# Risk Factors and Shoulder Dysfunction in Elite Male Fast Bowlers in South Africa

**A dissertation submitted to the Faculty of Health Sciences, University of the Free State, for the degree of Master of Science in Physiotherapy**

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**Declaration**

I, Keagan Rafferty, declare that this dissertation has been compiled of my own independent work.

This dissertation is being submitted in order to obtain a degree of Master in Physiotherapy (by dissertation), at the University of the Free State, Bloemfontein, Free State, South Africa.

This dissertation has not been submitted for any other degree or examination at this university or any other faculty or university.

01/06/2020

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I have proofread and edited the entire work including the Front pages ,the Main text, the List of References and the Appendices. This editing principally involves proofreading, language, style and grammar editing; as well as checking the text for clarity of meaning, sequence of thought and expression and tenses. I have also noted any inconsistencies in thought, style or logic, and any ambiguities or repetitions of words and phrases, and have corrected those errors which creep into all writing. I have written the corrections on the hard copy and have returned the document to the author, who is responsible for inserting these. Please note that this confirmation refers only to editing of work done up to the date of this letter and does not include any changes which the author or the supervisor may make later.

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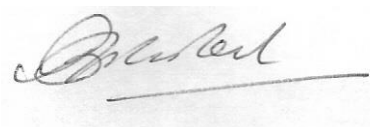

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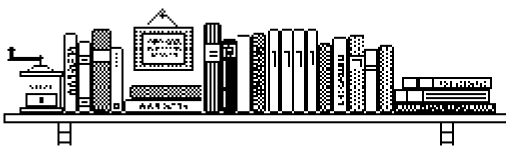

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**Abstract**

Cricket is one of the world's most popular sports. Cricketers are playing exponentially more matches due to the rise of wealth and opportunity, leaving modern-day fast bowlers at greater risk of injury. The aim of this study was to determine the intrinsic and extrinsic risk factors for shoulder dysfunction among elite male fast bowlers, 18 years and older, in South Africa.

This descriptive observational cross-sectional study utilised a non-randomised, convenience sampling method, recruiting 33 elite male South African fast bowlers as study participants. Data collection entailed a modified Kerlan-Jobe Orthopaedic Clinic (KJOC) Shoulder and Elbow questionnaire, which was completed by each participant and an assessment procedure including the measurement of shoulder range of motion and stability, which was conducted by the researcher to determine the intrinsic and extrinsic risk factors for shoulder dysfunction in the participants. Data collection took place at the cricket stadiums which hosted the Knights team during the 2018/2019 domestic cricket season.

Twenty-three participants (69.7%) were included in the shoulder dysfunction group and ten participants (30.3%) into the non-shoulder dysfunction group after classification by the researcher. Classification into the two groups were based on information obtained from the questionnaire and assessment procedure and participants meeting the conceptual definition of shoulder dysfunction as stated for this study. Results suggest that 23 (78.3%) participants in the shoulder dysfunction group were playing at franchise level, whereas 7 (70%) participants in the non-shoulder dysfunction group played at a provincial level. A higher chronic (1350) and acute (1175) bowling workload value was found within the non-shoulder dysfunction group, compared to the chronic (900) and acute (320) bowling workload values of 900 and 320 in the shoulder dysfunction group.

Fast bowlers should be screened by the team physiotherapist regularly for early detection of risk factors, particularly those playing at a higher level and who have completed more seasons. A greater understanding and awareness of the identified risk factors will improve current fast bowler injury prevention strategies, ultimately improving the quality of cricket.

**Acknowledgements**

I would like to express my gratitude and appreciation to the following people who played an important role in helping me along this journey:

This study would not have been possible without the strength and insight provided to me by my Heavenly Father.

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To my family for being patient with me, believing in me and being supportive throughout the journey.

*"And, when you want something, all the universe conspires in helping you to achieve it" - Paulo Coelho*

**Table of Contents**

**Appendices**

**List of Figures**

**List of Tables**

**List of Definition of Terms**

| | |
|---|---|
| Fast Bowler | A cricket player who adopts the role to bowl primarily within a team and who delivers the ball at a pace of 120 kilometres per hour (km/h) or more (Olivier, Taljaard, Burger, Brukner, Orchard, Gray, Botha, Stewart & Mckinon., 2016). |
| *Cricinfo* | A subdivision of ESPN, serving as a website exclusively for cricket news, live scores and cricket-related articles available at www.ESPN cricinfo.com (Schaefer, 2018). |
| eNCA | A South African 24-hour news broadcast channel and website (Moyo, 2016). |
| Dysfunction | An impairment or abnormal functioning of the body or region of the body predisposing to injury or illness (Radwan & Schultheiss, 2016). |
| Modifiable risk factors | Factors which are within one's control to change (Olivier *et al*., 2016) |
| Non-modifiable risk factors | Factors which one has no control over or the ability to change (Olivier *et al*., 2016). |
| Intrinsic | Personal characteristics inherent in an individual (Olivier *et al*., 2016). |
| Extrinsic | External or environmental factors not inherent in an individual (Olivier *et al*., 2016). |
| Franchise | A professional domestic cricket team constituted of two or more provincial unions acting in accordance with the rules of Cricket South Africa, competing in domestic cricket competitions (English, Nash & Martindale, 2018). |
| Over | A set of six consecutive balls delivered by a single bowler in a game of cricket (Viswanadha, Sivalenka, Jhawar & Pudi, 2017). |

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|---|---|
| First class match | A cricket match of three or more days adjudged to be the highest standard of domestic or international cricket (Olivier *et al*., 2016). |
| List A match | A limited over match (one-day) constituting the highest standard of limited over domestic cricket (Olivier *et al*., 2016). |
| Pro20 match | A match limited to 20 overs per team (one-day) constituting the highest standard of 20 over domestic and international cricket (Olivier *et al*., 2016). |
| Elite cricketer | A cricketer having played at least one first class, list A or Pro20 match (Olivier *et al*., 2016). |
| Mangaung | The local Bloemfontein municipality which sponsors the stadium where the Knights cricket team's headquarters are situated (Neethling, 2018). |
| Boundary | The outer perimeter of the playing field (Viswanadha *et al*., 2017). |
| Prehabilitation | A form of exercise one may do with the intention of preventing an injury before the actual occurrence (Gurlit & Gogol, 2019). |

**Conceptual Definition of Shoulder Dysfunction**

The conceptual definition for shoulder dysfunction for the current study is defined by an abnormality or impairment in the normal functioning of the shoulder girdle, including the occurrence of any **one** of the following factors:

- the participant currently living with shoulder pain or injury impairing their cricketing performance (Winter, Hawkins & Richard, 2014);
- the participant having missed game time in the last season due to shoulder problems;
- a previous medical history of repetitive shoulder injuries (Winter *et al*., 2014);
- an asymmetrical Glenohumeral Total Range of Motion (TROM) difference of >5° between the dominant and non-dominant shoulders (Manske, Wilk, Davies, Ellenbecker & Reinold, 2013).
- a Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) outcome of <25 repetitions (Lee & Kim, 2015); and
- a positive sign, on any single shoulder impingement tests on the participant's dominant shoulder compared to the non-dominant shoulder, including; Neer's, Hawkins-Kennedy, O'Brien's, empty can and Speed's test (Brukner & Khan, 2017).

**List of Abbreviations and Acronyms**

| | |
|---|---|
| ESPN | An acronym for a United States-based sports television channel, Entertainment and Sports Programming Network. The channel broadcasts world-wide sporting events and news (Bissell, May & Noyce, 2004). |
| CKCUEST | An acronym used for the Closed Kinetic Chain Upper Extremity Stability Test which is used to test an individual's upper limb stability (Lee & Kim, 2015). |
| BCCI | An acronym used for the Board of Control for Cricket in India. The sporting body responsible for the governing of cricket affairs in India, which is financially the strongest sporting body in the world (Agur, 2013). |
| IPL | An acronym used for the Indian Premier League. A renowned Pro20 tournament held in India where eight privately-owned teams offer highly lucrative contracts to many local Indian and international cricketers (Agur, 2013). |
| NFL | An acronym used for the National Football League. The renowned American football league hosts many local American football clubs which compete annually (Agur, 2013). |

**Chapter 1: Introduction**

Cricket is a popular team sport played by both men and women of all age groups around the world, predominantly by the British Commonwealth countries (McNamara, Gabbett, Naughton, Farhart & Chapman, 2013; Olivier *et al*., 2016). Two teams, consisting of eleven players each, compete against each other, where each specific player assumes a unique role within the team in the form of a batsman, bowler or all-rounder (McNamara *et al.,* 2013; Olivier *et al*., 2016). Cricket may be played according to three formats: namely multiday (five-day, four-day or three-day), 50 over or 20 over formats (Hulin, Gabbett, Blanch, Chapman, Bailey & Orchard, 2013). The variability in formats imposes a large physical demand on the modern-day professional cricketer due to the repetitive nature and the time requirements of the sport (McNamara *et al*., 2013). Despite the high physical demand, Orchard, Kountouris & Sims (2016) considered cricket to be a low injury risk sport due to the lack of physical contact between players and due to the fact that many of the documented injuries associated with cricket carry a low severity, usually allowing the cricketer a brisk return to play.

Fast bowlers fulfil a specialised position within a cricket team, which demands that the athlete bowls a large portion of the allocated overs (Dutton, Tama & Gray, 2019; Olivier *et al*., 2016) by repeatedly delivering a 156-gram cricket ball towards an opposing batsman, through movements known as their bowling action, at ball speeds exceeding 120 kilometres per hour (km/h) (Uddin & Kenneth, 2014; Olivier *et al.,* 2016). The number of overs a fast bowler may bowl varies according to the match regulations. In a 20 over match a bowler may bowl a maximum of four overs, ten overs in a 50 over match and limitless overs in a multiday match (McNamara *et al*., 2013).

Alternating between match formats during a cricket season poses a challenge for the fitness and conditioning of the fast bowler. The number and the intensity of deliveries, or the workload, a fast bowler is subjected to depends largely on the match format being played (Dutton *et al*., 2019; Gray, Aginsky, Derman, Vaughan & Hodges, 2016). The workload requirements may change during the cricket season due to the combination of formats being played throughout the season (Gabbett, 2016; Olivier *et al*., 2016). Although injury risk is a reality for fast bowlers, the professional team management expect professional fast bowlers to remain injury-free in order to be selected for their relevant team (Dutton *et al.*, 2019; Gray *et al.,* 2016; McNamara *et al*., 2013).

Cricket South Africa (CSA) has reported recent team selection difficulties as a result of fast bowlers diagnosed with shoulder injuries. Firdose Moonda, a CSA accredited journalist, released a report after the current South African leading test match wicket taker, Dale Steyn, injured his shoulder while bowling:

> "*Dale Steyn has been ruled out of South Africa's Test series in Australia and could face up to six months out of the game with a fractured right shoulder. He did damage to the shoulder, which he had broken last season, while bowling on the second morning of the first test in Perth. The cause of Steyn's injury was not entirely known and was left with a lengthy rehabilitation before returning to the field*" (Moonda, 2016).

Dale Steyn's shoulder problems continued to haunt him and ruled him out of the 2019 Indian Premier League (IPL), where it was stated by an article released by eNCA that Steyn's symptoms had been flared up in his right shoulder. An attempt to reach full fitness during the Cricket World Cup a few months later proved to be in vain, as Steyn was eventually ruled out of the tournament with continued shoulder problems (eNCA, 2019). Anrich Nortje, a 25-year-old cricketer, who made his debut for South Africa on the 3rd of March 2019, missed the inaugural 2019 IPL tournament due to a shoulder injury sustained days before the start of the tournament. Nortje went on to be ruled out of representing South Africa at the Cricket World Cup due to injury (Singh & Ojha, 2019).

In England, 23% of the 378 English first class fast bowlers reported they had a shoulder injury during the 2005 domestic season (Ranson & Gregory, 2008), while Walter (2020) reported that 13% of the 35 elite fast bowlers in New Zealand also sustained shoulder injuries between 2005-2016.

Considering the above-mentioned cases, emphasis should be placed on early injury detection and the need for optimal fast bowler injury prevention strategies, which is viewed as an essential role of a sport physiotherapist in all levels of sport. With the ever-increasing number of professional cricket matches being played, the impact of injury is far more significant to both the team and the individual (Dutton *et al*., 2019; Gray *et al.,* 2016). Only with a better understanding of the risk factors for shoulder dysfunction, will fast bowlers be managed more effectively by the medical and coaching staff. It is the team physiotherapist's role to provide treatment, rehabilitation of injuries and most importantly, provide support to the fast bowler through injury prevention and recovery interventions (Grant, Steffen, Glasgow, Phillips, Booth & Galligan, 2014). The perception that team physiotherapists only provide treatment for sport injuries is no longer valid, and it has become more evident that team physiotherapists are required to play a much bigger role in supporting the uninjured athlete and prevent injuries (Grant *et al*., 2014). A more comprehensive understanding of the modifiable risk factors for shoulder dysfunction is a necessity for the continual improvement of fast bowler management and for the longevity of the fast bowler's career (Schwellnus, Torbjørn, Alonso, Bahr, Clarsen, Dijkstra, Gabbett, Gleeson, Hägglund, Hutchinson, Janse Van Rensburg, Meeusen & Shephard, 2018).

There are specific risk factors outlined by the literature, which may predispose a fast bowler to a greater likelihood of sustaining an injury (Olivier *et al*., 2016; Orchard, Kountouris & Sims, 2017). Although the literature suggests a common correlation between high bowling workloads and lumbar stress-related injuries among the younger fast bowlers, the likelihood of shoulder injuries should also be considered (Johnson, Ferreira & Hush, 2011; Olivier *et al.,* 2016). Shoulder dysfunction among overhead athletes, as in fast bowlers, are multi-factorial in nature and commonly linked to the highly repetitive trait of fast bowling (Dutton *et al.,* 2019; Jobe & Pink, 1993; Wright, Hegedus, Tarara, Ray & Dischiavi, 2018).

**1.1 Extent of the Problem**

The biggest problem that fast bowlers are faced with is that they represent, undoubtedly, the greatest soft tissue and stress-related injury risk of all positions in cricket due to the high intensity and repetitive nature of their bowling actions (Dutton *et al.,* 2019; Maunder, Kidling & Cairns, 2017; Olivier *et al*., 2016). Though injuries to the shoulder girdle may not be regarded as severe or as common as injuries to the lumbar spine, there is also less available literature regarding shoulder dysfunction among elite fast bowlers. With the high number of balls bowled during training and match play, many underlying dysfunctionalities present in the bowler, leading to a variety of injuries, which may include the shoulder girdle (Dutton *et al*., 2019; Johnson *et al.,* 2011).

Altogether 38 studies related to shoulder injury prevention and injury risk factors were systematically reviewed by Asker, Brooke, Walden, Tranaeus, Johansson, Skillgate & Holm (2018), and the authors concluded that limited evidence surrounding the possible risk factors leading to shoulder injuries are available, most being non-modifiable (Asker *et al*., 2018; Wright *et al.,* 2018). Further research regarding risk factors associated with shoulder dysfunction is warranted and this will be considered and discussed further in this study.

### 1.2 Research Question

What are the intrinsic and extrinsic risk factors for shoulder dysfunction in elite male fast bowlers in South Africa?

### 1.3 Aim and Objectives of the Study

The aim of the study was to determine the intrinsic and extrinsic risk factors for shoulder dysfunction among elite male fast bowlers, 18 years and older, in South Africa.

In order to achieve the aim, the objectives of the study were:

- to describe the sample demographics including age, height, weight, BMI, limb dominance, gender and prior history of shoulder injury presenting as pain or injury;
- to describe the participant profile, including the number of professional seasons completed, current playing status, other sports currently played, missed game time (days), treatment received to the shoulder in the past professional season and level of competition;
- to determine the occurrence of intrinsic risk factors for shoulder dysfunction including dominant shoulder internal rotation deficit, scapular kinematics, shoulder impingement, posterior capsule tightness and upper limb stability by means of a physical objective assessment of shoulder range of motion, muscle strength and stability;
- to determine the occurrence of extrinsic injury risk factors for shoulder dysfunction at the time of study participation, including acute and chronic bowling workload, throwing workload, player's primary field position and perceptive overload in terms of bowling and throwing by means of a modified KJOC questionnaire based on the published literature; and

- to determine the association between the occurrence of shoulder dysfunction and the intrinsic and extrinsic risk factors, in particular modifiable risk factors including; bowling and throwing workload values, shoulder strength, stability and flexibility at the time of assessment.

**1.4 Significance of the Study**

The health and fitness of a modern-era elite athlete has become more pressing across global sporting codes due to the growing popularity and frequency of competitions in the modern era of sport (Engebresten, Steffen, Alonso, Aubry, Dvorak, Junge, Meeuwisse, Mountjoy, Renstrom & Wilkinson, 2010). The key to optimal injury prevention is the early detection of potential injury risk factors, which may predispose an athlete to a specific injury (Gabbett, 2016; Olivier *et al*., 2016). Though the injury risk factors associated with the relevant sporting codes seem to be well understood and investigated, injury prevention strategies will need to evolve continually and develop along with the high density of competitive sport being played all over the world to keep an athlete's injury-induced time out of competition to a minimum (Olivier *et al*., 2016; McNamara *et al.*, 2013; Pfirrmann, Herbst, Ingelfinger, Simon & Tug, 2016).

Cricket proves no different, where there has been an increase in workload demand and match density ever since the introduction of the 20 over format in 2005 (McNamara *et al*, 2013). Generally considered a low injury risk sport, cricket has a significant and unique workload injury risk factor, specifically relevant to fast bowlers (Gabbett, 2016; Olivier *et al*., 2016). The majority of studies involving fast bowlers place emphasis on the younger generation (under 24 years) including a high prevalence of lumbar stress reaction type injuries when compared to older fast bowlers (Arora, Paoloni, Kandwal & Diwan, 2014; Johnson *et al*., 2011; Sims, Kountouris, Orchard, Beakley & Saw, 2017). The severity of lumbar stress injuries in fast bowlers often leaves the athlete with prolonged time away from competition, lengthy rehabilitation protocols and large medical expenses (Dutton *et al*., 2019; Johnson *et al*., 2010).

Despite the prominent threat of stress-related injuries revealing itself amongst younger fast bowlers, there are many other significant injuries, which may hamper the career of an aspiring fast bowler (Johnson *et al*., 2010; Sims *et al.,* 2017), including hamstring strains, which have a seasonal incidence of eight point seven injuries per 100 players per season according to

Orchard *et al*. (2017), side and abdominal strains, wrist and hand fractures and groin injuries (Orchard *et al*., 2017; Wright *et al*., 2018). It is important that potential injuries are detected by the team physiotherapist, who is responsible for injury prevention and treatment within the team, as early as possible and managed correctly in order to create a platform for all upcoming fast bowlers to reach their potential.

Currently there is limited research focusing on fast bowler's shoulder dysfunction. The high bowling and throwing demands on fast bowlers are constant during the season and the bowler may well show early signs of fatigue or shoulder girdle tightness before presenting with pain and/or shoulder dysfunction (Desai, Yeole, Waghmare & Andhare, 2019; Mihata, Gates, McGarry, Neo & Lee, 2015). A more in-depth look at the current underlying intrinsic and extrinsic risk factors for shoulder dysfunction among South African elite male fast bowlers is therefore warranted. The detection and identification of risk factors for shoulder dysfunction among elite South African male fast bowlers may contribute to a better understanding of optimal player management and injury prevention strategies in cricket across the world. Team physiotherapists are in the unique position to take on a leadership role by utilising their specific skill set of evidence-based approaches to fast bowler injury prevention and treatment (Lifshitz, 2012).

This study will serve as a baseline study for further research regarding fast bowler shoulder injury prevention and will hopefully contribute to prolonging the careers of many upcoming fast bowlers, not only in South Africa, but also around the world.

### 1.5 Research Setting for the Study

This study was conducted at the local cricket stadiums, which hosted the Knights team during the 2018/2019 domestic cricket season. The majority of the home games were played at the Mangaung Cricket Oval in Bloemfontein, Free State. This stadium serves as the home base for the Knights cricket team and as the headquarters of the franchise. The other cricket stadiums where data collection took place included:

- Diamond Oval, Kimberley;
- Buffalo Park, East London;
- SuperSport Park, Centurion;
- The Wanderer's Stadium, Johannesburg; and

- Kingsmead Stadium, Durban.

Each of the aforementioned stadiums had a medical room or change room area with an available plinth. This served as an ideal area for the execution of this study as the participants were easily accessible and optimal privacy was readily available to conduct the study.

### 1.6 Outline of the Study

The design and organisation of the dissertation is set out below:

Chapter 1 served as an introduction to the presented research. The need for a better understanding of shoulder injury risk factors was highlighted, as well as an understanding of the role that risk factors play in the global improvement of fast bowler injury prevention. The research aims, objectives and significance of the study were also presented in the chapter.

Chapter 2 of the dissertation outlines the available literature surrounding the anatomy of the shoulder complex. The following intrinsic injury risk factors are identified according to the available literature and discussed: glenohumeral internal and external range of motion; posterior capsule tightness; scapular kinematics and shoulder stability where the Closed Kinetic Chain Upper Extremity Stability (CKCUES) test is described. A detailed discussion of the extrinsic injury risk factors is provided and a description of bowling and throwing workloads is outlined. The chapter concludes with a discussion of the role both throwing and fast bowling have in shoulder dysfunction.

Chapter 3 covers the methodology of the dissertation. The sample size of the population, and also the inclusion and exclusion criteria will be discussed. The data collection procedure will be outlined which includes the description of the questionnaire and shoulder assessment procedures. Ethical considerations and data analysis will also be included.

Chapter 4 will discuss the results of the study making use of tables and figures and will present the contribution of this study to the existing body of literature on shoulder dysfunction in elite South African fast bowlers.

Chapter 5 includes the discussion, highlighting the main findings and the relevance to the current literature.

Chapter 6 concludes the dissertation. The impact of the outcomes reached are discussed and suggestions for further research are presented.

## Chapter 2: Literature Overview

### 2.1 Introduction

Shoulder injuries account for between five to seven per cent of all documented injuries among cricketers, although between 69-85% of cricketers who experience pain or dysfunction in their shoulders are reportedly still able to train and play in matches (Desai *et al*., 2019; Dutton *et al*., 2019). The severity of shoulder injuries varies from career-ending to mild shoulder injuries which may not directly keep fast bowlers from competition for long periods compared to injuries to other areas for example the lumbar spine (Johnson *et al*., 2010; Sims *et al*., 2017). Though playing or training with shoulder pain or dysfunction may lead to further problems and impair performance, more so for a fast bowler than for other role-players, considering the load demand on a fast bowler's shoulder during bowling and throwing (Dutton *et al*. 2019, Gabbett, 2016; Olivier *et al.,* 2016).

Dutton *et al*. (2019) suggested that the most common structures affected by a shoulder injury to cricketers involve the rotator cuff musculature and tendons due to the overhead nature of fielding and bowling. Fast bowlers are subjected to both throwing and intensive bowling workloads due to the nature of their role within the team and due to the fact that fast bowlers have a tendency to field on the outer boundary of the playing field, requiring them to throw further distances than the other fielders closer to the pitch (Dutton *et al*., 2019, Gabbett, 2016; Olivier *et al*., 2016).

Olivier *et al*. (2016) identified intrinsic and extrinsic injury risk factors that predispose fast bowlers to a higher likelihood of sustaining injuries. The factors identified by Olivier *et al*. (2016) were classified as being extrinsic, intrinsic, environmental in nature, or physiological in nature. These factors were, however, not related to a particular region or a particular set of injuries, but rather indicated a degree of injury risk that a fast bowler might be subjected to according to the identified factors (Olivier *et al*., 2016). The identified risk factors will be described later in this chapter.

Many factors play a role in the development of shoulder dysfunction among fast bowlers, the most prevalent being throwing while fielding (Desai *et al*., 2019; Dutton *et al*., 2019). Repetitive overhead throwing according to Wilk, Obma, Simpson, Cain, Dugas & Andrews (2009) may compromise the delicate balance between glenohumeral internal and external rotation range of motion. Once the range of motion balance has been altered, the fast bowler will face an increased likelihood of a shoulder injury (Manske, Wilk, Davies, Ellenbecker & Reinold, 2013; Wilk *et al.,* 2009). There is currently limited literature available on the effects which an altered shoulder girdle may have on high bowling workloads in cricketers, which leaves room for further investigation.

A short overview of the anatomy of a normal shoulder girdle will be presented below which will outline the susceptible areas of possible injury.

**2.2 Anatomy of the Shoulder Girdle**

The shoulder girdle contains three primary bones, consisting of the clavicle, scapula and the humerus (Garbis, 2017). These bones are connected by four joints, namely; the glenohumeral joint (GHJ), the scapulothoracic joint, the acromioclavicular (AC) joint and the sternoclavicular (SC) joint. The GHJ is commonly referred to as the shoulder joint and is known to have the largest range of motion capability of all the joints within the human body (Fahn-Lai, Biewener & Pierce, 2019; Garbis, 2017).

The GHJ is made up of two surfaces, one being the proximal shallow glenoid cavity and the other, the distal head of the humerus forming a ball and socket joint. The capacity to move through large ranges within all three planes, predisposes the shoulder girdle to a variety of potential abnormalities and dysfunctionalities (Açar, Apaydın, Tekdemir & Bozkurt, 2017; Garbis, 2017). Other important structures forming the shoulder girdle include the rotator cuff, which is the name given to the group of muscles and tendons that surround the shoulder, providing support and allowing for the large range of motion. The muscles that form part of the rotator cuff are m. supraspinatus, m. subscapularis, m. infraspinatus and m. teres minor (Açar *et al*., 2017; Fahn-Lai *et al*., 2019) as can be seen in Figure 1.

The humerus is relatively loose fitting in the shoulder joint, allowing for the large range of motion, but also creating a greater vulnerability to instability and injury. The glenoid labrum is thus an important structure, forming a cuff of cartilage around the glenoid fossa, which creates additional structural support to the GHJ by increasing the articular surface of the joint (Garbis, 2017; Rosa, Borstad, Ferreira & Camargo, 2019).

There are several important ligaments that are found in the shoulder joint responsible for supplying structural support to the joints and structures in the shoulder girdle. The glenohumeral ligaments (GHL) are a group of ligamentous structures, which create a capsule surrounding the GHJ. The GHL include, amongst others, the trapezoid ligament, connecting the coracoid process and the distal clavicle, the acromioclavicular ligament, connecting the acromion and the clavicle and the coracoacromial ligament, connecting the coracoid process and the acromion (Açar *et al*., 2017; Garbis, 2017). Together with the labrum, the GHL provide a substantial amount of the total structural stability to the highly mobile GHJ (Fahn-Lai *et al*., 2019; Longo, van der Linde, Loppini, Coco, Poolman & Denaro*,* 2016).

Figure 1 below clearly depicts the anatomy and structure of the shoulder girdle as described above.

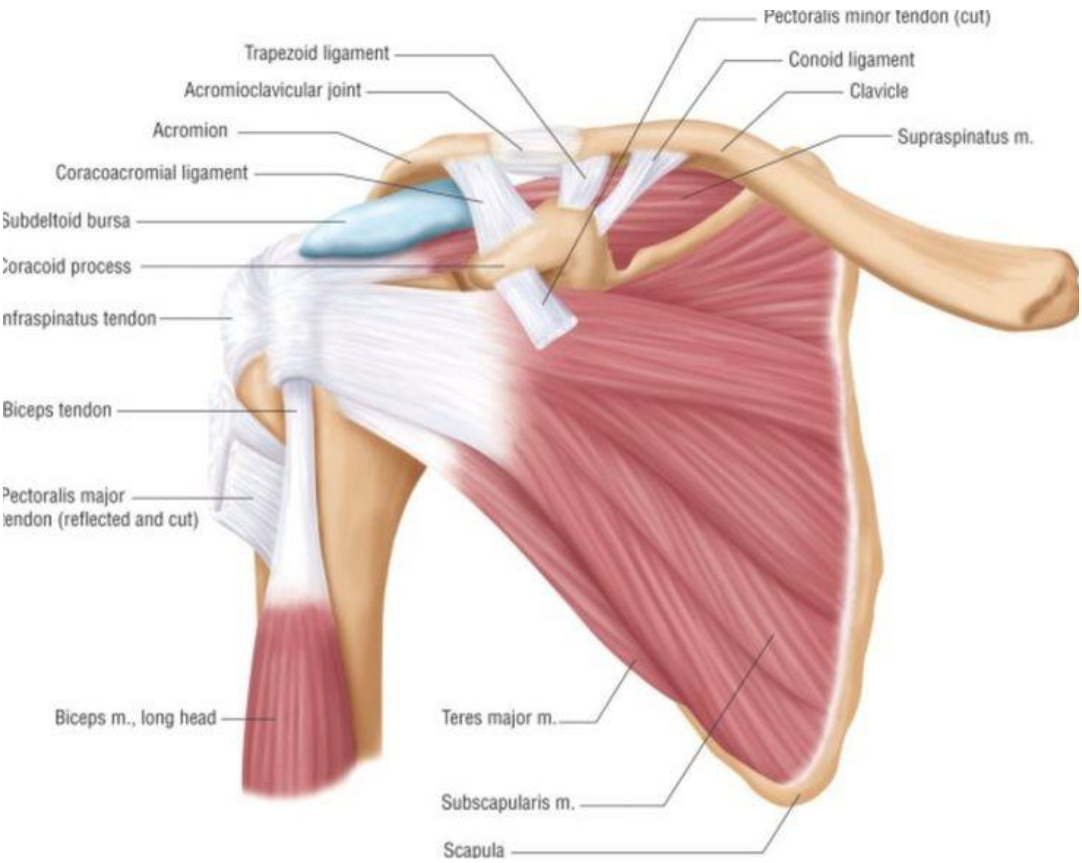



**Figure 1: Anatomy of the Shoulder Girdle**

(Robert Donatelli, 2013, Available online from: https://i.pinimg.com/736x/b5/78/1d/b5781d1780f98be5084402a760485191.jpg)

Shoulder dysfunction may present when there are abnormalities found within the structure of the associated joints and soft tissue acting upon the shoulder girdle. Abnormalities may alter the normal range of motion, the coordination of movements, strength and stability of the shoulder girdle and may eventually lead to further complications involving the elbow joint, the thoracic spine as well as the cervical spine (Açar *et al*., 2017; Cole & Horazdovsky, 2016).

### 2.3 Shoulder Dysfunction

Jobe & Pink (1993) indicated two types of shoulder pathological categories based on their study's participant age. The study by Jobe & Pnk (1993) related shoulder dysfunction to pathology, listing the occurrences of structural degeneration due to aging in the older population, shoulder instability, subacromial impingement and rotator cuff pathology. Fang & Walker (2005) contributed to the fact that the term shoulder dysfunction is multifactorial. The study by Fang & Walker (2005) linked a number of factors with their definition of shoulder dysfunction, including; paralysis, subluxation and chronic pain. A study by Bodor& Montalvo (2007) linked pain and weakness to their definition of shoulder dysfunction. Poor core stability and subacromial impingement was associated with shoulder dysfunction according to Hazar, Ulug & Yuksel.

Despite the lack of cricket and fast bowler research based on shoulder dysfunction, the multifactorial nature of shoulder dysfunction has been highlighted by the available literature. Cricket and fast bowler-related studies have further highlighted the specific prevalences and risks surrounding overhead athlete' shoulder dysfunction, leading to the conceptual definition of shoulder dysfunction used in this study (Brukner & Khan, 2017; Lee & Kim 2015; Manske *et al*., 2013; Winter *et al*., 2014)

### 2.4 Shoulder Injury Prevalence and Incidence

A study conducted by Thasneem (2016) indicated that fast bowlers are the most likely of all positions to sustain shoulder injuries and found that 15% of Sri Lankan high school fast bowlers aged between 12- and 19-years experienced shoulder pain during bowling. Dutton *et al*. (2019) stated that 18% of elite South African cricketers sustained a shoulder injury during the 2016/17 domestic cricket season, with an injury rate of 0.19 injuries per player per season with an annual prevalence of 1.1%. The detection of shoulder injuries amongst elite cricketers may be a challenge as many professional cricketers will attempt to not miss game time and rather change their throwing technique and fielding position to compromise for their injury (Dutton *et al*., 2019; Ranson *et al*., 2008). Walter (2020) went on to state that the shoulder region is one of the most likely injured regions in elite fast bowlers, with an injury incidence of 11.2% amongst elite New Zealand fast bowlers.

### 2.5 Scapular Kinematics and Dyskinesis

The scapulothoracic joint is a physiological joint between the anterior aspect of the scapula and the postero-lateral aspect of the chest wall (Myers, Oyama & Hibberd, 2013). The scapulothoracic joint is not considered to be a true joint in the sense that the concave anterior aspect of the scapula glides on the convex aspect of the chest wall. The joint requires mobility and stability during motion for the muscles acting on the glenohumeral joint to have a stable base on which to act (Cole & Horazdovsky, 2016; Moore, Dalley & Agur, 2014). The stabilising muscles associated with the stability and mobility of the scapulothoracic joint consist of:

- the upper, middle and lower trapezius mm.;
- m. serratus anterior; and
- mm. rhomboid major and minor.

The upper fibres of the m. trapezius are responsible for the elevation and retraction of the clavicle since the fibres of the muscle do not directly attach to the scapula. Elevation of the clavicle and AC joint facilitates the elevation of the scapula. The middle fibres of m. trapezius originate at the spine of the scapula and insert on the acromion process. The fibres are arranged to offset the lateral movement of the scapula during m. serratus anterior contraction and it is therefore the middle fibres of m. trapezius which play an important role in scapular stability (Açar *et al*., 2017; Fahn-Lai *et al*., 2019; Garbis, 2017).

The lower fibres of m. trapezius are largely responsible for the upward rotation of the scapula and inhibited m. trapezius lower fibres may lead to ineffective m. rhomboid and m. levator scapula function leading to shoulder dysfunction (Açar *et al*., 2017). The different parts of m. trapezius function independently and play an important role in the normal movement of the scapula (Ludewig & Reynolds, 2009). The m. serratus anterior may be described as being a sheet of muscle fibres between the ribs and the scapula (Açar *et al*., 2017; Ekstrom, Bifulco & Lopau, 2004) and is mainly responsible for the upward rotation of the scapula and an important scapulothoracic joint stabilising muscle, which provides a steady base to allow normal and effective glenohumeral joint function (Garbis, 2017; Phadke, Camargo & Ludewig, 2009).

The scapular stabiliser muscles have very distinct functions related to the scapula in terms of stabilising or mobilising in a particular direction. If there are any imbalances found between two or more respective scapular stabilisers, scapulothoracic joint dysfunction may result (Cole *et al.,* 2016; Lucado, 2011). Following is an overview of the anatomy and scapular kinematics and dyskinesis, the common mechanism of injury pertaining to the shoulder girdle will be described.

**2.6 Subacromial Impingement**

The most common injury to cricketers pertaining to the shoulder girdle is that of subacromial impingement (Dutton *et al*., 2019). The literature identifies two types of subacromial impingement, namely structural (internal) and functional (external) impingement. Structural impingement is largely a result of the presence of bony spurs in the subacromial space forming from the acromial process. This is known to cause extra pressure on the long head of the m. biceps tendon, m. supraspinatus tendon and the subacromial bursa, all of which may cause pain in the shoulder. Functional impingement is usually a result of a biomechanical alteration when there is an imbalance between the scapular stabilising muscles (Cole *et al.,* 2016; Page, 2011). Repetitive, high intensity throwing in cricketers often leads to an altered shoulder girdle structure, predisposing the cricketer to common shoulder impingement symptoms, which are often evident (Dutton *et al*., 2019; Olivier *et al*., 2016). Common sub-acromial impingement symptoms consist of shoulder pain with overhead use, difficulty reaching behind the back and weakness of the shoulder muscles (Cole *et al.,* 2016; Umer, 2012).

The intrinsic and extrinsic risk factors for shoulder dysfunction are discussed in greater detail below. The following aspects are commonly affected and are thus considered as being intrinsic injury risk factors for fast bowlers within the current study: deficit of dominant GHJ internal rotation, tightness of the posterior capsule, altered scapular kinematics and shoulder girdle instability.

## 2.7 Intrinsic Risk Factors of Shoulder Dysfunction

Intrinsic factors of shoulder dysfunction include personal characteristics such as anthropology, muscle strength, shoulder stability and flexibility of the shoulder girdle (Olivier *et al*., 2016). Shoulder dysfunction largely describes abnormalities in relation to the mentioned characteristics and may be attributable to specific risk factors including:

- deficient glenohumeral internal rotation range;
- poor scapular stability; and
- scapular kinematics (Green *et al*., 2013).

There are various structural and functional changes, often complex in nature, that may occur in the biomechanics of the shoulder during throwing and bowling (Cole *et al*., 2016; Mihata *et al.,* 2015). These changes may reach a point of failure and impede the overall shoulder functioning leading to pain or dysfunction (Cole *et al*., 2016; Gyftopoulos, Albert & Recht, 2014).

Common pathology experienced throughout arm circumduction include:

- Subacromial impingement: this is often caused by repetitive overhead shoulder activities and results in an inflammatory reaction within the rotator cuff tendons underneath the acromial arch (Dutton *et al*., 2019).
- Secondly there is Superior Labrum Anterior and Posterior (SLAP) lesions: which is an injury to the glenoid labrum at the site where the m. biceps brachii tendon originates (Lubiatowski, Kaczmarek, Slezak, Dlugosz, Breborowicz, Dudzinski, & Romanowski, 2014).
- Rotator cuff tendon injury: most commonly affecting the tendon of the m. supraspinatus tendon but may also include other regions of the rotator cuff. Damage to the tendon may present as fraying and progress to a complete tear of the tendon. (Lubiatowski *et al*., 2014).

The biomechanical alteration of the shoulder girdle commonly leads to functional impingement symptoms, including pain and shoulder dysfunction in fast bowlers (Page, 2011). A fast bowler's bowling action is known to predispose the player to a higher likelihood of sustaining a shoulder injury and mention should be made that bowlers with front-on bowling actions (refer to Figure 2) are more likely to sustain shoulder injuries compared to bowlers with side-on bowling actions (Figure 2), who stand a greater chance of sustaining lower back injuries (Aginsky, Lategan & Stretch, 2004). Although the biomechanics of a bowling action may predispose a bowler to greater risk of shoulder injury, it will not form part of the scope of this study and may lead to future investigation following the results from the current study.

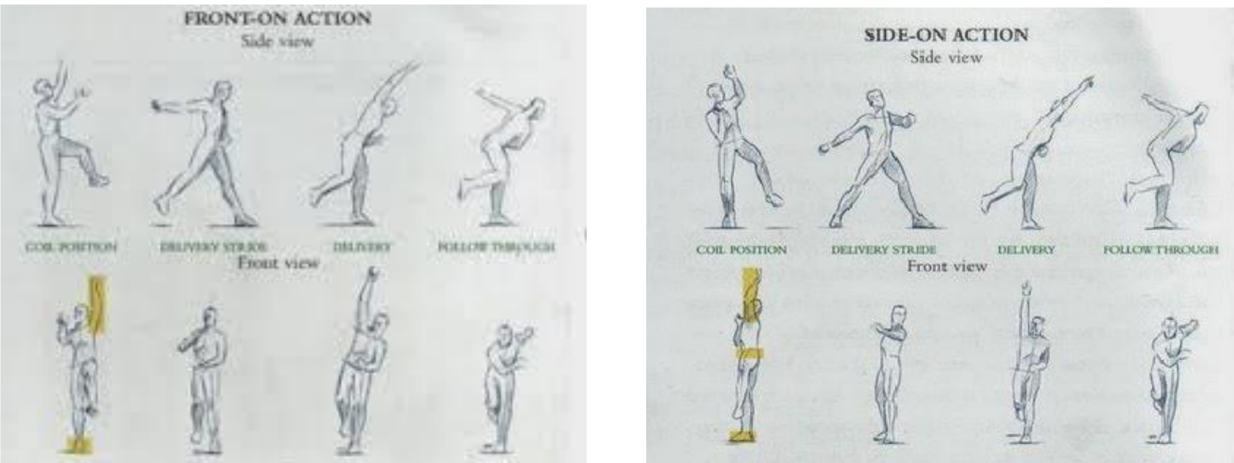



**Figure 2: Biomechanical Comparison between a Front on and Side on Bowling Action**

(Lienert & Pfeiffer, 2015, Available online from: https://lienertandpfeifferbiomechanicsblog.weebly.com/blog/biomechanics-blog-pace-bowling)

According to Olivier *et al.* (2016), intrinsic risk factors for non-contact injuries are mostly modifiable and intervention may well reduce injury risk. The first step in injury risk prevention is identifying the associated injury risk factors for shoulder dysfunction (Dutton *et al*., 2019; Olivier *et al*., 2016), and therefore the aim of the current study was to determine the intrinsic and extrinsic risk factors for shoulder dysfunction among elite male fast bowlers older than 18 years of age in South Africa. Each intrinsic modifiable risk factor identified in the literature will be discussed below.

### 2.7.1 Glenohumeral Rotation Ranges

There are chronic changes in the shoulder girdle's soft tissue and bony structures that are associated with repetitive high velocity throwing (Manske *et al.,* 2013; Sundaram, Bhargava & Karuppannan, 2012). Glenohumeral range of motion (ROM) deficits are often the result of these adaptations and are linked to pain, negative impact on player performance and shoulder problems (Brownstein, 2019; Sundaram *et al*., 2012). There is a noticeable decrease in the thrower's glenohumeral internal rotation and a subsequent increase in external rotation, which may reach the point where the loss of internal rotation exceeds the gain in external rotation, commonly referred to as Glenohumeral Internal Rotation Deficit (GIRD). A deficient internal rotation may impact the normal functioning of the shoulder girdle and may pose a risk of injury to the fast bowler (Manske *et al*., 2013; Sundaram *et al*., 2012).

Contrary to the effects of a deficient internal rotation ROM, when there is a greater increase in external rotation than GIRD, the rotational arc of the bowling arm is decreased, which increases the risk of possible impingement symptoms in fast bowlers (Manske *et al*., 2013; Mihata *et al*., 2015). Osseous changes in the shoulder have been documented radiologically when the GIRD is equal to the increase in external glenohumeral rotation. This occurrence may be regarded as a normal physiological adaptation should there be no symptoms of pain present (Sundaram *et al.,* 2012).

### 2.7.2 Glenohumeral Internal Rotation Deficit (GIRD)

GIRD, as explained by Burkhart, Morgan & Kibler (2003), may be related to shoulder pain if there is an unbalanced glenohumeral internal and external rotation strength and range of motion (Nakagawa, Yoneda, Mizuno, Hayashida, Yamada & Sahara, 2013). Please refer to Figure 3 depicting GIRD. According to Green *et al.* (2013), an increased internal: external strength ratio is observed predominantly in overhead throwing athletes when comparing their dominant and non-dominant arms. This suggests that there is a change in the throwing shoulder's strength patterns as a result of the substantial stress placed on the glenohumeral joint (Manske *et al*., 2013; Nakagawa *et al*., 2013). The shoulder is subjected to additional stressors throughout the bowling action whereby the internal rotators are concentrically responsible for acceleration of the upper limb, while the external rotators act eccentrically to decelerate the upper limb during the terminal phase of the bowling action (Brownstein, 2019; Scher, Anderson, Weber, Bajorek, Rand & Bey, 2010).

Despite the structural adaptation, which consists of an increase in glenohumeral external rotation and a decrease in internal rotation as mentioned by Mihata *et al*. (2013), Manske *et al.* (2015) suggested that the phenomenon of GIRD is in fact to be expected and may well be considered to be a normal occurrence in overhead athletes, despite the fact that according to Manske *et al*. (2013), the loss of glenohumeral rotation ranges may negatively impact an athlete's performance. There are two classifications of GIRD outlined by the study of Manske *et al*. (2013), including the 'normal' or anatomical GIRD and an abnormal or pathological GIRD.

Anatomical GIRD is defined as a decrease in glenohumeral internal rotation ROM of less than 18°-20° (Manske *et al*., 2013). The total glenohumeral rotation, including the sum of internal and external rotation ranges, or 'TROM', is required to be symmetrical in both shoulders. A loss of glenohumeral rotation ROM exceeding 18°-20° is classified as pathological GIRD should there be an associated TROM difference greater than 5° when comparing bilateral shoulder ranges. Emphasis is thus rather placed on the significance of deficient TROM when considering the likelihood of shoulder injuries in overhead athletes, than simply the loss of glenohumeral internal rotation (Manske *et al*., 2013; Mihata *et al*., 2015).

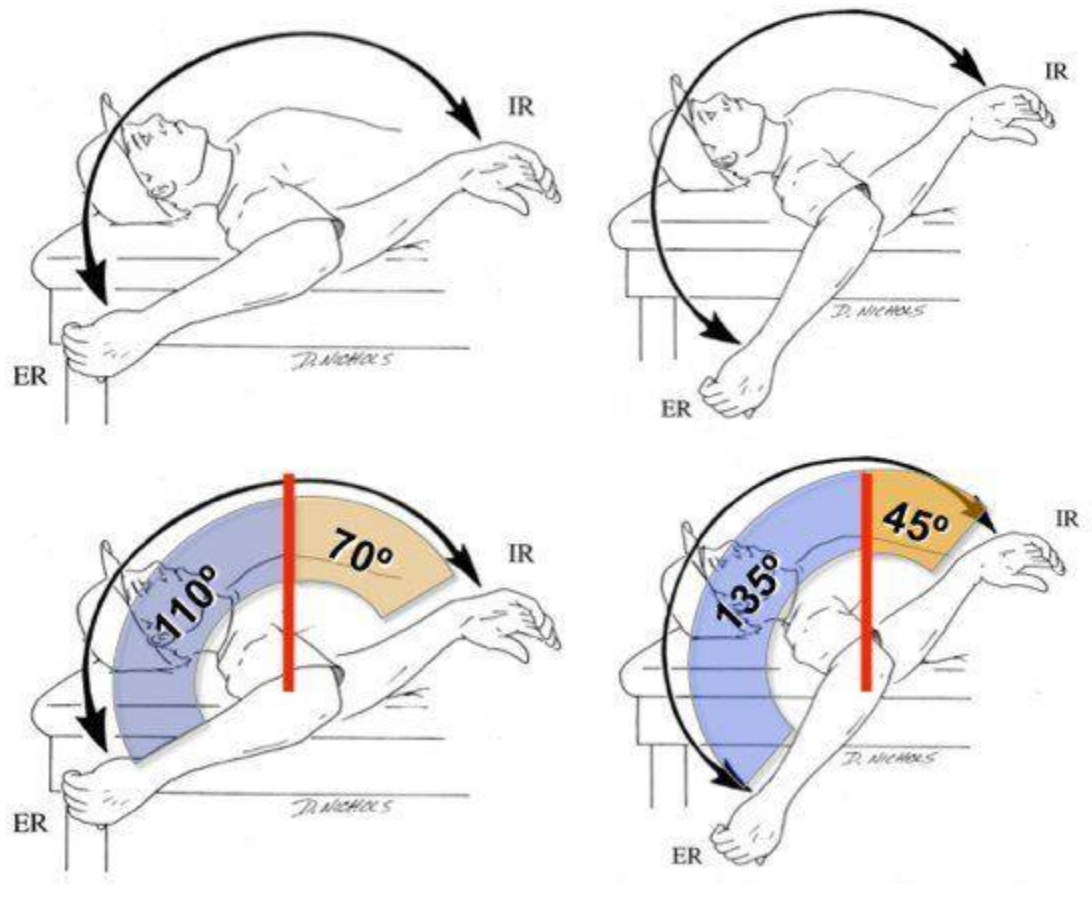



**Figure 3: An Illustration of GIRD Depicting the Shoulder Internal Rotation Deficit**

(Reinold, 2014, Available online from: https://mikereinold.com/gird-glenohumeral-internal-rotation-deficit/)

A study by Wilk, Macrina & Arrigo (2012) suggested that the lack of external ROM in the throwing shoulder is directly associated with an increased injury risk to the thrower's shoulder, while a decrease in glenohumeral internal rotation played a less significant role in the development of shoulder problems (Wilk *et al*., 2012). Hall (2014) indicated that a possible cause of shoulder restriction may be due to decreased muscle length in the m. infraspinatus and m. teres minor, and that shortening in these muscles might in fact limit glenohumeral internal rotation ROM.

### 2.7.3 Posterior Capsule Tightness

The posterior glenohumeral capsule is made up of the ligamentous structures of the posterior synovial capsule (Rosa *et al.,* 2019) and is known to play a role in securing the humeral head within the glenoid labrum and, if dysfunctional, is likely to be associated with shoulder pathology (Mihata *et al.,* 2015).

Mihata *et al*. (2015) suggested that tightness of the posterior capsule is attributed to the throwing athlete's loss of glenohumeral internal rotation, which may be further attributed to repetitive trauma to the shoulder as a result of throwing. The repetitive trauma to the shoulder girdle may predispose the athlete to more severe pathologies such as developing a SLAP lesion (Burkhart *et al*., 2003; Rosa *et al*., 2019). Posterior SLAP lesions are commonly found in throwing athletes with rotator cuff tendon damage near the posterior capsule, which are in close proximity to each other as seen in Figure 1. Tears in the anterior segment of the supraspinatus tendon were also seen in throwers with substantial posterior capsular tightness (Nakagawa *et al.*, 2013).

Sundaram *et al*. (2012) identified glenohumeral joint laxity as being essential for the overhead athlete in generating the necessary ball release velocity in throwing. Repetitive throwing is associated with 'normal' degeneration and may potentially lead to joint instability, but on the other hand, the excessive humeral head subluxation during throwing is related to high throwing load and is a common cause for pathological instability (Cole *et al*., 2016; Sundaram *et al*., 2012).

Results from magnetic resonance imaging (MRI) and arthroscopy studies indicate that the inferior aspect of the rotator cuff tendon usually makes contact with the posterior-superior glenoid during shoulder abduction and external rotation during the throwing action

(Sundaram *et al*., 2012). It was noted by Mihata *et al*. (2015) that there was a greater contact pressure between the rotator cuff tendon and glenoid in the posterior-superior aspect of the glenoid in overhead athletes with GIRD and posterior capsular tightness, which may predispose the athlete to a greater likelihood of shoulder pain.

A recent discovery of rotator cuff intervals, which may be described as a triangular space found between the m. subscapularis tendon, the m. supraspinatus tendon and the base of the coracoid process, may create glenohumeral instability, should these structures be compromised (Abreu & Recht, 2017). Rotator cuff interval lesions have been seen in throwing athletes with shoulder pain, but according to Nakagawa *et al*. (2013), are yet to be related to the presence of posterior capsular tightness. It was also found in the study by Nakagawa *et al.* (2013) that rotator interval lesions and long head m. biceps brachii injuries were common in the absence of posterior capsule tightness due to the excessive forces of throwing. Athletes with no posterior capsular tightness are more likely to develop rotator interval injuries, posterior supraspinatus tendon damage and SLAP lesions, while those with tight posterior capsules commonly develop more anterior m. supraspinatus tendon and SLAP injuries most likely because of the anterior translation of the humeral head (Nakagawa *et al.*, 2013; Rosa *et al*., 2019).

A study by Takagi, Oi, Tanaka, Inui, Fujioka, Tanaka, Yoshiya & Nobuhara (2014) further noted that increased horizontal shoulder abduction in the throwing action was to increase the anterior shear forces within the shoulder joint and improve the likelihood of shoulder injuries. Although the study identified the specific forces acting on the shoulder during pitching, the direction and amount of forces were not specified and this leaves room for future research (Takagi *et al*., 2014).

### 2.7.4 Scapular Kinematics

The glenohumeral joint is extremely dependent on the scapulothoracic joint to produce normal, smooth and coordinated upper limb movements (Saka, Yamauchi, Yoshioka, Hamada & Gamada, 2015). Dysfunctional scapular kinematics presenting as a downward rotated scapula may be observed during functional upper limb movements (shoulder flexion or abduction) and may further contribute to the identification of underlying shoulder problems in cricketers. It may also be seen that playing cricket at an elite level with poor scapular kinematics puts the athlete at far greater risk of sustaining a shoulder injury, primarily presenting as subacromial impingement and an inability to handle the throwing demands during match play (Cole *et al*., 2016; Green *et al*., 2013).

McClain, Tucker & Horner (2012) compared overhead and non-overhead athlete's scapular positioning by testing m. pectoralis minor length. The anterior scapular positioning was compared between the two groups at rest indicating that the overhead throwing group presented with significant anterior scapular positioning on the participant's throwing shoulder. There was, however, no association made between excessive anterior scapular position and shoulder pain in the study (McClain *et al.,* 2012).

A study by Mueller, Entezari, Rosso, McKenzie, Hasebrock, Cereatti, Croce, DeAngelis, Nazarian & Ramappa (2013) investigated whether scapular winging altered glenohumeral joint migration during the beginning phase of the throwing action among overhead athletes. The results of the study indicated that abnormal scapular positioning played a significant role in the development of anterior shoulder pain and instability of the shoulder.

It is evident that fast bowlers require optimum functioning of their shoulder girdles in order to perform at their best. Walankar & Momin (2019) confirmed the importance of shoulder strength, good scapular kinematics and stability for cricketers. The authors further made use of the Closed Kinetic Chain Upper Limb Stability (CKCUES) Test to assess upper limb function and stability across 86 male cricketers. The CKCUEST was found to be a reliable test with an exceptional test/retest reliability (ICC≥0.91). The results from Walankar & Momin (2019) indicated that there was a slightly higher average score amongst bowlers (23.26±4.61) than the average CKCUEST score of batsmen (21.88±3.57).

**2.8 Extrinsic Risk Factors of Shoulder Dysfunction**

There are extrinsic and intrinsic factors that have been identified by Olivier *et al*. (2016) and, in tandem, predispose the fast bowler to greater injury risk. Extrinsic factors commonly include environmental factors such as bowling workload, the player's role within the team and fielding position (Gabbett, 2016; Olivier *et al.,* 2016). Numerous studies have investigated the concept of bowling workload, which may be seen as the number of balls bowled by a particular bowler either during training or during match play within a specific time, usually calculated on a weekly basis (Alway, Brooke-Wavell, Langley, King & Peirce, 2019; Gabbett, 2016; Olivier *et al*., 2016). A workload that is too high or too low is likely to predispose a fast bowler to injury (Orchard *et al*., 2009). The normal workload values, workload monitoring and the prescription of the correct bowling workload have been investigated and will be discussed next.

### 2.8.1 Bowling Workload

Orchard *et al*. (2009) investigated the fast bowler's injury risk and the association to bowling workload. A total of 129 fast bowlers were included in their study and were monitored for a period covering ten cricket seasons. The results indicated that the bowlers who bowled in excess of 50 overs (300 balls) carried an injury incidence of 3.37 injuries per 1 000 overs bowled, for the following 21 days. This was significantly higher than the 1.77 injuries per 1 000 overs in the bowlers who bowled fewer than 50 overs. It was thus concluded that a large acute bowling workload may lead to a high injury risk for between 21 and 28 days following the acute spike in workload. Orchard *et al*. (2009) related the increase in injury incidence to damage caused to immature muscle tissue in the fast bowlers.

The idea of bowling workload was used in a study by Saw, Dennis, Bentley & Farhart (2010), who investigated the association between throwing workload and injuries to the upper limbs in Australian professional cricketers. Twenty-eight adult male cricketers aged between 18 and 32 years of age were included in the study during the 2007/2008 cricket season in Australia. Seven (25%) of the cricketers who took part in the study were reportedly injured during the season. Throwing more than 75 times per week and more than 40 times per day were the evident injury risk indicators in the study. It was concluded that an increased throwing workload had a direct link to the likelihood of sustaining an upper limb injury during a cricket season (Saw *et al.*, 2010). There is currently no literature associating high bowling and throwing workloads and shoulder dysfunction among elite fast bowlers and will be investigated during the current study.

Although a high bowling workload predisposes a bowler to a variety of likely injuries, there is an association between bowling workload and shoulder pain in predominantly overhead athletes (Gabbett, 2016; Green, Taylor, Watson & Arden*,* 2013; Orchard *et al.,* 2009). A study by Hulin *et al.* (2013) investigated the relationship between the acute (one week) and chronic (four-week average) bowling workload. The authors concluded that a high chronic workload was not necessarily a predictor of injury but a large spike in the acute bowling load was directly linked to a greater risk of injury in elite fast bowlers (Gabbett, 2016; Hulin *et al.*, 2013).

The concept of bowling workload is subjected to the repeated bowling action and has only recently been monitored amongst elite fast bowlers (Gabbett, 2016; Hulin *et al.,* 2013). Monitoring systems are currently in place, in which daily acute and chronic bowling workloads are recorded by counting the number of balls bowled by a particular fast bowler. The daily monitoring and capturing of workload have been proven to be the most efficient method for predicting injury risk among fast bowlers (Dutton *et al*., 2019). Despite the efficiency of the current monitoring systems, there is undoubtedly room for advancement in technological monitoring systems to create a more accurate injury risk value, considering all the risk factors present (McNamara *et al*., 2017).

Gabbett (2016) indicated that a safe workload prescription for the fast bowler is between 123-188 deliveries per week. Bowling fewer than 123 deliveries per week will increase the likelihood of acute spikes in the bowling workload, which may predispose a bowler to stress-related injuries, which are common to the lumbar spine and lower limbs (Gabbett, 2016; Olivier *et al*., 2016; Orchard *et al.,* 2009). However, consistently bowling more than the desired 188 deliveries per week will lessen the risk for spikes in the acute workload, but the gross total workload will be higher than desired. A high bowling workload poses an injury risk by inhibiting the optimal recovery required by a fast bowler for injury prevention (Gabbett, 2016; Olivier *et al.*, 2016). The study by Gabbett (2016) does not relate high workload to any specific injury and therefore creates an ideal platform for the current study to investigate the association between high bowling workload and shoulder dysfunction among fast bowlers.

### 2.8.2 Fielding Position

There is a common tendency for fast bowlers to field on the boundary during matches in order to rest and replenish in between bowling overs. Fast bowlers are thus required to throw further distances more often than other players in the team, which predisposes them to a greater likelihood of shoulder joint injuries (Dutton *et al*., 2019; Zaremski, Wasser & Vincent, 2017). Fielding positions on the outfield may provoke shoulder injuries as throwing a ball further distances requires a greater force to be produced within the shoulder girdle (Dutton *et al*., 2019; Zaremski *et al*., 2017) and therefore cricketers presenting with mild shoulder pain will often adopt fielding positions that require the ball to be thrown shorter distances and less often (Green *et al*., 2013). Fast bowlers are often subjected to both high bowling workloads and high throwing workloads, due to their primary role within the team and likely fielding positions, both creating greater injury risk to the fast bowler's shoulder girdle (Dutton *et al*., 2019; Gabbett, 2016; Olivier *et al*., 2016).

**2.9 Throwing versus Fast Bowling**

Fast bowlers display a complex skill where a 156-gram cricket ball is repeatedly bowled towards an opposing batsman at speeds exceeding 120 km/h (Dutton *et al*., 2019; Uddin & Kenneth, 2014). There are particular biomechanical features of a bowling action, refer to Figure 4, which are likely to lead to various injuries when the bowling action is repeated at high intensity (Kountouris, Portus & Cook, 2012). The bowling action's biomechanics and throwing biomechanics both exert unique stressors on the shoulder structure as fast bowlers are expected to bowl and throw during match play (Dutton *et al*., 2019; Olivier *et al*., 2016).

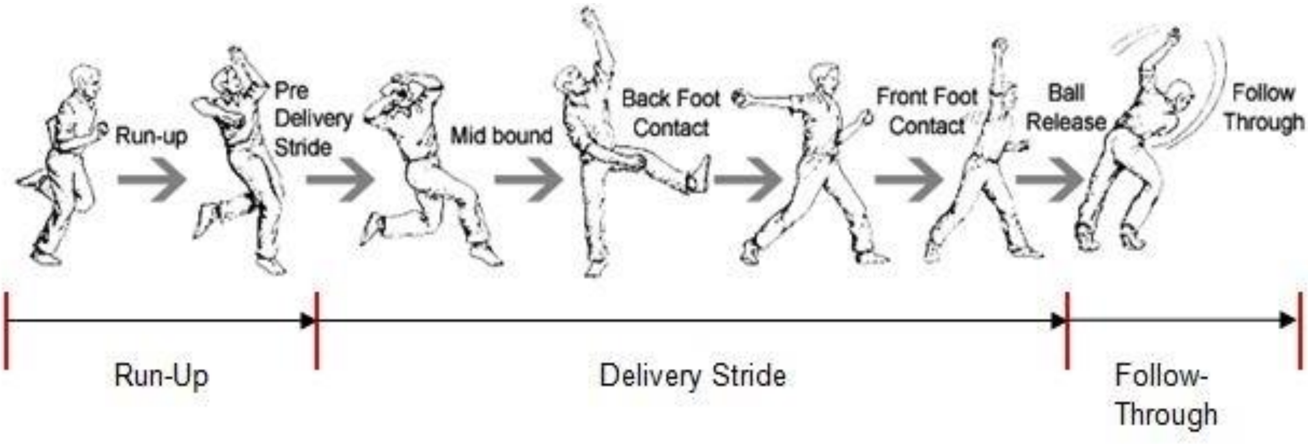



**Figure 4: Illustration of a Fast Bowling Action**

(Round, 2010, Available online from: https://theconversation.com/fast-bowlers-can-reduce-injury-risks-and-inflict-pain-in-the-ashes-15876)

Cricket may be considered to be an overhead sport due to the high demand for throwing, while fielding (Dutton *et al*., 2019; Green *et al*., 2013) is one of the primary activities of cricket and involves every player in the team, refer to Figure 5. According to Wilk *et al*. (2009), the throwing shoulder requires enough mobility to allow sufficient external rotation in order to generate the necessary torque, while control of the shoulder's movement patterns and integrity of the stability structures are just as important as the shoulder's laxity, which significantly limits injury risk. Repetitive throwing often leads to the compromise of the delicate balance between mobility and stability of the shoulder girdle, which increases the likelihood of a shoulder injury (Manske *et al*., 2013; Wilk *et al*., 2009).

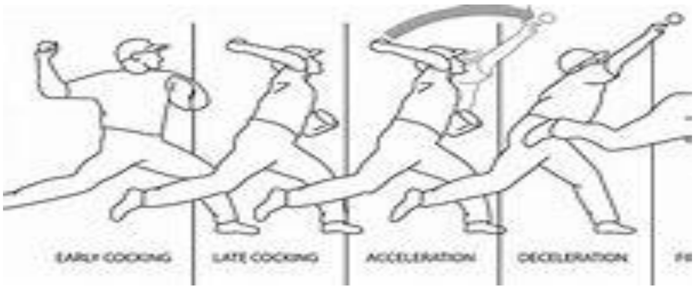



**Figure 5: Illustration of a Throwing Action**

(Abbasi, 2019, Available online from: http://emma4503.wix.com/mclelbow#!signs-and-symptoms---aetiology)

Although a bowler's shoulder pain is most likely a result from throwing rather than directly from bowling, the literature indicates the peak distraction force within the shoulder during fast bowling to be similar to that of baseball pitchers, who are subjected to persistent high shoulder injury (Stuelcken, Ferdinands, Ginn & Sinclair, 2010; Zaremski *et al.,* 2017). Salter, Sinclair & Portus (2007) concurred that bowling places a distraction force on the shoulder girdle due to the high circumduction speed during the ball release phase of the bowling action. The shoulder distraction force is thought to play a substantial role in sustaining shoulder injuries in baseball players and may similarly be an influencing factor in the development of fast bowler's shoulder pain (Salter *et al*., 2007; Zaremski *et al*., 2017). The distraction force within the shoulder joint therefore requires stabilisation from the rotator cuff muscles to maintain the humeral head safely within the glenoid cavity to prevent possible subluxation or dislocation (Salter *et al*., 2007, cited in Stuelcken *et al*., 2010).

The number of balls bowled during a cricket match or practice, exceed the number of balls thrown by the particular bowler, which leads to the hypothesis that the specific shoulder forces during bowling are large enough to have a significant impact on the development of shoulder pain. However, in the absence of data corroborating this statement further investigation is required (Salter *et al*., 2007; Stuelcken *et al*., 2010).

According to Stuelcken *et al.* (2010), the rotator cuff muscles may be overloaded due to the high repetition of distraction forces when the bowler is subjected to high bowling loads. The data obtained during the study of Stuelcken *et al.* (2010) indicated that the bowling shoulder requires an optimal eccentric external to concentric internal rotation strength, which proves necessary for the required dynamic stability in the shoulder. Dysfunctional rotator cuff muscles may enhance the role of the m. biceps brachii to provide the required dynamic stability of the shoulder throughout the bowling action. Although m. biceps brachii acts throughout the circumductory motion of the upper limb to maintain elbow extension, it too may become injured and overloaded (Cole *et al*., 2016; Zaremski *et al*., 2017). If there is a lack of stability throughout or at specific intervals of the upper limb's movement, the labrum and supporting ligaments are at greater risk of injury, and this in turn, leads to a greater severity of the injury (Stuelcken *et al.*, 2010).

M. biceps brachii is predominantly active during the ball release phase of the bowler's action, controlling the movement of the upper limb (Uddin & Kenneth, 2014). A study by Wormgoor, Harden & Mckinon (2010) reported that there is a strong link between the ball release speed of the fast bowler and the relative strength of shoulder extension prior to the ball release phase. It could be hypothesised that bowlers with greater strength in the dominant shoulder are able to generate a greater ball velocity at delivery (Wormgoor *et al.,* 2010).

Saw *et al.* (2010) suggest that only 0.75% of total playing time was missed due to shoulder injury among elite Australian cricketers over a 10-year period. However, many upper limb incidences go undetected as minor shoulder injuries may not affect batting and bowling disciplines significantly (Cole *et al*., 2017). Although throwing efficiency may be somewhat impeded, affected players will remain eligible for selection based on their specific role (batting or bowling) within the team. The tendency for players not to report minor shoulder problems is a strong factor related to chronic shoulder pain and continues to be a challenge for team medical staff (Saw *et al.*, 2010; Zaremski *et al*., 2019).

Although research reports reveal that shoulder injuries amongst professional cricketers make up between five and seven percent of all reported injuries, the incidence of shoulder problems is probably underestimated due to under reporting of injuries (Green *et al.,* 2013). The majority of shoulder problems do not require cricketers to be side-lined, but often have an impact on the player's performance (Dutton *et al*., 2019; Green *et al.,* 2013). Quantifying the prevalence of shoulder problems among fast bowlers may be challenging due to the unpredictability of external factors such as player fatigue, travel stress and the common practice of changing beds and pillows when on tour (Olivier *et al*., 2016).

## 2.10 Anthropometrics

The matter of an athlete's anthropometric profile and the suitability to a particular sporting code has been well researched among athletes competing at the highest level in the relevant sporting codes (Johnstone, Mitchell, Hughes, Watson, Ford & Garrett, 2014). Stretch (1993) suggests that there are morphological differences between batsmen, bowlers and all-rounders competing at provincial and international levels. Fast bowlers, for example, have a tendency to be tall, lean and have longer legs than the other role-players (Johnstone *et al*. 2014). Koley (2011) investigated the anthropometric profile of Indian male cricketers and, when compared to the results of the study by Stretch (1993), concluded that the Indian inter-university male cricketers were both shorter and lighter in comparison to cricketers of alternate nationalities. The Indian cricketers additionally reported having lower Body Mass Index (BMI) values and, although contradictory, higher fat percentages (Koley, 2011).

Expanding on the idea of an athlete's anthropometric profile, a study by Jespersen, Verhagen, Holst, Klakk, Heidemann, Trifonov, Franz & Wedderkopp (2013) compared the association between total body fat percentage (TBF%) and BMI on the prevalence of lower extremity injuries among school-going children. Though the populations between Jespersen *et al*., (2013) and the current study are not comparable, no other literature is available. A total of 673 lower extremity injuries were reported in two and a half years, revealing that overweight children (BMI >25) have a greater likelihood of sustaining lower extremity injuries. The study revealed that the measurement of TBF% is a greater risk factor predictor measurement than BMI, as greater adiposity may suggest a lower proportion of lean muscle mass (Jespersen *et al*. 2013). Though the study by Jespersen *et al*. (2013) does not make an association between BMI and shoulder dysfunction, there is room for the current study to determine whether there is an association between greater adiposity and shoulder dysfunction in elite fast bowlers.

## 2.11 Role of the Physiotherapist in Sport

A team physiotherapist has become one of the most important members of the health team that manages a sport team.

A document was compiled through the High-Performance Centre (HPC) of the University of Pretoria, which described the integral role of physiotherapy in sport teams, including outreach in sport, injury prevention, recovery, rehabilitation, teaching and research. The physiotherapist in an advisory capacity would advise the coaching team and professionals regarding actions to avoid any injuries and as part of prevention, and the physiotherapist would be involved in conditioning and training of the athlete. In order to promote optimal recovery, the physiotherapist should aim to regain functionality of the athlete as soon as possible soon to be followed by rehabilitation to regain optimal muscle strength and mobility. The teaching role of the physiotherapist in the team should not be underestimated and should aim to improve knowledge that the athlete and the coaching team needs regarding injury prevention and rehabilitation. A role, which is essential for all involved in sport but sometimes ignored, is that of research. It is the duty of team physiotherapist to conduct research studies that could contribute towards not only the prevention of injuries but also to optimise the treatment and rehabilitation of athletes across all sporting codes (Le Roux, 2020).

Every elite cricket team has a qualified physiotherapist on the medical staff with the intention of minimising missed game time due to injury. A physiotherapist plays an integral role in injury prevention, treatment and rehabilitation of the players in the respective cricket team. It is important for the physiotherapist to have good working relationship with the players to enhance the treatment and player expectations regarding rehabilitation once injured (Quartey, Afidemenyo & Kwakye, 2019). It is required of the physiotherapist to understand the loads and physical demands of cricket and primarily those of a fast bowler who are renowned to be the most injury prone of all cricketers. By gaining insight into the risk factors for shoulder dysfunction, injury management of fast bowlers will be enhanced, and physiotherapeutic treatments improved.

### 2.12 Conclusion

Fast bowlers are naturally susceptible to sustaining various types of injuries throughout their careers. Many shoulder injuries go unnoticed and may impair the bowling and throwing performance of the fast bowlers exponentially. Investigating the intrinsic and extrinsic risk factors surrounding shoulder dysfunction could enhance the management of elite fast bowlers by the responsible physiotherapist, who may further prevent the fast bowler's time out of competition due to injury by gaining knowledge of the respective risk factors that play a role in shoulder dysfunction. The objective of the team physiotherapist should extend beyond treating sport injuries and should encompass a broader perspective of prehabilitaion and restoration of the physical health of the athlete.

The methodology chapter of this study will follow, in which the inclusion and exclusion criteria for this study, ethical considerations, method of the study and the data analysis will be described.

## Chapter 3: Methodology

### 3.1 Introduction

In the methodology chapter, the study's aims and objectives, the study population, sample and testing procedure will be discussed as well as a detailed description of the questionnaire and assessment procedures.

### 3.2 Aims and Objectives of the Study

The aim of the study was to determine the intrinsic and extrinsic risk factors for shoulder dysfunction among elite male fast bowlers older than 18 years of age in South Africa.

In order to achieve the aim, the objectives of the study are set out below.

- Describe the sample demographics including age, height, weight, BMI, limb dominance, gender and prior history of shoulder injury presenting as pain or injury.
- Describe additional intrinsic information forming the participant's profile, including the number of seasons completed, current playing status, other sports currently played, missed game time, treatment received to the shoulder and the level of competition.
- Determine the occurrence of intrinsic risk factors for shoulder dysfunction including: dominant shoulder internal rotation deficit, scapular kinematics, shoulder impingement, posterior capsule tightness and upper limb stability by means of a physical objective assessment of shoulder range of motion, muscle strength and stability.
- Determine the occurrence of extrinsic injury risk factors for shoulder dysfunction at the time of participation in the study including acute and chronic bowling workload, throwing workload, players' primary field position and perceptive overload in terms of bowling and throwing by means of a modified KJOC questionnaire based on published literature.
- Determine the association between the occurrence of shoulder dysfunction and the intrinsic and extrinsic risk factors in particular modifiable risk factors including: bowling and throwing workload values, shoulder strength, stability and flexibility at the time of assessment.

### 3.3 Study Design

A descriptive observational cross-sectional design was used to perform this study.

### 3.4 Sample/Study Participants

#### 3.4.1 Study Population

There was no census or literature indicating the exact number of current fast bowlers in South Africa at the time of the current study. A calculation, based on the modern team selection nature, suggested that in general an average of five fast bowlers were included in a specific team. This was the case for the thirteen senior provincial teams, six franchise teams and one international team in South Africa at the time of data collection. Therefore, it is anticipated by the researcher that there are approximately 100 (5 X 20) elite fast bowlers who are currently playing in South Africa. The teams are summarised below.

**Table 1: List of Elite Cricket Teams in South Africa**

| South Africa International Team | | |
|---|---|---|
| **Senior Provincial Teams** | **Franchise Teams** | |
| Northern Gauteng<br>Southern Gauteng<br>Kwa-Zulu Natal Coastal Region<br>Kwa-Zulu Nata Inland Region<br>Free State<br>Northern Cape<br>North West<br>Western Province<br>Eastern Province<br>South-Western Districts<br>Border<br>Boland<br>Eastern Gauteng | Titans: | Northerns and Easterns Cricket Unions |
| | Lions: | Gauteng and North West Cricket Unions |
| | Knights: | Free State and Northern Cape Cricket Unions |
| | Dolphins: | Kwa-Zulu Natal Coastal and Inland Cricket Unions |
| | Warriors: | Eastern Cape and Border Cricket Unions |
| | Cobras: | Western Cape and Boland Cricket Unions |

The diagram below describes the level of competition of all first-class cricket teams in South Africa.

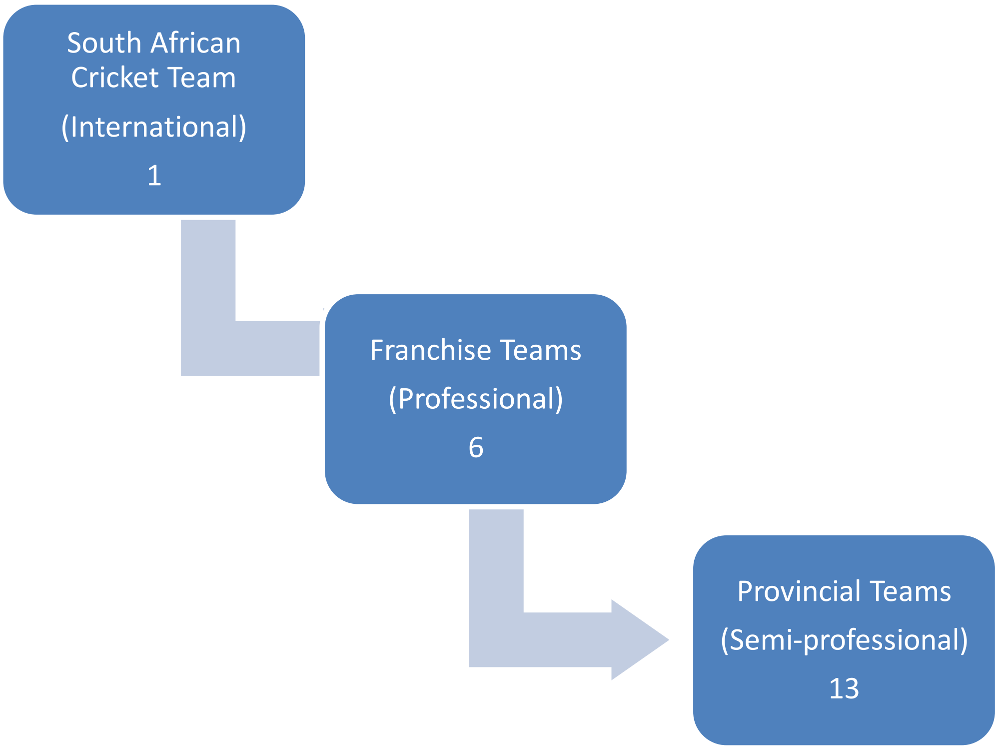



**Figure 6: Summary of First-class Teams in South Africa**

### 3.4.2 Study Sample

A non-randomised, convenience sampling method was utilised in this study. All available fast bowlers within the national team, six franchise teams and their affiliated provincial teams (as outlined in Figure 6 above) were included in the study sample as they were easily accessible to the researcher during the cricket season. The international players to be invited to participate in this study would form part of the franchise teams as no international matches were taking place at the time of data collection. The researcher was based in Bloemfontein, Free State and employed as the Knights franchise team physiotherapist at the time of the study.

Thirty-three participants were invited to participate in the study, depending on each franchise's team selection and the number of injuries reported within each team. Most franchise teams did not travel with injured players, though the players often formed part of the squad when playing a home game and therefore would impact the total population during the time of data collection. An average of five to six fast bowlers were invited per franchise squad depending on the team's selection at the time of data collection. Fast bowlers in the respective teams were deemed easily accessible for the researcher during the end of the 2018/2019 cricket season and constituted a large portion of the gross population.

### 3.4.3 Sample size

The sample size was estimated according to a calculation using an average of five fast bowlers being included in each of the six designated cricket teams. Therefore, a total estimated sample size of 30 elite South African fast bowlers were invited to partake in this study. This number would equate to 30% of the total estimated study population.

## 3.5. Inclusion Criteria

Inclusion criteria for the study are set out below.

- The participants were male cricket players classified as fast bowlers within the respective team. This constituted any player whose primary role in the team was to bowl at a pace of 120km/h or more (Olivier *et al*., 2016). This information was obtained according to available player profiles, whereby a specific player is classified into categories including a batsman, all-rounder, spin bowler or fast bowler.
- It was required of each participant to have played at least one first class, list A or Pro20 match to be eligible for the study. Any cricketer having not played at this level would be considered non-elite and not be included in the study (Olivier *et al.,* 2016).
- Participants were required to be competitively participating in cricket matches during the time frame of the study.
- Participants would be included regardless of their handedness/limb dominance.

### 3.6 Exclusion Criteria

Exclusion criteria for the study appear below.

- Female fast bowlers were not included in the current study as female fast bowlers reportedly sustain significantly less injuries overall compared to male fast bowlers, which would affect the results of this study substantially (Inge, Orchard, Kountouris, Saw, Sims & Saw, 2019).
- Currently injured players who were unable to perform the shoulder testing due to post-operative protocols, excessive pain or immobility of the upper limb experienced during the assessment procedure were also excluded.
- Participants who sustained match time-loss injuries, whereby their selection within the team had been forfeited as a result of their injury as they are not able to bowl (Orchard *et al*., 2016).

### 3.7 Measurement Instruments/Outcome Measures

Fast bowling is unique, and the combination of both bowling and throwing at high velocities and high loads would put stress on the athlete's shoulder which is rather different to any other singular sport played around the world (McNamara *et al*., 2013; Black, Gabbett, Cole & Naughton, 2016). The load on the fast bowler's shoulder may be most similar to those of baseball pitchers in comparison, due to the high velocity and repetitive nature of their throwing actions (Black *et al*., 2016; Dutton *et al*., 2019). Therefore, identification of the most specific measurement tools and specific questionnaires was based largely on the current assessment tools used in throwing athletes. The measurement tools used in the current study are described in more detail below.

#### 3.7.1 Survey-based Outcomes

There are several survey-based measurement outcomes described in the available literature to determine upper limb dysfunction and post-operative wellness of the shoulder among various sportsmen.

A frequently used questionnaire for assessing shoulder pain and musculoskeletal disorders is the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire (Rysstad, Røe, Haldorsen, Svege & Strand, 2017). A study by Radwan & Schultheiss (2016) compared the

DASH questionnaire and the Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow score (KJOC) questionnaire in quantifying shoulder functionality. Both measures were found to be sensitive, reliable and specific to determining the prevalence of shoulder dysfunction (Radwan & Schultheiss 2016). Despite the DASH being easier and taking less time to complete than the KJOC, both share an equal effectiveness as measurement tools for assessing shoulder functionality (Radwan & Schultheiss, 2016; Rysstad *et al*. 2017).

It is clear from the literature that the KJOC questionnaire is effective in differentiating between participants with current shoulder pain, those currently playing with pain and those without any pain (Kraeutler, Ciccotti, Dodson, Frederick, Cammarota & Cohen, 2013; Merolla, Corona, Zanoli, Cerciello, Giannotti, & Porcellini, 2017; Radwan & Schultheiss, 2016). The KJOC has also been used in the assessment of baseball pitchers who are subjected to high throwing loads (Radwan & Schultheiss, 2016). The assessment of baseball pitchers may be similar to that of the fast bowler in terms of the distraction forces generated during the arm acceleration phase of the throwing and bowling action (refer to Figures 4 and 5 respectfully), whose load is two-fold (Black *et al*., 2018), hence the reason for using the KJOC as the platform for the current study's survey-based outcome measures.

### 3.7.2 The Modified KJOC Questionnaire

The questionnaire (Appendix A) used in this study was modified by the researcher based on published literature as outlined in the literature overview section of this study. Additional questions were added to the KJOC questionnaire by the researcher in order to make it more specific to this study. These questions included participant demographics, including age, height, weight and limb dominance in order to create a more holistic profile of the participants. The terminology of the KJOC was also modified by the researcher from being baseball-specific to being cricket-specific, to ensure that the questionnaire was more relatable for the participants and to ensure that they would be able to answer questions more accurately. Phrases such as 'major league' were changed to 'first-class' and 'pitcher' changed to 'bowler'. The mentioned modifications are highlighted in Appendix A and did not alter the reliability of the questionnaire as the main components remained unchanged.

The modified KJOC questionnaire obtained demographic information of the study participants in order to create a participant profile and to obtain information to compare between the two study groups, including age, handedness/limb dominance when bowling and throwing, height, weight and previous seasons played at an elite level. The participants' height and weight were not measured by the researcher, but recorded according to the measurements on the players' previous musculoskeletal assessment which is taken according to their respective cricket union's seasonal screening. The participants were asked to write down their height and weight measurements recorded on their latest screening, and if they were unsure of these, the measurements were measured using a floor scale and measuring tape. The participants BMI was subsequently calculated by the researcher according to calculation: BMI = weight (kg)/height ($m^2$) (Koley, 2011). The sample demographics served as non-modifiable risk factors in this study.

Information regarding the modifiable risk factors for shoulder dysfunction was obtained by means of the questionnaire. Questions related to the participants' current shoulder health were asked together with the amount of limitation (if any) the shoulder had on their current cricket performance. The participants were questioned about any prior shoulder injury or pain that might have occurred during their professional career and if the injury had been sustained during training or match play. Questions were also posed to participants to determine whether the self-reported prior shoulder injuries or pain that might have occurred had been specifically cricket related or not. The researcher also deemed it necessary to enquire whether the participant was, or was not, playing at the same level at the time of the study, and if so if they felt that their shoulder played a role in that being the case. Furthermore, the participants were also asked to state whether or not they felt as if they threw or bowled too much on a weekly basis. Participants were provided with the opportunity to state whether or not they felt at the time of the study that their throwing and bowling requirements predisposed them to experiencing shoulder dysfunction.

A self-reported acute bowling workload was calculated by the researcher by subjectively obtaining the estimated number of balls bowled during one week by the participant during the time leading up to the data collection. The chronic bowling workload was calculated by the researcher in the same manner for each participant by means of determining the average number of balls bowled per week over four consecutive weeks leading up to the time of the study.

Additionally, a self-reported perceived exertion rating (RPE) which was scaled from 1 to 10, accompanied the number of balls bowled (as seen on Appendix A). The number '10' on the scale was deemed to be maximal exertion, where the participant could not exert more effort, and a zero value was deemed as minimal or no exertion (Gabbett, 2016). This was done in order to determine the intensity of the balls bowled by each participant. The average workload value was calculated by the researcher in which the two values obtained (acute bowling workload and RPE) were multiplied together (Hulin *et al*., 2013). For example, if a fast bowler reportedly bowled an average weekly total of 120 balls at an average RPE of 8/10, the average workload value would amount to 960 (120 X 8).

Throwing workload of participants were obtained in a similar manner. Subjective questions were posed in the questionnaire to participants in order to estimate the number of balls thrown during fielding practice, warm-up drills and as throw down exercises respectively. An RPE value was linked to the value as previously described with the bowling workload in order to obtain a throwing workload value (Saw *et al*., 2010).

The questionnaire obtained information which, according to the conceptual definition of shoulder dysfunction used in this study, were able to categorise participants into the shoulder dysfunction and non-shoulder dysfunction group. The assessment procedure followed and additionally classify the participants into two groups, which will be used to compare the results obtained as set out in the next chapter.

### 3.7.3 The Assessment

The shoulder assessment followed the completion of the questionnaire and was conducted by the researcher, who is a qualified musculo-skeletal physiotherapist who had been appointed as a cricket team physiotherapist for two years and who had shared experience with head physiotherapists in the Cricket South Africa management in terms of musculo-skeletal screening procedures, and registered with the Health Professions Council of South Africa (HPCSA). This added to the reliability of the results obtained by the assessment procedure. The assessment procedure, as mentioned, took place in the provided medical room or change room area, where a plinth was available. The necessary patient privacy was ensured at all times by using screens or curtains in the area. All available fast bowlers were assessed according to a standardised screening evaluation, whereby each test was performed in the same manner and in the same order for each participant. The assessment procedure addressed the specific intrinsic risk factors associated with the identified shoulder problems.

The intrinsic risk factors that were assessed included:

- bilateral glenohumeral internal rotation (Manske *et al*.,2013);
- bilateral glenohumeral external rotation (Manske *et al*.,2013);
- shoulder impingement Brukner & Khan, 2017); and
- shoulder girdle stability (Lee & Kim, 2015).

According to Asker *et al*. (2018), in order to consider an athlete having a shoulder problem, the athlete should present with any of the following: sub-acromial impingement, labral tears or damage, instability and rotator cuff tendon pathology as the presence of these disorders would determine whether the participant has a shoulder problem or not.

The identified intrinsic injury risk factors were assessed among the study participants according to the assessment procedure outlined above and the data was obtained in conjunction with the extrinsic risk factors and demographic data obtained by the modified KJOC questionnaire in order to determine if the participants meet the conceptual definition of shoulder dysfunction.

The equipment required for the assessment procedure included a plinth in order to position the participant optimally for accurate measurements, strips of rigid tape to mark the respective hand position areas for the CKCUES test and other measurement tools consisting of:

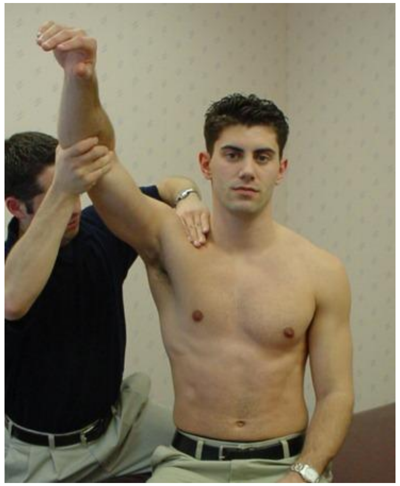
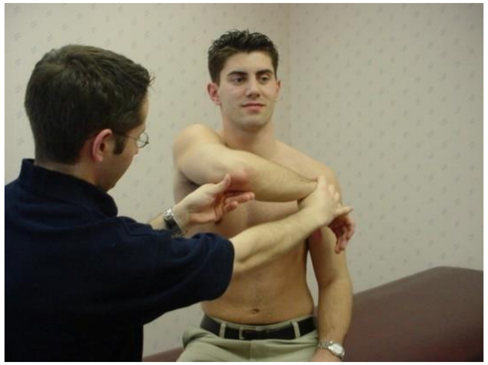
- a goniometer to measure range of motion objectively and reliably (Kolber & Hanney, 2012);
- a measuring tape to measure the exact distance used for the CKCUES test (91,4 cm) and participant height;
- an electronic floor scale used to measure participant weight; and
- a stopwatch was used to time the test accurately (Lee & Kim, 2015).

The specific tests which were carried out in this procedure are described in detail in Table 2.

**Table 2: Description of Assessment Tests**

| TEST | METHOD | ASPECT ASSESSED | EXAMPLE |
|---|---|---|---|
| Glenohumeral Internal Rotation | Participant lying supine on a plinth with the participant's upper limb perpendicular to level of the plinth. The olecranon process used as the '0' point on the goniometer. A passive shoulder internal rotation was measured at end range with the goniometer, which objectively measured glenohumeral internal rotation range of motion in degrees. The test was conducted on both shoulders to compare any differences to the dominant shoulder. | GIRD<br>Posterior capsule tightness<br>(15-20° deficit compared to non-throwing arm). | <br>(Brukner & Khan, 2017) |
| Glenohumeral External Rotation | Participant lying supine on a plinth as with the internal rotation assessment, with the participant's upper limb perpendicular to level of the plinth. The olecranon process used as the '0' point on the goniometer. Passive shoulder external rotation was measured at | GIRD | (Brukner & Khan, 2017) |

| | | | |
|---|---|---|---|
| | end range with a goniometer and measurements between the dominant and non-dominant shoulders were obtain as with the internal range test. | | |
| Closed Kinetic Chain Upper Extremity Stability Test<br><br>(CKCUEST) | Two strips of tape, 3.8 cm in width, were placed on the floor parallel to each other 91.4 cm apart. The test was started with the participant's hands on each strip obtaining the 'push up' position. The participant was instructed to use alternate hands to reach across and tap the opposite hand as many times as possible within a 15 second-time frame. The opposite hand had to repeat the same movement once the hand had reached the starting position. The researcher will observe that the participants maintain good mechanics throughout the execution of the test, ensuring optimal lumbo-pelvic stability and minimal movement of the feet in the push-up plank position. Normal value is total of 25 repetitions within 15 seconds. | Dynamic scapula-thoracic stability and shoulder girdle strength. | <br><br>(Lee & Kim, 2015). |

| | | | |
|---|---|---|---|
| Neer's Test | The participant was seated with the scapula stabilised by the researcher while passively elevating the shoulder looking for sub-acromial pain (positive sign) by attempting to compress the participant's humeral head into the acromion. The presence of sub-acromial pain is indicative of a positive test. | Sub-acromial impingement |  (Brukner & Khan, 2017) |
| Hawkins-Kennedy Test | The participant was seated with his shoulder placed in 90° shoulder flexion by the researcher and 90° elbow flexion. The researcher then internally rotated the arm. The presence of sub-acromial pain is indicative of a positive test. | Sub-acromial impingement |  (Brukner & Khan, 2017) |

| | | | |
|---|---|---|---|
| Apprehension-relocation Test | With the participant in sitting, the researcher placed the participants’ arm in 90° shoulder abduction and 90° elbow flexion. The researcher passively externally rotated the arm searching for any sign of apprehension or withdrawal. The test was then repeated with the researcher applying downward pressure on the glenohumeral joint. | Glenohumeral instability (Anterior) |  (Brukner & Khan, 2017) |
| Empty can Test | The participant was seated and asked to elevate both arms to 90° flexion and abduct 30° pointing their thumbs downward. The researcher provided a downward resistive force to test the participant’s resistive strength in this position, searching for pain in the shoulder joint when the force was applied by the researcher. | SLAP lesions |  (Brukner & Khan, 2017) |

| | | | |
|---|---|---|---|
| O'Brien's Test | The participant was seated and placed one arm in 90° shoulder flexion, 40° horizontal adduction and maximal internal rotation. The researcher applied downward resistive pressure on the wrist searching for pain in the shoulder. | SLAP lesions<br>Labral pathology<br>Acromioclavicular pathology | <br>(Brukner & Khan, 2017) |
| Speed's Test | The participant was seated with their shoulder flexed to 45°, elbow fully extended and in supination, the researcher then applied a downward manual resistance on the participant's forearm. The test is considered to be positive is pain is reproduced in the bicipital groove or in the region of the bicep tendon (anterior shoulder). | Long head of m. biceps brachii pathology<br>Superior Labral Tears<br>Bicipital Tendonitis | <br>(Brukner & Khan, 2017) |

Glenohumeral internal and external rotation ranges of the study participants were compared to normative values as set out in Table 3 below, which indicates the normative glenohumeral internal and external rotation values for professional baseball pitchers (Manske *et al*., 2013).

**Table 3: Normative Range of Motion Measures (in Degrees) for Overhead Athletes**

| Dominant Arm | Non-Dominant Arm | 'N' | Population/Age |
|---|---|---|---|
| ER: 132+11 | 127+11 | 369 | Professional Baseball Pitchers<br>Mean Age: 25.6 years |
| IR: 52+12 | 63+12 | | |
| **TR: 184** | | | |

"N" - total population included in the testing of the study by Manske *et. al.* (2013)

ER – external rotation

IR – internal rotation

TR – total range

### 3.7.4 Classification of Participants

The conceptual definition for shoulder dysfunction for the current study is defined by an abnormality or impairment in the normal functioning of the shoulder girdle, including the occurrence of any **one** of the following factors:

- the participant currently living with shoulder pain or injury impairing their cricketing performance (Winter, Hawkins & Richard, 2014);
- the participant having missed game time in the last season due to shoulder problems;
- a previous medical history of repetitive shoulder injuries (Winter *et al*., 2014);
- an asymmetrical Glenohumeral Total Range of Motion (TROM) difference of >5° between the dominant and non-dominant shoulders (Manske, Wilk, Davies, Ellenbecker & Reinold, 2013).
- a Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) outcome of <25 repetitions (Lee & Kim, 2015); and
- a positive sign, on any single shoulder impingement tests on the participant's dominant shoulder compared to the non-dominant shoulder, including; Neer's, Hawkins-Kennedy, O'Brien's, empty can and Speed's test (Brukner & Khan, 2017).

### 3.7.5 Validity and Reliability of the Tests

There is a lack of available literature regarding evidence-based shoulder assessment tests used by practitioners (Gismervik, Drogset, Granviken, Rø & Leivseth, 2017). Gismervik *et al.* (2017) conducted a systematic review and meta-analysis on the validity of shoulder diagnostic tests used by medical practitioners including physiotherapists. The study suggested the use of specific physical examination tests of the shoulder (PETS) including: the anterior apprehension test for SLAP lesions with a sensitivity of 0.74 (0.61, 0.84) and specificity value of 0.45 (0.35, 0.55), Hawkins-Kennedy test for subacromial impingement with a sensitivity value of 0.58 (0.50, 0.66) and specificity value of 0.67 (0.47, 0.83) and empty can test for rotator cuff tears with the sensitivity value of 0.74 (0.39, 0.92) and specificity value of 0.77 (0.69, 0.83), rather than other shoulder assessment tests.

Tucci, Martins, Sposito, Camarini & de Oliveira (2014) conducted a study investigating the reliability of the CKCUES test in people without subacromial impingement. Tucci *et al*. (2014) concluded that the CKCUES test is reliable when assessing upper extremity stability in sedentary and sport specific males and females. A test-retest reliability test of the CKCUES test by Goldbeck & Davies (2000) confirmed a high reliability (0.92) for the CKCUES test in male athletes.

However, Apeldoorn, Den Arend, Schuitemaker, Egmond, Hekman, Van Der Ploeg, Kamper, Van Tulder & Ostelo (2019) suggested that the majority of shoulder assessment tests show insufficient reliability. This was confirmed by May, Chance-Larsen, Littlewood & Saad (2010), who stated that there is definitely a lack of evidence regarding the reliability of all shoulder assessment tests despite still being used by clinicians.

Future research will need to investigate the reliability and validity of the shoulder assessment measures to further enhance the quality of shoulder injury assessment. Despite the current uncertainty regarding the shoulder tests, using the same tests would create constancy and create a form of comparison among participants and ultimately provide measures to identify abnormalities in the shoulder girdle functioning.

### 3.8 Pilot Study

Two Bloemfontein-based elite fast bowlers were included in the pilot study which took part prior to the commencement of the domestic Pro20 competition in April 2019. The pilot study took place in the team change room area at the Mangaung Oval in Bloemfontein, Free State. The aims of the pilot study were:

- to determine the feasibility and acceptability of the questionnaire;
- to determine the feasibility and acceptability of the assessment procedure;
- to calculate the time required for the study participants to read the information document, sign the informed consent form and have an opportunity to ask any necessary questions related to taking part in the study; and
- to determine the timeframe required for a participant to complete the questionnaire and for the researcher to execute the relevant assessment procedure, which will be necessary information to provide to participants prior to signing informed consent.

The pilot study followed the same procedures as set out for the main study including both completing the questionnaire and assessment procedures. It was evident that the questionnaire and assessment procedure were well understood by the study participants, and a total completion time of seven minutes was required for reading the information document and signing the informed consent document. The total time taken for the questionnaire to be completed and the assessment procedure to be executed was approximately 25 minutes per participant. No further problems related to conducting the study were encountered during the pilot study. Thus, no modifications were made to the questionnaire or to the assessment procedure and therefore the results that were obtained from the two pilot study participants were automatically included in the final study.

### 3.9 Testing Procedure

The study's data collection took place at the relevant cricket stadiums which hosted the Knights team during the 2018/2019 domestic cricket season. The study proceeded during the respective team's training session, the day prior to the respective match.

The participants were identified by a player profile sheet made available by the team's head coach or manager, which delineated each player's primary role in their respective team. The participants were ultimately classified as fast bowlers if their primary role within the team was to bowl at speeds exceeding 120km/h as stipulated in the inclusion criteria of the study.

The participants, once identified as being fast bowlers, were approached at the beginning of the training session on the day prior to the respective match was scheduled and provided with the information document. The information document (Appendix D) outlined the reason for the study being conducted and explained why each participant was encouraged to participate. The information document clearly indicated the associated risks and benefits associated with participating in the study and the participants were assured that they would not be penalised in any way if they did not voluntarily agree to take part in the study. This process was done in the available team room or change room area at each stadium.

The study was explained step by step to the participants by the researcher before they started to complete the questionnaire. The questionnaire was completed in the presence of the researcher to ensure consistency in the answering of the questions and also allowed the researcher to answer any questions which the participants might have had prior to participating in the study. The participant was taken to the allocated testing room once the questionnaire had been completed and the assessment procedure was conducted by the researcher as set out in the assessment section in this chapter. The designated testing room was the stadium medical room or change room where optimal privacy for the participant was ensured by being isolated in the room.

Each participant was assigned a study number once they had started the study to ensure confidentiality throughout the study. Only the researcher had access to the master list, which correlated the participant's name and study number, throughout the study. Participants were asked to remove their shirt during the assessment procedure. This was outlined in the informed consent, which was signed by each participant before participating in the study.

The researcher followed a standardised assessment procedure with each participant where each test was performed utilising the same technique and in the same order throughout the evaluation process. The testing techniques and specific order of execution of each test is set out in more detail in Table 2.

The results from each test were recorded and written down by the researcher on a structured evaluation form (Appendix E). Once the questionnaire and evaluation procedures had been completed for a particular participant, the two corresponding forms for each participant were securely filed according to the participant's study number, which had been assigned by the researcher. The data obtained by the questionnaire and from the assessment procedure was transferred onto an Excel spreadsheet by the researcher and double checked by the researcher one day later to ensure no errors had occurred during the process. The data was then handed in to the allocated biostatistician from the Department of Biostatistics at the University of the Free State, for data analysis.

The flow diagram (Figure 7) below depicts the testing procedure followed during the study.

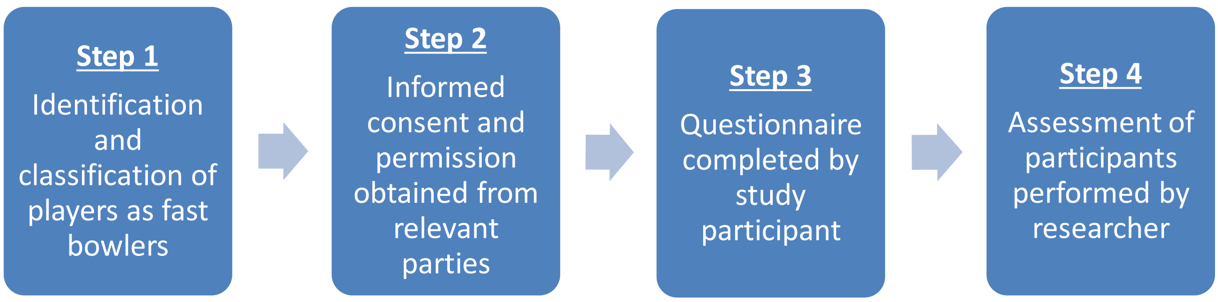



**Figure 7: Flow Diagram of the Testing Procedure**

**3.10 Statistical Analysis and Data Management**

Data analysis was performed by the Department of Biostatistics at the University of the Free State. Descriptive statistics, namely frequencies and percentages for categorical data, medians and percentiles for numerical data were calculated. The prevalence of shoulder dysfunction was calculated and described by means of 95% confidence intervals. Shoulder dysfunction or non-shoulder dysfunction were associated by means of the Fisher's Exact Test for categorical data and the Kruskal-Wallis Test for numerical data. The risk factors of shoulder dysfunction among elite male fast bowlers in South Africa were calculated and described by means of 95% confidence intervals.

### 3.11 Ethical Considerations

The study conformed to the principles of the Declaration of Helsinki (World Medical Association, 2013). Ethical approval was obtained from the HSREC (Contact: +27 51 401 9111) of the Faculty of Health Sciences at the University of the Free State (Appendix F), with the ethical clearance number: *UFS-HSD2019/0182/2506*. Permission was obtained from the respective franchise Chief Executive Officers (CEOs) (Appendix G) before commencing with the pilot and full study respectively. Informed consent to participate in the study was obtained by all the study participants (Appendix B).

Participants were made aware prior to commencement of the study that participation was voluntary and non-participation would not affect their team selection in any manner. The participants were informed that they could withdraw from the study at any stage without being penalised in any way. A brief information document (Appendix D) was issued to the participant which provided background information and context as to why the study was being conducted. An informed consent form complying with the elements required by the HSREC at the University of the Free State was read by the participants and signed before they took part in the study.

Participants were made aware of the fact that their shirts would have to be removed during the assessment procedure of the study. The participants' privacy was ensured prior to the removal of their shirt by means of conducting the assessment in an enclosed area. No form of remuneration was offered to the participants who participated in the study.

If any tests were found positive, or any clinically significant findings were detected during the evaluation procedure, the participants were notified via email by the researcher following the completion of the evaluation. The participants were made aware that it was their prerogative to share the information with their respective team physiotherapist if they preferred to do so.

Each study participant was assigned a study number in the order in which they had participated. This study number ensured confidentiality of the participant and aligned with a master list of the participants name and the assigned study number. This was done to link any positive findings and the participants' name, should a report be sent to the respective team physiotherapist. No other person had access to the master list, and it was securely filed and kept by the researcher for the duration of the study. Once the necessary study documentation had been completed by a participant, the documents were filed according to study number in a physical file held by the researcher and stored securely in a locked office.

The data was transferred from the documents onto an Excel spreadsheet by the researcher, and repeated a day later to ensure accuracy of the data which was transferred. The spreadsheet was sent to the Department of Biostatistics at the University of the Free State, in which only the study number was associated to the relevant data which was recorded. The data was analysed by the respective biostatistician and returned to the researcher who was then able to investigate the results for discussion and recommendation purposes.

All data has been stored in a safe and secure area and will be kept for seven years following the time of the study, according to good clinical research practice. The data has been stored on a password-protected computer and no name is identifiable on the data as only the participants' study number is linked to the data. Raw data may be accessible should a reviewer require any data, though the names of participants will be kept anonymous as only the study number will be made available. No information will be made available to anyone else besides the researcher, unless required by law.

All the study documentation, including the appendices, were available in English. This was possible as all the participants were contracted by their relevant cricket unions, who offer contractual documentation in English according to Cricket South Africa (CSA) regulations. It may then be considered that all the participants, who have previously understood and signed their contracts of employment through their cricket unions, were sufficiently literate to take part in the study should the documentation be written in English. Should any case of illiteracy or misunderstanding present, the researcher will be available to verbally explain all information documentation and assist with the completion of all documentation which is required for participation in the current study. The pilot study participants proved to have had no problems reading the information document and completing the questionnaire.

### 3.12 Conclusion

This study set out to serve as a baseline study for further research regarding shoulder injury prevention in fast bowlers and hopefully contribute to prolonging the careers of many upcoming fast bowlers. The methodology outlined the questionnaire and assessment procedure in detail in order to obtain the necessary data to classify the study participants into a shoulder dysfunction and non-shoulder dysfunction group. The results and comparisons between the two groups will follow in the results chapter.

# Chapter 4: Results

## 4.1 Enrolment of Study Participants

Thirty-three elite male South African fast bowlers who met the inclusion criteria were enrolled in the current study. All the participants (N=33) completed both the questionnaire and the assessment procedure of the study as outlined in the methodology chapter. There were no participants who dropped out of the study, voluntarily left or who were excluded during the data collection of the study. Non-parametric tests (the Kruskal-Wallis test) were used to identify statistical differences between the groups and the two-sided Fisher's Exact test was used to identify associations between risk factors and shoulder dysfunction in this study.

## 4.2 Classification of Participants into Shoulder Dysfunction and Non-shoulder Dysfunction Groups

The participants were classified as either having shoulder dysfunction, or not, by the prevalence of any one injury risk factor which was identified at the completion of the questionnaire and assessment procedure as per the conceptual definition of shoulder dysfunction. The participants were further compared in terms of a 'Shoulder Dysfunction' and a 'Non-Shoulder Dysfunction' group throughout the results chapter in this study.

Table 4 depicts the prevalence of positive shoulder impingement tests and the CKCUES test values to determine upper limb instability. A '+' indicates a positive test where symptoms or pain were reproduced in the shoulder of the participant specific to each test. A positive would ultimately classify the respective participant into the shoulder dysfunction group. A '-' indicates a negative test, where no symptoms or pain in the shoulder were reproduced. The '-' or '+' signs were stated for bilateral shoulders in Table 4 in the format of left shoulder/right shoulder as indicated by 'L/R' in the table below the name of the test. Therefore "-/-" indicated that the left and the right shoulder is both negative. Participants in the non-shoulder dysfunction group were clear of any positive tests. The shoulder dysfunction and non-shoulder dysfunction groups are set out in Table 4.

The first column where a ‘yes’ is an indicator of the participants within in the shoulder dysfunction group and ‘no’ an indicator of the participants in the non-shoulder dysfunction group respectively. The headings of the table, from left to right, include: Neer’s, Hawkins-Kennedy, Apprehension-relocation, Empty-can, O’Brien’s, Speeds and the CKCUES test. These tests are followed in the table by values for the frequency (*f*), percentage (%), cumulative frequency (*f)* and cumulative percentage (%).

**Table 4: Prevalence of Shoulder Impingement and Instability**

| Shoulder Dysfunction | Neer's L/R | Hawkins- L/R | Apprehension L/R | Empty L/R | O'Briens L/R | Speed's L/R | CKCUEST L/R | *f* | % | Cumulative *f* | Cumulative % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 23 * | 1 | 3.03 | 1 | 3.03 |
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 24 * | 4 | 12.12 | 5 | 15.15 |
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 25 | 1 | 3.03 | 6 | 18.18 |
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 28 | 4 | 12.12 | 10 | 30.30 |
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 30 | 1 | 3.03 | 11 | 33.33 |
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 34 | 1 | 3.03 | 12 | 36.36 |
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 21 * | 1 | 3.03 | 13 | 39.39 |
| Yes | -/- | -/- | -/- | -/- | -/+ * | -/- | 26 | 1 | 3.03 | 14 | 42.42 |
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 27 | 1 | 3.03 | 15 | 45.45 |
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 28 | 1 | 3.03 | 16 | 48.48 |
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 32 | 1 | 3.03 | 17 | 51.52 |
| Yes | -/- | -/- | -/- | +/- * | +/- * | -/- | 25 | 1 | 3.03 | 18 | 54.55 |
| Yes | -/- | -/+ * | -/- | -/- | -/- | -/- | 30 | 1 | 3.03 | 19 | 57.58 |
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 27 | 1 | 3.03 | 20 | 60.61 |
| Yes | -/- | -/- | -/- | -/- | -/- | -/- | 30 | 1 | 3.03 | 21 | 63.64 |
| Yes | -/- | -/- | -/- | -/- | +/- * | -/- | 25 | 1 | 3.03 | 22 | 66.67 |
| Yes | +/- * | -/- | +/- * | +/- * | +/- * | -/- | 17 * | 1 | 3.03 | 23 | 69.70 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No | -/- | -/- | -/- | -/- | -/- | -/- | 28 | 1 | 3.03 | 24 | 72.73 |
| No | -/- | -/- | -/- | -/- | -/- | -/- | 30 | 3 | 9.09 | 27 | 81.82 |
| No | -/- | -/- | -/- | -/- | -/- | -/- | 30 | 1 | 3.03 | 28 | 84.85 |
| No | -/- | -/- | -/- | -/- | -/- | -/- | 26 | 1 | 3.03 | 29 | 87.88 |
| No | -/- | -/- | -/- | -/- | -/- | -/- | 34 | 1 | 3.03 | 30 | 90.91 |
| No | -/- | -/- | -/- | -/- | -/- | -/- | 29 | 1 | 3.03 | 31 | 93.94 |
| No | -/- | -/- | -/- | -/- | -/- | -/- | 28 | 1 | 3.03 | 32 | 96.97 |
| No | -/- | -/- | -/- | -/- | -/- | -/- | 31 | 1 | 3.03 | 33 | 100.00 |

*** indication of abnormality**

**+ positive test**

**- negative test**

Seven of the 23 participants (30.4%) who were classified as having shoulder dysfunction in this study had CKCUES test scores below the average value of 25. Five of the seven (71.4%) participants with sub-optimal CKCUEST scores (<25) had no positive shoulder impingement tests on either shoulder.

All participants within the non-shoulder dysfunction group were free from shoulder impingement on either shoulder and, in addition, obtained CKCUEST scores of ≥25 repetitions. None of the study participants showed signs of bicipital tendonitis, presenting with negative Speed's tests for all the participants within both groups.

Additionally, glenohumeral TROM also had to be considered in order to classify shoulder or non-shoulder dysfunction in participants. Please refer to Table 5 on the following page for the results.

**Table 5: Comparison of Glenohumeral TROM**

| Shoulder Dysfunction | TROM Left | TROM Right | *f* | % | Cum. f | Cum. % |
|---|---|---|---|---|---|---|
| Yes | <Normal * | <Normal * | 1 | 3.03 | 1 | 3.03 |
| Yes | Normal | Normal | 1 | 3.03 | 2 | 6.06 |
| Yes | Normal | Normal | 1 | 3.03 | 3 | 9.09 |
| Yes | >Normal* | <Normal * | 1 | 3.03 | 4 | 12.12 |
| Yes | >Normal* | Normal | 1 | 3.03 | 5 | 15.15 |
| Yes | <Normal * | <Normal * | 1 | 3.03 | 6 | 18.18 |
| Yes | Normal | <Normal * | 2 | 6.06 | 8 | 24.24 |
| Yes | Normal | Normal | 4 | 12.12 | 12 | 36.36 |
| Yes | Normal | >Normal * | 1 | 3.03 | 13 | 39.39 |
| Yes | Normal | >Normal* | 1 | 3.03 | 14 | 42.42 |
| Yes | >Normal * | <Normal * | 1 | 3.03 | 15 | 45.45 |
| Yes | >Normal * | <Normal * | 2 | 6.06 | 17 | 51.52 |
| Yes | >Normal * | Normal | 2 | 6.06 | 19 | 57.58 |
| Yes | >Normal * | >Normal * | 1 | 3.03 | 20 | 60.61 |
| Yes | >Normal * | >Normal* | 1 | 3.03 | 21 | 63.64 |
| Yes | >Normal* | <Normal * | 1 | 3.03 | 22 | 66.67 |
| Yes | >Normal* | Normal | 1 | 3.03 | 23 | 69.70 |
| No | Normal | Normal | 10 | 30.30 | 33 | 100.00 |

***indication of abnormality**

Four of the 23 participants (17.39%) within the shoulder dysfunction group presented with a right-sided glenohumeral TROM of greater than 186°, which may be considered an absolute value in terms of TROM measurement (Manske *et al*., 2013). Two participants presented with a left-sided glenohumeral total rotational range of greater than 186°. The participants who presented with absolute ROM values presented with the finding in one shoulder only, none of the participants presenting with absolute values presented with absolute values bilaterally. Eleven participants in the shoulder dysfunction group (47.83%) presented with right glenohumeral TROM values greater than the normal range of 150°-180°, whereas only two of the participants (8.7%) in the same group presented with ranges less than normal. Four of the participants (17.39%) in the shoulder dysfunction group presented with left glenohumeral TROM values higher than the normal values, whereas nine presented with values less than the normal values.

Figure 8 below depicts the number of participants who were classified as having shoulder dysfunction and those with non-shoulder dysfunction in the current study.

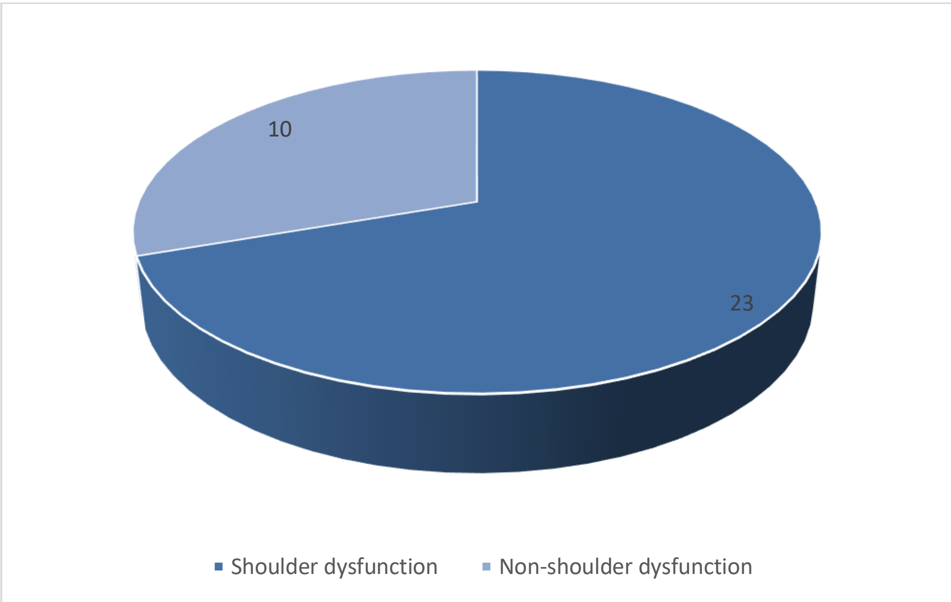



**Figure 8: Participants with Shoulder Dysfunction and Non-shoulder Dysfunction (N=33)**

A total of 23 participants (69,7%) were classified by the researcher as having shoulder dysfunction and ten (30,3%) participants having no shoulder dysfunction. This classification was based on the prevalence of risk factors identified by the researcher.

## 4.3 Comparison of Demographic and Anthropometric information of participants with shoulder dysfunction and without shoulder dysfunction

### 4.3.1 Participant Age

Participant age and anthropometric information of participants within both the shoulder dysfunction and non-shoulder dysfunction groups were not normally distributed, and non-parametric tests (Kruskal-Wallis test) were used to compare the groups. The median age of the participants in the shoulder dysfunction group (n=23) was 26 years (interquartile range: 24-30 years, and range 18-36 years). The median age of the non-shoulder dysfunction group (n=10) was 25 years (interquartile range: 22-27 years, and range 18-30 years). There was no statistically significant difference (p=0.175) between the two groups regarding age. The p-value was set as $< 0.05$ for the study.

### 4.3.2 Participant BMI

The BMI values for the participants were not normally distributed either (K-S d = 0.905, $p < 0.001$). The median BMI of the participants in the shoulder dysfunction group (n=23) was 25 (interquartile range: 23-27, and range 19-35). The median BMI of the non-shoulder dysfunction group (n=10) was 24 (interquartile range: 24-26, and range 20-29) and revealed no statistically significant difference (p=0.388) between the two groups regarding BMI. The Fisher's Exact test indicated a p=0.710 revealing no association between BMI and shoulder dysfunction. The relative risk (RR) was 0.889 with 95% CI [0.579; 1.387] indicating that BMI is not considered to be a risk factor for shoulder dysfunction.

### 4.3.3 Comparison of Participant's Hand Dominance

Figure 9 below indicates the number of left-hand and right-hand dominant participants within the shoulder dysfunction group, as well as those participants within the non-shoulder dysfunction group.

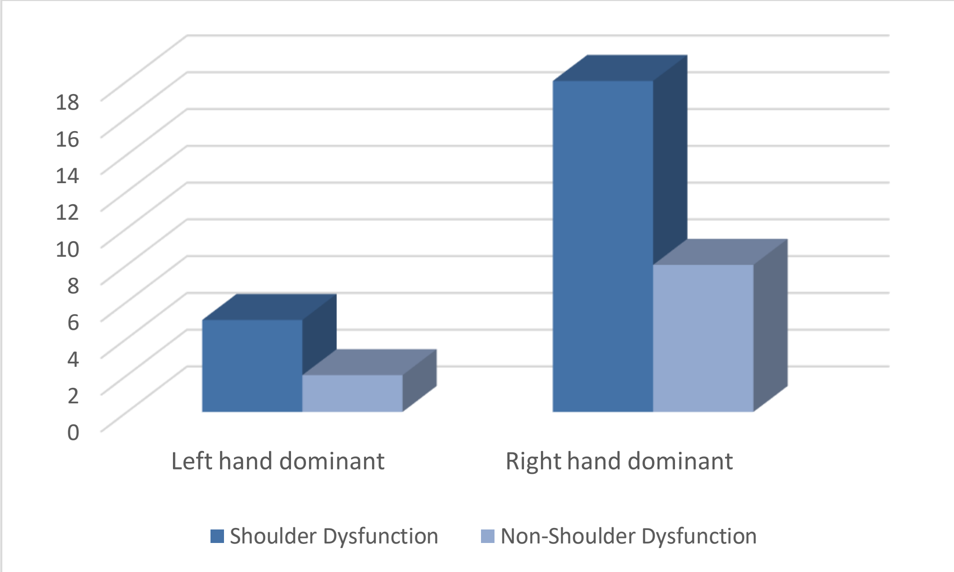



**Figure 9: Participant's Hand Dominance with Shoulder Dysfunction (n=10) and Non-Shoulder Dysfunction (n=23)**

There was a high prevalence of right-handed dominance within both groups, with 18 participants (78.3%) in the shoulder dysfunction group and eight participants (80%) within the non-shoulder dysfunction group. There was no statistically significant difference between the two groups regarding the risk factor of hand dominance. There was also no association between hand dominance and shoulder dysfunction found as indicated by the two-sided Fischer's Exact test (p=1.000). The RR value was 1.032 with 95% CI [0.605; 1.760] indicating that hand dominance was not found to be a risk factor for shoulder dysfunction in this study, but was not statistically significant, as 1 is included in the confidence interval of the relative risk.

### 4.3.4 Playing Profile of Participants

The remaining intrinsic information was also obtained utilising the questionnaire and created a playing profile for each participant based on their current playing status.

#### 4.3.4.1 Number of Seasons Played

The first question posed to the participants regarding their playing profile was the number of professional cricket seasons that they had played. The number of seasons played for participants in both the shoulder dysfunction and non-shoulder dysfunction groups were not normally distributed and non-parametric tests (Kruskal-Wallis test) were used to compare the two groups. The median number of seasons the participants in the shoulder dysfunction group played (n=23) was six seasons (interquartile range: 4-11 seasons, and range 0 -18 seasons played). The median number of seasons played for the non-shoulder dysfunction group (n=10) was one and a half seasons (interquartile range: 1-6 seasons, and range: 0-9 seasons played). The Kruskal-Wallis test indicated a statistically significant difference between the two groups in relation to the number of seasons played (p= 0.020). Please refer to Table 6and Table 7below.

**Table 6: Number of Seasons Played by the Shoulder Dysfunction Group (n = 33)**

| Number of Seasons | *f* | % | Cum. *f* | Cum. % |
|---|---|---|---|---|
| 0 | 2 | 8.70 | 2 | 8.70 |
| 1 | 1 | 4.35 | 3 | 13.04 |
| 2 | 1 | 4.35 | 4 | 17.39 |
| 3 | 1 | 4.35 | 5 | 21.74 |
| 4 | 1 | 4.35 | 6 | 26.09 |
| 5 | 2 | 8.70 | 8 | 34.78 |
| 6 | 4 | 17.39 | 12 | 52.17 |
| 7 | 3 | 13.04 | 15 | 65.22 |
| 8 | 1 | 4.35 | 16 | 69.57 |
| 10 | 1 | 4.35 | 17 | 73.91 |
| 11 | 1 | 4.35 | 18 | 78.26 |
| 12 | 2 | 8.70 | 20 | 86.96 |
| 16 | 1 | 4.35 | 21 | 91.30 |
| 17 | 1 | 4.35 | 22 | 95.65 |
| 18 | 1 | 4.35 | 23 | 100.00 |

**Table 7: Number of Seasons Played by the Non-shoulder Dysfunction Group (n = 10)**

| Number of Seasons | *f* | % | Cum. *f* | Cum. % |
|---|---|---|---|---|
| 0 | 2 | 20.00 | 2 | 20.00 |
| 1 | 3 | 30.00 | 5 | 50.00 |
| 2 | 2 | 20.00 | 7 | 70.00 |
| 6 | 1 | 10.00 | 8 | 80.00 |
| 7 | 1 | 10.00 | 9 | 90.00 |
| 9 | 1 | 10.00 | 10 | 100.00 |

#### 4.3.4.2 Current Playing Status

The participants were also asked whether they were currently playing or not. Twenty-two of the 23 (95.7%) participants who were classified as having shoulder dysfunction by the researcher were actively playing during the 2018/2019 domestic cricket season in South Africa. The one participant who was not currently playing was not selected for the particular match which took place during the data collection timeframe. As expected, 100% of the participants within the non-shoulder dysfunction group were playing at the time of the study and had not been side-lined due to injury. There was, however, no association found according to the two-sided Fisher's Exact test (p=1.000) between currently playing and shoulder dysfunction. The RR value was 0.688 with 95% CI [0.544; 0.869] indicating that current playing status is a protective factor for shoulder dysfunction and statistically significant as 1 is excluded from the confidence interval.

All the participants (n=23) within the shoulder dysfunction group stated that they were actively playing during the 2018/19 domestic cricket season, during the time of the study, without any upper limb complaints, despite being classified in the study as having shoulder dysfunction. Eight of the ten (80%) participants within the non-shoulder dysfunction group confirmed that they were playing without any trouble in their upper limbs, while the remaining two participants stated they were still able to play yet admitted to having trouble in their upper limb whilst playing. There was no statistically significant difference found between the two groups regarding playing status with a shoulder problem (p=0.085). None of the participants who took part in the study were found to be ruled out of game time due to upper limb injury.

#### 4.3.4.3 Other Sports Played

In addition, participants were asked if they participated in any other sports. One participant (4.35%) in the shoulder dysfunction group indicated that he played field hockey, while six (60%) participants in the non-shoulder dysfunction group indicated that they played golf as an additional sport. A total of 16 participants out of the 33 participants (48.5%) who were included in the study chose not to answer the question, implying that they did not play other sports.

#### 4.3.4.4 Missed Game Time

Whether a participant missed game time during the season was another question posed to participants. No association was evident according to the Fisher's Exact test (p=1.000) when considering the participants within either group had missed game time in the last season or not. An RR value of 1.179 with 95% CI [0.710; 1.957] is indicative that missing game time was not found to be a risk factor for shoulder dysfunction in this study but was not statistically significant as 1 is included in the confidence interval of the relative risk. Figure 10 below indicates the number of participants who missed game time in the shoulder dysfunction group compared to the non-shoulder dysfunction group.

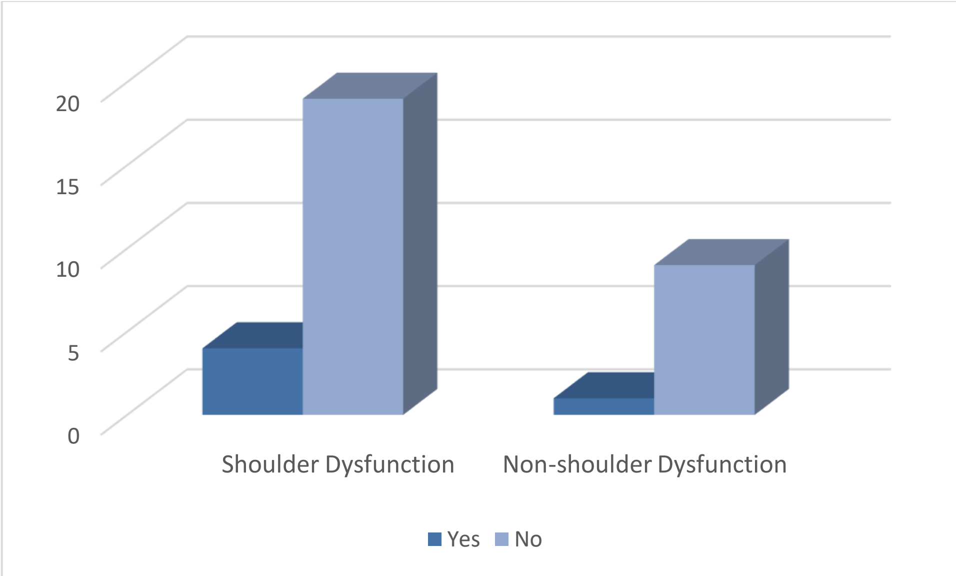



**Figure 10: Number of Participants that Missed Game Time in the Shoulder Dysfunction and Non-shoulder Dysfunction Groups (N=33)**

#### 4.3.4.5 Prevalence of Previous Shoulder Injury

Four participants (17.4%) in the shoulder dysfunction group had missed game time in the season due to injury and five (21.7%) of the participants had reported that they had been previously diagnosed with a shoulder injury in their time playing cricket at an elite level. Two (40%) of the participants who had been previously diagnosed with a shoulder injury had sustained soft tissue injuries and one (20%) sustained a rotator cuff injury. There was no association between being previously diagnosed with a shoulder injury and shoulder dysfunction (p=1.000) and a RR value of 1.032 with 95% CI [0.605; 1.756] indicates that hand dominance was not found to be a risk factor for shoulder dysfunction in this study, but it was not statistically significant as 1 is included in the confidence interval of the relative risk.

#### 4.3.4.6 Treatment Received

A total of nine participants in the shoulder dysfunction group reported that they had received treatment to their shoulder in the past cricket season, pertaining to 39.1%, which proved similar to three participants (30.0%) within the non-shoulder dysfunction group. There was no association found between treatment received for their shoulder in the past cricket season and shoulder dysfunction (p=0.710). An RR value of 1.125 with 95% CI [0.721; 1.756] suggests that previously receiving treatment for a shoulder was not found to be a risk factor for shoulder dysfunction in this study, but it was not statistically significant as 1 is included in the confidence interval of the relative risk. Seven out of the nine (77.8%) participants within the shoulder dysfunction group had received physiotherapy treatment, while the other two (22.2%) resorted to surgical intervention. There was no association found (p=0.091) regarding the treatment received for their shoulder and shoulder dysfunction. Eight (66.7%) of the participants who had received treatment in the non-shoulder dysfunction group reported rest as a form of treatment. The effective sample size for this question was only 12 participants as the remainder of the participants did not provide any information regarding the specific treatment they received for their shoulder.

#### 4.3.4.7 Highest vs Current Level of Competition

The participants' level of cricket participation was also explored by the researcher. Please refer to Table 8 for the highest versus the current participation level of the participants in both the shoulder dysfunction and non-shoulder dysfunction groups. Eighteen (78.3%) of the participants within the shoulder dysfunction group (n=23) were playing at a franchise level in South Africa during the time of the study, compared to four provincial participants and one international participant. Seven of the participants (70%) in the non-shoulder dysfunction group were playing at a provincial level, compared to four participants (17.4%) within the shoulder dysfunction group. There were six (18.2%) participants who had previously achieved the highest level of international cricket in their careers, though at the time of the study, only one of the six (16.7%) participants were currently still playing at an international level. The results should, however, be interpreted with caution due to the small sample size. All six participants who had played at an international level fell within the shoulder dysfunction group. There was an association (p=0.001) when considering the highest level at which the participants had played and shoulder dysfunction. There was also an association (p=0.013) found between the level at which the participants played during the time of the study and shoulder dysfunction. None of the participants showed a difference in the level of their highest versus current playing levels as a result of shoulder injury.

**Table 8: Highest versus Current Level of Competition of Participants in the Shoulder Dysfunction and Non-shoulder Dysfunction Groups**

| Highest Level | Current Level | Shoulder Dysfunction *f* | Shoulder Dysfunction % | Non-Shoulder Dysfunction *f* | Non-Shoulder Dysfunction % |
|---|---|---|---|---|---|
| Provincial | Provincial | 2 | 8.70 | 7 | 70.00 |
| Franchise | Provincial | 2 | 8.70 | 0 | 0 |
| Franchise | Franchise | 13 | 56.52 | 3 | 30.00 |
| International | Franchise | 5 | 21.74 | 0 | 0 |
| International | International | 1 | 4.35 | 0 | 0 |

The results of the study pertaining to the bowling and throwing workload will follow and will be compared between the participants within the shoulder dysfunction and non-shoulder dysfunction groups respectively. The workload values will be calculated as the number of balls bowled or thrown by a particular participant and multiplied by the correlating RPE factor. This will give an indication of the amount of work completed by a participant in terms of throwing and bowling, which would naturally load the shoulder girdle.

### 4.4 Bowling and Throwing Workload Comparisons

#### 4.4.1 Bowling Workload

The workload values for the participants in each group may be seen in Table 9 The mean values for the number of balls participants had bowled on average per week over the last four weeks (chronic) were 14 for the shoulder dysfunction group and 25 for the non-shoulder dysfunction group. A mean score difference of 12 indicates that participants who do not have shoulder dysfunction had a higher average number of balls bowled over the last four weeks. A statistically significant difference (p=0.001) was found between the two groups in terms of the estimated number of balls bowled per week for the last four consecutive weeks prior to the execution of the study. The shoulder dysfunction group bowled significantly more deliveries than the non-shoulder group. A p-value of 0.002 was found when comparing the estimated number of balls bowled within the previous seven days (acute), whereas a p-value of 0.004 was found for the acute workloads and 0.008 was found for the chronic workloads.

There is a statistical significance found when comparing the chronic and acute workload between the shoulder dysfunction and non-shoulder dysfunction groups.

Similar results were found when comparing the number of balls bowled by the participants in the last week (acute workload). The mean values were 14 for the shoulder dysfunction group and 25 for the non-shoulder dysfunction group. An identical difference of 12 between the mean values was found in the four-week average values thereby reinforcing the hypothesis that the participants within the non-shoulder dysfunction group bowl more balls per week than those within the shoulder dysfunction group. Refer to Table 9 below.

**Table 9: Workload Variables for Shoulder Dysfunction Group (n=23) and Non-Shoulder Dysfunction Group (n=10)**

| | **Median** | | **Lower Quartile** | | **Upper Quartile** | | **Minimum** | | **Maximum** | | **p-value** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | Dysfunction | Non-dysfunction | Dysfunction | Non-dysfunction | Dysfunction | Non-dysfuncti on | Dysfunction | Non-dysfunction | Dysfunction | Non-dysfunction | |
| **Average balls bowled over four weeks (chronic)** | 100 | 162 | 75 | 130 | 120 | 210 | 30 | 90 | 150 | 360 | 0.001 * |
| **Intensity** | 8 | 7 | 8 | 7 | 9 | 9 | 5 | 7 | 10 | 10 | 0.136 |
| **Workload value** | 900 | 1350 | 480 | 910 | 1080 | 1470 | 240 | 900 | 1500 | 2520 | 0.002 * |
| **Average balls bowled previous week (acute)** | 40 | 137 | 30 | 60 | 118 | 240 | 20 | | 192 | | 0.002 * |
| **Intensity** | 8 | 7.5 | 7 | 7 | 9 | | 6 | | 10 | | 0.467 |
| **Workload value** | 320 | 1175 | 252 | 600 | 826 | 1680 | 160 | 240 | 1536 | 2304 | 0.008 * |

***statistically significant difference**

### 4.4.2 Throwing Workload

The opposite was evident when comparing the number of balls that were thrown by participants in total and the total throwing workload value. The Kruskal-Wallis test indicated no statistically significant difference (p=0.938) when comparing the total number of balls thrown between the two respective groups, or when comparing the total throwing workload values between the two groups (p=0.531).

The participants classified as having shoulder dysfunction had a mean score of 19 throws during their fielding practices, 18 for their warmup drills and a mean of 15 for throw downs during training sessions. These values are higher than that of the mean values of 12 and 14 for the fielding practice throws and warm-up drills of the participants who are not classified as having shoulder dysfunction. The mean score of the throw downs for the non-shoulder dysfunction group was 20, proving slightly higher than that of the shoulder dysfunction group. The shoulder dysfunction group had an overall total throw mean score of 17 proving identical to the mean total throw value of participants in the non-shoulder dysfunction group. Please refer to Table 10below.

**Table 10: Throwing Workload for Shoulder Dysfunction Group (n = 23) and Non-shoulder Dysfunction Group (n=10)**

| | **Median** | | **Lower Quartile** | | **Upper Quartile** | | **Minimum** | | **Maximum** | | **p-value** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | Dysfunction | Non-dysfunction | Dysfunction | Non-dysfunction | Dysfunction | Non-dysfunction | Dysfunction | Non-dysfunction | Dysfunction | Non-dysfunction | |
| **Total balls thrown** | 70 | 73 | 50 | 50 | 120 | 90 | 35 | 20 | 520 | 290 | 0.938 |
| **Intensity** | 7 | 6 | 7 | 6 | 9 | 8 | 6 | 5 | 10 | 10 | 0.219 |
| **Workload value** | 495 | 408 | 360 | 336 | 900 | 900 | 240 | 120 | 3640 | 2610 | 0.531 |

### 4.5 Participant Perception of Overload

Nine of the ten participants within the non-shoulder dysfunction group stated that they did not feel that they were 'over-bowled', and 21 (91.3%) of the participants within the shoulder dysfunction group felt they do not 'bowl too much'. Twenty-two of the participants (95.7%) in the shoulder dysfunction group felt they did not necessarily throw too many balls and eight of the ten participants (80%) within the non-shoulder dysfunction also felt that they did not necessarily throw too many balls either. There was no association regarding the participant's perception of bowling overload (p=1.000) and with an RR value of 0.952 with 95% CI [0.414; 2.192] the perceived bowling overload is a protective factor for shoulder dysfunction, however not statistically significant, as 1 is included in the confidence interval. Similarly, no association was found regarding the participants' perception of throwing overload (p=0.212) and with an RR value of 0.455 with 95% CI [0.090; 2.285] the perceived throwing overload is also a protective factor for shoulder dysfunction in this study, however not statistically significant, as 1 is included in the confidence interval. Please refer to Table 11 below.

**Table 11: Comparison of Playing Status of Participants**

| | | **Playing without arm trouble** | **Playing with arm trouble** | **Over-bowled** | **Not over-bowled** | **Throw too much** | **Do not throw too much** |
|---|---|---|---|---|---|---|---|
| **Shoulder Dysfunction Group (n=23)** | **Total** | 23 | 0 | 2 | 21 | 1 | 22 |
| | **Percentage** | 100.00 | 0.00 | 8.70 | 91.30 | 4.35 | 95.65 |
| | **Cum. %** | 74.19% | 0.00 | 66.67 | 70.00 | 33.33 | 73.33 |
| **Non-shoulder Dysfunction Group (n=10)** | **Total** | 8 | 2 | 1 | 9 | 2 | 8 |
| | **Percentage** | 80.00 | 20.00 | 10.00 | 90.00 | 20.00 | 80.00 |
| | **Cum. %** | 25.81 | 100.00 | 33.33 | 30.00 | 66.67 | 26.67 |

## Chapter 5: Discussion

### 5.1 Introduction

With the ever-evolving nature of modern professional sport, the management of injuries by team physiotherapists have become highly important due to the potential match time that may be missed by an athlete due to injury. A scientific approach is needed by physiotherapist towards the prevention, management and rehabilitation of sport injuries due to the high number of matches, tournaments and increases training sessions to get players ready (le Roux, 2020).

In the cricketing sphere, fast bowlers have been predicted as being the most likely to get injured due to the nature of their role within the team (McNamara *et al*., 2013). Numerous studies have therefore been conducted on injuries in high level fast bowlers, predominantly on the lumbar spine region, however, there is a lack of research relating to fast bowlers and shoulder injuries (McNamara *et al*., 2013; Olivier *et al*., 2016; Johnson *et al*., 2011).

The literature, however, indicates that the majority of minor shoulder injuries do not keep a cricketer from playing, and may be managed in a variety of ways (Dutton *et al.,* 2019). A common method typically involves a change of fielding position, where the athlete is not required to throw far distances (Cole *et al*., 2016: Dutton *et al*., 2019; Mihata *et al*., 2015). There is, however, nowhere to hide for the fast bowler who is extremely reliant on the optimal functioning and health of the dominant shoulder girdle for throwing and bowling at high intensities and volumes (Dutton *et al*., 2019). This chapter will provide an outline of the study's objectives, provide a classification of shoulder dysfunction, a discussion of the study's results and the significance that each identified risk factor had for fast bowlers with shoulder dysfunction.

By fulfilling the objectives of the study as set out in the methodology chapter of this study, physiotherapists involved in elite cricket teams will have a more comprehensive knowledge of the risk factors associated with shoulder dysfunction in elite fast bowlers.

### 5.2 Classification of Shoulder Dysfunction

Twenty-three (69.7%) of the 33 participants who took part in the study were classified as having shoulder dysfunction according to the conceptual definition for shoulder disfunction for the current study, which was outlined previously (see concept clarification). This equated to 69.70% of the study population who were classified as having shoulder dysfunction. The remaining ten (30.3%) study participants were clear of any abnormalities and were thus regarded as not having shoulder dysfunction. Interestingly, the majority of the study participants were classified as having shoulder dysfunction in this study despite currently playing at an elite level and were not side-lined by a shoulder injury. The remaining ten participants were grouped into the 'non-shoulder dysfunction' group in order to compare the results between the two respective groups for the remainder of the study. Four participants (17.4%) in the shoulder dysfunction group had missed game time in the last season due to shoulder injury, proving similar to the 18% of cricketers who sustain shoulder injury according to Dutton *et al*. (2019)

Deficits in the dominant shoulder's GHJ internal rotation or excess external rotation were not considered to be stand-alone factors for defining shoulder dysfunction, should the TROM value fall within the normal ranges (150°-180°) (Manske *et al.,* 2013). Deficits in the dominant shoulder's GHJ internal rotation and excess external rotation are also not necessarily considered to be pathological, rather a normal adaptation in an overhead athlete according to Manske *et al.* (2013). This was supported in the current study, where participants within the non-shoulder dysfunction group presented with deficient GHJ internal ROM yet reported no symptoms of dysfunction. A detailed discussion of the study's results will follow.

**5.3 Demographic and Anthropometric Information of Participants**

**5.3.1 Age**

It is clear that there is limited literature available related to the average age of elite fast bowlers in South Africa, but there is a common tendency for fast bowlers to retire in their mid-30's. Thorley (2020) found that  functional performance declines across all male fast bowlers to have played test matches over the last 50 years, and that more successful fast bowler were able to compete at an elite level for longer periods, well into their thirties. The researcher further stated that contrary to slower test match bowlers, fast bowlers' performance and wicket-taking ability does deteriorate towards the latter stage of their elite career (Thorley, 2020).

There was a similarity between the average age of the participants within the shoulder dysfunction and non-shoulder dysfunction group, with median values of 26 and 25 years respectively. No statistically significant difference was indicated between the two groups regarding the participants' ages and no evident association between older fast bowlers and a higher prevalence of shoulder dysfunction was found. Despite this finding, Johnson *et al.* (2011) suggested that fast bowlers under 24 years of age are more prone to stress-related injuries due to the bone density factor in their lumbar spine and pelvis. Although this may not be relevant information to the current study due to the area of injury, further research may investigate the bone density factor of the fast bowler's shoulder girdle and the prevalence of shoulder injuries. Higher injury prevalence in younger fast bowlers was not confirmed in this study as the shoulder dysfunction and non-shoulder dysfunction groups showed similar median age values over the age of 24 years.

### 5.3.2 BMI

Jespersen *et al*. (2013), however, suggested that there was a connection between high BMI values and increased lower limb injuries amongst overweight youths, though the study did not investigate any correlation with upper limb injuries. Despite three participants within the current study's shoulder dysfunction group being considered to be obese, recording BMI values in excess of 30 (Jespersen *et al*., 2013; Turkeri, Ozturk, Buyuktas & Ozturk, 2019), there was no statistically significant difference nor any association found between high BMI values and shoulder dysfunction when comparing the two groups. The population in the study of Jerspersen *et al.* (2013) were youths and, therefore, no comparison to the current study's population in terms of the BMI values can be made.

No statistically significant differences or associations were found in the results comparing the shoulder dysfunction and non-shoulder dysfunction groups in this study. Fast bowler BMI can therefore not be considered a risk factor for shoulder dysfunction in elite fast bowlers.

### 5.3.3 Limb Dominance

Limb dominance was another factor investigated in this study. Buenaventura Cas, Lynch & Paracchini (2019) stated that approximately 90% of the population are right-handed, where limb dominance may be determined primarily as a binary trait by means of a preferred hand for writing. Subsequently the dominant limb develops greater strength and coordination as it is more commonly used in everyday tasks. There was, as expected, a high prevalence of right hand dominant fast bowers who took part in the study, as reflected in the general population. Eighteen of the 23 participants (78.3%) who were classified as having shoulder dysfunction were right-handed. A similar prevalence was found in the non-shoulder dysfunction group, where 80% of the participants were right-hand dominant. With the similar findings between the shoulder dysfunction and non-shoulder dysfunction group, no association could be made between the participant's limb dominance and shoulder dysfunction, and clear that limb dominance was not a risk factor for shoulder dysfunction in this study. However, no literature related to limb dominance as a risk for shoulder dysfunction was available and could not be utilised for comparison in this study.

**5.4 Other Sports Played**

Seven participants within the shoulder dysfunction group reportedly played other sports in their free time. Six of the seven stated they played golf on a regular basis and the other played league field hockey. A study conducted by Lee, Hong, Jeon, Hwang, Moon, Han & Jeong (2017) investigated the characteristics of golf-related shoulder pain in Korean amateur golfers. The researchers concluded that the golfer's non-dominant shoulder was typically the area where pain and injury was most likely to occur. More specifically, the m. supraspinatus was most commonly damaged in the non-dominant shoulder of the golfers, which was strongly linked to the amount of time practicing or playing golf (Lee *et al*., 2017). There was no link observed by Lee *et al*. (2017) regarding dominant shoulder injury and time spent playing or practicing golf however. Although the m. supraspinatus was, similarly, a structure commonly injured by throwing (Dutton *et al*., 2019), a golf swing is known to load the non-dominant shoulder (Lee *et al.,* 2017) and therefore not believed to play a direct role in injuring a bowler's bowling and throwing arm.

Interestingly, there was a higher percentage of participants who played hockey (50%) and rugby (33.33%) in the non-shoulder dysfunction group compared to those in the shoulder dysfunction group. It is known that the shoulder girdle is loaded throughout a hockey match and that asymmetry regarding scapular muscle strength is evident (Vanderstukken, Jansen, Mertens & Cools, 2019). Although rugby is regarded as a contact sport, no participants within the shoulder dysfunction group reportedly played rugby. Despite this finding, no participants in the non-shoulder dysfunction group showed any injury risk factors for shoulder dysfunction. Therefore, no association could be made in terms of participants playing other sports and the prevalence of shoulder dysfunction.

### 5.5 Number of Seasons Played

There is no literature available regarding the number of seasons played and risk of shoulder dysfunction. There was, however, a statistically significant difference found between the two groups when comparing the number of professional seasons which they had completed thus far. A median of six completed professional seasons was found in the shoulder dysfunction group, compared to only one and a half-completed seasons in the non-shoulder dysfunction group. The statistical significance in the number of seasons played by the participants indicates that the participants in the shoulder dysfunction group played more seasons than those in the non-shoulder dysfunction group.

Many professional cricketers have the habit of playing cricket in various other tournaments across the world during the year outside of the domestic season. A common trend is to play cricket in the United Kingdom during the South African winter months (May until September), which is the time where the domestic season is not active. This may be related back to the chronic and acute bowling workload risk factor, where, although a higher chronic bowling workload may be protective, not having time between seasons to rest and condition may serve as further risks (McNamara *et al*., 2016). This may similarly be the case for international cricketers who are required to prepare and play during various times of the year, in various Northern and Southern hemisphere countries. Being available for selection, such as in tournaments hosted in other countries, may cause minor injuries to be neglected by the respective cricketer and undetected by the team medical staff in the attempt to remain available for selection. The current environment of elite fast bowlers makes workload monitoring and injury management by the team physiotherapist more challenging as they often represent more than one professional team and play in many tournaments around the world (McNamara *et al*., 2016).

### 5.6 Missed Game Time

Dutton *et al*. (2019) indicated that a total of 32% of all shoulder injuries result in missed game time in professional South African cricketers, though this finding was not specific to elite fast bowlers. The current study compared the participants within the shoulder dysfunction and non-shoulder dysfunction groups in terms of whether they had been unavailable for selection in the previous cricket season due to shoulder injury. A total of 82.61% of the participants reported that they had not missed any game time in the last season due to injury, whereas four participants in the shoulder dysfunction group stated that they had in fact missed game time due to shoulder injury. Only one of the participants in the non-shoulder dysfunction group had reportedly missed game time in the last season due to shoulder problems. The results of the study clearly indicated that there is no association between shoulder dysfunction and missed game time in the previous season. While it has been proven that continued playing despite having shoulder dysfunction may impede performance (Ranson & Gregory, 2008; Olivier *et al*., 2020), there may be progressive damage done to the shoulder. However, one might surmise that missing game time allows for time to rest and to deload. The current study found that missed game time was not considered a risk factor for fast bowlers to develop shoulder dysfunction and further research needs to be conducted regarding the time away from competition and risk of injury.

### 5.7 Prevalence of Shoulder Injuries

Five of the participants within the shoulder dysfunction group stated that they had been diagnosed with a shoulder injury at some stage during their cricket career. This equated to 21.74% of the participants, similar to the 20% within the non-shoulder dysfunction group. Past shoulder injuries are therefore not considered to be notable risk factors for shoulder dysfunction within fast bowlers. Dutton *et al*. (2019), however, made mention to the possibility of future research investigating the reason behind recurrent shoulder injuries in cricketers.

Of the 21.74% of participants within the shoulder dysfunction group who had reportedly been diagnosed with a shoulder injury in their time as a professional cricketer, 8.70% sustained soft tissue injuries, 8.70% suffered a GHJ dislocation or glenoid labrum injuries and 4.35% rotator cuff tendon injuries. All the participants within the non-shoulder dysfunction group who reported past shoulder injury diagnoses stated the injuries were soft tissue in nature. Although no association was found between being previously diagnosed with a shoulder injury and having shoulder dysfunction, the prevalence of soft tissue related rotator cuff injuries could be linked to the high throwing loads related to the overhead nature of cricket, which is known to have an adaptive effect on the shoulder girdle (Dutton *et al*., 2019; Manske *et al*., 2013; Mihata *et al*., 2015). It is known that posterior capsule tightness, GIRD and rotator cuff dysfunction all influence the positioning of the scapula and alter scapula-thoracic rhythm, predisposing the fast bowler to a greater likelihood of sustaining a shoulder injury (Cole *et al.,* 2016; Smith, Kotajarvi & Padgett 2002).

**5.8 Treatment Received**

Nine out of the 23 participants within the shoulder dysfunction group reported that they had received treatment on their shoulder during their time playing professional cricket. No association was found between treatment received for a shoulder problem in the past cricket season and shoulder dysfunction. Although no association was found between the treatment received and shoulder dysfunction, the treatment received was not considered a risk factor for shoulder dysfunction in this study. It could be hypothesised that the treatment and rehabilitation received was appropriate for the specific injury to restore optimal functioning to the shoulder girdle. However, the findings regarding the relative risk factor were not statistically significant which would be attributed to the small sample size and the results should therefore be interpreted with caution.

Seven of the participants said that the treatment they had received was physiotherapeutic. This may, however, have involved maintenance treatment and not necessarily the treatment of a diagnosed injury. Unfortunately, the type of treatment was not explored during the study, and therefore the hypothesis is speculative in nature. The remaining two participants received surgical interventions for their shoulder injuries. Thirty percent of those within the non-shoulder dysfunction group had received a form of treatment to their shoulder. The majority stated they only required rest and no surgical or physiotherapy intervention.

When classifying the participants within the shoulder dysfunction group in terms of the professional level at which they were playing, 65.22% were playing at franchise level at the time of conducting the study. Altogether 26.09% of the participants were competing at an international level and the remaining 8.70% at a provincial level. It is important to note that 70% of the participants within the non-shoulder dysfunction group were competing at a provincial level and the remaining 30% at franchise level at the time of this study. It may lead to the hypothesis that the higher the level of competition, the greater the associated injury risk. It may also be a result of workload differences, as the provincial cricketers in South Africa play their first-class matches over three days, franchise cricketers over four days and the international players over five days. Elite fast bowlers who represent more than one team may also encounter difficulties with workload management and injury prevention as different physiotherapists will take responsibility at different times, which may enhance the risk of injury (McNamara *et al*., 2016). The intensity of match play may also be a reason for the increased injury prevalence amongst the higher-level fast bowlers as proven from the results in the current study.

**5.9 Highest vs Current Level of Competition**

There was an association found between the highest and current level of competition of the participants and shoulder dysfunction. None of the participants showed a difference in the level of their highest versus current playing levels as a result of shoulder injury. Further, none of the participants within either of the groups stated that a shoulder problem was the reason for them competing at a lower level than what they previously did.

**5.10 The Occurrence of Intrinsic Injury Risk Factors in Shoulder Dysfunction**

As per definition of shoulder dysfunction in the current study (see concept clarification), the participants within the non-shoulder dysfunction group were clear of any positive shoulder impingement signs on bilateral Neer's, Hawkins-Kennedy, Apprehension-Relocation, Empty can, O'Brien's and Speed's tests. As expected, due to the vigorous nature of the throwing and bowling loads on the shoulder girdle, a positive O'Brien's tests proved to be the most prevalent among the shoulder dysfunction group, with four of the participants having positive signs of glenoid labral pathology. Although it was mentioned by Dutton *et al*. (2019) that subacromial impingement is the most common symptom of shoulder dysfunction, the normal adaptation of decreased GHJ internal rotation and increased external rotation, as suggested by Manske *et al*. (2013), could have been the reason for the lower than expected prevalence of subacromial impingement in the participants with shoulder dysfunction. It was expected that there would be a higher prevalence of subacromial impingement on the dominant limb due to the nature of throwing and the associated anatomical adaptations that occur by means of posterior capsule tightness and GIRD. Only one particular participant tested positive on the right-sided Neer's test, suggesting rotator cuff impingement or bursa pathology, positive apprehension-relocation test, suggesting glenohumeral instability, positive empty can test, reinforcing the presence of rotator cuff impingement and/or pathology and a positive O'Brien's test suggesting glenoid labral pathology.

#### 5.10.1 Shoulder Instability

The CKCUES test was used in this study specifically to assess the participants upper limb function and stability. The test was used in the same manner as in the study conducted by Walankar & Momin (2019) who stated the test was reliable and specific for the assessment of cricketers.

The participants in the non-shoulder dysfunction group all recorded CKCUES test totals of 25 repetitions and above, while seven of the 23 participants within the shoulder dysfunction group had below standard CKCUES test values < 25 repetitions, indicating below par shoulder girdle stability as suggested by Lee & Kim (2015). This could lead to the notion of suboptimal conditioning and reinforcing the need for specific shoulder prehabilitaion to improve the shoulder girdle stability prior to the onset of shoulder injury.

#### 5.10.2 Glenohumeral Range of Motion Deficit

A loss of GHJ range of motion has been known to impede shoulder performance in a variety of overhead athletes (Dutton *et al*., 2019; Manske *et al*.,2013). According to a study conducted by Manske *et al* (2013), the phenomenon of GIRD, however, should be considered a normal finding in overhead athletes and not necessarily pathological. In fact, without the deficit in GHJ rotation, the athlete would most likely not be able to acquire the necessary external rotation needed to throw or bowl as required (Manske *et al*., 2013). Functional GIRD or the gain in external rotation were, therefore, not used as defining factors for shoulder dysfunction in the current study. This was confirmed by Burkhart *et al*. (2003) who stated that as long as the GIRD is less or the same as the external rotation gained in the athlete's shoulder, there will be no abnormalities in the shoulder's kinematics or functionality.

The literature has suggested that the combined ranges of GHJ internal and external rotation or TROM, should ideally be as symmetrical as possible in overhead athletes for optimal injury prevention. However, the TROM should not exceed an absolute range of 186°. Exceeding this total range was proven to leave the athlete at high risk of shoulder injury and to GHJ instability (Manske *et al*., 2013). Six of the 23 participants (26.1%) within the shoulder dysfunction group recorded TROM values greater than 186°, with the majority on the participant's dominant right-hand side. This finding was most likely due to high throwing loads or the possibility of poor throwing technique which are known to increase GHJ external rotation range of motion and could subsequently lead to a greater risk of subacromial impingement symptoms or shoulder girdle instability. This reinforces the importance of a strict throwing workload guideline for all fast bowlers, correct biomechanical coaching and specific shoulder prehabilitation programmes to strengthen the rotator cuff muscles (Walter, Petersen & Basu, 2020).

As mentioned above, there was a tendency for the participants within the shoulder dysfunction group to have dominant shoulder TROM values greater than the normal range. The opposite was, however, seen with the non-dominant shoulder, where there was a tendency for TROM values to fall well below the normal range of motion. This may be attributable to the normal anatomical adaptations of the shoulder girdle to the repetitive nature of throwing and bowling (Dutton *et al*., 2019; Manske *et al.,* 2013). This may also be due to an early onset of GHJ instability and weakness of the rotator cuff muscles. There is room for further research investigating TROM asymmetry and shoulder injuries in cricketers as the available literature focused on overhead athletes in the broader sense, rather than specifically on the fast bowler population.

**5.11 The Occurrence of Extrinsic Injury Risk Factors in Shoulder Dysfunction**

Hulin *et al*. (2013) was the first to investigate the association between acute and chronic bowling workloads on the injury risk of fast bowlers. Although the researchers found that a sudden spike in bowling workload increases the chance of injury to the fast bowler in the following week, it was also noted that high bowling workloads over a one-week and a four-week period lowered the chance of injury during the following week (Hulin *et al*., 2013). This could support the idea that high bowling loads contribute to improved conditioning of the athlete and further prevent injury compared to lower workloads (Gabbett, 2016; Hulin *et al*., 2013). This study found a statistically significant difference when comparing the total number of balls bowled between the shoulder dysfunction and non-shoulder dysfunction groups, supporting the findings by Hulin *et al.* (2013) that bowling workloads can play a protective role in shoulder dysfunction.

### 5.11.1 Bowling Workload

McNamara *et al*. (2016) reiterated that both a high bowling workload and an abnormally low bowling workload have been associated with a greater chance of fast bowlers sustaining an injury. There was, however, no indication of the specific injury, which was likely to be sustained, simply a greater risk of injury (McNamara *et al*., 2016; Olivier *et al*., 2016). Gabbett (2016) further indicated that a safe workload prescription is between 123-188 deliveries per week, values higher or lower than what is set out may increase the injury risk for an elite fast bowler.

The participants within the shoulder dysfunction group subjectively reported to have bowled, on average, within the range of 30 to 150 balls per week for four consecutive weeks, which constituted their chronic bowling workload. The mode for the intensity, or RPE, at which the balls were bowled was eight out of ten, where 'ten' was considered maximal exertion when bowling a particular ball (Gabbett, 2016). The lower range of these values fell short of the recommended minimum of 123 deliveries as set out by Gabbett (2016). The shoulder dysfunction group had bowled far fewer balls on average over the last four weeks compared to those within the non-shoulder dysfunction group, with mean scores of 13 balls for the participants within the shoulder dysfunction group and 25 balls for the participants within the non-shoulder dysfunction group. Bowling more deliveries over a period of time may, therefore, have a protective factor on injury risk in fast bowlers (Gabbett, 2016; McNamara *et al*., 2016).

#### 5.11.1.1 Acute and Chronic Bowling Workload

The chronic bowling workloads for the participants within the shoulder dysfunction group ranged from a minimum of 240 to a maximum of 1 500 with a median value of 900 over four consecutive weeks. This study showed a statistically significant difference between the two groups in terms of the number of balls bowled over four weeks and the estimated number of balls bowled within one week, supporting this fact. McNamara *et al*. (2017) made further mention of the risk that an acute spike in the bowling workload may create, ultimately reinforcing the importance of fast bowlers maintaining a consistent weekly bowling load.

The acute bowling workloads ranged from a minimum of 160 to a maximum of 1 536 with a median value of 320 for the participants within the shoulder dysfunction group. There was a considerable difference when comparing the median values of chronic and acute bowling workloads, which may be due to the time frame of the data collection. The study's data collection took place during the domestic Pro20 tournament, which has become renowned for complicating the workload monitoring and injury management of fast bowlers for a number of reasons, including increased match density and the unpredictable nature of the shortened format (McNamara *et al*., 2017). The bowlers were restricted to bowling a maximum of four overs in a match due to the limited over nature of Pro20 cricket. The limitation of maximum balls bowled by a bowler during match play would have lowered the total number of balls bowled by the participants, and therefore impacting the workload value (Gabbett, 2016; McNamara *et al*., 2017; Olivier *et al*., 2016).

When comparing the chronic and acute bowling workloads to that of the non-shoulder dysfunction group, the shoulder dysfunction group's participants showed higher values in both their chronic and acute workloads. The chronic workloads ranged from a minimum of 900 to a maximum of 2 520 with a median value of 1 350. The acute workload values ranged from a minimum of 240 to a maximum of 2 304 with a median value of 1 175. Despite the timing of data collection, the non-shoulder dysfunction group showed similar values across the chronic and acute workload values. This may be indicative of maintaining a constant workload throughout the season, which could prove to be protective in nature as there were no evident acute spikes in the workload. The data found in the current study correlated to the findings of Gabbett (2016) and McNamara *et al*. (2013), who agreed that higher workload values could well carry a protective factor for fast bowlers compared to lower workload values as there is a decreased likelihood for acute workload spikes.

The chronic bowling workload factor proved to be significantly different between the shoulder dysfunction and non-shoulder dysfunction groups. The shoulder dysfunction group had nearly half of the bowling workload over four weeks compared to those with in the non-shoulder dysfunction group. A similar result was seen in the acute workload factors between the two groups, where the shoulder dysfunction group were bowling significantly less in terms of average number of balls bowled in a week, compared to those within the non-shoulder dysfunction group. Once again, this confirms that a higher bowling workload may be protective to fast bowlers as suggested by McNamara *et al*. (2013).

### 5.11.2 Throwing Workload

The throwing workload values proved to be more comparable between the shoulder dysfunction and non-shoulder dysfunction group than that of the bowling workloads. The median values for the total throws were 495 throws for the shoulder dysfunction group and 408 throws for the non-shoulder dysfunction group. Although throwing is known to have the greatest effect on the shoulder girdle of all the single actions, throwing loads were not definitive in the current study's determination of shoulder dysfunction.

Comparing the two respective groups in terms of their throwing workloads, both groups reported a similar number of throws during fielding practice and during pre-match warm-up drills. However, there was a difference between the number of throw downs between the two groups with the shoulder dysfunction group averaging ten throws on average per week, and the non-shoulder dysfunction group, 38 throws on average per week. Interestingly, the non-shoulder dysfunction group reportedly did more throw downs than those in the shoulder dysfunction group, yet the total throws between the two groups were 70 for the shoulder dysfunction group and 72.5 for the non-shoulder dysfunction group, respectively. This study found no statistically significant difference when comparing the total number of balls thrown between the two respective groups, or when comparing the total throwing workload values between the two groups.

Dutton *et al.* (2019) suggested that an acute spike in throwing workload may predispose an athlete to possible shoulder injuries as in the case of bowling workload. It was also noted that throwing more than 75 times in a week increases the likelihood of shoulder injury in an athlete by more than one and a half times. Fortunately, both study groups threw less than 75 times in a week on average, though the total throw values of both groups were close to the value of 75 throws as indicated by Dutton *et al.* (2019). A consideration may be to assess the necessity for fast bowlers to do throw downs during training and/or closely monitor the number of throw downs done by fast bowlers during a week by team trainers or coaches as this may impact the total throws and subsequently injury risk. This is similar to bowling workloads, maintaining a consistent throwing workload is recommended in optimal throwing injury prevention (Dutton *et al*., 2019; Olivier *et al.,* 2020).

## 5.12 Current Playing Status

All of the participants within the shoulder dysfunction group stated that they were playing without any shoulder problems during the 2018/19 domestic cricket season, despite being classified as having shoulder dysfunction in this study. Two of the ten participants within the non-shoulder dysfunction group, however, stated that they were playing with mild discomfort in their dominant shoulder. There were no participants from either group who were ruled out of selection due to an injury to their shoulder and no statistically significant differences were found between the two groups regarding their playing status and shoulder dysfunction. Although many minor shoulder injuries may go undetected (Dutton *et al*., 2019), the current playing status of the participant was considered to be a protective factor for shoulder dysfunction in this study. Despite the current study indicating a benefit in continued playing with a shoulder dysfunction, Walter (2020) suggested that high bowling and throwing loads, together with limited rest, may in fact weaken the rotator cuff muscles in the fast bowler's shoulder. Olivier *et al*. (2020) additionally added that there may be a negative effect on player performances associated with the continued playing of those who are carrying minor shoulder injuries. This emphasises the importance of the workload guidelines for both bowling and throwing in injury prevention (McNamara *et al*., 2017; Olivier *et al*., 2016).

## 5.13 Participant Perception of Overload

The majority of the participants in both groups perceived that they were not bowling too much and reported being satisfied with their current bowling workloads. This was no surprise as no association was found between each participant's perception of bowling overload and shoulder dysfunction, however, despite lacking statistical significance, perceived bowling overload may be considered a protective factor for shoulder dysfunction. Pote, Proctor, McEwan, Davy, & Christie (2019) evaluated the physical perception of fast bowlers during certain stages of their bowling spell. The study concluded that the lowest exertion rating by the fast bowers was experienced after bowling their initial six deliveries and their highest rating was at after 60 deliveries (Pote *et al*., 2019). Fortunately, fast bowlers very seldomly bowl 60 deliveries in a row during match play or during training, but alternatively bowl in spells of a few overs depending on the match format and their conditioning or training requirements (Gabbett, 2016). It could, therefore, be hypothesised that the current training structures allow for adequate breaks between bowling spells and that there is control of bowling workloads within professional teams, preventing the fast bowlers from experiencing overload.

Similarly, the majority of participants also reported that they perceived that they did not throw too many balls, during fielding practice, warmups or during throw down drills, nor was any association made between perceived throwing load and shoulder dysfunction. As is the case with the perceived bowling overload, throwing overload is also regarded as a protective factor for shoulder dysfunction in this study. No available literature could be found relating to the psychological aspects associated with perceptions of bowling and throwing overload in fast bowers, which might play a role in the cricketer's perception of overload, whether factually correct or not. The psychological aspects influencing a fast bowler's performance did not form part of the scope of the current study, but it would be interesting to research the perception of bowling and throwing workload compared to the actual bowling and throwing workload of fast bowlers. Once again, the small sample size could have been the reason why the results did not achieve statistically significance and therefore the findings should be interpreted with caution.

**5.14 The Team Physiotherapist**

It is essential that a sports team physiotherapist knows and loves the relevant sporting code which the team is involved with, in order to be successful as a team physiotherapist. As part of the multidisciplinary team of the cricketer, it is important for the physiotherapist to not only understand the significance of the physical demands on the fast bowler or any other position within the team, but also have insight into the psychological demands of the sport due to the various formats of cricket and the prolonged seasons (Brukner & Khan, 2007). If the team physiotherapist understands the demands and the technical aspects of cricket, this will improve their ability to recognise and prevent possible injury risk factors, further leading to the facilitation and development of sport specific rehabilitation and injury prevention programmes. The team physiotherapist is, thus, an important member of the multidisciplinary sports medicine team. According to Simpson (2004) the umbrella of sport medicine encompasses a number of professions to deal with the athletic population, with the responsibility for human performance (exercise physiology, biomechanics, sport psychology, sport nutrition, strength and conditioning specialist and massage therapist), injury prevention and recognition (physician, physiotherapist and trainer), therefore ideally positioning the physiotherapy profession within the sport arena.

### 5.14 Conclusion

The results of the current study indicate a strong association between shoulder dysfunction within elite South African fast bowlers and the number of seasons played. However, no significant association was found between a fast bower's age and injury risk. Participants competing at an international level may be more prone to shoulder dysfunction, together with those who bowl chronically fewer deliveries than the recommended number. This is becoming an ever-increasing concern for fast bowlers, who are following the trends of playing greater volumes of cricket since the introduction of various lucrative global Pro20 tournaments. This may predispose fast bowlers to prevalent acute workload spikes and therefore greater risk of injury. Despite higher workload values representing a protective factor for fast bowlers, fast bowlers should stay within the guidelines set out by Gabbett (2016) to optimise holistic injury prevention. High throwing loads are also known to incorporate a high injury risk factor for an overhead athlete's shoulder, despite the anatomical adaptation that occurs as made mention to by Manske *et al.* (2013). Despite the adaptation, significant TROM differences between the shoulders predispose the athlete to shoulder injuries and should be monitored regularly.

# Chapter 6: Conclusion and Recommendations

## 6.1 Introduction

The current study was undertaken in order to determine the risk factors associated with shoulder dysfunction in elite male South African fast bowlers. In pursuit of this aim, several objectives were identified in the study, and will be discussed below.

## 6.2 Answering the Study Aim and Objectives

The first objective was to obtain the sample demographics by means of a self-compiled questionnaire based on the available literature. There was no significance drawn from the data obtained concerning participant age, height and limb dominance data. The prevalence of shoulder injury within the past season prior to the execution of the study was considered to be a defining factor for shoulder dysfunction in the current study.

The next objective of the study was to determine the external injury risk factors for fast bowlers which were outlined by available literature. The identified external risk factors were assessed by the questionnaire used in the study. The results obtained by the study suggested that higher bowling workloads carry a protective factor against shoulder dysfunction and limit acute spikes, which are closely related to injury risk. The number of cricket seasons completed by fast bowlers and the level at which they compete further showed an association with shoulder dysfunction despite the fast bowler's age.

The third objective was to identify the extensive intrinsic injury risk factors that were highlighted for fast bowlers by literature. It was noted that there is a normal physiological and anatomical adaptation that occurs in the dominant shoulder of fast bowlers who are subjected to high bowling and throwing loads. Shoulder stability and impingement were identified as the most common intrinsic factors found within participants in the shoulder dysfunction group in the study.

The occurrence of both intrinsic and extrinsic risk factors was used in the study to determine two distinct groups, namely; the shoulder dysfunction group who met the definition of shoulder dysfunction mentioned in the discussion chapter of this study, and the non-shoulder dysfunction group, who were clear of any identified injury risk factors. Nearly seventy percent

(69.70%) of the participants were classified as having shoulder dysfunction, with a joined prevalence of intrinsic and extrinsic risk factors despite currently competing professionally.

### 6.3 Summary and Results

It was found that the number of professional seasons completed by the fast bowlers, despite their age, was a prevalent factor in those with shoulder dysfunction. With the ever-increasing number of cricket matches scheduled in the calendar year and lucrative contracts offered by various global tournaments, fast bowlers are subjected to higher bowling and throwing loads and periods without sufficient rest.

Additional factors which were proven to be significant, included a higher level of competition and suboptimal (<120 deliveries) bowling workload per week and chronic high throwing workloads per week (>75 throws per week). Despite the greater demand for bowling load in the modern era, periods of lower bowling workloads, however, were seen as a greater injury risk to fast bowlers compared to constantly high bowling workloads as there was a lower prevalence of spikes in the athlete's workload values. Shoulder instability and sub-acromial impingement featured regularly among the fast bowlers with shoulder dysfunction.

### 6.4 Limitations of the Study

Although the sample size used in this study included a comparable sample of the total population available, the small sample size of 33 participants impacted the data analysis. A larger population size would have been able to accurately identify the prevalence of each of the identified risk factors more accurately.

The cross-sectional nature of the study caused a limitation as the data collection could have ideally taken place across all three match formats to create more accurate workload totals. However, this was limited by the timeframe and budget for this study.

The biomechanical risk factors of the fast bowlers bowling and throwing action could not be investigated in this study due to the lack of resources.

There may be recall bias involved regarding the participants determination of the number of throws they did during training, warm up drills and throw down drills. Additionally, the recall bias involved with the respective rate of perceived exertion (RPE) of the respective throws.

The use of clinical shoulder assessment tests in the study by one assessor without evidence of intrarater reliability was further proven to be a limitation in this study.

### 6.5 Recommendations

Based on the experience and the insight gained during the study, recommendations for clinical practice, and identified areas in which further research might be required, have been put forward.

#### 6.5.1 Clinical Recommendations

The following clinical recommendations can be made:

- Fast bowlers should be monitored and assessed by a physiotherapist on a regular basis in order to assess identified injury risk factors and receive interventions or treatments including prehabilitation.
- Specific bowling and throwing workload guidelines should be compiled for a cricketer by the team physiotherapist or medical staff. These may be involved and continually adapted and modified in terms of the extrinsic risk factors and special attention given to those involved with younger, more at risk, fast bowlers.
- Coaches and team trainers involved in all levels of cricket should be educated and be made aware of the impact which high throwing workloads may have on a developing fast bowler, before the bowler reaches the elite ranks and gets exposed to higher bowling demands. This could be done by compiling a document which could be circulated nationally to each union, or by means of workshops which may be held annually and presented by Cricket South Africa (CSA) representatives.
- Fast bowler-specific prehabilitation programmes could be compiled by team physiotherapists. The programmes should be individualised and be made available for all trainers and fast bowlers in South Africa to allow for the natural anatomical adaptations of high throwing and bowling loads, but also to strengthen their shoulder girdle and prevent shoulder dysfunction and risk of injury.
- Shoulder girdle instability proved to be a common trend, evident among the participants within the shoulder dysfunction group. Rehabilitation regimes should be put in place once abnormalities are detected to ensure optimal shoulder health in fast bowlers, targeted at scapula-thoracic stability. Additionally, shoulder impingement

proved relatively prominent in the shoulder dysfunction group in the study and could be linked to the prevalence of below average shoulder stability. Early detection of abnormalities and early rehabilitative intervention are both recommended (Brukner & Khan, 2017).

- Bowling workload guidelines have been established by Gabbett (2016) to assist coaches and fast bowlers during their preparation and training. However, it is essential for coaches follow these bowling workload guidelines and therefore more extensive research is required to establish secure throwing loads. Better awareness on the topic of fast bowler injury prevention should be created among professional coaches who are responsible for planning fielding practice.

**6.5.2 Recommendations for Future Research**

- The establishment of appropriate normative values for the objective tests used to assess fast bowler shoulder dysfunction is recommended. This should allow for a 'normal' adaptation in the throwing and bowling shoulder of the fast bowler.
- Continued research into ways to optimise bowling and throwing workloads in fast bowlers should be done to remain up to date with the evolving nature of the modern game. Further research could be done to investigate biomechanical differences in the bowling actions of left- and right-handed bowlers. Optimal management and injury prevention are dependent on the knowledge of both the fast bowler and coaching or training staff involved. There should be a continued effort to achieve progress in terms of educating both the bowler and coach.
- It is recommended that further research should be done on the biomechanical aspects of the throwing technique in fast bowlers in order to establish the most efficient throwing technique for a shoulder subjected to high bowling loads.
- There is room for further research investigating glenohumeral TROM asymmetry and shoulder injuries in cricketers, as the available literature has focused on overhead athletes in a general sense, rather than specifically on the fast bowler population.
- Further investigation may be necessary in determining the reliability and validity of shoulder assessment diagnostic tests used by medical practitioners to determine which tests should be preferred when an athlete's shoulder is assessed.

- There should be continued insight into the efficiency of a fast bowler's throwing and bowling biomechanics and a broader knowledge of this information made known to all involved with the continually developing coaching and treatment techniques of young fast bowlers. This would create a culture of injury awareness and a greater attention towards prolonging the career of all fast bowlers.
- Due to the increased number of tournaments for cricketers during their career, there is a need to investigate the effects of travel and optimal recovery of fast bowlers as there may be a possible correlation with injury risk.

**6.6 Conclusion**

This study has identified the specific intrinsic and extrinsic injury risk factors associated with shoulder dysfunction in elite South African fast bowlers. This study revealed that fast bowlers who play at a higher level of competition, who have played a substantial number of professional seasons and who have lower than prescribed bowling and higher than recommended throwing workloads are at greater risk of developing shoulder dysfunction.

Specific recommendations to further research for all physiotherapists and fast bowlers have been put forward in order enhance their knowledge surrounding risk factors for shoulder dysfunction in elite fast bowlers. This is in an attempt to improve fast bowler injury management by physiotherapists and ultimately improve the quality of cricket.

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## Appendices

### Appendix A: Questionnaire

**Questionnaire**

**This questionnaire consists of 25 questions. Please read each question carefully and answer to the best of your ability.**

Study Number ____________________

1. What is your Age ____________________ Years
2. Today's Date
3. Dominant Hand

| | |
|---|---|
| Left | Right |

4. Current height ____________________ Metres
5. Current weight ____________________ Kg

6. Other Sports Played Currently ____________________

7. Number of cricket seasons completed prior to current season ____________________

8. Is your bowling arm/shoulder currently injured? | Yes | No |

9. Are you currently playing cricket this season? | Yes | No |

10. Have you missed game or practice time in the last season due to an injury to your shoulder? | Yes | No |

11. Have you been diagnosed with an injury to your shoulder during your time playing cricket as a professional? | Yes | No |

If yes, what was the diagnosis ____________________

12. Have you received treatment to your shoulder or elbow during your time playing cricket? | Yes | No |

13. If yes, what was the treatment?

| |
|---|
| Rest |
| Therapy |
| Surgery |

14. What was the highest level cricket you've played at?

____________________

15. What is your current level of competition? ______________________

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

| Yes | No |
|---|---|

17. Estimate the average number of balls you have bowled per week for the past FOUR weeks: ______________ Balls

18. Please rate the intensity at which these balls were bowled by marking an X on the scale below:

0 1 2 3 4 5 6 7 8 9 10

Low intensity Moderate intensity High intensity

19. How many balls have you bowled in the last 7 days? ______________ Balls

20. Please rate the intensity at which these balls were bowled by marking an X on

the s
belo

0 1 2 3 4 5 6 7 8 9 10

Low intensity Moderate intensity High intensity

21. Estimate the average number of balls you throw per week during:

Fielding practice ______________ Throws

Warm up activity ______________ Throws

Throw downs/training ______________ Throws

22. Please rate the intensity at which these balls were thrown by marking an X on the scale below:

0 1 2 3 4 5 6 7 8 9 10

Low intensity Moderate intensity High intensity

23. Please check the ONE category only that best describes your current status:

| | |
|---|---|
| Playing without any arm trouble | |
| Playing, but with arm trouble | |
| Not playing due to arm trouble | |

24. Do you feel that you are over bowled? Yes No

25. Do you feel that you throw too many balls? Yes No

**Thank you for completing the Questionnaire**

**Appendix B: Informed Consent Document for Participants**

CONSENT TO PARTICIPATE IN RESEARCH

You have been asked to participate in a research study, titled:

"**Risk Factors and Shoulder Dysfunction in Elite Male South African Fast Bowlers"**

You have been informed about the study by the researcher, Keagan Rafferty.

You may contact Keagan Rafferty (researcher) at cell phone number 083 290 3667 at any time if you have questions about the research or if you are injured as a result of the research.

You may contact the Secretariat of the Health Sciences Research Ethics Committee, UFS at telephone number (051) 4017794/5 if you have questions about your rights as a research subject.

Your participation in this research is voluntary, and you will not be penalized or lose benefits if you refuse to participate or decide to terminate participation.

If you agree to participate, you will be given a signed copy of this document as well as the participant information sheet, which is a written summary of the research.

The research study, including the above information has been verbally described to me. I understand what my involvement in the study means and I voluntarily agree to participate.

______________________ ____________________

Signature of Participant Date

______________________ ____________________

Signature of Witness Date

## Appendix C: CEO Informed Permission Document

PERMISSION TO PARTICIPATE IN RESEARCH

The contracted fast bowlers in this team/union have been asked to participate in a research study, titled:

"**Risk Factors and Shoulder Dysfunction in Elite Male Fast Bowlers in South Africa"**

You have been informed about the study by the researcher, Keagan Rafferty.

You may contact Keagan Rafferty (researcher) at cell phone number 083 290 3667 at any time if you have questions about the research.

You may contact the Secretariat of the Health Sciences Research Ethics Committee, UFS at telephone number (051) 4017794/5 if you have questions about your rights as a research subject.

The participation of the cricketers in this research is voluntary, and they will not be penalized or lose benefits if they refuse to participate or decide to terminate participation.

If you agree to allowing the cricketers to participate, you will be given a signed copy of this document as well as the participant information sheet, which is a written summary of the research.

The research study, including the above information has been verbally described to me. I understand what my involvement in the study means and I give permission for the respective cricketers to participate in this study.

______________________

Signature of CEO

______________________

Signature of Witness

**Appendix D: Information Document**

INFORMATION DOCUMENT

**"Risk Factors and Shoulder Dysfunction in Elite Male South African Fast Bowlers"**

Dear Cricketer

Thank you for showing interest in this study.

I am currently enrolled as a master's student at the University of the Free State and looking to gather information regarding injuries to fast bowlers in cricket. Cricket is and has been a passion of mine for many years. By doing this study I am attempting to improve the injury prevention strategies and ultimately improve the game of cricket. In order to obtain the necessary information for the research to take place, and for the partial fulfilment of my master's degree, informed consent from participating fast bowlers is a necessity.

The study will determine the risk factors for shoulder dysfunction among elite South African Fast Bowlers. The research will hopefully be able to contribute to the optimal player management of fast bowlers, by taking a deeper look at the following data including;

- How much you, the bowler, has bowled
- How much you, the bowler, has thrown
- Your predominant fielding position(s)
- History of your shoulder problems
- Evaluation of internal risk factors including flexibility/stiffness and painful positions of your dominant shoulder.

You are hereby invited to participate in this research study and to help get answers which shall contribute to improving injury prevention strategies of fast bowlers.

**Requirements**

If you agree to participate in this study, you will be required to complete a questionnaire where personal information will be obtained such as your age, limb dominance etc. together with information related to the pain or discomfort you experience when it comes to using your shoulder during bowling and throwing and to what extent the pain currently limits you from performing these tasks.

Secondly, the researcher, who is a qualified physiotherapist, will assess your shoulder, evaluating the stiffness and perceived pain in specific positions, which will contribute to the accuracy of the information.

The entire study should not take longer than 30 minutes to complete.

**Risks**

All the information obtained will be kept strictly confidential and only be provided if required by law. Each participant will acquire a study number on signing informed consent, which will then serve as the participant's identity throughout the course of study.

It will be required that you remove your shirt during the shoulder assessment procedure, though optimal privacy will be ensured.

No interventions or treatments will be performed at any time during the study and no treatment will be allowed if requested by participants.

**Benefits**

By taking part in this study you will be contributing to answering the question surrounding the prevalence of underlying shoulder problems amongst elite South African fast bowlers.

If any significant findings are seen during the shoulder assessment the researcher will refer the participant to the allocated team physiotherapist and communicate the necessary information.

Any information on the study, while you are involved in the research will be given in a confidential manner once the results are available.

No financial reimbursements or incentives will be given to you for taking part in the study.

**Your Participation is voluntary,** and refusal to participate will involve no penalty or loss of benefits to which you are entitled. If you wish to discontinue your participation in the study, there will be no penalty or loss of benefits to which you are entitled to.

**Confidentiality**

Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law.

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Health Sciences Research Ethics Committee and the Medicines Control Council.

**For any questions regarding the research study, please feel free to contact the researcher, Keagan Rafferty at 083 290 3667, at any time.**

**For any problems or complaints please contact the HSREC Secretariat and Chair at telephone number (051) 4017794/**

## Appendix E: Evaluation Recording Form

Participant Number ____________

Limb Dominance [ Left ] [ Right ]

1. Shoulder Internal Rotation ______ Left ______ Right

2. Shoulder External Rotation ______ Left ______ Right

3. Shoulder Impingement Tests

Neer's Test ______ Left ______ Right

Hawkins-Kennedy Test ______ Left ______ Right

Apprehension-relocation Test ______ Left ______ Right

Empty can Test ______ Left ______ Right

O'Brien's Test ______ Left ______ Right

Speed's Test ______ Left ______ Right

5. CKCUES Test ____________ repetitions in 15s

## Appendix F: Ethical Approval from the HSREC

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**Health Sciences Research Ethics Committee**

22-May-2019

**Dear Mr Keagan Rafferty**

Ethics Clearance: **Risk Factors and Shoulder Dysfunction in Elite Male Fast Bowlers in South Africa**
Principal Investigator: **Mr Keagan Rafferty**
Department: **Physiotherapy Department (Bloemfontein Campus)**

**APPLICATION APPROVED**

Please ensure that you read the whole document

With reference to your application for ethical clearance with the Faculty of Health Sciences, I am pleased to inform you on behalf of the Health Sciences Research Ethics Committee that you have been granted ethical clearance for your project.

Your ethical clearance number, to be used in all correspondence is: **UFS-HSD2019/0182/2506**

The ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

We request that any changes that may take place during the course of your research project be submitted to the HSREC for approval to ensure we are kept up to date with your progress and any ethical implications that may arise. This includes any serious adverse events and/or termination of the study.

A progress report should be submitted within one year of approval, and annually for long term studies. A final report should be submitted at the completion of the study.

The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite), Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

For any questions or concerns, please feel free to contact HSREC Administration: 051-4017794/5 or email EthicsFHS@ufs.ac.za.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours Sincerely

Dr. SM Le Grange
Chair : Health Sciences Research Ethics Committee

**Health Sciences Research Ethics Committee**
**Office of the Dean: Health Sciences**
T: +27 (0)51 401 7795/7794 | E: ethicsfhs@ufs.ac.za
IRB 00006240; REC 230408-011; IORG0005187; FWA00012784
Block D, Dean's Division, Room D104 | P.O. Box/Posbus 339 (Internal Post Box G40) | Bloemfontein 9300 | South Africa
www.ufs.ac.za

## Appendix G: Signed CEO Permission Forms

PERMISSION TO PARTICIPATE IN RESEARCH

Dear Mr Fredericks                                                                 24 May 2019

With your permission, the contracted fast bowlers in this team/union will been invited to participate in a research study, titled:

“**Risk Factors and Shoulder Dysfunction in Elite Male Fast Bowlers in South Africa”**

An information document is amended below to this permission document, whereby the outline of the study is given together with all the relevant benefits and risks associated with this study.

You may contact Keagan Rafferty (researcher) at cell phone number 083 290 3667 at any time if you have questions about the research.

You may contact the Secretariat of the Health Sciences Research Ethics Committee, UFS at telephone number (051) 4017794/5 if you have questions about your rights as a research subject.

The participation of the cricketers in this research is voluntary, and they will not be penalized or lose benefits if they refuse to participate or decide to terminate participation.

If you agree to allow the cricketer’s participation in this study, you will be given a signed copy of this document, if required.

I understand what my involvement in the study means and I give permission for the respective cricketers contracted by this franchise or union to participate in this study.

____________________

Signature of CEO

____________________

Signature of Witness

PERMISSION TO PARTICIPATE IN RESEARCH

Dear Mr Jacobs 24 May 2019

With your permission, the contracted fast bowlers in this team/union will been invited to participate in a research study, titled:

“**Risk Factors and Shoulder Dysfunction in Elite Male Fast Bowlers in South Africa”**

An information document is amended below to this permission document, whereby the outline of the study is given together with all the relevant benefits and risks associated with this study.

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You may contact the Secretariat of the Health Sciences Research Ethics Committee, UFS at telephone number (051) 4017794/5 if you have questions about your rights as a research subject.

The participation of the cricketers in this research is voluntary, and they will not be penalized or lose benefits if they refuse to participate or decide to terminate participation.

If you agree to allow the cricketer’s participation in this study, you will be given a signed copy of this document, if required.

I understand what my involvement in the study means and I give permission for the respective cricketers contracted by this franchise or union to participate in this study.

Signature of CEO

Signature of Witness

PERMISSION TO PARTICIPATE IN RESEARCH

Dear Mr van Heerden 24 May 2019

With your permission, the contracted fast bowlers in this team/union will been invited to participate in a research study, titled:

**"Risk Factors and Shoulder Dysfunction in Elite Male Fast Bowlers in South Africa"**

An information document is amended below to this permission document, whereby the outline of the study is given together with all the relevant benefits and risks associated with this study.

You may contact Keagan Rafferty (researcher) at cell phone number 083 290 3667 at any time if you have questions about the research.

You may contact the Secretariat of the Health Sciences Research Ethics Committee, UFS at telephone number (051) 4017794/5 if you have questions about your rights as a research subject.

The participation of the cricketers in this research is voluntary, and they will not be penalized or lose benefits if they refuse to participate or decide to terminate participation.

If you agree to allow the cricketer's participation in this study, you will be given a signed copy of this document, if required.

I understand what my involvement in the study means and I give permission for the respective cricketers contracted by this franchise or union to participate in this study.

____________________

Signature of CEO

____________________

Signature of Witness

PERMISSION TO PARTICIPATE IN RESEARCH

Dear Mr Williams 24 May 2019

With your permission, the contracted fast bowlers in this team/union will been invited to participate in a research study, titled:

**"Risk Factors and Shoulder Dysfunction in Elite Male Fast Bowlers in South Africa"**

An information document is amended below to this permission document, whereby the outline of the study is given together with all the relevant benefits and risks associated with this study.

You may contact Keagan Rafferty (researcher) at cell phone number 083 290 3667 at any time if you have questions about the research.

You may contact the Secretariat of the Health Sciences Research Ethics Committee, UFS at telephone number (051) 4017794/5 if you have questions about your rights as a research subject.

The participation of the cricketers in this research is voluntary, and they will not be penalized or lose benefits if they refuse to participate or decide to terminate participation.

If you agree to allow the cricketer's participation in this study, you will be given a signed copy of this document, if required.

I understand what my involvement in the study means and I give permission for the respective cricketers contracted by this franchise or union to participate in this study.

______________________
Signature of CEO

______________________
Signature of Witness

PERMISSION TO PARTICIPATE IN RESEARCH

Dear Mr Dien 24 May 2019

With your permission, the contracted fast bowlers in this team/union will been invited to participate in a research study, titled:

"**Risk Factors and Shoulder Dysfunction in Elite Male Fast Bowlers in South Africa"**

An information document is amended below to this permission document, whereby the outline of the study is given together with all the relevant benefits and risks associated with this study.

You may contact Keagan Rafferty (researcher) at cell phone number 083 290 3667 at any time if you have questions about the research.

You may contact the Secretariat of the Health Sciences Research Ethics Committee, UFS at telephone number (051) 4017794/5 if you have questions about your rights as a research subject.

The participation of the cricketers in this research is voluntary, and they will not be penalized or lose benefits if they refuse to participate or decide to terminate participation.

If you agree to allow the cricketer's participation in this study, you will be given a signed copy of this document, if required.

I understand what my involvement in the study means and I give permission for the respective cricketers contracted by this franchise or union to participate in this study.

______________________

Signature of CEO

______________________

Signature of Witness

## Appendix H: Turnitin Report

turnitin

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