive throwing movements, adaptive changes occur which position the humeral head more posteriorly (Greenberg et al. 2015). This occurrence is termed retrotorsion or retroversion (Greenberg et al. 2015). Humeral retroversion angle decreases with age (Edelson 1999). At birth, retroversion angles are 78° and this decreases to about 25 - 35° in adulthood (Edelson 1999). Greater than 45° of humeral retroversion can be seen in Little League pitchers, from youth through to adulthood (Sabick et al. 2005). These humeral changes occur in the dominant shoulder, therefore it is seen as being an adaptive change (Greenberg et al. 2015). This results in an external rotational gain and internal rotation loss of 10° - 17° (Reagan et al. 2002; Scolaro & Kelly 2010). This internal rotation loss and external rotation gain can occur due to adaptive changes such as humeral retroversion or due to soft tissue changes which includes a tight or lax joint capsule (Reagan et al. 2002; Scolaro & Kelly 2010).

2.5.6 Shoulder pathology

Shoulder pain in cricketers can occur due to a variety of mechanisms of injury. Shoulder pathology can occur in the presence of anterior capsule laxity during the cocking phase of throwing (Mihata et al. 2015). This finding has been confirmed by Mihata et al. (2015) in cadavers where anterior capsule laxity caused anterior displacement of the head of the humerus, ERG and impingement within the joint. They found that the infraspinatus tendon, the superior part of the supraspinatus tendon and the posterosuperior labrum were the structures impinged between the glenoid fossa and the greater tuberosity of the humerus. Therefore anterior capsule laxity can results in shoulder pathology and pain (Mihata et al. 2015).

Another throwing related pathology is the posterior capsule tightness of the glenohumeral joint (Dashottar & Borstad 2012). In cricket players, it is found that large distraction forces are imposed on the posterior tissues of the shoulder joint during the deceleration phase of bowling (Steulcken et al. 2010). The scapular retractor muscles, the shoulder abductors and the shoulder external rotators contract eccentrically to counteract the distraction forces (Dashottar & Borstad 2012). The authors indicated that these tissue adaptations occur causing stiffness which presents as GIRD and results in decreased glenohumeral adduction (Dashottar & Borstad 2012). These posterior capsular adaptations change the joint kinematics and predispose the athlete to labral and rotator cuff injuries (Kinsella et al. 2014).

The anterior capsule laxity and posterior capsule tightness contributes to changes in the glenohumeral rotation contact point during the cocking phase in throwing (Fessa et al. 2015). The authors propose that the new rotational point allows the greater tuberosity to clear the glenoid cavity with ease. Normally, the biceps tendon is tensioned in abduction and external rotation (Boyle, Haag & Limb 2009), but further tensioning takes place from the ERG, which causes SLAP lesions and peel back of the labrum (Fessa et al. 2015).

A shortened pectoralis minor muscle length is evident in athletes complaining of shoulder pain during throwing movements (Moezy, Sepehrifar & Dodaran 2014). In overhead athletes, the scapula is malpositioned and associated with scapula anterior tilting, downward rotation and internal rotation (Edmonds & Dengerink 2014). These same scapular positions are reproduced with pectoralis minor muscle contraction during arm elevation (Phadke, Camargo & Ludewig 2009). This abnormal positioning of the scapula places the glenoid cavity and the greater tuberosity closer together. During the cocking phase, the closer orientation of the glenoid cavity and head of the humerus causes impingement of the posterior tissues (Kinsella et al. 2014). Therefore lengthening exercises for the pectoralis minor muscle may be influential in decreasing shoulder pain (Moezy, Sepehrifar & Dodaran 2014)

2.6 The role of shoulder rotation ROM, GIRD, ERG and shoulder pain, throwing arc ROM and pectoralis minor muscle length in shoulder injuries

2.6.1 Shoulder rotation ROM, GIRD, ERG and shoulder pain

Decreased internal rotation ROM (Dashottar & Borstad 2012) and increased external rotation ROM (Mihata et al. 2015) are not significant contributors to shoulder injuries. In elite female cricket players, only a decreased active internal rotation ROM of 42.8° in the dominant shoulder is a cause of shoulder injury compared to 49.4° in the non-dominant shoulder (Steulcken, Ginn & Sinclair 2008). In this elite female population, the active external rotation ROM was 89.1° in the no pain dominant shoulder as compared to 82.5° in cricketers with pain, however, the external rotation ROM values of these two groups were not significant contributors to the development of injuries (Steulcken, Ginn & Sinclair 2008). In male cricket players, the rotational ROM is not associated with shoulder injury (Aginsky, Lategan & Stretch 2004). The players in this study had a larger passive external rotation ROM of 116.22° injured and 116.83° in the uninjured group. This may be due to the injured (84°) and uninjured (89.75°) group having larger passive internal rotation ROM (Aginsky, Lategan & Stretch 2004). As a result shoulder pain has been associated with decreased internal rotation ROM in cricketers.

Large internal rotation difference (IRD), the difference between the dominant and non-dominant internal rotation ROM, has been associated with shoulder pain. In overarm cricket players and bowlers, the IRD of 10° was a cause of shoulder pain compared to 6.8° in the no pain group (Giles & Musa 2008). Giles & Musa (2008) found that the external rotation difference (ERD) were not significant in the pain (9.7°) and no pain (7.5°) group. Larger rotational differences were found in a pain free population of spin bowlers and fast bowlers (Sundaram, Bhargava & Karuppannan 2012). In the study by Sundaram, Bhargava & Karuppannan (2012), the IRD of the spin bowlers was 12.90° and fast bowlers was 11.58°, and the ERG of the spin bowlers was 23.46° and 15.23° in fast bowlers.

The differences in rotational ROM causing shoulder pain may be due to the different age ranges used within the studies (Sundaram, Bhargava & Karuppannan 2012). The mean ages of 17.97 – 18.48 (Sundaram, Bhargava & Karuppannan 2012) and 18.1 years of age (Giles & Musa 2008) were similar, but Giles & Musa (2008) included younger participants from 11 – 35 years of age. Shoulder rotational properties are different in younger athletes. In young adolescent baseball players more internal rotation ROM is available before tissue adaptations have taken place (Astolfi et al. 2015). IRD causes shoulder pain, however, the degree of difference causing the pain may be reliant upon the age of the athlete.

GIRD is classified as normal anatomical and pathological GIRD (Manske et al. 2013b). Manske et al. (2013b) described normal anatomical GIRD as internal rotation loss of less than 18° – 20° with the same total rotational ROM bilaterally in overhead athletes. They characterised pathological GIRD as an internal rotation loss that is greater than 18° – 20°, with a loss of more than 5° in the total rotation ROM between the dominant and non-dominant shoulder. A baseball study proposed that GIRD greater than 15° has been associated with shoulder injuries, but in the study, the GIRD group had a mean GIRD of 20.19° (Thomas, Swanik & Swanik 2010). Subsequently, they proposed that GIRD values greater than 15° result in shoulder pain, because they create changes in the scapula positioning, movement and increases shoulder protraction.

2.6.2 Throwing arc ROM

Cricket studies have investigated throwing arc ROM in different populations (Giles & Musa 2008; Steulcken, Ginn & Sinclair 2008) and these populations have included a combination of genders and age groups. In overarm cricket players and wicket keepers, a difference of 0.4° between the dominant and non-dominant throwing arc ROM did not prove to be statistically significantly different (Giles & Musa 2008). In elite Australian female cricket players, throwing arc ROM in the dominant and non-dominant shoulder within the pain (125.3° and 131.4°) and no pain group (133.2° and 129.6°), no statistically significant differences were found (Steulcken, Ginn & Sinclair 2008). However, in overhead athletes, a difference greater than 5° between the dominant and non-dominant total arc ROM has been associated with shoulder injuries (Manske et al. 2013b). Throwing arc ROM has been evaluated in elite female cricketers (Steulcken, Ginn & Sinclair 2008), adolescent to adult male and female mixed group of cricketers (Giles & Musa 2008) as well as in baseball pitchers (Manske et al. 2013a), however, it has not been assessed in an only male cricket population with participants over the age of 18.

Table 1: A comparison of data between the injured and uninjured group regarding internal rotation ROM, external rotation ROM, IRD, ERG and throwing arc ROM

Study	**Participants**	**Injured group**	**Uninjured group**	**P value**
		Internal rotation ROM		
Steulcken, Ginn & Sinclair 2008	elite female fast bowlers (n = 36) (22.5 ± 4.5 years of age)	42.8° active IR ROM of the dominant shoulder 49.4° active IR ROM of the non-dominant shoulder		P = 0.015
Aginsky, Lategan & Stretch 2004	Male fast bowlers (n = 21) (17 – 36 years of age)	84° passive dominant IR ROM	89.75° passive dominant IR ROM	P = 0.361
		External rotation ROM		
Steulcken, Ginn & Sinclair 2008	elite female fast bowlers (n = 36) (22.5 ± 4.5 years of age)	82.5° active ER ROM of the dominant shoulder	89.1° active ER ROM of the dominant shoulder	P > 0.05
Aginsky, Lategan & Stretch 2004	Male fast bowlers (n = 21) (17 – 36 years of age)	116.22° passive ER ROM of the dominant shoulder	116.83° passive ER ROM of the dominant shoulder	P = 0.884
		Internal rotation difference		
Giles & Musa 2008	Male and female overarm cricket players (n = 118) (11 – 35 years of age)	10° IRD between the dominant and non-dominant shoulder	6.8° IRD between the dominant and non-dominant shoulder	P = 0.03
Sundaram, Bhargava & Karuppannan 2012	Elite male fast and spin bowlers (n = 66) (18.86 ± 1.93 years of age)		12.90° IRD in spin bowlers and 11.58° IRD in fast bowlers	P = 0.549
		External rotation gain		
Giles & Musa 2008	Male and female overarm cricket	9.7° ERD between the dominant and	7.5° ERD between the dominant and	P = 0.23

	players (n = 118) (11 – 35 years of age)	non-dominant shoulder	non-dominant shoulder	
Sundaram, Bhargava & Karuppannan 2012	Elite male fast and spin bowlers (n = 66) (18.48 (3.68) years of age) (18.86 ± 1.93 years of age)		23.46° ERD in spin bowlers and 15.23° ERD in fast bowlers	P = 0.005
GIRD				
Manske et al. 2013b		pathological GIRD: internal rotation loss greater than 18° – 20°, with more than 5° loss of total rotation ROM between the dominant and non-dominant shoulder	anatomical GIRD: internal rotation loss of less than 18° – 20° with the same total rotational ROM bilaterally	
Thomas, Swanik & Swanik 2010	Baseball players (n = 43) (18.86 ± 1.93 years of age)	GIRD of 20.19°	GIRD of 8.89°	
Throwing arc ROM				
Giles & Musa 2008	Male and female overarm cricket players (n = 118) (11 – 35 years of age)		0.4° difference between the dominant and non-dominant TA ROM	P = 0.582
Steulcken, Ginn & Sinclair 2008	elite female fast bowlers (n = 36) (22.5 ± 4.5 years of age)	125.3° TA ROM of the dominant shoulder and 131.4° of the non-dominant shoulder	133.2° TA ROM of the dominant shoulder and 129.6° of the non-dominant shoulder	P > 0.05 between injury groups and P > 0.05 between limb dominance

2.6.3 Pectoralis minor muscle length

The pectoralis minor muscle is a triangular shaped muscle that inserts onto the coracoid process. In cadavers, the muscle fibres are stretched more and rapidly during 150° of shoulder flexion and scaption, and lengthen less and slowly with 90° of abduction and external rotation. The most lengthening occurs at 30° of flexion with scapula retraction and half the stretch occurs with scapula retraction at 0° of flexion (Muraki et al. 2009), which is the length testing position in studies (Lewis & Valentine 2007; Struyf et al. 2014).

A study was conducted regarding pectoralis minor muscle measurements in participants with and without shoulder pathology (Lewis & Valentine 2007). The method used by the authors was to measure the distance from the acromion to the plinth with the patient in supine. They found that pectoralis minor length test distance in symptomatic participants was 6.1cm (2.9 – 10.1cm) and 6.3cm (3.5 – 9.5cm) on the dominant side in asymptomatic participants. The lower mean value in the symptomatic group could be because of the low minimum value of 2.9cm. However, the symptomatic group had the largest maximum range of 10.1cm which is associated with a shortened pectoralis muscle length (Lewis & Valentine 2007). A shortened pectoralis minor muscle length has been associated with shoulder pain (Moezy, Sepehrifar & Dodaran 2014) as it causes scapula anterior tilting, downward rotation and internal rotation (Edmonds & Dengerink 2014) which results in impingement within the glenohumeral joint during throwing movements (Kinsella et al. 2014). More research is required regarding the pectoralis minor muscle length in different populations complaining of shoulder pain.

2.7 Measurement apparatus

2.7.1 Shoulder rotational ROM: Goniometer

The goniometer has excellent intra-rater reliability (ICC 0.94 – 0.95) and good concurrent validity compared to a digital inclinometer (ICC 0.85 – 0.95), when measuring active shoulder ROM (Kolber & Hanney 2012). Kolber & Hanney (2012) found that the limitations of using a goniometer are that the measurement of external rotation ROM is 2° – 16° less than the inclinometer, and internal rotation ROM is 3° –

15° greater than the inclinometer. This may occur as assumptions were made as to when the stationary arm appears to be parallel or perpendicular to the ground (Szekeres, MacDermid & Rooney 2015). The goniometer displays excellent intra-rater reliability and good concurrent validity, even though there is a large measurement range of 2° – 16° difference that may exist (Kolber & Hanney 2012). The reliability and validity of the goniometer are acceptable, therefore it was used to measure ROM in the pilot study, however, due to difficulties which were encountered with the use of the goniometer, the inclinometer was considered.

2.7.2 Shoulder rotational ROM: Manual inclinometer

In overhead athletes, the bubble inclinometer has fair inter-rater reliability with an intraclass correlation coefficient of (ICC) 0.53 – 0.62 and excellent intra-rater reliability when measuring glenohumeral total rotation (ICC 0.93 – 0.96), external rotation ROM (ICC 0.97 – 0.99) and internal rotation ROM (ICC 0.96 – 0.98) with the patient in the supine position (Kevern, Beecher & Rao 2014). Similar results were obtained using a manual inclinometer in 10 college participants. The results demonstrated excellent intra-rater (ICC 0.90 – 0.96) and good inter-rater (ICC 0.72 – 0.97) reliability when performed by two blinded investigators with the inclinometer strapped to the participant's distal forearm (Dwelly et al. 2013).

Construct validity with a bubble goniometer displays a good relationship between posterior shoulder tightness and internal rotational ROM ($r = 0.88$) and an inverse relationship between external rotation ROM and shoulder tightness ($r = -0.07$) (Kolber & Hanney 2010). The limitation in many of the studies methods involved the scapula not being stabilised during ROM measurements. The use of the manual inclinometer demonstrates good construct validity, excellent intra-rater reliability and good inter-rater reliability, therefore the inclinometer replaced the goniometer in this study when the goniometer was problematic in the measurement of shoulder rotation ROM.

2.7.3 Pectoralis minor muscle length: Caliper

Measurement of the pectoralis minor muscle has been investigated with the use of a caliper (Struyf et al. 2014). This method, within the study, measured the distance between the coracoid process and the fourth rib, on full expiration in participants with and without shoulder impingement. The value is calculated as a percentage of the body height (pectoralis minor length/height x 100). This method has good intra-rater reliability (ICC 0.76–0.93), and moderate inter-rater reliability (ICC 0.64 – 0.72) (Struyf et al. 2014). The caliper has good intra-rater reliability, moderate inter-rater reliability, however, the validity of the tool needs to be established. The use of the caliper can be considered if measurements with the right angle ruler produce difficulties during the study.

2.7.4 Pectoralis minor length test measurement: Ruler

Measurements of the pectoralis minor muscle length test distance have been performed using a right angled ruler, with the participant lying in supine (Lewis & Valentine 2007; Weber et al. 2015). The measurement was taken from the posterior part of the acromion process to the plinth by the authors. A normal value of 2.54cm was proposed, and any measurements larger than 2.54cm was seen as being pathological (Sahrmann 2002), but in two studies the measurement values were larger than the proposed value of 2.54cm (Lewis & Valentine 2007; Weber et al. 2015). In symptomatic and normal participants the dominant shoulder had a mean range of 6.1 ± 1.3cm and 6.3 ± 1.4cm, respectively (Lewis & Valentine 2007). In participants where a 65N and 85N posterolateral force was applied to the coracoid process, measurements of 4.5cm and 3.9cm were recorded (Weber et al. 2015). The measurements revealed excellent intra-rater reliability with ICC 0.92 – 0.96 (Lewis & Valentine 2007) and ICC 0.97 – 0.99 (Weber et al. 2015).

Diagnostic accuracy was 100% sensitivity and 0% specificity (Lewis & Valentine 2007). The poor diagnostic accuracy is because validation studies are using 2.54cm as the normal value. However, this is not accurate because participants with no pathology should ideally be obtaining measurements less than 2.54cm, but they are obtaining larger values. A new normal value to separate pathological and normal pectoralis minor length test distance is required for a true diagnostic accuracy to be established with this measurement tool. The right angle ruler was used in this study as it is a reliable tool with a simple measuring method.

2.8 Conclusion

The shoulder plays an important part in all specialities of cricket. Shoulder injuries occur due to many variables. By monitoring the variables such as shoulder rotation ROM, GIRD, ERG, throwing arc ROM and pectoralis minor muscle length, and their association with shoulder pain, the identification of potential causative variables can take place. This may provide the basis for further research into sport specific prevention and rehabilitation programmes for shoulder injuries in cricket players.

CHAPTER 3: Method

3.1 Introduction

The aim of the study was to determine if there is an association between the shoulder rotational ROM, throwing arc ROM, pectoralis minor muscle length, and the dominant shoulder injury, in the first three months of a cricket season. The method section will describe the: study design, study participants, study variables, instrumentation and outcome measures, procedure, ethics and data analysis used.

3.2 Study design

This was a prospective, observational cohort study.

3.3 Participants

3.3.1 Sample size

Thirty six elite male cricketers volunteered to participate in the study. Evidence from previous studies have shown that glenohumeral internal ROM among uninjured players was 39.4° with standard deviation of 11.1°. The ROM among injured was 33.3° with a standard deviation of 9.2° (Almeida et al. 2013). Our study postulated a 10% difference between the injured and uninjured group. At 0.05 level of significance, with a power of 80%, an effective sample size of 36 participants is required to draw statistical inference to the general population.

3.3.2 Sample selection

Volunteers were recruited from the following teams: the Highveld Lions, the Gauteng strikers, the provincial Gauteng under 19 team and the Marks Park premier league team. These teams were exposed to similar pre-season training routines and all the teams partook in training sessions as well as multiple games weekly, during this three month period. All of the teams involved in the study participated in the same T20 league. The first three months of the season is a high training and match workload period for all the teams involved in the study.

Inclusion criteria

- Provincial or club premier league male cricket players from any of the following teams: the Highveld Lions, the Gauteng strikers, the provincial Gauteng under 19 team and the Marks Park premier league team.
- Cricket players aged 18 years or older.
- Players exposed to a weekly cricket related training workload (which includes batting, bowling, fielding, wicket keeping, fitness, gym training or rehabilitation exercises) as monitored during the first three months of the cricket season.
- Current dominant shoulder pain did not affect availability for match or practice.
- Players that sustain injuries which does not interfere with their participation in cricket related training and matches.

Exclusion criteria

- Players not cleared to play after previous surgeries.
- Injuries, other than dominant shoulder injuries, that caused the player not to be exposed to a weekly typical cricket related training and match schedule as monitored during the first three months of the cricket season.
- Injuries, including dominant shoulder injuries, sustained before the start of the season/monitoring period which lead to the player not being cleared to return to play and therefore not being exposed to any cricket related training and match workload during the first three months of the season.
- Participation in other overhead sports on a weekly basis during the monitoring period. Participation in other overhead sports was monitored with the training and match workload. The participant was only excluded if they participated in the other overhead sport weekly, over two or more weeks consecutively.
- Heart conditions: arrhythmias, rheumatic heart disease, ischaemic heart disease or inflammatory heart disease due to its pain referral pattern close to the shoulder area.
- The current use of anti-inflammatory or analgesics, as they may mask current shoulder or neck pain.

3.4 Variables

3.4.1 Independent

- Shoulder external rotation ROM
- Shoulder internal rotation ROM
- Throwing arc ROM
- GIRD
- ERG
- Pectoralis minor length test distance

3.4.2 Dependent

- Injured
- Uninjured

3.4.3 Confounding variables

- Age
- Training workload
- Initial pain

3.5 Instrumentation and Outcome Measures

3.5.1 Definition of an injury

According to the cricket injury consensus statement in 2005, a significant injury restricts a player from being selected for matches, or during a match renders a player incapable of batting, bowling or wicket keeping (Orchard et al. 2016). This definition was revised in 2016 to include general time loss injuries which considers players lack of participation in matches or training due to an injury (Orchard et al. 2016). Non-significant injuries have been described as musculoskeletal conditions that cause a bowler to miss one day or more of sports activity or an injury that took place during a sporting activity that needed medical treatment and resulted in the bowler ceasing the activity (Olivier et al. 2015).

Based on the two definitions above (Orchard et al. 2016; Olivier et al. 2015), the definition of injury in this study was: any dominant shoulder pain that occurs during or after cricket training or matches involving batting, bowling, fielding or wicket keeping, resulting in the cessation or limitation of that sporting activity. In this study, we focused on non-contact injuries. Any dominant shoulder injuries that occurred due to reasons that were not cricket related were noted, but their data were analysed separately.

3.5.2 Shoulder internal and external ROM

Shoulder internal and external rotation ROM was initially measured with a standard, two arm plastic SAEHAN goniometer, which was found to have excellent intra-rater reliability and good concurrent validity (Kolber & Hanney 2012).

The use of the goniometer was changed to the inclinometer because of challenges that occurred during the pilot study (refer to chapter 3.5.1). The universal manual inclinometer (UI01A) with a long lever arm was used to measure shoulder internal and external rotation ROM. The inclinometer has excellent intra-rater reliability (Dwelly et al. 2013) and good construct validity (Kolber & Hanney 2010). The horizontal position of the universal inclinometer was established with the use of a spirit level.

Measurements were taken, with the patient lying in supine on the plinth, by the research assistant and myself (the researcher). The research assistant and the researcher were qualified physiotherapists, the researcher had three years of working experience and the research assistant had two years of working experience as qualified physiotherapists. The scapula was stabilised by the research assistant by applying pressure over the coracoid process. The researcher passively abducted the shoulder into 90° abduction and full external rotation. The researcher performed all the measurements. The inclinometer was placed on the anterior distal forearm for external rotation and posterior distal forearm for internal rotation (Sundaram, Bhargava & Karuppannan 2012).

Figure 2 Shoulder external rotation ROM measurement

Figure 3 Shoulder internal rotation ROM measurement

GIRD and ERG were calculated as follows:

GIRD: non dominant minus dominant shoulder internal rotation ROM

ERG: non dominant minus dominant shoulder external rotation ROM (Almeida et al. 2013)

3.5.3 Throwing arc ROM

Throwing arc ROM was the full rotation ROM that is available for throwing. It was calculated as follows: throwing arc ROM = shoulder internal rotation ROM + shoulder external rotation ROM (Giles & Musa 2008; Steulcken, Ginn & Sinclair 2008).

3.5.4 Pectoralis minor muscle length

Pectoralis minor muscle length was assessed through the pectoralis minor muscle length test distance (acromion to plinth distance). Pectoralis minor muscle length test distance was measured by the researcher with the patient lying in supine on the plinth, elbows flexed and hands resting on the lateral part of the abdomen (Lewis & Valentine 2007; Sahrmann 2002). The distance from the posterior part of the acromion process to the plinth was measured in centimeters on both shoulders using a rigid plastic right angle ruler (Lewis & Valentine 2007).

In a text by Sahrmann (2002), she proposed that the value of 2.54cm (1 inch) could be used to determine scapula anterior tilting and shoulder protraction (Sahrmann 2002). This was recommended within the textbook and it wasn't proposed based on a certain population. Studies have used the 2.54cm as a normal value for the acromion to plinth distance for the measurement of the pectoralis minor muscle length (Lewis & Valentine 2007; Weber et al. 2015), however, this was just a suggestion. The use of this value was not able to identify pathology, which resulted in the poor validity of the tool. The procedure used to test pectoralis minor muscle length (acromion to plinth distance) had acceptable intra-rater reliability but it lacked diagnostic validity (Lewis & Valentine 2007).

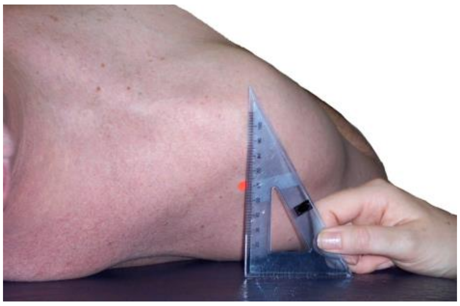

Figure 4 The pectoralis minor length test distance (Lewis & Valentine 2007)

3.5.5 Questionnaires

The pre-season questionnaire (Appendix A) included the inclusion and exclusion criteria, which was used to establish the participants' eligibility. In the questionnaire, the participant reported with a yes/no answer if they currently had shoulder pain at rest, during or after training. If the participant indicated the presence of current shoulder pain, then they were questioned verbally to find out if they had been cleared to return to play. If a participant indicated that they participate in an overhead sport, besides cricket, on a weekly basis, then they were not excluded immediately. Their participation in the second overhead sport was monitored with a training workload calendar (Appendix B) and the participant was excluded only if participation occurred weekly, over two or more weeks consecutively.

3.5.6 Data capturing forms

The intra-rater reliability was recorded using the pre-season measurements form (Appendix C) during the pilot study. The pre-season measurements form contained a table for the shoulder internal rotation ROM, shoulder external rotation ROM and pectoralis minor muscle length to be recorded for the right and left shoulder.

The injury monitoring questionnaire (Appendix D) included questions pertaining to the participant's age, the number of seasons that the player has been playing cricket for, the participants highest team selection and the participants main skills (ie. batsman, bowler, fielder). Questions regarding the injury included the date of the injury, the region (eg. the shoulder, the biceps), the side (dominant or non-dominant) and the nature of the injury (contact/ non-contact). The participant was asked to provide a brief description as to how the injury occurred and the activity which took place when the injury occurred (e.g. batting training). The questionnaire inquired about the management following the injury, the limitations caused by the injury and if this was a reoccurrence of a previous injury.

Development and testing of the injury monitoring questionnaire (Appendix D)

Content validity of the injury monitoring questionnaire was established by a panel of four physiotherapists. The test retest reliability was gained by emailing and distributing the injury monitoring questionnaire to four participants during the pre-season. The form was completed by these four participants initially and again a week later, with the answers based on their previous shoulder injury. One participant completed the form online and the other three participants completed the form by hand.

The following discrepancies occurred during the testing of the form. The form completed online contained a typing error discrepancy when answering the number of seasons that the participant had played cricket for. The question regarding the playing position was recorded differently by one player, in both forms. He recorded his playing position as being a bowler in one form and a fielder and bowler in the second form. This discrepancy would not affect findings because all cricket players field apart from the wicketkeeper. A discrepancy was found regarding the date of the previous shoulder injury in two forms. One participant did not record the date on both forms and the second participant recorded two separate dates which were 5 days apart. The description of the injury was worded differently in the initial and follow up forms, but the descriptions described the same event and contained similar information.

Minor discrepancies were found between the initial form that was completed and the second form. These discrepancies were eliminated by asking the participants to complete every question on the form and the participant was allowed to contact the researcher to provide an explanation of any question that was not understood. The researcher did not provide answers to the questions, but only provided an explanation. The discrepancy regarding the dates of the injury sustained was eliminated by contacting the participants and providing them with an injury monitoring form within a week of their injury, allowing them to recall the exact injury date.

3.5.7 Training and match workload

Training and match workload was seen as a potential confounding factor. It was obtained from the players' training schedules, match selection and participation in games and training was gained from the coaches and confirmed with the players in person or telephonically. It was recorded in a calendar format (Appendix B). Training and match workload was calculated as a percentage (days of activity/total days of inclusion in the study). A day of activity, in the study, was defined as any physical activity that occurred that day which included cricket training, gym training, rehabilitation exercises, cricket game or any other sport. The total days of inclusion in the study for the injured participants were calculated up to and including the day of injury and it was presented as a percentage.

3.6 Procedure

3.6.1 Pilot Study

A pilot study took place during the pre-season on 10% (n = 4) of the study participants. Standard testing procedures were used as described above. The tests were performed in the following order and were retested immediately after the first series of tests were performed: shoulder external ROM, shoulder internal ROM and pectoralis minor length test distance. A goniometer was the initial measurement tool used to measure the shoulder rotational ROM during the pilot study. However, during the pilot study, it was difficult to estimate the angle at which the long lever of the goniometer was perpendicular to the ground, therefore the goniometer reliability results from the pilot study were not used in the main study analysis. The use of the goniometer was changed to a universal inclinometer. The intra-rater reliability of the universal inclinometer was established by measuring the same study participants twice during the main study. The results of the intra-rater reliability are presented in chapter 4.1.

3.6.2 Main Study

A meeting was held with the head coach of the Highveld Lions, Gauteng Strikers and Marks Park cricket club to explain the testing procedures and the purpose of the study (Figure 3).

Procedure

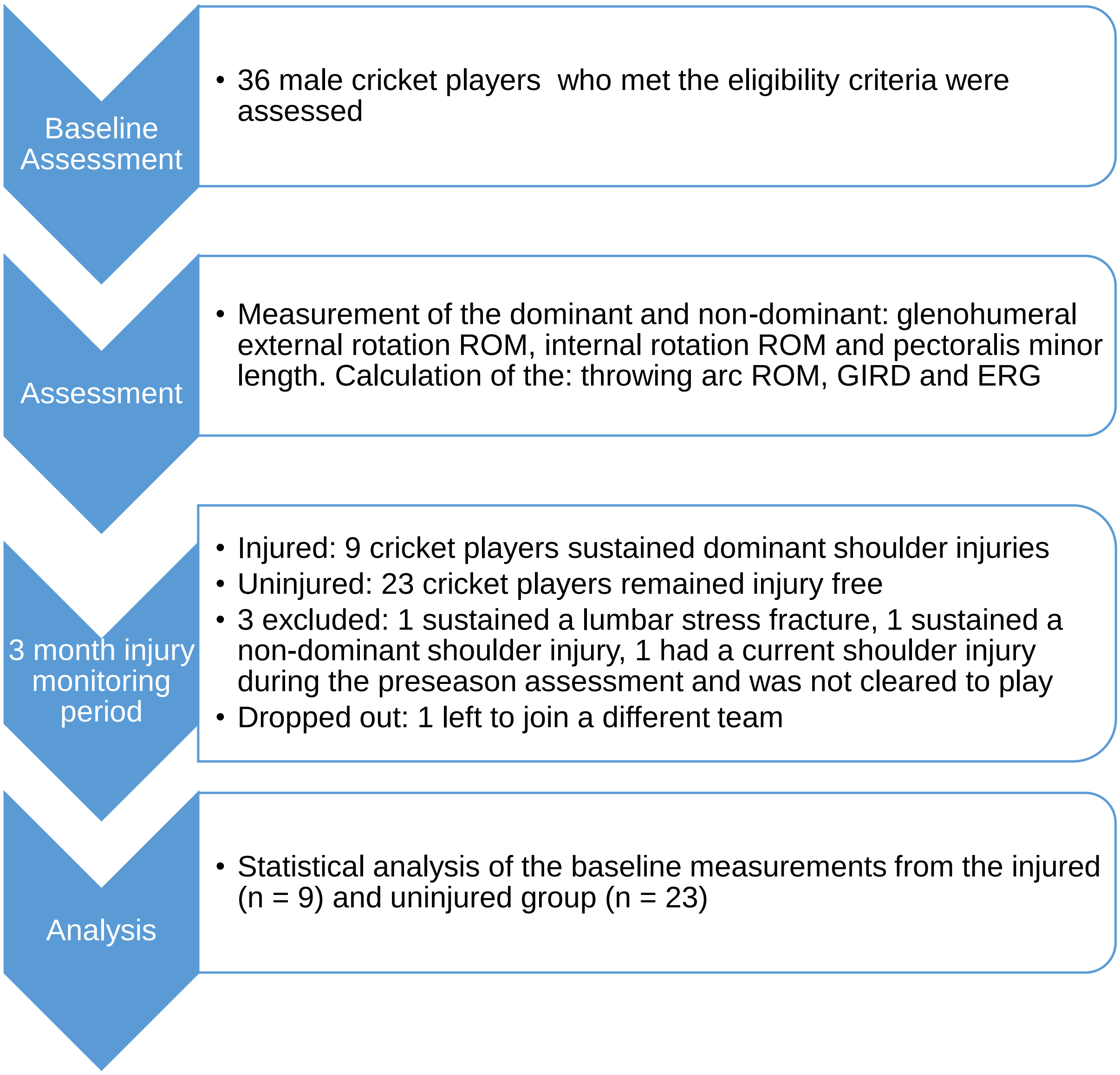

Figure 5: Flow diagram of the main study procedure

Involvement in the study was explained verbally as well as in writing to all participants (Appendix E). Participants who gave written informed consent (Appendix F) completed a short questionnaire (Appendix A) regarding the eligibility criteria. Study participants who met the inclusion criteria were assessed during the last week of the pre-season and first three weeks of the in-season. Their baseline measurements were recorded on the pre-season measurements form (Appendix C). Baseline assessments took place at the Wanderers stadium and at the Marks Park cricket club. The participants were assessed by myself, the researcher. The research assistant stabilised the scapula while I measured and recorded the baseline rotational ROM and pectoralis minor length test distance.

The participants were monitored from September to November 2015. They were contacted weekly via WhatsApp, phone call or communicated in person to confirm their shoulder injury status and to gain their training and match workload. All of the shoulder injuries were reported to the researcher, Lions physiotherapist, coach or trainer. After sustaining a dominant shoulder injury that met the injury criteria (dominant shoulder pain from cricket-related activities which is experienced during cricket training or matches, which caused cessation or limiting of that sporting activity), the participant filled out a short questionnaire (Appendix D) on hard copy regarding their injury.

3.7 Ethical Considerations

Ethical clearance was obtained from the Human Research Ethics Committee (Medical) of the University of the Witwatersrand (Reference no M150612) (Appendix G). Permission from the Highveld Lions (Appendix H), Gauteng Cricket Board (Appendix I) and Marks Park cricket club (Appendix J) was requested and granted to access the teams' players. Informed written consent was obtained from the participants (Appendix F).

Participation was voluntary and they were allowed to withdraw from the study without suffering repercussions. Information from participants was used only for the purpose of this study and was available to the participants only. Participants' names were written on the consent forms, pre-season and post injury questionnaires. The names were converted into study numbers once the data were captured on Microsoft Excel; this is to allow the correct data to be linked with the correct participant. As this was a longitudinal study, it was crucial to link the follow up data to the same participants' baseline data and therefore names were initially written on the questionnaires.

3.8 Data Analysis

Participants' personal details were entered into and stored using Microsoft Access. Baseline data were entered into Microsoft Excel spreadsheets. The data were analysed using STATA statistics/data analysis version 13.1.

The intra-rater reliability of the shoulder internal rotation ROM, shoulder external rotation ROM and pectoralis minor muscle length test distance were analysed using the Pearson's correlation. The correlations were evaluated as follows: $0.00 < r < 0.25$ depicting a minimal or no relationship present; $0.25 < r < 0.50$ representing a fair relationship; $0.50 < r < 0.75$ illustrating a moderate to good relationship; and $r > 0.75$ characterising a good to excellent relationship (Portney & Watkins 2009).

Once the three month data collection was completed, the data were separated into two groups: the injured and uninjured group. The data from four participants were removed before the analysis. The data of the injured and uninjured group were compared.

The Skewness-Kurtosis (Sk) test for normality was used to determine if the data were normally distributed between two independent groups (injured and uninjured group). The normally distributed variables were: age, dominant and non-dominant internal rotation ROM, dominant external rotation ROM, dominant throwing arc ROM, dominant and non-dominant pectoralis minor muscle length test distance, GIRD and workload. These variables were analysed using independent t-tests between the injured and uninjured groups. The confidence interval determined the effect size. The following variables were not normally distributed: non-dominant external rotation ROM, non-dominant throwing arc ROM and ERG. These variables were analysed between the injured and uninjured group using the Mann-Whitney U tests. A chi-squared test of independence analysed the relationship between initial pain and injury.

Data were then analysed with the Sk test to see if two related variables (dominant and non-dominant variables) from the same participant could be compared to each other. The data between the entire group, injured and uninjured group regarding four variables (internal rotation ROM, external rotation ROM, throwing arc ROM and pectoralis minor muscle length test distance) were analysed for normality. The Sk analysed the normality based on the difference between the dominant to non-dominant data for the four variables. The following data were not normally distributed: in the entire group - external rotation ROM and throwing arc ROM; in the injured group - external rotation ROM and throwing arc ROM; and in the uninjured group - external rotation ROM. Normally distributed data were analysed with the paired t-test and not normally distributed data were analysed with the Sign test between the dominant and non-dominant measurements. Statistical significance was set at $p < 0.05$. Where appropriate, Cohen's *d* effect sizes were calculated for each of the comparisons. Effect sizes of 0.2, 0.5 and 0.8 were interpreted as small, medium and large, respectively (Cohen 1998).

A logistic regression analysis using the Stepwise Wald method was used to determine the relationship between the variables. The model contained the following four variables: non-dominant external rotation ROM, non-dominant pectoralis minor muscle length test distance, workload and initial pain.

CHAPTER 4: Results

4.1 Introduction

This study aimed to establish the association between the shoulder rotation ROM, throwing arc ROM, pectoralis minor muscle length as measured at the start of the cricket season and shoulder injuries sustained during the first three months of the cricket season. The results chapter will provide: the results for the intra-rater reliability of the tests (shoulder internal rotation ROM, shoulder external rotation ROM and pectoralis minor length test distance of the dominant and non-dominant shoulder), a description of the participants in the study, the results of the analysis between the injured and uninjured group, the results from the comparison between the dominant and non-dominant shoulder and a logistic regression analysis with regards to the variables and injury.

4.2 Intra-rater Reliability

Table 2: Intra-rater reliability of the shoulder tests (n = 4)

Variable	**Pearson's r**
Dominant internal rotation ROM	0.948
Dominant external rotation ROM	0.974
Dominant pectoralis minor muscle length test distance	0.989
Non-dominant internal rotation ROM	0.960
Non-dominant external rotation ROM	0.998
Non-dominant pectoralis minor muscle length test distance	0.981

Pearson's r were obtained using the Pearson's correlation coefficient

The internal rotation ROM and external rotation ROM were measured using the inclinometer. The pectoralis minor length test distance was measured using the right angle ruler. The intra-rater reliability from the four participants revealed good results (Table 2), therefore the use of the inclinometer and right angle ruler were reliable for use in this study.

4.3 Participants characteristics and injuries sustained

Shoulder measurements were completed for 36 male, provincial (n = 30) and club (n = 6) cricket players. Four participant's data were removed before the analysis as they were not exposed to the typical cricket training and match workloads. They were excluded from the study for the following reasons: one sustained a dominant shoulder injury post assessment and prior to the start of the season/monitoring period. The second acquired a non-dominant shoulder injury during the season and the last participant was diagnosed with a lumbar stress fracture and he participated in regular swimming training and minimal cricket related activities). The non-dominant shoulder injury was not included in the injured group as the non-dominant shoulder does not perform throwing or bowling. One participant dropped out because he left to join a different team soon after the pre-season assessments were completed and did not participate in injury and training and match workload monitoring.

Thirty two participants' baseline data with a mean age of 23.56 (SD ± 4.27; range 18-33 years) years were analysed. Of the thirty two participants, nine participants (28%) with a mean age of 23.00 years (SD ± 5.26) sustained dominant shoulder injuries and twenty three participants with a mean age of 23.78 years (SD ± 3.93) remained uninjured. Age was found not to be significantly different between the injured and uninjured group ($p = 0.65$).

Skills classification of the nine injured participants were as follows: three all-rounders, four bowlers, one batsman and one wicket keeper. All of the dominant shoulder injuries were gradual onset non-contact injuries, of which eight occurred with throwing and one was due to bowling.

4.4 The difference between injured and uninjured participants

Table 3: A comparison between the injured and uninjured group (parametric data)

Variable	Injured (n = 9) Mean (SD)	Uninjured (n = 23) Mean (SD)	Cohen's *d* (95% CI)	P value
Dominant internal rotation ROM (°)	51.30 (9.53)	51.48 (14.91)	0.014 [-0.757,0.784]	0.98
Dominant external rotation ROM (°)	121.60 (18.10)	121.61 (14.91)	0.001 [-0.771,0.771]	0.99
Dominant throwing arc ROM (°)	172.90 (19.65)	173.09 (20.38)	0.009 [-0.761,0.78]	0.98
Dominant pectoralis minor muscle length test distance (cm)	5.09 (0.86)	5.70 (0.94)	0.677 [-0.124,1.451]	0.10
Non-dominant internal rotation ROM (°)	59.11 (12.45)	64.09 (13.30)	0.387 [-0.395,1.157]	0.34
Non-dominant pectoralis minor muscle length test distance (cm)	4.82 (1.17)	4.76 (0.99)	0.055 [-0.828,0.713]	0.87
GIRD (°) [a]	7.78 (12.70)	12.61 (13.16)	0.373 [-0.406,1.146]	0.35
Workload (%)	0.56 (0.18)	0.66 (0.16)	0.587 [-0.181,1.389]	0.15

P values were obtained using independent t-tests
* Denotes statistical significance ($p < 0.05$)
a) A negative value occurs when the non-dominant internal rotation ROM is smaller than the dominant internal rotation ROM
GIRD – glenohumeral internal rotational deficit;

For the normally distributed data, no statistically significant differences regarding all of the variables (dominant and non-dominant internal rotation ROM, dominant external rotation ROM, dominant throwing arc ROM, dominant and non-dominant pectoralis minor muscle length test distance, GIRD and training and match workload) were found between the injured and uninjured group (Table 3). Cohen's *d* effect size was found to be medium for dominant pectoralis minor muscle length test distance (*d* = 0.677), with the injured group obtaining a higher mean value. The non-dominant mean internal rotation ROM was larger in the uninjured group and the effect size was found to be small (*d* = 0.387). The mean GIRD values were greater in the uninjured group and the effect size was small (*d* = 0.373). The mean workload percentage was larger in the uninjured group and the effect size was medium (*d* = 0.587).

Table 4: A comparison between the injured and uninjured group (non-parametric data)

Variable	Injured (n = 9) Median (IQR)	Uninjured (n = 23) Median (IQR)	P value
Non-dominant external rotation ROM (°)	114 (110 - 130)	120 (110 - 130)	0.69
Non-dominant throwing arc ROM (°)	178 (164 - 190)	182 (168 - 200)	0.46
ERG (°) [a]	0 (-6 - 4)	-2 (-16 - 8)	0.82

P values were obtained using the Mann-Whitney U tests
* Denotes statistical significance (p < 0.05)
a) A negative value occurs when the non-dominant external rotation ROM is smaller than the dominant external rotation ROM
ERG – external rotation gain;
IQR – interquartile range (25 – 75% percentile);

For the data that were not normally distributed, no significant difference was found regarding the non-dominant external rotation ROM, non-dominant throwing arc ROM and ERG between the injured and uninjured group (Table 4).

4.5 The difference between dominant and non-dominant side

4.5.1 Entire group

Table 5: A comparison between the dominant and non-dominant shoulder in the entire group (n = 32) (parametric data)

Variable	Dominant Mean (SD)	Non-dominant Mean (SD)	Cohen's *d* (95% CI)	P value
Internal rotation ROM (°)	51.44 (13.46)	62.69 (13.07)	0.848 [0.125,1.571]	< 0.0001*
Pectoralis minor muscle length test distance (cm)	5.53 (0.94)	4.78 (1.03)	0.761 [-1.478,-0.043]	0.0001*

P values were obtained using paired t-tests
* Denotes statistical significance (p < 0.05)

Paired t-tests between the dominant and non-dominant measurements presented statistically significant differences regarding the internal rotation ROM ($p < 0.0001$) and pectoralis minor muscle length test distance ($p = 0.0001$) (Table 5). Pre-season, the entire group displayed greater non-dominant internal rotation ROM. Larger dominant pectoralis minor muscle length test distance (acromion to plinth distance which denotes reduced muscle length) (which denotes shorter pectoralis minor muscle lengths) were also found. Internal rotation ROM revealed a large effect size ($d = 0.848$) and pectoralis minor muscle length test distance revealed a medium effect size ($d = 0.761$) using the Cohen's *d*.

Table 6: A comparison between the between the dominant and non-dominant shoulder in the entire group (n = 32) (non-parametric data)

Variable	**Dominant** **Median (IQR)**	**Non-dominant** **Median (IQR)**	**P value**
External rotation ROM (°)	123 (112 - 130)	117 (111 - 130)	0.0037*
Throwing arc ROM (°)	173 (161 - 210)	181 (168 - 195)	0.016*

P values were obtained using Sign tests
* Denotes statistical significance ($p < 0.05$)

The Sign test used to analyse the non-parametric data disclosed significant differences between the dominant and non-dominant external rotation ROM ($p = 0.0037$) and throwing arc ROM ($p = 0.016$) (Table 6). A comparison of the measurements found that the external rotation ROM was increased on the dominant side (123°) and the throwing arc ROM was increased on the non-dominant side (181°).

4.5.2 Injured group

Table 7: A comparison between the dominant and non-dominant shoulder in the injured group (n = 9) (parametric data)

Variable	**Dominant** **Mean (SD)**	**Non-dominant** **Mean (SD)**	**Cohen's *d* (95% CI)**	**P value**
Internal rotation ROM (°)	51.33 (9.54)	59.11 (12.45)	0.701 [-0.645,2.048]	0.10
Pectoralis minor muscle length test distance (cm)	5.09 (0.87)	4.82 (1.17)	0.262 [-1.574,1.05]	0.32

P values were obtained using paired t-tests
* Denotes statistical significance ($p < 0.05$)

Paired t-tests used to analyse the dominant and non-dominant internal rotation ROM ($p = 0.10$) and pectoralis minor length test distance ($p = 0.32$), revealed no statistical significance, therefore there were no differences between the sides (Table 7). Cohen's *d* effect size was medium ($d = 0.701$), where the injured group displayed smaller mean values of dominant internal rotation ROM on the dominant side (51.33°) than on the non-dominant side (59.11°). The effect size was small for pectoralis minor muscle length test distance ($d = 0.262$) with the dominant shoulder mean measurements obtaining a larger result compared to the non-dominant value.

Table 8: A comparison between the dominant and non-dominant shoulder in the injured group (n = 9) (non-parametric data)

Variable	**Dominant** **Median (IQR)**	**Non-dominant** **Median (IQR)**	**P value**
External rotation ROM (°)	124 (110 - 130)	114 (110 - 130)	1.00
Throwing arc ROM (°)	180 (168 - 192)	178 (164 - 190)	0.18

P values were obtained using Sign tests
* Denotes statistical significance ($p < 0.05$)

The results from the analysis of non-parametric data in the injured participants between the dominant and non-dominant shoulder obtained no significant results, between the sides, when analysing external rotation ROM (p = 1.00) and throwing arc ROM (p = 0.18) (Table 8). In this group, the medians were larger for both the external rotation ROM (124°) and throwing arc ROM (180°) on the dominant side.

4.5.3 Uninjured group

Table 9: A comparison between the dominant and non-dominant shoulder in the uninjured group (n = 23) (parametric data)

Variable	**Dominant** **Mean (SD)**	**Non-dominant** **Mean (SD)**	**Cohen's *d* (95% CI)**	**P value**
Internal rotation ROM (°)	51.48 (14.91)	64.09 (13.30)	0.893 [0.035,1.75]	0.0001*
Throwing arc ROM (°)	173.09 (20.38)	184.91 (19.53)	0.592 [-0.243,1.427]	0.005*
Pectoralis minor muscle length test distance (cm)	5.70 (0.94)	4.76 (0.99)	0.974 [-1.838,-0.109]	0.0002*

P values were obtained using paired t-tests
* Denotes statistical significance (p < 0.05)

In injury free participants (n = 23), paired t-tests between the dominant and non-dominant shoulder produced significant differences regarding internal rotation ROM, throwing arc ROM and pectoralis minor muscle length test distance (Table 9). The internal rotation ROM (64.09°) and throwing arc ROM (184.91°) had a larger ROM on the non-dominant shoulder whereas the pectoralis minor muscle length test distance (acromion to plinth distance / denotes a shorter muscle) was larger on the dominant side (5.70 cm). The effect size was large for internal rotation ROM (d = 0.893), large for pectoralis minor muscle length test distance (d = 0.974) and medium for throwing arc ROM (d = 0.592)

Table 10: A comparison between the dominant and non-dominant shoulder in the uninjured group (n = 23) (non-parametric data)

Variable	Dominant Median (IQR)	Non-dominant Median (IQR)	P value
External rotation ROM (°)	122 (113 - 132)	120 (110 - 135)	0.52

P values were obtained using Sign tests
* Denotes statistical significance ($p < 0.05$)

The external rotation ROM in the uninjured group (n = 23), analysed with the Sign test, depicted no significant difference with regards to external rotation ROM between the dominant and non-dominant shoulder (Table 10). The difference between the medians was less amongst the injured participants.

4.6 The relationship between initial pain and injury

The chi-squared test of independence was used to analyse the relationship between initial shoulder pain which was experienced at rest, during or after training (which was reported pre-season) with regards to injury. Six out of nine of the injured participants reported current shoulder pain during the baseline testing and four out of twenty three participants in the uninjured group reported current shoulder pain during the baseline testing. The chi-squared test found a statistically significant difference between injury classification and initial pain, χ^2 (n = 32) = 7.31 (p = 0.007*).

4.7 The relationship between injury and multiple variables

A logistic regression analysis using the Stepwise Wald method was conducted with the following variables: age, dominant internal rotation ROM, dominant external rotation ROM, dominant pectoralis minor length test distance, non-dominant internal rotation ROM, non-dominant external rotation ROM, non-dominant pectoralis minor muscle length test distance, initial pain and workload. The model was found to have a statistically significant fit, χ^2 (n = 32) = 19.60, (p = 0.03), however, none of the variables in the model were statistically significant, suggesting that the variables were not related to injury.

CHAPTER 5: Discussion

5.1 Introduction

The purpose of this study was to determine if there is an association between the shoulder rotation ROM, throwing arc ROM, pectoralis minor length, and dominant shoulder injury as monitored in the first three months of a cricket season.

5.1.1 Shoulder internal rotation ROM and GIRD

There was no significant difference in shoulder internal rotation ROM of the dominant ($p = 0.98$) and non-dominant ($p = 0.34$) upper limb, between the uninjured participants compared to the injured ones. The findings in this study are similar to previous cricket studies (Aginsky, Lategan & Stretch 2004; Steulcken, Ginn & Sinclair 2008), where no significant difference was found between the injured and uninjured group regarding internal rotation ROM. The findings were similar, however, differences were found with the participants' demographics, the measurement apparatus used to measure the internal rotation ROM and the time period of the measurements which occurred either prior to the injury or post-injury.

In elite female fast bowlers ($n = 26$) dominant (bowling) shoulder, decreased mean active internal rotation ROM of 42.80° occurred in injured participants and 44.10° in their uninjured participants (Steulcken, Ginn & Sinclair 2008), however, the difference was not significant ($p > 0.05$). The ROM was obtained with the use of a long arm goniometer during the beginning of the cricket season (Steulcken, Ginn & Sinclair 2008). The injured and uninjured groups produced a greater degree of decreased internal rotation ROM of the dominant and non-dominant shoulder, possibly due to investigators measuring active ROM and less likely due to the participants being female and only fast bowlers (Steulcken, Ginn & Sinclair 2008). Active ROM tests the amount of movement that the participant can perform and involves the neuromuscular system, whereas passive ROM is the amount of movement that the joint can perform when an external force is applied to move the joint to its largest range (Tveita et al. 2008). The injured group also displayed a smaller degree of internal rotation ROM as compared to the uninjured group (Steulcken, Ginn & Sinclair 2008).

Male, provincial fast bowlers (n = 21) displayed decreased passive internal passive internal rotational ROM of 84.00° in the injured and 89.75° in the uninjured group (Aginsky, Lategan & Stretch 2004), but the difference was not significant ($p = 0.361$). These participants' passive ROM was measured with a Leighton flexometer and they were classified as being injured if they previously sustained a bowling shoulder injury (Aginsky, Lategan & Stretch 2004). The injury definition by Aginsky, Lategan & Stretch (2004) was different to ours as their injuries occurred prior to the measurements and our injuries occurred post-measurement. The degree of internal rotation ROM depends upon whether passive or active ROM is obtained, with passive internal rotation ROM displaying larger ROM values. However, irrespective of the active or passive ROM measured, the difference in internal rotation ROM when compared between the injured and uninjured group is not associated with injury (Aginsky, Lategan & Stretch 2004; Steulcken, Ginn & Sinclair 2008).

In the entire group and uninjured group, the dominant glenohumeral joints had decreased mean internal rotation ROM as compared to the non-dominant sides. The difference in internal rotation ROM was statistically significant for the entire group ($p < 0.0001$) and uninjured group ($p = 0.0001$). The effect size were large in the entire group ($d = 0.848$) and uninjured group ($d = 0.893$). Although the above findings were not statistically significant in the injured group ($p = 0.10$), a medium effect size was found ($d = 0.701$). These differences may occur due to the repetitive nature of throwing and bowling which causes humeral retroversion (Reagan et al. 2002) or soft tissue adaptations of the posterior glenohumeral joint capsule, resulting in a decreased internal rotation ROM (Dashottar & Borstad 2012).

The statistically significant differences between the dominant and non-dominant internal rotation ROM, in the entire group and uninjured group, as well as the large effect sizes, indicate that asymmetries occurred between the shoulders. Similar large asymmetries were found in spin bowlers (12.90°) and fast bowlers (11.58°) that remained injury free (Sundaram, Bhargava & Karuppannan 2012) therefore these asymmetries may play an injury preventive role. The study by Sundaram, Bhargava & Karuppannan (2012) was similar to this study regarding the measurement procedure and the use of an only male population.

Different results were found by Giles & Musa (2008), as their injured overarm cricket players and bowlers had a larger IRD of 10° and a smaller IRD of 6.8° in their uninjured group. The uninjured group, in this study, had a larger IRD of 12.61° between the dominant and non-dominant internal rotation ROM and a smaller IRD of 7.78° in the injured group. The study by Giles & Musa (2008) was different to this study as it was retrospective observational study. Their measurements were taken during the offseason post shoulder pain and injury (Giles & Musa 2008), therefore the participants may have received treatment and rehabilitation which may have involved correction of any asymmetries before shoulder measurements took place. In this study and the study by Sundaram, Bhargava & Karuppannan (2012), large internal rotation ROM asymmetries were identified in participants that remained injury free. This brings forth the assumption that internal rotation asymmetry, where less internal rotation ROM is present in the dominant shoulder, prior to the occurrence of shoulder injury, may be protecting the joint from developing an injury.

The preventative role of these asymmetries might not be confined only to the glenohumeral joint. Similar asymmetries have been found lower in the kinetic chain, where adolescent fast bowlers that were uninjured had asymmetrical core muscle thickness (Gray et al. 2015; Olivier 2016b). These abdominal adaptations may produce changes further up the kinetic chain resulting in asymmetrical upper limb muscle changes, as seen by Grobbelaar (2003). These asymmetrical hypertrophic changes were evident on the dominant upper half of the chest, dominant upper arm and forearm in fast bowlers (Grobbelaar 2003). These asymmetries which occur in multiple areas of the kinetic chain, this may be due to the nature of cricket which involves asymmetrical movements of limbs during batting, bowling and fielding.

Dominant and non-dominant shoulder differences, especially when it comes to internal rotation, is characterised by the term GIRD in the literature (dominant minus non-dominant internal rotation ROM). In our study, no statistically significant difference ($p = 0.35$) in the GIRD between the injured and uninjured groups were found and the effect size was small ($d = 0.373$). Since the alpha level is high (a = 0.05), there is a possibility of rejecting the null hypothesis, although a larger sample size would be desirable and may have produced a statistically significant p value (Sullivan & Feinn 2012). These GIRD results were within the anatomical GIRD values of less than 18° - 20° with a less than 5° loss of throwing arc ROM (Manske et al. 2013b). Manske et al. (2013b) classified GIRD as being pathological if there was more than 18° - 20° GIRD with a more than 5° loss of total arc ROM. Their study was a clinical commentary and they based this pathological classification on previous studies.

The range determined for GIRD and the addition of the throwing arc ROM to the definition was chosen due to varied standard deviations regarding pathological GIRD in studies and the loss of throwing arc places strain on the static and dynamic stabilisers of the shoulder (Manske et al. 2013b). In context, GIRD values in this study were smaller than the 19.7° GIRD found in shoulder impingement participants (Myers et al. 2006), 18° GIRD found in participants with muscle imbalances (Guney et al. 2016) or 15° GIRD found in participants with altered scapular movement (Thomas, Swanik & Swanik 2010). GIRD may have had less of a contribution to injuries within our population, because the GIRD values in our study, in the injured and uninjured group were lower than problematic values from previous studies.

5.1.2 Shoulder external rotation ROM and ERG

The mean external rotation ROM for the dominant ($p = 0.99$) and non-dominant shoulder ($p = 0.69$) displayed no significant difference between the uninjured group as compared to the injured group. Previous cricket studies also have found no statistically significant changes, regarding external rotation ROM in a pain free dominant shoulder group as compared to a painful or injured dominant shoulder group (Aginsky, Lategan & Stretch 2004; Steulcken, Ginn & Sinclair 2008). In elite, female cricket players the active external rotation ROM was 82.5° in the injured ($n = 12$) and 89.1° in the uninjured group ($n = 14$) (Steulcken, Ginn & Sinclair 2008). The authors were investigating the ROM and strength in female bowlers with and without previous shoulder pain. A significant difference was not found ($p > 0.05$) when comparing the external rotation ROM in the injured and uninjured group (Steulcken, Ginn & Sinclair 2008), and our study agreed with these findings.

In another study containing male cricket players, the passive ROM was 116.22° in the injured (n = 9) and 116.83° in the uninjured group (n = 12) (Aginsky, Lategan & Stretch 2004). The authors investigated shoulder rotational ROM as well as isokinetic glenohumeral rotational strength in relation to shoulder injuries. None of the variables (internal rotation ROM (p = 0.361), external rotation ROM (p = 0.884), concentric and eccentric internal rotation torque (p = 0.356 – 0.965), concentric and eccentric external rotation torque (p = 0.131 – 0.933) displayed significant differences between the injured and uninjured groups, therefore shoulder ROM and shoulder rotation torque weren't associated with injury.

Within the study by Aginsky, Lategan & Stretch (2004), however, trends were identified with decreased ERs:IRs torque values (72.13Nm) in injured participants indicating a rotator cuff muscle imbalance. Strengthening of shoulder rotators to a larger ERs:IRs (IRs:ERs of 62.31%) in baseball players resulted in a decrease in shoulder pain (Cha et al. 2014), therefore cricket players would require a relatively large external rotator torque in relation to the internal rotator torque to remain injury free. These studies associated shoulder pain and injury with a rotator cuff muscle imbalance. The external rotation ROM was not associated with injury in this study, however, muscle imbalance may have been a contributing factor towards the development of a shoulder injury.

The external rotation ROM between the upper limbs was significantly different in the entire group only (p = 0.0037). No significant difference was found between the dominant and non-dominant external rotation ROM in the injured (p = 1.00) and uninjured groups (p = 0.52). Steulcken, Ginn & Sinclair (2008) did not agree with these findings as their entire group did not produce a significant dominant compared to non-dominant external rotation ROM difference (p > 0.05), however, their uninjured group had a significant between limb difference (p = 0.044). Their uninjured group produced significant results and obtained a medium effect size (*d* = 0.53), therefore between limb asymmetry occurred between the limbs (Steulcken, Ginn & Sinclair, 2008). Their study differed to ours as no significant between limb asymmetry regarding external rotation ROM was noted in our uninjured group.

The entire group in this study obtained significant results (p = 0.0037) possibly due to the sample size. Steulcken, Ginn & Sinclair (2008) included twenty six participants and in this study, the desirable sample size was thirty six participants but we analysed thirty two participants' data. The previous study (Steulcken, Ginn & Sinclair 2008) and this study contained small sample sizes in their entire group, which resulted in smaller amounts of participants in the injured and uninjured groups. The entire group and subgroups all contained participants with shoulder pain, which limits the homogeneity of the groups and is a confounder to finding differences between the groups. The result was significant, possibly due to less homogeneity between the groups, and the entire group containing a larger amount of participants as compared to the injured, uninjured group and previous study (Steulcken, Ginn & Sinclair 2008), therefore a smaller difference in the entire group was viewed as being statistically significant

ERG (dominant minus non-dominant external rotation ROM) displayed no significant difference ($p = 0.82$) between the injured and uninjured participants. The ERG occurs due to stretching of the anterior capsule causing laxity (Mihata et al. 2015) or due to adaptations such as humeral retroversion (Reagan et al. 2002). Mihata et al. (2015) indicated that these soft tissue changes lead to impingement of structures during the cocking phase of throwing, therefore causing shoulder injury and pain. These adaptive changes and pathology were evident in the study of Giles & Musa (2008), however, their findings were similar to ours as their pain and no pain group did not obtain significant ERG values. They found external rotational differences between pain (9.7°) and no shoulder pain (7.5°) for the cricket participants (Giles & Musa 2008). In this study, the ERG values were 0° in the injured group and 2° in the uninjured group. These findings may be similar because in the study by Giles & Musa (2008) and in this study, the population was similar. Giles & Musa (2008) included bowlers, over arm cricket players and wicket keepers, which is similar to my study participants, in which we termed the participants as bowlers, fielders, all-rounders or wicketkeepers. Our study is in agreement with the previous study that ERG was not associated with injury in these populations of cricket players.

The external rotation ROM is interpreted with the internal ROM in mind, as both the measurements should add up to a desirable throwing arc ROM (Manske et al. 2013a). Ideally, according to Manske et al. (2013a), the dominant shoulder exhibits 10 - 15° more external rotation in conjunction with a 10 - 15° decrease in internal rotation of the non-dominant shoulder. The ERG in this study may be equivalent to the decrease in internal rotation ROM, because the sum of the internal rotation ROM and external rotation ROM is approximately 180°. So the ERG may be seen as adaptive changes that occur due to the loss of internal rotation.

5.1.3 Throwing arc ROM

The mean dominant ($p = 0.98$) and non-dominant throwing arc ROM ($p = 0.46$) (shoulder internal ROM + shoulder external ROM) was not significant in the uninjured group as compared to the injured group. The dominant throwing arc ROM in the injured and uninjured group was less than 180°, however, it wasn't significantly different. Throwing arc ROM of 180° has been proposed to be a desirable value, and anything less is considered to be pathological (Manske et al. 2013b), however, the results in this study did not agree with this. The participants may have remained injury free due to compensation from other segments of the body.

Kanlayanaphotpom (2014) found that a decrease in shoulder rotation ROM was associated with an increase in thoracic kyphosis. In baseball players, the shoulder rotational ROM was decreased due to posterior shoulder tightness (Laudner et al. 2013). In order to overcome these restrictions causing a decrease in glenohumeral ROM, the athletes may compensate with movements from the thoracolumbar spine (Laudner et al. 2013). Laudner et al. (2013) found that baseball pitchers had significantly increased thoracolumbar rotation ($p = 0.007$) to their non-throwing side compared to other positional baseball players. In cricket fast bowlers, the kinematic evaluation identified lumbar flexion, rotation and lateral flexion, from the period of the back foot contact until the follow though phase (Ferdinands, Kersting & Marshall 2009). During these phases of bowling, a large degree of shoulder rotation takes place (Ferdinands, Kersting & Marshall 2009). The thoracolumbar movement identified in baseball pitchers (Laudner et al. 2013) and cricket fast bowlers (Ferdinands, Kersting & Marshall 2009) may be compensatory movement to allow the glenohumeral joint to move through the required ROM, even when a restriction causes a decrease in the ROM (Laudner et al. 2013).

Further analysis found that the entire group ($p = 0.016$) and uninjured group ($p = 0.005$) displayed significance between limb (dominant and non-dominant) differences with regards to throwing arc ROM. The non-dominant shoulder produced larger throwing arc ROM values as compared to the dominant shoulder in both groups (entire group and uninjured group). A medium effect size (*d* = 0.592) was identified between the dominant and non-dominant throwing arc ROM in the uninjured group. Throwing arc ROM related injuries have been related to a pathological GIRD of more than 18° – 20°, with an associated loss of more than 5° of total arc ROM (Manske et al. 2013b). The entire group and uninjured participants in this study had greater than 5° difference without the associated GIRD.

Previous studies have found that pathology occurs with greater than 5° difference between limbs. Cricket studies have found no pain or injury associated with a difference of 3.6° in elite, female fast bowlers (Steulcken, Ginn & Sinclair 2008) and 0.4° in male, overarm cricket players and wicket keepers (Giles & Musa 2008). Our population did not conform to this norm, as the uninjured group had a greater than 10° difference and the injured group had a less than 5° difference between the dominant and non-dominant throwing arc. The injury free participants did not conform to the norm possibly due to the significant asymmetries (p = 0.005) and medium effect size (*d* = 0.592) identified, between the dominant and non-dominant throwing arc ROM. The asymmetries may be involved in injury prevention, as seen lower down in the kinetic chain for abdominal muscles during bowling (Gray et al. 2015; Olivier 2016b). Furthermore, cumulative asymmetries in the kinetic chain, involving abdominal musculature as well as throwing arc ROM, may be providing a protective mechanism instead of isolated throwing arc asymmetries.

5.1.4 Pectoralis Minor muscle length

According to the knowledge of the researcher, this is the first study to investigate the influence of pectoralis minor muscle length in a cricket population. Results revealed no significant difference between the injured and uninjured group regarding the dominant (p = 0.10) and non-dominant (p = 0.87) pectoralis minor muscle length test distance (acromion to plinth distance). However, the effect size of the dominant pectoralis minor length test distance, between the groups (injured and uninjured group), was medium (*d* = 0.677) with a smaller value (acromion to plinth distance) in the injured group. A larger sample size may have produced significant results, however, from the medium effect size, it is evident that a difference exists for the dominant pectoralis minor muscle length between the injured and uninjured cricket participants.

In this study, no difference was found between the injured and uninjured group regarding the dominant (p = 0.10) and non-dominant (p = 0.87) pectoralis minor length test distance. Previous studies have investigated the reliability of pectoralis minor muscle length measurements, therefore an analysis between their pathological and injury free participants was not performed. Mean measurement results have been presented in this study and in previous studies (Lewis & Valentine 2007; Struyf et al. 2014). In this study, the effect size was medium regarding the dominant pectoralis minor length test distance, with a small mean value of 5.09cm in the injured group (acromion to plinth distance) and a mean of 5.7cm in the uninjured group, suggesting a longer dominant pectoralis minor muscle length in the injured group's dominant shoulder. The medium effect size displays a difference between the two groups, however, the difference is not statistically significant and previous studies only provide mean values in their investigations.

Similar mean results were obtained by previous studies (Lewis & Valentine 2007; Struyf et al. 2014). Lewis & Valentine (2007) used the same measurement technique of measuring the distance of the posterior part of the acromion to the plinth, in participants with non-specific shoulder pain, rotator cuff tendinopathy and other shoulder pathologies. These participants were recruited from orthopaedic and physiotherapy outpatient practices (Lewis & Valentine 2007). Their results also displayed a shorter mean acromion to plinth distance of 6.1cm in the symptomatic dominant pectoralis minor muscle as compared to 6.3cm in the asymptomatic non-dominant pectoralis minor muscle (Lewis & Valentine 2007).

Struyf et al. (2014), with the use of a caliper to directly measure pectoralis minor muscle length, they also found longer muscle lengths (9.66% of participants height) on the symptomatic side in participants with subacromial impingement syndrome, as compared to the dominant side in asymptomatic participants (9.17% & of participants height) (Struyf et al. 2014). These participants were recruited from orthopaedic surgeons and physician referrals (Struyf et al. 2014). These results are a comparison between two groups, therefore height, analysis method and the study population used, may influence results obtained.

The analysis used within the studies (Lewis & Valentine 2007; Struyf et al. 2014) have compared the pectoralis minor measurement on the dominant side in asymptomatic subjects and the symptomatic side in subjects with shoulder region pathology. This comparison, between injured and uninjured groups, does not take into account length differences in accordance with the height of the subject, as height may have a possible influence on muscle length. This should be considered when interpreting the pectoralis minor measurements in this study and the results by Lewis & Valentine (2007). Struyf et al. (2014) converted their measurements into a body height normalised value, but their measurements displayed a similar trend with a longer pectoralis minor in symptomatic shoulders as compared to a shorter dominant pectoralis minor in asymptomatic subject.

The entire group ($p = 0.0001$) and uninjured group ($p = 0.0002$) displayed significant asymmetries with regards to dominant to non-dominant measurements of pectoralis minor length test distance. The effect size was found to be medium in the entire group ($d = 0.761$) and large in the uninjured group ($d = 0.974$). The values of the non-dominant pectoralis minor muscle length test distance was found to be significantly smaller (longer pectoralis minor muscle length) as compared to the dominant side (shorter pectoralis minor muscle length) in the entire group and uninjured group (larger acromion to plinth distance). These results suggest that the dominant pectoralis minor muscle lengths are shorter on the dominant sides and longer on the non-dominant side. The injured group, however, did not display a shorter dominant pectoralis minor muscle as mentioned in a previous review (Moezy, Sepehrifar & Dodaran 2014).

A previous study looked at the role of the scapula in injured and uninjured cricket players. They found that injured participants' scapulae displayed increased downward rotation (Edmonds & Dengerink 2014) which is associated with a tightened pectoralis minor muscle (Moezy, Sepehrifar & Dodaran 2014). However, the pectoralis muscle contraction produces the same downward rotation during arm elevation (Phadke, Camargo & Ludewig 2009). This brings forward the assumption that the pectoralis minor muscle's resting length may not have a direct influence on shoulder injuries, but the concentric action of the muscle may have an effect during overhead movements to influence scapula dysfunction and the development of shoulder injuries.

5.1.5 Training and match workload

No significant difference was found in terms of workload between the injured and uninjured participants, however, the effect size was medium (*d* = 0.587) with a larger workload percentage found in the uninjured group. Saw et al. (2011) found that the risk of shoulder injuries increased with more than 75 throws per week and more than 40 throws per day. In this study, the difference in workload between the injured and uninjured group was not statistically significant ($p = 0.15$), but the effect size was medium. The population in this study might not have reached this throwing threshold, therefore it was not one of the significant contributors of shoulder injury. However, workload was not only based on throwing as it contained variables such as: bowling, batting and game time. The injured group had a smaller workload compared to the uninjured group, therefore a lighter workload may be a cause of injury.

The time period in which the study took place, the first three months, was a high workload period. During this time cricket players partook in pre-season training following a low workload period. Following the pre-season training, they participated in fitness and skills sessions as well as all formats of cricket games. This increase in workload did not have any significant difference between the injured and uninjured. The injured group in this study had a lower workload percentage possibly due to six out of nine participants starting the season with dominant shoulder pain.

5.1.6 Initial pain

In this study, the number of participants with initial pain was significantly different between the injured and uninjured group ($p = 0.007$). Six out of nine injured participants reported initial shoulder pain during the baseline assessments as compared to four out of twenty three uninjured participants reporting initial shoulder pain. Initial pain was the presence of shoulder pain that was experienced at rest, during or after training during the preseason assessment period. The presence of initial pain was not considered to be exclusion criteria as it did not limit the participants' training and they were cleared to play. It was considered to be exclusion criteria if the initial shoulder pain matched with the injury definition.

This study's injury definition was: any shoulder pain that occurs during or after cricket training or matches involving batting, bowling, fielding or wicket keeping, resulting in the cessation or limitation of that sporting activity. Initial pain is related to the development of shoulder injuries. Within this study and in English and Welsh club players, it was found that players continued to train and play games with shoulder pain (Giles & Musa 2008; Ranson & Gregory 2008). The pain affects their bowling and fielding capabilities as they anticipate feeling the shoulder pain (Ranson & Gregory 2008). Cricket players should address their shoulder pain at an early stage with treatment or rehabilitation to prevent the development of a future shoulder injury.

5.1.7 Cricket skills

In this study, the number of bowlers (n = 4) that sustained shoulder injuries outnumbered the all-rounders (n = 3), batsman (n = 1) and wicket keeper (n = 1). However, the mechanism of injury was not associated with the skill (batsman, bowler or wicketkeeper) of the participant, as the majority of the injuries were due to throwing while fielding and only one shoulder injury was due to bowling. This may be due to cricket players being required to field, irrespective of them being a specialist batsman or bowler (Lockie, Callaghan & Jeffriess 2014). The only cricketer exempt from this requirement is the wicket keeper. These fielders require great strength to retrieve and throw the ball over long distances to dismiss batsmen (Lockie, Callaghan & Jeffriess 2014; Tennant 2009).

Muscle strength is required not only for throwing long distances, but it is essential for resisting distraction forces which are applied to the glenohumeral joint during the deceleration phase of throwing (Dashottar & Borstad 2012; Escamilla & Andrews 2009). Throwing has been identified previously as one of the main causes of shoulder injury, however, it is important to identify other causes such as throwing biomechanical faults, an underlying muscle imbalance or symmetry observed during assessments.

5.2 Conclusion

The variables assessed were not associated with shoulder injury. Similarities and differences have been found when comparing the results of this study to findings from previous studies, regarding the development of shoulder injuries in cricket players. The variables that were similar included: shoulder internal rotation ROM, shoulder external rotation ROM, GIRD, ERG, workload, initial pain and cricket skills. Throwing arc ROM produced different results as compared to literature. The role of pectoralis minor length plays in causing shoulder injuries has not been investigated previously, so we are unable to compare it to a different cricket population. The role that asymmetries play in cricket players remaining injury free is emerging within literature, and this study's findings supports literature regarding asymmetry playing a protective role in cricket players. The protective role of these asymmetries should be verified with larger sample size and based over a longer period of time.

CHAPTER 6: Conclusion, limitations and recommendations

6.1 Introduction

The aim of the study was to determine if there is an association between the shoulder rotational ROM, throwing arc ROM, pectoralis minor muscle length, and dominant shoulder injury. Previous studies have not investigated pectoralis minor muscle length in cricket players.

6.1.1 Conclusion based on the objectives of the study

The objectives of the study were:

To determine baseline shoulder rotation ROM, throwing arc ROM and pectoralis minor muscle length during the last week of the pre-season and first three weeks of the in-season

Baseline shoulder measurements were obtained pre-season and during the first three weeks of the in-season. The baseline measurements obtained were similar to findings found in previous literature, except for throwing arc ROM which was different to previous literature and pectoralis minor muscle length, which has not been investigated in cricket players.

To determine the dominant shoulder injury incidence as monitored in the first three months of a cricket season.

Nine out of thirty two participants sustained dominant shoulder injuries, whereas twenty three participants remained injury free.

To determine if there is an association between shoulder rotation ROM, throwing arc ROM, pectoralis minor muscle length, and the dominant shoulder injury.

The measurements between the injured and uninjured group did not differ significantly, except for the existence of present pain during the pre-season screening. The present pain occurred more frequently in participants who developed shoulder injuries during the first three months of the in-season, suggesting that initial pain may be associated with injuries occurring later on.

Significant asymmetries were present between four variables in the entire group (internal rotation ROM, external rotation ROM, throwing arc ROM and pectoralis minor muscle length) and three variables in the uninjured group (internal rotation ROM, throwing arc ROM and pectoralis minor muscle length). These asymmetries may be involved in injury prevention whereas symmetries observed in the injured group may play a role in injury development during the season. Assessment at the beginning of the cricket season suggests that initial pain is a contributor to the development of shoulder injuries in cricket players. The logistic regression model containing these variables did not identify any of the variables to be of significance.

The findings of this study were similar to previous studies regarding internal and external rotation adaptive changes, GIRD, ERG, initial pain, workload and cricket skill. The results were different regarding throwing arc ROM and the asymmetries in the uninjured group. More investigations should be conducted on the role of pectoralis minor in cricket populations.

6.2 Limitations

This study included participants that had current shoulder pain at the beginning of the season (the beginning of the monitoring period), which occurs after the preseason training period. Ten participants presented with shoulder pain at the beginning of the season and six participants pain may have increased to the point where the pain was affecting their ability to train and play games. Shoulder pain may indicate pathology, therefore an alternate injury definition may have been used in this study which would include shoulder pain as a variable. This study conformed to definitions used in previous studies (Olivier et al. 2015; Orchard et al. 2016) which records an injury once it causes cessation of an activity. In this case, the presence of shoulder pain in these bowlers did not cause cessation of an activity or time-loss and were therefore included. The importance of shoulder pain should be highlighted and possibly added to future injury definitions, so that more injuries may be captured and addressed at earlier stage, before they result on match or training time-loss.

The identification and inclusion of participants with initial shoulder pain, may have an influence on the measurements of the variables that were obtained. The ROM obtained may be a cause of shoulder pain, or the effect of shoulder pain. Four participants with shoulder pain were included in the uninjured group and six participants were included in the injured. Therefore differences found between the groups may have been affected due to less homogeneity between the groups. Initial shoulder pain was a confounding variable within this study and participants were separated into the injured and uninjured group according to the injury definition.

Differences between the groups should be interpreted with the sample size in mind. There were nine participants in the injured group, twenty three in the uninjured group and thirty two in the entire group. Thirty six participants was the required amount of participants needed, therefore the study have been underpowered. The entire group contained a larger sample size, therefore smaller differences in the entire group was found to be statistically significant.

Differentiating between the different skills (batting, bowling, fielding and wicket keeping) was outside the realm of this study. Certain skills may have produced more shoulder pain and asymmetries as compared to the others. A skills diary containing the duration of time spent on each skill or specific amount throws, catches or overs bowled would have provided more insight into the development of these shoulder injuries. This study was based on the initial part of the in-season (first three months). During this period, the players are possibly fatigued, as it follows an intensive preseason training, it includes training sessions and all formats of cricket games are played during this time period. Non-contact injuries may develop gradually over time, so a longitudinal study may have captured more injuries.

6.3 Recommendations

6.3.1 Recommendations for future research

This study described shoulder injuries that occurred during the first three months of the cricket season. Future research should describe shoulder injuries that occur during the entire cricket season in order to determine the part of the season during which most of the shoulder injuries occur. A larger sample may allow for subgroup analysis where shoulder injuries can be further investigated in terms of different skills (spin bowlers, fast bowlers) within the game of cricket. Longitudinal observational studies can investigate, the effect, that between limb symmetries and asymmetries have on cricket players. This will provide information in the future, regarding the protective role or long term injurious role that asymmetries have in cricketers. Injury prevention programmes may be developed and tested based on the findings of this study.

6.3.2 Clinical recommendations

To the authors' knowledge, this is the first study to investigate pectoralis minor muscle length in a cricket population. The standard measurement of the pectoralis minor muscle length in supine with 0° flexion only provides half the amount of lengthening to the muscle (Muraki et al. 2009). However, this measurement position allows the clinical physiotherapist to determine if there is symmetry between the pectoralis minor lengths, which may place a cricket player at risk for injury development. Further testing of the pectoralis minor muscle lengths may be performed by placing the shoulder in 150° of flexion or at 30° of flexion with scapula retraction, when the muscle is in a lengthened position (Muraki et al. 2009).

At present, the ROM and pectoralis minor measurement is not required to be added to the pre-season screening tool as no significant differences were found between the injured and uninjured group. Internal rotation ROM, throwing arc ROM and pectoralis minor symmetries were noticed within the injured group whereas asymmetries between limb dominance were present within the uninjured group. If future longitudinal studies find an association between injured and uninjured groups, or if asymmetries are found to relate to injury prevention, then ROM and pectoralis minor muscle length measurements can be added to the pre-season screening tool. The long term implications of symmetries between limbs is still to be investigated but it is important to remember that cricket is an asymmetrical sport, so asymmetries occur with the demands of this sport. Therefore the clinician should identify and address other causes of shoulder pain and dysfunction that may be present, such as scapula dysfunction or rotator cuff muscle imbalance. The presence of shoulder pain should be addressed after the pre-season screening to prevent possible injuries from occurring.

References

1. Aginsky, KD., Lategan, L., Stretch, RA., 2004, 'Shoulder injuries in provincial male fast bowlers - predisposing factors', *Sports Medicine* 16(1), 25-28.
2. Almeida, GPL., Silveira, PF., Rosseto, NP., Barbosa, G., Ejnisman, B., Cohen, M., 2013, 'Glenohumeral range of motion in handball players with and without throwing-related shoulder pain', *Journal of Shoulder and Elbow Surgery* 22, 602-607.
3. Astolfi, MM., Struminger, AH., Royer, TD., Kaminski, TW., Swanik, CB., 2015, 'Adaptations to the shoulder to overhead throwing in young athletes', *Journal of Athletic Training* 50(7), 726-732
4. Bartlett, RM., Stickill, NP., Elliott, BC., Burnett, AF., 1996, 'The biomechanics of fast bowling in men's cricket: A review', *Journal of Sports Sciences* 14, 403-424.
5. Boyle, S., Haag, M., Limb, D., 2009, 'Shoulder arthroscopy, anatomy and variants - part 2', *Orthopedics and Trauma* 23(5), 365-376.
6. Brukner, P., & Khan, K., 2012, *Clinical Sports Medicine*, McGraw-Hill education, Australia.
7. Burkhart, SS., Morgan, CD., Kibler, MD., 2003, 'The disabled throwing shoulder: spectrum of pathology part III: the SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation', *The Journal of Arthroscopic and Related Surgery* 19(6), 641-661.
8. Cha, JY., Kim, JH., Hong, J., Choi, YT., Kim, MH., Cho, JH., Ko, IG., Jee, YS., 2014,'A 12-week rehabilitation program improves body composition, pain sensation, and internal/external torques of baseball pitchers with shoulder impingement symptom', *Journal of Exercise Rehabilitation* 10(1), 35-44.
9. Cohen, J., 1998, *Statistical power analysis for the behavioural sciences (2nd edition)*, Lawrence Erlbaum Associates, Hillsdale New Jersey
10. Das, NS., Usman, J., Choudhury, D., Osman, NA., 2014, 'Nature and pattern of cricket injuries: The Asian cricket council under-19, elite cup' *PLoS One*. 9(6),e100028. http://dx.doi.org/10.1371/journal.pone.0100028.

11. Dashottar, A., Borstad, J., 2012, ‘Posterior glenohumeral joint capsule contracture’, *British Elbow and Shoulder Society, Shoulder and Elbow* 4, 230 – 236.
12. Dhillon, M., Garg, B., Soni, R., Dhillon, H., Prabhakar, S., 2012, ‘Nature and incidence of upper limb injuries in professional cricket players a prospective observation’ *Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology* 4(42).
13. Dwelly, PM., Tripp, BL., Odai, ML., McGinn, PA., 2013, ‘Reliability of the clinical application of a mechanical inclinometer in measuring glenohumeral motion’ *Section on Allied Health Professionals, 5th Annual College of Education Research Conference*, 2007 Florida international university, Miami Florida, 2007.
14. Edelson, G., 1999, ‘Variations in the retroversion of the humeral head’, *Journal of Shoulder and Elbow Surgery* 8(2), 142-145.
15. Edmonds, EW., & Dengerink, DD., 2014, ‘Common conditions in the overhead athlete’, *American Academy of Family Physicians* 89(7), 537-541.
16. Greenberg, EM., Fernandez, AF., Lawrence, JTR., McClure, P., 2015, ‘The development of humeral retrotorsion and its relationship to throwing sports’, *Sports Health* 7(6), 489-496.
17. Escamilla, RF., Andrews, JR., 2009, ‘Shoulder muscle recruitment patterns and related biomechanics during upper extremity sports’, *Sports Medicine* 39(7), 569-590.
18. Farrar, NG., Malal, JJG., Fischer, J., Waseem, M., 2013, ‘An overview of shoulder instability and its management’, *The Open Orthopaedics Journal* 7, 338-346.
19. Ferdinands, RED., Kersting, U., Marshall, RN., 2009, ‘Three-dimensional lumbar segment kinetics of fast bowling in cricket’, *Journal of Biomechanics* 42, 1616-1621.
20. Fessa, CK., Peduto, A., Linklater, J., Tirman, P., 2015, ‘Posterosuperior glenoid internal impingement of the shoulder in the overhead athlete: Pathogenesis, clinical features and MR imaging findings’, *Journal of Medical Imaging and Radiation Oncology* 59, 182–187.

21. Giles, K., Musa, I., 2008, ‘A survey of glenohumeral joint rotational range and non-specific shoulder pain in elite cricketers’, *Physical Therapy in Sports* 9, 109-116.
22. Glazier, PS., Wheat, JS., 2014, ‘An integrated approach to biomechanics and motor control of cricket fast bowling techniques’, *Sports Medicine* 44, 25-36.
23. Gray, J., Aginsky, K., Derman, W., Vaughan, CL., Hodges, PW., 2015, ‘Symmetry, not asymmetry, of abdominal muscle morphology is associated with low back pain in cricket fast bowlers’, *Journal of Science and Medicine in Sport*’, 19(3), 222-226.
24. Gregory, PL., Batt, ME., Wallace, WA., 2002, ’Comparing injuries of spin bowling with fast bowling in young cricketers’, *Clinical Journal of Sports Medicine* 12(2), 107-112.
25. Grobbelaar, HW., 2003, ‘Upper body anthropometrical differences amongst participants of asymmetrical (fast bowlers in cricket) and symmetrical (crawl stroke swimmers) sport and sedentary individuals in South Africa,’ PhD dissertation, North-West University.
26. Guney, H., Harput, G., Colakoglu, F., Baltaci, G., 2016, ‘The effect of glenohumeral internal rotation deficit on functional rotator strength ratio in adolescent overhead athletes’, *Journal of Sport Rehabilitation* 25(1), 52-57.
27. Hosseinimehr, S., Anbarian, M., Norasteh, A., Fardmal, J., Khosravi, T., 2015, ‘The comparison of scapula upward rotation and scapulohumeral rhythm between dominant and non-dominant shoulder in male overhead athletes and non-athletes’, *Manual Therapy* 20, 758-762.
28. Kanlayanaphotporn, R., 2014, ‘Changes in sitting posture affect shoulder range of motion’, *Journal of Bodywork and Movement Therapies* 18(2), 239-243.
29. Kevern, M., Beecher, M., Rao, S., 2014, ‘Reliability of measurement of glenohumeral internal rotation, external rotation, and total arc of motion in 3 test positions’, *Journal of Athletic Training* 49(5), 640-646. doi:10.4085/1062-6050-49.3.31
30. Kinsella, SD., Thomas, SJ., Huffman, GR., Kelly, JD., 2014, ‘The thrower’s shoulder’ *Orthopedic Clinics of North America* 45, 387-401.
31. Kolber, M., Hanney, W., 2010, ‘The reliability, minimal detectable change and construct validity of a clinical measurement for identifying posterior shoulder tightness’, *North American Journal of Sports Physical Therapy* 5(4), 208-219.

32. Kolber, M., Hanney, W., 2012, ‘The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: a technical report’*, The International Journal of Sports Physical Therapy* 7(3), 306-313.
33. Laudner, K., Lynall, r., Williams, JG., Wong, R., Onuki, T., Meister, K., 2013, ‘Thoracolumbar range of motion in baseball pitchers and position players’, *The International Journal of Sports Physical Therapy* 8(6), 777-783.
34. Laxmi, R., Prosenjit, P., & Shahid, MD., 2015, ‘Prevalence of shoulder injuries and altered scapula positioning in young elite cricketers’, *International Journal of Sports Sciences and Fitness 5*(1), 130-161.
35. Lewis, J., Valentine, R., 2007, ‘The pectoralis minor length test: a study of intra-rater reliability and diagnostic accuracy in subjects with and without shoulder symptoms’, *BMC Musculoskeletal Disorders* 8(64), 1-10.
36. Lockie, RG., Callaghan, SJ., & Jeffriess, MD., 2014, ‘Acceleration kinematics in cricketers: Implications for performance in the field’, *Journal of Sports Science and Medicine* 13, 128-136.
37. Manske, RC., Grant-Nierman, M., Lucas, B., 2013a, ‘Shoulder posterior internal impingement in the overhead athlete’, *The International Journal of Sports Physical Therapy* 8(2), 194-204.
38. Manske, R., Wilk, KE., Davies, G., Ellenbecker, T., Reinold, M., 2013b, ‘Glenohumeral motion deficits: friend or foe?’, *The International Journal of Sports Physical Therapy* 8(5), 537-553.
39. Mihata, T., McGarry, M., Neo, M., Ohue, M., Lee, TQ., 2015, ‘Effect of anterior capsule laxity on horizontal abduction and forceful internal impingement in a cadaver if model of the throwing shoulder’, *American Journal of Sports Medicine* 43, 1758-1763.
40. Moezy, A., Sepehrifah, S., Dodaran, MS., 2014, ‘The effects of scapular stabilization based home exercise therapy on pain, posture, flexibility and shoulder mobility in patients with shoulder impingement syndrome: a controlled randomised clinical trial’, *Medical Journal of the Islamic Republic of Iran* 28, 1-15.
41. Muraki, T., Aoki, M., Izumi, T., Fujii, M., Hidaka, ME., Miyamoto, M., 2009, ‘Lengthening of the pectoralis minor muscle during passive shoulder motions and stretching techniques:a cadaveric biomechanical study’, *American Physical Therapy Association* 89(4), 333-341.

42. Murray, IR., Ahmed, I., White, NJ., Robinson, CM., 2013, ‘Traumatic anterior shoulder instability in the athlete,’ *Scandinavian Journal of Medicine & Science in Sports*, 23, 387-405.
43. Myers, J., Laudner, KG., Pasquale, MR., Bradley, JP., Lephart, SM., 2006, ‘Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathological internal impingement’, 2006, *American Orthopaedic Society for Sports Medicine* 34(3), 385-391.
44. Nunes, T., Coetzee, B., 2007, ‘The contribution of isokinetic strength parameters to the performance of cricket batsmen’, *Isokinetic and Exercise Science* 15(3), 233-244.
45. Olivier, B., Stewart, AV., Olorunju, SAS., McKinon, W., 2015, ‘Static and dynamic balance ability, lumbo-pelvic movement control and injury incidence in cricket pace bowlers’, *Journal of Science and Medicine in Sport* 18, 19-25.
46. Olivier, B., Taljaard, T., Burger, E., Brukner, P., Orchard, J., Gray, J., Stewart, A., McKinnon, W., 2016a, ‘Which extrinsic and intrinsic factors are associated with non-contact injuries in adult cricket fast bowlers?’ *Sports Medicine* 46, 79-101.
47. Olivier, B., 2016b, ‘Asymmetrical abdominal muscle morphometry is present in injury free adolescent cricket pace bowlers: a prospective observational study’, thesis, Department of physiotherapy, University of the Witwatersrand.
48. Orchard, J., James, T., Kountouris, T., Portus, M., 2010, ‘Changes to injury profile (and recommended cricket injury definitions) based on increased frequency of Twenty20 cricket matches’, *Open Access Journal of Sports Medicine* 1, 63-76.
49. Orchard, J., Newman, D., Stretch, R., Frost, W., Mansingh, A., Leipus, A., 2005, ‘Methods for injury surveillance in international cricket’, *Journal of Science and Medicine in Sport* 8(1), 1-14.
50. Orchard, J., Ranson, C., Olivier, B., Dhillon, M., Gray, J., Langley, B., Mansingh, A., Moore, IS., Murphy, I., Patricios, J., Alwar, T., Clark, CJ., Harrop, B., Khan, HI., Kountouris, A., Macphail, M., Mount, S., Mupotaringa, A., Newman, D., O’Reilly, K., Peirce, N., Saleem, S., Shackel, D., Stretch, R., Finch, CF., 2016, ‘International consensus statement on injury surveillance in cricket: a 2016 update’, *British Journal of Sports Medicine* 0, 1-7

51. Phadke, V., Camargo, PR., Ludewig, PM., 2009, 'Scapular and rotator cuff muscle activity during arm elevation: a review of normal function and alterations with shoulder impingement', *Rev Bras Fisioter* 13(1),1-9.
52. Portney, LG. & Wattkins, MP., 2009, Foundations of Clinical Research: Application to practice (3rd edition), Pearson Prentice Hall, London.
53. Portus, MR. & Farrow, D., 2011, 'Enhancing cricket batting skill: Implications for biomechanics and skill acquisition research and practice', *Sports Biomechanics* 10(4), 294-305.
54. Ranson, C. & Gregory, P., 2008, 'Shoulder injury in professional cricketers', *Physical Therapy in Sport* 9, 34-39.
55. Ranson, C., Hurley, R, Rugless, L., Mansingh, A., Cole, J., 2013, 'International cricket injury surveillance: a report of five teams competing in the ICC Cricket World Cup 2011' *British Journal of Sports Medicine* 47, 637-643.
56. Reagan, KM., Meister, K., Horodyski, MB., Werner, DW., Carruthers, C., Wilk, K., 2002, 'Humeral retroversion and its relationship to glenohumeral rotation in the shoulder of college baseball players', *The American Journal of Sports Medicine* 30(3), 354-360.
57. Sabick, MB., Kim, YK., Torry, MR., Keirns, MA., Hawkins, RJ., 2005, 'Biomechanics of the shoulder in youth baseball pitchers: implications for the development of proximal humeral epiphysiolysis and humeral retroversion', *American Journal of Sports Medicine* 33(11), 1716-1722.
58. Sachlikidis, A. & Salter, C., 2007, 'A biomechanical comparison of dominant and non-dominant arm throws for speed and accuracy', *Sports Biomechanics* 6(3), 334-344.
59. Sahrmann, S., 2002, *Diagnosis and Treatment of Movement Impairment Syndromes*, Mosby, London.
60. Saw, R., Dennis, RJ., Bentley, D., Farhart, P., 2011, 'Throwing workload and injury risk in elite cricketers', *British Journal of Sports Medicine* 45, 805-808.
61. Scibek, J., Carcia, CR., 2012, 'Assessment of Scapulohumeral rhythm for scapular plane shoulder elevation using a modified digital inclinometer', *World Journal of Orthopaedics* 3(6), 87-94.
62. Seroyer, ST., Nho, SJ., Bach, BRB., Bush-Joseph,CA., Nicholson, GP., Romeo, AA., 2010, 'The kinetic chain in overhead and pitching: its potential role

for performance, enhancement and injury prevention', *Sports Health* 2(2), 135-146.

63. Steulcken, MC., Ferdinands, RE., Ginn, K., Sinclair, P., 2010, 'The shoulder distraction force in cricket fast bowling', *Journal of Applied Biomechanics* 26, 373-377.
64. Steulcken, MC., Ginn, K., Sinclair, PJ., 2008, 'Shoulder strength and range of motion in elite female cricket fast bowlers with and without a history of shoulder pain', *Journal of Science and Medicine in Sport* 11, 575-580.
65. Stretch, RA., 2003, 'Cricket injuries: a longitudinal study of the nature of injuries to South African cricketers' *British Journal of Sports Medicine* 37, 250-253.
66. Stretch, RA., Trella, C., 2012, 'A 3 year investigation into the incidence and nature of cricket injuries in elite South African schoolboy cricket', *South African Journal of Sports Medicine* 24(1), 10-14.
67. Struyf, F., Meeus, M., Fransen, E., Roussel, N., Jansen, N., Truijen, S., Nijs, J., 2014, 'Intrerater and intrarater reliability of the pectoralis minor muscle length measurement in subjects with and without shoulder impingement symptoms', *Manual Therapy* 19, 294-298.
68. Sullivan, GM. & Feinn, R., 2012, 'Using effect size – or why the P value is not enough' *Journal of Graduate Medical Education* 4(3), 279-282.
69. Sundaram, B., Bhargava, SKN. Karuppannan, S., 2012, 'Glenohumeral rotational range of motion differences between fast bowlers and spin bowlers in elite cricketers' *The International Journal of Sports Physical Therapy* 7(6), 576-585.
70. Tennant, A., 2009, *Cricket Manual: The official guide to playing the game*. Haynes Publishing, United Kingdom.
71. Thomas, SJ., Swanik, KA., Swanik, CB., 2010, 'Internal rotation deficits affect scapular positioning in baseball players', *Clinical Orthopaedics and Related Research* 468, 1551-1557.
72. Tveita, EK., Ekeberg, OM., Juel, NG., Bautz-Holter, E., 2008, 'Range of shoulder motion in patients with adhesive capsulitis; IIntra-tester reproducibility is acceptable for group comparisons', *BioMed Central Musculoskeletal Disorders* 4(49), 1-9.
73. Weber, C., Enzler, M., Wieser, K., Swanenburg, J., 2015, 'Validation of the pectoralis minor length test: a novel approach', *Manual Therapy* 1-6

74. Wyland, DJ., Pill, SG., Shanley, E., Clark, JC., Hawkins, RJ., Noonan, TJ., Kissenberth, MJ., Thigpen, CA., 2012, 'Bony adaptations of the proximal humerus and glenoid correlate within the throwing shoulder of professional baseball players', *American Journal of Sports Medicine* 40(8), 1858-1862.

Appendix A : Pre-season questionnaire (inclusion/exclusion criteria)

Study number:	
Name:	
Date of birth	
Right/left handed	
Bowling upper limb (R/L)	
Throwing upper limb (R/L)	

Have you had or do you have any of the following?

Please tick the relevant box if you:	**(Tick)**
Currently have shoulder pain?	
Have a recent neck or shoulder surgery for which you are receiving rehab, and you are not medically cleared to returned to play	
Have a current neck injury that causes pain with or without movement	
Have a heart condition such as: arrhythmias, rheumatic heart disease, ischemic heart disease or inflammatory heart disease	
Currently use anti-inflammatories or analgesics	
Participate in other overhead sports on a weekly basis	

Please note any other information that you think is relevant:

Appendix B : Workload monitoring calendar

This calendar represents each day of the three months in which we will be monitoring if you get a shoulder injury. Within each block please state if you took part in the following:

- Batting
- Bowling
- Fielding
- Wicket keeping
- Gym
- Fitness
- Game
- If you partook in any other sport, then please state the name of the sport
- None: if you performed no activity during that day

	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
Aug/Sept	31	1	2	3	4	5	6
	7	8	9	10	11	12	13
	14	15	16	17	18	19	20
	21	22	23	24	25	26	27
Sept/Oct	28	29	30	1	2	3	4
	5	6	7	8	9	10	11
	12	13	14	15	16	17	18
	19	20	21	22	23	24	25
Oct/Nov	26	27	28	29	30	31	1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	29

Appendix C : Pre-season measurements form

Study number:

Date of assessment:

Measurement	**Left**	**Right**
Shoulder internal rotation ROM		
Shoulder external rotation ROM		
Pectoralis minor muscle length		

Appendix D : Injury monitoring questionnaire

Answer all questions below

Study number:

Name

Age:

Today's date:

Number of seasons playing cricket:

Highest team selection:

Playing position:

Batsman

Fielder

*Bowler

*If you are a bowler please specify which type of bowler: ____________________

Injury surveillance

Have you suffered an injury this week?

Injury definition: any shoulder pain that occurs during or after cricket training or matches involving batting, bowling, fielding or wicket keeping, resulting in the cessation or limitation of that sporting activity

Yes/No

If yes, please specify:

	Injury 1	Injury 2	Injury 3
Date of injury			
Region			

Side of the injury (If applicable)

	Injury 1		Injury 2		Injury 3	
	Dominant	Non-Dominant	Dominant	Non-Dominant	Dominant	Non-Dominant
Left						
Right						
Bilateral						

How did the injury occur?

	Injury 1	Injury 2	Injury 3
Contact			
Non-contact			

Briefly, explain how the injury occurred:

Injury 1:

Injury 2:

Injury 3:

During which activity did the injury/injuries occur?

	Injury 1	Injury 2	Injury 3
Batting training			
Batting Match			
Bowling training			
Bowling match			
Fielding training			
Fielding match			
Gym			
Fitness			
Other			

Management of injury/injuries:

	Injury 1	Injury 2	Injury 3
Surgery			
Medication			
Physiotherapy			
Strapping			
Brace			
Rest			
No treatment			
Other			

If you consulted with a medical professional please specify profession and diagnosis:

Significance of injury: (Specify number of sessions missed or adjusted)

	Injury 1	Injury 2	Injury 3
Limitations during training			
Limitations during match			
Unable to participate in Match			
Unable to participate in training			

Have you previously suffered from the same injury/injuries?

	Injury 1	Injury 2	Injury 3
Yes			
No			
Year of previous injury			

Appendix E : Information document

Physiotherapy

August/September 2015

MSc Sports Physiotherapy Study: Shoulder injury in cricketers: The role of shoulder rotation ROM, throwing arc ROM and Pectoralis minor muscle length – observational cohort

Dear Cricketer

I am a master's student in the Department of Physiotherapy at the University of the Witwatersrand. I am inviting you to participate in a study to determine the risks of shoulder injuries in cricketers. This study will be investigating shoulder rotation range of movement (ROM), throwing arc ROM and pectoralis minor muscle length and their association with shoulder injuries. Information obtained within the study will be used to complete my research report in partial fulfilment of the MSc Sports Physiotherapy programme. This study was awarded ethical approval by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand (Reference no M150612).

This study will identify which components may be main contributors of shoulder injuries in cricket by performing measurements during the pre-season and identifying their association with injury.

What is involved in the study?

The study will take place from September to November 2015. You will complete a short questionnaire to determine your eligibility in the study. At the end of the pre-season, 3 tests will be performed on both of your shoulders. You may experience post testing tenderness on both shoulders after the tests are performed. You will be contacted weekly regarding your shoulder injury status. If you sustain a shoulder injury, you are to report it immediately to the researcher, Lions physiotherapist, coach or to the trainer. They will provide you with a short questionnaire to fill out, regarding your shoulder injury. You will return this form to the researcher. If you would like to complete the form online then the researcher can be contacted to email a form to you.

Participation

Your participation in this study is voluntary and you are allowed to withdraw at any time. If you refuse to participate or withdraw from the study, you will not suffer any repercussions.

Confidentiality

You will be assigned a study number. Your details such as your name will be written on the consent form, pre-season questionnaire and post injury questionnaire. The designation of the study numbers will only be accessible by the researcher. The names will be converted into study numbers once the data is captured on excel. Names will be written on the top right hand corner of the questionnaire and as soon as you have handed in the questionnaires and the study number has been verified, the top right hand corner of the questionnaire will be torn off and thrown away. This will leave the questionnaire with only the study number on. Information received from participants will only be used for the purpose of this study. Data that may be reported in scientific journals and at congresses will not include any information which identifies you as a participant in the study. Any information uncovered regarding your test results as a result of your participation in this study will be held in strict confidence. You will be informed of any finding of importance to your health but this information will not be disclosed to any third party without your permission.

Contact information

If you require any more information regarding the study, please feel free to contact me on 083 773 5228. To report any ethical issues, please contact Prof Cleaton Jones Tel: 011-717-2700, the chair of the Human Research Ethics Committee (Medical) of the University of the Witwatersrand

Yours truly

Bhakti Lala

PHYSIOTHERAPIST & RESEARCHER

Appendix F : Informed consent form

MSc Sports Physiotherapy Study: Shoulder injury in cricketers: The role of shoulder rotation ROM, throwing arc ROM and Pectoralis minor muscle length – observational cohort

I ___________________________________ agree to participate in the study as explained to me in the information document. By signing this form, I hereby agree to answer the questionnaires and participate in the measurements at the end of the pre-season and at the incidence of shoulder injury.

I understand that I will incur no costs to participate, and I will receive no monetary remuneration to participate in the study. I acknowledge that my participation is voluntary and I am allowed to withdraw at any time from the study.

Signature of participant	
Signature of researcher	
Date	
For office use only: Study number	

Appendix G : Human Research Ethics Committee (Medical) clearance certificate

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

R14/49 Miss Bhakti Lala

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M150612

NAME: (Principal Investigator)	Miss Bhakti Lala
DEPARTMENT:	Physiotherapy Bidvest Wanderes Stadium
PROJECT TITLE:	Shoulder Injury in Cricketers: The Role of Sholder Rotation Range of Movement, throwing Arc Range of Movement and Pectoralis Minor Muscle Length
DATE CONSIDERED:	26/06/2015
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr Benita Olivier and Miss Nadia Gillion
APPROVED BY:	Professor P Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	10/07/2015

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

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**.

Principal Investigator Signature

Date 10 July 2015

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix H : Letter to the Highveld Lions

Physiotherapy

August 2015

MSc Sports Physiotherapy Study: Shoulder injury in cricketers: The role of shoulder rotation ROM, throwing arc ROM and Pectoralis minor muscle length – observational cohort

Dear Highveld Lions Head Coach / Manager

I am a master's student in the Department of Physiotherapy at the University of the Witwatersrand. I am asking for permission to conduct a study to determine the risks of shoulder injuries in cricketers. This study will be investigating shoulder rotation range of movement (ROM) throwing arc ROM and pectoralis minor muscle length and their association with shoulder injuries. Information obtained within the study will be used to complete my research report in part fulfilment of the MSc Sports Physiotherapy programme. This study was awarded ethical approval by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand (Reference no M150612).

This study will identify which components may be the main contributors of shoulder injuries in cricket by performing measurements during the pre-season and identifying their association with injury.

What is involved in the study?

The team players that we are asking for permission to conduct the study on are: the Highveld Lions squad.

The study will take place from September to November 2015. A short questionnaire will be completed to determine the team member's eligibility in the study. At the end of the pre-season, 3 tests will be performed on both of their shoulders. They may

experience post testing tenderness on both shoulders after the tests are performed. The players will be contacted weekly regarding their shoulder injury status. If they sustain a shoulder injury, they are to report it immediately to the researcher, Lions physiotherapist, coach or to the trainer. These staff members will provide the player with a short questionnaire to fill out, regarding their shoulder injury. They will return this form to the researcher. If they would like to complete the form online then the researcher can be contacted to email a form to them.

Participation

The team member's participation in this study is voluntary and they are allowed to withdraw at any time. If the team members refuse to participate or withdraw from the study, they will not suffer any repercussions.

Confidentiality

Each participant will be assigned a study number. The questionnaires and data will correspond to the study number. Participant's confidential details will be written in the consent form, pre-season questionnaire and post injury questionnaire. The consent form designation of the study numbers will only be kept by the researcher. The names will be converted into study numbers once the data is captured on excel. Names will be written on the top right hand corner of the questionnaire and as soon as participants have handed in the questionnaires and the study number has been verified, the top right hand corner of the questionnaire will be torn off and thrown away. This will leave the questionnaire with only the study number on. Information received from participants will only be used for the purpose of this study. Data that may be reported in scientific journals will not include any information which identifies the team members as a participant in the study. Any information uncovered regarding their test results as a result of their participation in this study will be held in strict confidence. They will be informed of any finding of importance to their health or continued participation in this study but this information will not be disclosed to any third party without their permission.

Contact information

If you require any more information regarding the study, please feel free to contact me on 083 773 5228. To report any ethical issues, please contact Prof Cleaton Jones Tel: 011-717-2700, the chair of the Human Research Ethics Committee (Medical) of the University of the Witwatersrand

Yours truly

Bhakti Lala

PHYSIOTHERAPIST & RESEARCHER

Approval to conduct the study:

Signature:

Date: 18 August 2015

Name and Designation: Geoffrey Toyana
Highveld Lions Head Coach

Signature:

Date:

Name and Designation:

Appendix I : Letter to the Gauteng Cricket Board

Physiotherapy

July 2015

MSc Sports Physiotherapy Study: Shoulder injury in cricketers: The role of shoulder rotation ROM, throwing arc ROM and Pectoralis minor muscle length – observational cohort

Dear Gauteng Cricket Board

I am a master's student in the Department of Physiotherapy at the University of the Witwatersrand. I am asking for permission to conduct a study to determine the risks of shoulder injuries in cricketers. This study will be investigating shoulder rotation range of movement (ROM), throwing arc ROM and pectoralis minor muscle length and their association with shoulder injuries. Information obtained within the study will be used to complete my research report in part fulfilment of the MSc Sports Physiotherapy programme. This study was awarded ethical approval by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand (Reference no M150612).

This study will identify which components may be the main contributors of shoulder injuries in cricket by performing measurements during the pre-season and identifying their association with injury.

What is involved in the study?

The team players that we are asking for permission to conduct the study on are: the strikers, 2nd tier and u19 squad.

The study will take place from September to November 2015. A short questionnaire will be completed to determine the team member's eligibility in the study. At the end of the pre-season, 3 tests will be performed on both of their shoulders. They may

experience post testing tenderness on both shoulders after the tests are performed. The players will be contacted weekly regarding their shoulder injury status. If they sustain a shoulder injury, they are to report it immediately to the researcher, Lions physiotherapist, coach or to the trainer. These staff members will provide the player with a short questionnaire to fill out, regarding their shoulder injury. They will return this form to the researcher. If they would like to complete the form online then the researcher can be contacted to email a form to them.

Participation

The team member's participation in this study is voluntary and they are allowed to withdraw at any time. If the team members refuse to participate or withdraw from the study, they will not suffer any repercussions.

Confidentiality

Each participant will be assigned a study number. The questionnaires and data will correspond to the study number. Participant's confidential details will be written in the consent form, pre-season questionnaire and post injury questionnaire. The consent form designation of the study numbers will only be kept by the researcher. The names will be converted into study numbers once the data is captured on excel. Names will be written on the top right hand corner of the questionnaire and as soon as participants have handed in the questionnaires and the study number has been verified, the top right hand corner of the questionnaire will be torn off and thrown away. This will leave the questionnaire with only the study number on. Information received from participants will only be used for the purpose of this study. Data that may be reported in scientific journals will not include any information which identifies the team members as a participant in the study. Any information uncovered regarding their test results as a result of their participation in this study will be held in strict confidence. They will be informed of any finding of importance to their health or continued participation in this study but this information will not be disclosed to any third party without their permission.

Contact information

If you require any more information regarding the study, please feel free to contact me on 083 773 5228. To report any ethical issues, please contact Prof Cleaton Jones Tel: 011-717-2700, the chair of the Human Research Ethics Committee (Medical) of the University of the Witwatersrand

Yours truly

Bhakti Lala

PHYSIOTHERAPIST & RESEARCHER

Approval to conduct the study:

Signature:

Date: 08/07/2015

Name and Designation: ENOCH NKWE
GAUTENG STRIKERS HEAD COACH
AND HIGH PERFORMANCE COORDINATOR

Signature:

Date: 08/07/2015

Name and Designation: Sandile Masengemi
Gauteng U19 Coach and High performance
Assistant Coach

Appendix J : Letter to the Marks Park Cricket Club

Physiotherapy

September 2015

MSc Sports Physiotherapy Study: Shoulder injury in cricketers: The role of shoulder rotation ROM, throwing arc ROM and Pectoralis minor muscle length – observational cohort

Dear Gauteng Cricket Board

I am a master's student in the Department of Physiotherapy at the University of the Witwatersrand. I am asking for permission to conduct a study to determine the risks of shoulder injuries in cricketers. This study will be investigating shoulder rotation range of movement (ROM), throwing arc ROM and pectoralis minor muscle length and their association with shoulder injuries. Information obtained within the study will be used to complete my research report in part fulfilment of the MSc Sports Physiotherapy programme. This study was awarded ethical approval by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand (Reference no M150612).

This study will identify which components may be the main contributors of shoulder injuries in cricket by performing measurements during the pre-season and identifying their association with injury.

What is involved in the study?

The team players that we are asking for permission to conduct the study on are: the Marks Park Premier League squad.

The study will take place from September to November 2015. A short questionnaire will be completed to determine the team member's eligibility in the study. At the end of the pre-season, 3 tests will be performed on both of their shoulders. They may

experience post testing tenderness on both shoulders after the tests are performed. The players will be contacted weekly regarding their shoulder injury status. If they sustain a shoulder injury, they are to report it immediately to the researcher, Lions physiotherapist, coach or to the trainer. These staff members will provide the player with a short questionnaire to fill out, regarding their shoulder injury. They will return this form to the researcher. If they would like to complete the form online then the researcher can be contacted to email a form to them.

Participation

The team member’s participation in this study is voluntary and they are allowed to withdraw at any time. If the team members refuse to participate or withdraw from the study, they will not suffer any repercussions.

Confidentiality

Each participant will be assigned a study number. The questionnaires and data will correspond to the study number. Participant’s confidential details will be written in the consent form, pre-season questionnaire and post injury questionnaire. The consent form designation of the study numbers will only be kept by the researcher. The names will be converted into study numbers once the data is captured on excel. Names will be written on the top right hand corner of the questionnaire and as soon as participants have handed in the questionnaires and the study number has been verified, the top right hand corner of the questionnaire will be torn off and thrown away. This will leave the questionnaire with only the study number on. Information received from participants will only be used for the purpose of this study. Data that may be reported in scientific journals will not include any information which identifies the team members as a participant in the study. Any information uncovered regarding their test results as a result of their participation in this study will be held in strict confidence. They will be informed of any finding of importance to their health or continued participation in this study but this information will not be disclosed to any third party without their permission.

Contact information

If you require any more information regarding the study, please feel free to contact me on 083 773 5228. To report any ethical issues, please contact Prof Cleaton Jones Tel: 011-717-2700, the chair of the Human Research Ethics Committee (Medical) of the University of the Witwatersrand

Yours truly

Bhakti Lala

PHYSIOTHERAPIST & RESEARCHER

Approval to conduct the study:

Signature:

Date: 1 September 2015

Name and Designation: Yasin Manack. Head Coach @ Marks Park CC.

Signature:

Date:

Name and Designation:

Appendix K : Summary of assessors feedback

WITS UNIVERSITY

School of Therapeutic Sciences

Faculty of Health Sciences · Private Bag 3, Wits, 2050, South Africa
Tel: +27 11 717 2063/4 · Fax : 27 11 717 2066/086 553 5964 · E-mail: irene.jansevannoordwyk@wits.ac.za · www.wits.ac.za

THERAPEUTIC Sciences

SUMMARY OF ASSESSORS FEEDBACK

Date of Assessor Group Meeting : 22 July 2015

Assessor Group : Group 3

Student Number : 302563

Student Name : LALA

		Yes	No
i.	Revision of the protocol to the Supervisor / Head of Department: (**Candidates**: x1 copy of protocol, list of corrections (x1), supervisor's approval letter (x1) - submit to: Mrs I Janse van Noordwyk, Room 4B02, Level 4, Medical School)		
ii.	Revision of the protocol to the satisfaction of the Assessor Group: (**Candidates**: copies of protocol (x2), list of corrections (x2), supervisor approval letter (x2) - submit to: Mrs I Janse van Noordwyk, Room 4B02, Level 4, Medical School)		
iii.	Revision of the protocol and resubmission of the revised protocol to the next Assessor Group Meeting: (**Candidates**: as per the guidelines for submission to an assessors meeting - submit to: Mrs I Janse van Noordwyk, Room 4B02, Level 4, Medical School)		
iv.	Candidate goes ahead	✓	

Name and Signature of Chair of Assessor Group:

[signature]

M.P. DANCKWERTS

Appendix L : Plagiarism declaration

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I BHAKTI LALA (Student number: 302563) am a student registered for the degree of MSc (PHYSIOTHERAPY) in the academic year 2015/16

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/o without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided wor except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me i there is a belief that this is not my own unaided work or that I have failed to acknowledge th source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection software indicating the level of plagiarism in my research document.

Signature: [signature] Date: 11 January 2017

Appendix M : Turn it in report

Final report

by Bhakti Lala

FILE	720_BHAKTI_LALA_FINAL_REPORT_1155_1276530173.DOCX (1.57M)		
TIME SUBMITTED	10-JAN-2017 09:01AM	WORD COUNT	24701
SUBMISSION ID	684537997	CHARACTER COUNT	143824

Final report

ORIGINALITY REPORT

13%	7%	9%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Zachary Barrett-O'Keefe. "Maximal Strength Training: The Effects on Intramuscular Economy and its Determinants : 1345", Medicine & Science in Sports & Exercise, 05/2010 Publication	1%
2	Byrnes, M.L.. "Physiological studies of the corticomotor projection to the hand after subcortical stroke", Clinical Neurophysiology, 19990301 Publication	<1%
3	www.ncbi.nlm.nih.gov Internet Source	<1%
4	Sports Injuries, 2015. Publication	<1%
5	www.science.gov Internet Source	<1%
6	Submitted to Sheffield Hallam University Student Paper	<1%
7	Submitted to University of Limerick Student Paper	<1%

8	www.scielo.br Internet Source	<1%
9	Submitted to Pennsylvania State System of Higher Education Student Paper	<1%
10	uir.unisa.ac.za Internet Source	<1%
11	Jeremy S Lewis. "The pectoralis minor length test: a study of the intra-rater reliability and diagnostic accuracy in subjects with and without shoulder symptoms", BMC Musculoskeletal Disorders, 2007 Publication	<1%
12	www.meresearch.org.uk Internet Source	<1%
13	wiredspace.wits.ac.za Internet Source	<1%
14	Jaspers, Arne, Michel S. Brink, Steven G. M. Probst, Wouter G. P. Frencken, and Werner F. Helsen. "Relationships Between Training Load Indicators and Training Outcomes in Professional Soccer", Sports Medicine, 2016. Publication	<1%
15	Sports Injuries to the Shoulder and Elbow, 2015. Publication	<1%
16	&NA;, . "Abst D-FreeCommPosters :",	<1%

Medicine & Science in Sports & Exercise, 2012.
Publication

17	scholarship.shu.edu Internet Source	<1%
18	Verrall, G.. "Hip joint range of motion reduction in sports-related chronic groin injury diagnosed as pubic bone stress injury", Journal of Science and Medicine in Sport, 200503 Publication	<1%
19	Struyf, Filip, Mira Meeus, Erik Fransen, Nathalie Roussel, Nick Jansen, Steven Truijen, and Jo Nijs. "Interrater and intrarater reliability of the pectoralis minor muscle length measurement in subjects with and without shoulder impingement symptoms", Manual Therapy, 2014. Publication	<1%
20	Levine, W.N.. "Shoulder adaptive changes in youth baseball players", Journal of Shoulder and Elbow Surgery, 200609/10 Publication	<1%
21	Shoulder Arthroscopy, 2014. Publication	<1%
22	library.effatuniversity.edu.sa Internet Source	<1%
23	Jan, J., T. Benkalfate, and P. Rochcongar.	

	"The impact of recurrent dislocation on shoulder rotator muscle balance (a prospective study of 102 male patients)", Annals of Physical and Rehabilitation Medicine, 2012. Publication	<1%
24	Neander, Kerstin, and Ingemar Engström. "Parents' Assessment of Parent-Child Interaction Interventions— A Longitudinal Study in 101 Families", Social Work and Child Services, 2011. Publication	<1%
25	www.sajsm.org.za Internet Source	<1%
26	usir.salford.ac.uk Internet Source	<1%
27	ira.lib.polyu.edu.hk Internet Source	<1%
28	www.scribd.com Internet Source	<1%
29	www.scielo.org.za Internet Source	<1%
30	vc.bridgew.edu Internet Source	<1%
31	ujdigispace.uj.ac.za Internet Source	<1%
	ARMSTRONG, C. "A COMPARISON OF	

32	DOMINANT AND NON-DOMINANT HAND STRENGTHS", The Journal of Hand Surgery British & European Volume, 1999. Publication	<1%
33	Submitted to La Trobe University Student Paper	<1%
34	Submitted to Leeds Metropolitan University Student Paper	<1%
35	Giles, K.. "A survey of glenohumeral joint rotational range and non-specific shoulder pain in elite cricketers", Physical Therapy in Sport, 200808 Publication	<1%
36	www.yogaforsports.co.za Internet Source	<1%
37	create.canterbury.ac.uk Internet Source	<1%
38	Olivier, Benita, Tracy Taljaard, Elaine Burger, Peter Brukner, John Orchard, Janine Gray, Nadine Botha, Aimee Stewart, and Warrick Mckinon. "Which Extrinsic and Intrinsic Factors are Associated with Non-Contact Injuries in Adult Cricket Fast Bowlers?", Sports Medicine, 2015. Publication	<1%
39	Submitted to The Hong Kong Polytechnic University Student Paper	<1%

40	Kirchhoff, Chlodwig, Volker Braunstein, Stefan Milz, Christoph M Sprecher, Sonja Kirchhoff, Mathias Graw, Andreas B Imhoff, and Stefan Hinterwimmer. "Age and gender as determinants of the bone quality of the greater tuberosity: A HR-pQCT cadaver study", BMC Musculoskeletal Disorders, 2012. Publication	<1%
41	"Ninth Congress of the European Society for Surgery of the Shoulder and the Elbow", Journal of Shoulder and Elbow Surgery, 199703/04 Publication	<1%
42	Picha, Kelsey J. Harding, Josie L. Blive. "Glenohumeral and hip range-of-motion and strength measures in youth baseball athletes. (original rese", Journal of Athletic Training, June 2016 Issue Publication	<1%
43	Submitted to Whittier College Student Paper	<1%
44	Submitted to University of Strathclyde Student Paper	<1%
45	Forthomme, Benedicte, Valerie Wieczorek, Anne Frisch, Jean-Michel Crielaard, and Jean-Louis Croisier. "Shoulder Pain among High-Level Volleyball Players and Preseason Features :", Medicine & Science in Sports &	<1%

Exercise, 2013.
Publication

46	Submitted to University of New South Wales Student Paper	<1%
47	www.smarttjournal.com Internet Source	<1%
48	bmcpublichealth.biomedcentral.com Internet Source	<1%
49	journals.plos.org Internet Source	<1%
50	Erika Nelson-Wong. "Repeatability of Clinical, Biomechanical, and Motor Control Profiles in People with and without Standing-Induced Low Back Pain", Rehabilitation Research and Practice, 2010 Publication	<1%
51	dspace.uevora.pt Internet Source	<1%
52	Atlas of Functional Shoulder Anatomy, 2008. Publication	<1%
53	etd.uwc.ac.za Internet Source	<1%
54	Submitted to University of Bath Student Paper	<1%
55	Tyler, Timothy F., Timothy Roy, Stephen J. Nicholas, Gilbert W. Gleim, George J. Davies,	<1%

Kevin E. Wilk, Todd Ellenbecker, and Timothy F. Tyler. "Reliability and Validity of a New Method of Measuring Posterior Shoulder Tightness", Journal of Orthopaedic and Sports Physical Therapy, 1999.
Publication

56	Submitted to University of Nottingham Student Paper	<1%
57	Submitted to CSU Northridge Student Paper	<1%
58	Submitted to Edge Hill University Student Paper	<1%
59	Submitted to The Robert Gordon University Student Paper	<1%
60	Hosseinimehr, Seyed Hossein, Mehrdad Anbarian, Ali Asghar Norasteh, Javad Fardmal, and Mohammad Taghi Khosravi. "The comparison of scapular upward rotation and scapulohumeral rhythm between dominant and non-dominant shoulder in male overhead athletes and non-athletes", Manual Therapy, 2015. Publication	<1%
61	Submitted to University of East London Student Paper	<1%
62	jssm.org Internet Source	<1%

63	Submitted to Montana State University, Billings Student Paper	<1%
64	Submitted to University of Birmingham Student Paper	<1%
65	García-Pérez, Miguel Angel, Jane Moreno-Mercer, Juan J. Tarín, and Antonio Cano. "Similar efficacy of low and standard doses of transdermal estradiol in controlling bone turnover in postmenopausal women", Gynecological Endocrinology, 2006. Publication	<1%
66	Submitted to University of St. Augustine Student Paper	<1%
67	Submitted to A.T. Still University - Missouri Student Paper	<1%
68	Submitted to University of Auckland Student Paper	<1%
69	www.aetmis.gouv.qc.ca Internet Source	<1%
70	Submitted to King's College Student Paper	<1%
71	mhcirl.ie Internet Source	<1%
72	Submitted to Oxford Brookes University Student Paper	<1%

73 Submitted to Institute of Technology, Tallaght <1%
Student Paper

---

74 Miller, Robert H., Frederick M. Azar, and Thomas W. Throckmorton. "Shoulder and Elbow Injuries", Campbell s Operative Orthopaedics, 2013. <1%
Publication

---

75 socialwork-socialpolicy.tcd.ie <1%
Internet Source

---

76 ecommons.usask.ca <1%
Internet Source

---

77 Fieseler, Georg, Philipp Jungermann, Alexander Koke, Lars Irlenbusch, Karl-Stefan Delank, and René Schwesig. "Glenohumeral range of motion (ROM) and isometric strength of professional team handball athletes, part III: changes over the playing season", Archives of Orthopaedic and Trauma Surgery, 2015. <1%
Publication

---

78 Shanley, Ellen, Charles A. Thigpen, J.C. Clark, Douglas J. Wyland, Richard J. Hawkins, Thomas J. Noonan, and Michael J. Kissenberth. "Changes in passive range of motion and development of glenohumeral internal rotation deficit (GIRD) in the professional pitching shoulder between <1%

spring training in two consecutive years", Journal of Shoulder and Elbow Surgery, 2012.
Publication

79	O Faude. "Risk factors for injuries in elite female soccer players", British Journal of Sports Medicine, 7/6/2006 Publication	<1%
80	unitec.researchbank.ac.nz Internet Source	<1%
81	Kammerlind, Ann-Sofi, Pia Bergquist Larsson, Torbjörn Ledin, and Elisabeth Skargren. "Reliability of clinical balance tests and subjective ratings in dizziness and disequilibrium", Advances in Physiotherapy, 2005. Publication	<1%
82	Submitted to University of Brighton Student Paper	<1%
83	Imaging in Sports-Specific Musculoskeletal Injuries, 2016. Publication	<1%
84	sajsm.org.za Internet Source	<1%
85	scholar.ufs.ac.za:8080 Internet Source	<1%
86	aut.researchgateway.ac.nz Internet Source	<1%

87	ecommons.udayton.edu Internet Source	<1%
88	www.yorku.ca Internet Source	<1%
89	Rimmke, Nathan, Tristan Maerz, Ross Cooper, Sailaja Yadavalli, and Kyle Anderson. "Arthroscopic suture bridge rotator cuff repair: functional outcome, repair integrity, and preoperative factors related to postoperative outcome", The Physician and Sportsmedicine, 2016. Publication	<1%
90	F. Struyf. "Scapular positioning in overhead athletes with and without shoulder pain: a case-control study : Scapular positioning in overhead athletes", Scandinavian Journal of Medicine and Science in Sports, 05/2010 Publication	<1%
91	Talukdar, Kaushik, John Cronin, James Zois, and Anthony. P. Sharp. "The role of rotational mobility and power on throwing velocity :", The Journal of Strength and Conditioning Research, 2014. Publication	<1%
92	"New Findings on Athletic Training Described by Investigators at University of Delaware (Adaptations ", Health & Medicine Week, Dec 18 2015 Issue Publication	<1%

93	Carradice, D., N. Samuel, T. Wallace, F. A. K. Mazari, J. Hatfield, and I. Chetter. "Comparing the treatment response of great saphenous and small saphenous vein incompetence following surgery and endovenous laser ablation: a retrospective cohort study", Phlebology, 2012. Publication	<1%
94	e-collection.library.ethz.ch Internet Source	<1%
95	genesis.fitness2live.com.au Internet Source	<1%
96	Umut Akgun. "Direction of the load on the elbow of the ball blocking handball goalie", Knee Surgery Sports Traumatology Arthroscopy, 05/2008 Publication	<1%
97	scholarworks.boisestate.edu Internet Source	<1%
98	Oyama, Sakiki, Candice P. Goerger, Benjamin M. Goerger, Scott M. Lephart, and Joseph B. Myers. "Effects of Non-Assisted Posterior Shoulder Stretches on Shoulder Range of Motion Among Collegiate Baseball Pitchers", Athletic Training & Sports Health Care, 2010. Publication	<1%

www.neaygeia.gr

99	Internet Source	<1%
100	"CSM 2005 Orthopaedic Section Research Abstracts: Platform Presentations (Abstracts PL1-PL64)", Journal of Orthopaedic and Sports Physical Therapy, 2005. Publication	<1%
101	Morey J. Kolber. "Strength testing using hand-held dynamometry", Physical Therapy Reviews, 06/01/2005 Publication	<1%
102	Lim, Jin-Yong, Tae-Ho Kim, and Jung-Seok Lee. "Reliability of measuring the passive range of shoulder horizontal adduction using a smartphone in the supine versus the side-lying position", Journal of Physical Therapy Science, 2015. Publication	<1%
103	epublications.bond.edu.au Internet Source	<1%
104	www.pitt.edu Internet Source	<1%
105	Crawford, S. A., D. M. Walsh, and A. P. Porter-Armstrong. "Hammocking: The effect of cushion covers on interface pressure measurements", Disability and Rehabilitation Assistive Technology, 2006. Publication	<1%

106	Sousa, Catarina de Oliveira, Paula Rezende Camargo, Ivana Leão Ribeiro, Rodrigo Bezerra de Menezes Reiff, Lori Ann Michener, and Tania Fátima Salvini. "Motion of the shoulder complex in individuals with isolated acromioclavicular osteoarthritis and associated with rotator cuff dysfunction: Part 1 – Three-dimensional shoulder kinematics", Journal of Electromyography and Kinesiology, 2014. Publication	<1%
107	www.biomedcentral.com Internet Source	<1%
108	Black, Georgia M., Tim J. Gabbett, Michael H. Cole, and Geraldine Naughton. "Monitoring Workload in Throwing-Dominant Sports: A Systematic Review", Sports Medicine, 2016. Publication	<1%
109	www.scitechnol.com Internet Source	<1%
110	Stevens, Kathryn, Andrew Kwak, and Stephen Poplawski. "The Biceps Muscle from Shoulder to Elbow", Seminars in Musculoskeletal Radiology, 2012. Publication	<1%
111	file.scirp.org Internet Source	<1%
112	lib.tkk.fi	

Internet Source

<1%

113 Amela Karahasanovic. "Comparing of feedback-collection and think-aloud methods in program comprehension studies", Behaviour & Information Technology, 03/2009 <1%

Publication

114 Yang, Jing-lan, Shiau-yee Chen, Ching-Lin Hsieh, and Jiu-jenq Lin. "Effects and predictors of shoulder muscle massage for patients with posterior shoulder tightness", BMC Musculoskeletal Disorders, 2012. <1%

Publication

115 BRAATEN, ALYSSA J., THOMAS D. PARSONS, ROBERT McCUE, ALFRED SELLERS, and WILLIAM J. BURNS. "NEUROCOGNITIVE DIFFERENTIAL DIAGNOSIS OF DEMENTING DISEASES: ALZHEIMER'S DEMENTIA, VASCULAR DEMENTIA, FRONTOTEMPORAL DEMENTIA, AND MAJOR DEPRESSIVE DISORDER", International Journal of Neuroscience, 2006. <1%

Publication

116 www.ostrc.no <1%

Internet Source

117 Kerr, M.. "The topical niacin sensitivity test: An inter- and intra-rater reliability study in <1%

healthy controls", Prostaglandins, Leukotrienes & Essential Fatty Acids, 200807/08
Publication

118	Vairo, Giampietr L, Michele L Duffey, Brett D Owens, and Kenneth L Cameron. "Clinical descriptive measures of shoulder range of motion for a healthy, young and physically active cohort", Sports Medicine Arthroscopy Rehabilitation Therapy & Technology, 2012. Publication	<1%
119	vuir.vu.edu.au Internet Source	<1%
120	McIntosh, L., K. McKenna, and L. Gustafsson. "Active and Passive Shoulder Range of Motion in Healthy Older People", British Journal of Occupational Therapy, 2003. Publication	<1%
121	Wong, Christopher Kevin Borstad, John D.. "On "resting position variables ..." Borstad. Phys Ther. 2006;86(4):549-557.(Letters to the Editor)(L", Physical Therapy, Oct 2006 Issue Publication	<1%
122	Almeida, Gabriel Peixoto LeÃ£o, Paula Fiquetti Silveira, NathÃ¡lia Polisello Rosseto, Gisele Barbosa, Benno Ejnisman, and MoisÃ©s Cohen. "Glenohumeral range of motion in handball players with and without throwing-related shoulder pain", Journal of	<1%

Shoulder and Elbow Surgery, 2012.
Publication

123 Kolber, Morey J, Sheila B Saltzman, Kristina S Beekhuizen, and Ming-Shun S Cheng. "Reliability and minimal detectable change of inclinometric shoulder mobility measurements", Physiotherapy Theory and Practice, 2009.
Publication
<1%

124 mro.massey.ac.nz
Internet Source
<1%

125 webcache.googleusercontent.com
Internet Source
<1%

126 Risberg-Berlin, Birgit, Anna Rydén, Riitta Ylitalo Möller, and Caterina Finizia. "Development of a clinical instrument improving rehabilitation of olfaction with the Nasal Airflow-Inducing Maneuver in Swedish laryngectomized patients", Acta Oto-Laryngologica, 2009.
Publication
<1%

127 "Orthopaedic Section Poster Presentations (Abstracts OPO1–OPO236)", Journal of Orthopaedic and Sports Physical Therapy, 2016.
Publication
<1%

128 Moore, Stephanie D., Kevin G. Laudner, Todd A. Mcloda, and Michael A. Shaffer. "The
<1%

Immediate Effects of Muscle Energy Technique on Posterior Shoulder Tightness: A Randomized Controlled Trial", Journal of Orthopaedic and Sports Physical Therapy, 2011.
Publication

129	etheses.whiterose.ac.uk Internet Source	<1%
130	Thomas, Stephen J., Charles B. Swanik, Jill S. Higginson, Thomas W. Kaminski, Kathleen A. Swanik, John D. Kelly, and Levon N. Nazarian. "Neuromuscular and stiffness adaptations in division I collegiate baseball players", Journal of Electromyography and Kinesiology, 2012. Publication	<1%
131	etd.lsu.edu Internet Source	<1%
132	uhra.herts.ac.uk Internet Source	<1%
133	profiles.jefferson.edu Internet Source	<1%
134	www.bodybuilding.com Internet Source	<1%
135	Shafi, Mohamed. "Cricket Injuries: an Orthopaedist's Perspective : Cricket Injuries", Orthopaedic Surgery, 2014. Publication	<1%

136	dspace.lboro.ac.uk Internet Source	<1%
137	m.blog.daum.net Internet Source	<1%
138	Morais, Nuno, and Joana Cruz. "The pectoralis minor muscle and shoulder movement-related impairments and pain: Rationale, assessment and management", Physical Therapy in Sport, 2016. Publication	<1%
139	arrow.dit.ie Internet Source	<1%
140	Submitted to University of Stellenbosch, South Africa Student Paper	<1%
141	Abbott, J.H.. "Mobilization with movement applied to the elbow affects shoulder range of movement in subjects with lateral epicondylalgia", Manual Therapy, 200108 Publication	<1%
142	Chant, Chris B., Robert Litchfield, Sharon Griffin, and Lisa M. F. Thain. "Humeral Head Retroversion in Competitive Baseball Players and Its Relationship to Glenohumeral Rotation Range of Motion", Journal of Orthopaedic and Sports Physical Therapy, 2007. Publication	<1%

143	Borstad, John D.. "Measurement of Pectoralis Minor Muscle Length: Validation and Clinical Application", Journal of Orthopaedic and Sports Physical Therapy, 2008. Publication	<1%
144	Amin, Nirav H.; Ryan, John; Fening, Stephen D.; Soloff, Lonnie; Schickendantz, Mark S. and Jones, Morgan. "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. Publication	<1%
145	Oyama, Sakiko, Elizabeth E. Hibberd, and Joseph B. Myers. "Changes in humeral torsion and shoulder rotation range of motion in high school baseball players over a 1-year period", Clinical Biomechanics, 2013. Publication	<1%
146	Arthroscopy and Sport Injuries, 2016. Publication	<1%
147	Lee, Ji-hyun, Heon-seock Cynn, Tae-lim Yoon, Chang-hee Ko, Woo-jeong Choi, Sil-ah Choi, and Bong-sam Choi. "The effect of scapular posterior tilt exercise, pectoralis minor stretching, and shoulder brace on scapular alignment and muscles activity in subjects with round-shoulder posture",	<1%

Journal of Electromyography and Kinesiology, 2015.
Publication

148	A. M. Cools. "Descriptive profile of scapulothoracic position, strength and flexibility variables in adolescent elite tennis players", British Journal of Sports Medicine, 07/01/2010 Publication	<1%
149	Borstad, John D.. "Resting position variables at the shoulder: evidence to support a posture-impairment association.(Re", Physical Therapy, April 2006 Issue Publication	<1%
150	Magarey, Mary E.. "A Physiotherapy Perspective on Management of Degenerative Rotator Cuff Tendinopathy :", Techniques in Shoulder and Elbow Surgery, 2012. Publication	<1%

EXCLUDE QUOTES ON
EXCLUDE BIBLIOGRAPHY ON
EXCLUDE MATCHES OFF