

**An investigation into the use of the Functional Movement Screen™ as a predictor of injury in CrossFit athletes in the eThekwinini municipality**

By

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I, Michelle Richardson, do declare that this dissertation is reprehensive of my own work in both conception and execution (except where acknowledgements indicate the contrary).

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## **DEDICATION**

This dissertation is dedicated to my parents, Steve and Riëtte Richardson, thank you for your never-ending support. Also, to Keaton Luke Parker for his constant strength and love. Without the support of my friends and family that surround me, this would not be possible. Finally, this is dedicated to Jesus Christ, my Lord and saviour, from whom all my strength comes.

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# ABSTRACT

**Background:** CrossFit is a popular and unique exercise training programme and competition. Despite the popularity of this training programme there is a high incidence of injury amongst the athletes. The Functional Movement Screen™ (FMS™) is a pre-participation assessment which grades seven tests which screen fundamental movement patterns of athletes to possibly predict future injury. No studies have successfully looked at the use of the FMS™ to predict injury in CrossFit athletes.

**Aims:** The aim of this study is to establish the normative values of the FMS™, which have yet to be determined for CrossFit athletes, and to determine the use of these values as a predictor for future injury.

**Methods:** The methodology included scoring 61 CrossFit athletes using the FMS™ one month prior the “United We Stand (UWS) Games 2017”. Additionally, the athletes were required to fill out a questionnaire which was used to assess for additional risk factors for injury. The athletes were thereafter tracked documenting CrossFit specific injury over the course of the one month training period that lead up to and included participation in the “UWS Games 2017” in order to compile a injury profile. The mean FMS™ was then compared to the injuries sustained.

**Results:** The research sample revealed that the mean FMS™ score for CrossFit athletes was 17.73 out of 21. There was no significant link between the mean value when compared to the injury rates and this was therefore not a predictor of injury. There were significant findings that showed that using components of the FMS™ as a method of injury prediction in CrossFit athletes was possible; specifically, a low trunk stability push-up test score increased the likelihood of sustaining injury and previous injury negatively impacted the shoulder mobility test. Further findings suggested that Body Mass Index (BMI) negatively impacted the performance of the FMS™, and the boxes with which the athletes were affiliated, influenced the total FMS™ scores. The most common types of injuries recorded were joint dysfunction and muscle strain and the most common locations of injury were the shoulder, knee and lower back.

**Conclusions:** Aspects of the FMS™ were a statistically significant predictor of injury in CrossFit athletes, specifically that of the shoulder mobility test and the trunk stability push-up test. Other findings concluded that factors such as the BMI and the box that athletes trained under influenced the FMS™ outcome. The normative value of 17.73 out of 21 for the FMS™

was provided as reference values for CrossFit athletes in order to assist with the interpretation of future scores when screening athletes.

**Key words:** CrossFit, Functional Movement Screen™, pre-participation screen, injuries, quantitative, musculoskeletal injuries, injury profile, risk factors

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## LIST OF ABBREVIATIONS

### **BMI**

Body Mass Index

### **FMS™**

Functional Movement Screen™

### **“UWS Games 2017”**

United We Stand CrossFit Games 2017

### **WOD**

Work Out of the Day

### **Kg**

Kilograms

### **M**

Meters

### **HIIT**

High intensity interval training

### **HIPT**

High intensity power training

# DEFINITIONS

## **Acute Injury**

For the purposes of this research an acute injury is defined as an injury which occurs suddenly because of macro-trauma or aggravation of a chronic complaint (Da Silva 2015).

## **Aerobic Fitness**

Any various sustained exercises, such as jogging, rowing, swimming, or cycling, that stimulate and strengthen the heart and lungs, thereby improving the body's use of oxygen.

## **Affiliate**

An official attachment or connection to an organization (Tao 2012).

## **Air Squat**

A CrossFit specific exercise where athletes are standing straight up, squats down until their hips are below their knees and then stands back up until the hips are once again fully extended (UWS Manual 2013).

## **Anaerobic fitness**

Exercise consisting of brief intense bursts of physical activity, such as weightlifting and sprints, where the oxygen demand surpasses oxygen supply.

## **Bar Muscle Up**

A CrossFit specific exercise where athletes lift a weight with the elbows fully locked and hips are fully open (UWS Manual 2013).

## **Boxes**

Within the CrossFit community the CrossFit gyms are referred to as 'boxes' (Tao 2012).

## **Burpee**

An exercise that consists of a series of movements starting and ending in a standing position (Forster 2014). It involves a squat thrust and dropping into the plank position before returning to the standing position (UWS Manual 2013).

### **Box Jump Over**

This involves a quick powerful movement consisting of a pre-stretching or countermovement that activates the stretch shortening cycle (Ebben *et al* 2008). A box jump starts in a squat position, facing a box. A jump is then initiated, the knees and hips flexed to bring the body vertically for the feet to land on the box, ending in a squat position, then standing by extending at the hips and then stepping down to the ground.

### **Chin To Bar Pull Up**

An exercise where the bar is held with palms facing the athlete (supinated grip) and is then followed by pulling the body up to where chin crosses the bar. The arms are straight and hips are fully open, with the whole head above the line of the pull up bar (UWS Manual 2013).

### **Chronic Type Injuries**

For the purposes of this research a chronic injury is defined as an injury because of repetitive micro-trauma, stress or trauma to soft tissue structures and improper healing of these structures resulting in pain for a pro-longed period (Da Silva 2015).

### **Clean and jerk**

This is a lift that consists of two weightlifting movements, the clean and the jerk. The clean involves moving the weighted barbell from the floor to the racked position across the deltoid muscles and clavicles. The jerk then involves lifting the barbell above the head until the arms are straight and the bar is stationary (Tao 2012).

### **Core Strength**

The strength of the underlying muscles of the torso, which help determine posture.

### **Deadlift**

An exercise which starts with the movement from a bent over position; with the knees and hips flexed, back straight, feet are hip width apart with the hands in an alternating grip on the bar outside the legs. The lift is performed by extending the knees and hips, keeping the shoulder posterior to the bar, resulting in a fully erect end position, with the bar at hip level (Da Silva 2015).



### **Double Under Skip**

This is an exercise where a skipping rope is used and the rope passes under the athlete's feet twice with one jump (Tao 2012).

### **Fast Twitch Muscle Fibers**

These are types of muscle fibers which are good for rapid movements like jumping to catch a ball or sprinting for the bus. They contract quickly, but get tired fast, as they consume a lot of energy.

### **Front Squat**

A squat performed using a grip on the bar that is wider than that of the shoulders; the bar should rest across the clavicles, upper chest and anterior deltoids. The arms should be parallel to the floor, chest elevated and torso rigid at the beginning of the movement. Feet should be spaced between shoulders and hip width apart. On the descending portion of the squat, the hips and pelvis move posteriorly with hip flexion, followed by knee flexion and anterior knee motion. The back and head remain neutral. The concentric phase of the lift begins by pushing through the center of the feet, lifting out of the bottom end of the movement and ends when hips and knees have reached full extension (Da Silva 2015).

### **Functional exercise**

A classification of exercises that consists of movements of daily living. There is an involvement of multi-planar, multi-joint movement placing a demand on the musculature and innervation of the body's core.

### **Functional Movement Screen™**

Pre-participation screening tool designed to identify compensatory movement patterns that are indicative of increased injury risk and inefficient movement that causes reduced performance (Cook *et al* 2006).

### **Glucose**

A simple sugar which is an important energy source in living organisms and is a component of many carbohydrates.

## **Glycolytic Metabolic Pathways**

A term used to describe the metabolic pathway involving the degradation of glucose into pyruvate and energy used to form adenosine triphosphate (ATP) and reduced nicotinamide adenine dinucleotide (NADH).

## **Gymnastics**

An exercise that increases strength, suppleness and agility, especially when using special apparatus in the gymnasium (Adamson 2007).

## **Handstand Walk**

The athlete walks on their hands in a handstand position from one point to another. If any part of the athlete's body aside from the hands contacts the ground the athlete must begin their next attempt from behind the point that their rear hand last contacted the floor (UWS Manual 2013).

## **Hang To Overhead**

A CrossFit specific exercise where athletes use a barbell and start by hanging the barbell at the level of the hips and end in the front squat position (UWS Manual 2013).

## **High Intensity Interval Training**

This is a form of interval training, a cardiovascular exercise strategy alternating short periods of intense anaerobic exercise with less intense recovery periods.

## **High Intensity Power Training**

This is a type of training that maximizes aerobic fitness levels. HIPT differs from high intensity interval training (HIIT) as there is an emphasis on high levels of power output, multi-joint activities and rest periods throughout training.

## **Injury**

Based on Chorba *et al's* (2010) injury definition and for this research, injury was defined as: any acute or chronic injury that prevents an athlete from participating to their full potential or causes them to miss training.

## **Kinematic Chain**

This is a term used for the human body which represents how forces occur during human motion and how segments of the body are linked together.

## **Kinesiology**

The study of the principles of mechanics and anatomy in relation to human movement.

## **Medicine Ball Clean**

A medicine ball is a soft, large, pillow like ball that ranges in weight. Initially the starting position and posture is that of a deadlift, followed by the lift where the athlete must shift to front squatting position with the ball and then move to the clean. The clean involves moving the ball from the floor to the racked position across the deltoid muscles and clavicles (UWS Manual 2013).

## **Micro Trauma**

This includes the micro-tearing of muscle fibers, the sheath around the muscle and the connective tissue. It can also include stress to the tendons and to the bones.

## **Neuroendocrine Response**

This is a change in the body that affects an athlete neurologically or hormonally.

## **Olympic Weight Lifting**

A sporting discipline in which an athlete attempts to lift a maximum weight in a single lift of a loaded barbell. Two lifts form part of this discipline, namely, the snatch and clean and jerk (Butragueño *et al* 2014).

## **Overhead Squat**

Performed with the bar overhead using a wide grip, centered over the heels and elbows locked in extension (Chiu and Burkhardt 2011). This is a variation of the standard powerlifting squat technique.

## **Oxidative Metabolic Pathways**

This is the metabolic pathway in which cells use enzymes to oxidize nutrients, thereby releasing energy which is used to produce adenosine triphosphate (ATP).

## **Phosphagen Metabolic Pathways**

Humans produce ATP (energy) through this pathway, consisting of many enzyme-catalyzed chemical reactions.

## **Powerlifting**

A sporting discipline that consists of three attempts at maximal weight on three lifts. These are the squat, bench press, and deadlift (Butragueño *et al* 2014).

## **Proprioception**

This is the sense of the relative position of one's own parts of the body and strength of effort being employed in movement.

## **Pull Up**

The body is suspended by the arms in either a supinated or pronated grip on a bar and the body is lifted up by muscular effort (Tao 2012).

## **Push Press**

This is a CrossFit exercise where the bar is fully gripped and resting on the athlete's torso. The athlete then extends their legs and hips and presses the bar upwards. The movement is complete with the bar in line with the athlete's mid foot and the hips, knees and arms are fully extended (UWS Manual 2013).

## **Rhabdomyolysis**

A condition in which damaged skeletal muscle breakdown material is released into the bloodstream and results in kidney damage. Exertional rhabdomyolysis occurs when extreme exercise overload results in skeletal muscle breakdown (Ciccolella *et al* 2014).

## **Shoulder To Overhead**

A CrossFit exercise where the athlete moves the bar from a position at shoulder level, extending the elbows and brings the bar overhead ("UWS Games 2017" 2013).

## **Skeletally Mature Athletes**

Athletes over that age of 18 years.

## **Snatch**

Involves lifting a barbell from the floor to an overhead position at arm's length in a single continuous movement (Waller *et al* 2007).

**Thruster**

A CrossFit exercise where a front squat is done followed by a push press (Tao 2012).

**Toe To Bar**

In the toes to bar, the athlete must go from a full hanging position from the pull up bar, following having the toes touch the pullup bar. At the start of each repetition, the arms must be fully extended with the feet off the ground, and the feet must be brought back behind the bar and the rest of the body (UWS Manual 2013).

**Trail Run**

A sport which involves outdoor running on hiking trails.

**Work Out Of The Day (WOD)**

The “Workout of the Day” is the workout CrossFit athletes perform on a given day. Many individuals and affiliates follow WODs (Glassman 2010).



# CHAPTER ONE

## INTRODUCTION

### 1.1 INTRODUCTION

The scientific evidence supporting the benefits of participating in sports is undeniable. A programme of regular exercise which challenges cardiorespiratory, neuromotor, flexibility and resistance of a person beyond that of the normal activities of daily living, allows for an improvement and maintenance of both physical and mental health (Garber *et al* 2011). Over the years many different exercise methods have been created in order to achieve the best level of physical fitness. As further discoveries are made known in understanding the way the human body functions, as are new methods of conditioning and improving the physical state of the body being developed (Le Corre 2014). In the past, the majority of the exercise programmes designed were aimed at reducing body fat percentage through a regular routine of walking or jogging at a moderate intensity. The outcomes of these exercise programmes have shown poor results in weight loss. There is accumulating evidence to suggest that in place of these poor methods of weight loss, high intensity exercise is more beneficial (Boutcher 2011). Extreme conditioning programmes are being developed and involve aggressive, high intensity training in order to gain optimal fitness and weight loss (Bergeron *et al* 2011).

CrossFit is a challenging and relatively new developing workout programme, created by Greg Glassman, who allowed a platform for high intensity training to be carried out at a rapid and repetitive rate with limited recovery time (Weisenthal *et al* 2014). The programme incorporates various aspects of gymnastics, powerlifting and Olympic lifting. The aim of CrossFit, as proposed by Glassman (2007), is to prepare athletes for unpredictable circumstances experienced in their day-to-day activities. This is achieved by carrying out a workout routine with rapidly changing, high intensity functional activities (Glassman 2007). The goal of CrossFit is to conduct a conditioning workout programme aimed at achieving a generalised and comprehensive level of fitness (Paine *et al* 2010).

The term *high intensity power training* is frequently used when describing the nature of CrossFit. This is due to the extreme strength and endurance characteristics incorporated into

the workout programmes, as well as the use of maximum power output activities that use the entire kinematic chain. CrossFit necessitates high intensity power training, which has known aerobic fitness benefits, as stated by Smith *et al* (2013). These aerobic fitness health benefits are a strong representation of the effectiveness of CrossFit for all athletes involved (Smith *et al* 2013).

The benefits of CrossFit are achieved through the high intensity workout programmes that are done through the Work Out of the Day (WOD). These WODs are new each day and are widespread throughout the CrossFit community. The WODs are different each day, they are challenging and include a variety of high intensity exercises. Releasing a different WOD each day ensures that different areas of the body are targeted (Paine *et al* 2010).

There are various CrossFit competitions that take place around the world. One competition in particular is the United We Stand CrossFit Games. This competition is unique because any level of athlete may compete, not only elite athletes. It is a three-day competition that includes an array of functional movements within a competitive setting (Warr 2014).

Sound research has been conducted supporting the benefits of CrossFit, however, the nature of the workout programme allows for some scrutiny with regards to the safety of the sport (Hak 2013), who points out that there are many known cases of athletes developing injuries while participating in CrossFit. Various studies have been conducted to instigate the frequency of injury in CrossFit (Chachula *et al* 2016; Da Silva 2015; Hak 2013; Mehrab *et al* 2017; Montalvo *et al* 2017; Sprey *et al* 2016; Weisenthal *et al* 2014). Weisenthal *et al* (2014) conducted an injury profile study that encompassed an array of widespread injury. Chachula *et al* (2016) revealed that there are significant associations between CrossFit related injuries and previous joint injury, and that previously injured athletes were four times more likely to sustain injury during CrossFit. Nonetheless, it has not yet been identified whether these injuries were as a direct result of CrossFit or not. Pre-existing biomechanical abnormalities that athletes carried into the sport may also influence the injuries (Chachula *et al* 2016). Additional studies have identified specific factors which may increase the likelihood of sustaining an injury during CrossFit training. These include a high training load and volume (Bergeron 2011), a longer period of experience with CrossFit training (Sprey 2016) and inadequate performance of movement (Summit 2016). A review of all current CrossFit scientific literature found that there has yet to be firmly established findings with regards to the benefits and risks of CrossFit (Claudino *et al* 2018). The uncertainty in the possible causes of injury in CrossFit athletes may



be identified using the FMS™. It has already been made known that previous injury is a risk factor for future injury, but the FMS™ may provide a scientific value for this risk factor.

The FMS™ is a pre-participation tool designed to help identify varying degrees of biomechanical limitations when participating in a particular activity. The FMS™ comprises seven functional tests which are graded according to the athletes quality of movement. It assesses the quality of movement within the kinematic chain, along with restrictions and alterations in normal movement patterns (Chorba *et al* 2010). It is used to identify functional movement imbalances and weakness, which may be detected through various compensatory mechanisms that predispose an athlete to injury. By identifying an athlete's limitations and deficits, one can strategise an injury prevention protocol. The FMS™ is therefore a type of pre-participation screen that can help athletes to predict injury, by bringing attention to an athlete's biomechanical deficits and identifying any risk of injury when engaging in activity. This is done by providing specific normative values from grading the seven FMS™ tests, for each type sport. Normative values allow fitness professionals to compare athlete scores to ideal scores for that sport. These normative values are determined using the mean FMS™ score of the athletes and can be compared to injuries sustained to see whether the normative values can be used to predict injury (Cuson 2010).

The seven tests were created using principles of an athlete's proprioception and kinesiology abilities (Cook *et al* 2006). The investigation into the use of the FMS™ as a pre-participation tool in the prediction of injury has previously been conducted and these studies concluded successful predictors of injury within the particular fields investigated (Bock and Orr 2015; Cuson 2010; Kiesel *et al* 2007; Lisman *et al* 2013; Schneiders 2011). With regards to CrossFit, these normative values have yet to be successfully determined as a predictor of injury. This research investigates the normative values for the Functional Movement Screen™ (FMS™) and its association to injury in CrossFit athletes competing in the "United We Stand (UWS) CrossFit Games 2017", within the eThekweni municipality.

## **1.2 AIM**

The aim of this study was to determine the normative values of the FMS™ in CrossFit athletes and to investigate the use of the normative values as a predictor of injury in CrossFit athletes in the eThekweni municipality. The study also aims to gain insight into the nature of injury in

CrossFit athletes during the training for and competing at the “UWS Games 2017”. Additionally, it aimed to determine a possible link between athletes’ low FMS™ scores and injury occurrence. Furthermore, this study also aimed to determine additional risk factors for injury including previous injury, age, height, weight and amount of time practising CrossFit.

### 1.3 OBJECTIVES

- a. To evaluate the scores of the FMS™ in CrossFit athlete’s pre-participation and to determine the normative values of the FMS™ as a predictor of injury.
- b. To determine demographic data and additional risk factors which might predispose athletes to injury occurrence pre-participation such as: previous injury, age, height, weight and amount of time practising CrossFit.
- c. To compile an injury profile of the athletes during the training period for and participation at the “United We Stand CrossFit Games 2017”.
- d. To determine any association between low FMS™ scores and injury occurrence.

### 1.4 HYPOTHESIS

**Hypothesis:** A low score on the FMS™ is a predictor of injury in CrossFit athletes in the eThekweni municipality.

**Null Hypothesis:** A low score on the FMS™ is not a predictor of injury in CrossFit athletes in the eThekweni municipality.

### 1.5 RATIONALE

The intense nature of CrossFit allows for much speculation into the safety of how the athletes execute some of the exercises, as there is a high occurrence of musculoskeletal injuries. This might allow for technique to be compromised due to the high intensity exercises being

performed against time (Weisenthal *et al* 2014:). Details of the frequency, distribution and type of injuries involved with CrossFit, might give further understanding as to why the injuries occurred (Sanders 2013).

The FMS™ aims at assessing an athlete's physical condition before engaging in an activity. This information could be used to give insight into possible performance limitations which might be the causative factors for injury occurrence in athletes. This assessment was created to identify these functional limitations within the kinematic chain and to identify how they might cause an athlete to develop injuries during an exercise such as CrossFit (Sanders 2013).

The FMS™ evaluates the performance of the seven functional movements; in which scores are calculated from the grading on how well each athlete performs these movements. The movements include: a deep squat, hurdle step in-line lunge, active straight leg raiser, shoulder mobility test, trunk stability push-up and a quadruped rotary stability test (Teyhen 2012). When reviewing CrossFit and the exercises performed during the WODs, a large overlap in the functional movements done during CrossFit and the FMS™ was found (Cook *et al* 2006).

## **1.6 BENEFITS**

The CrossFit community can use the normative values of the FMS™ as a guide to screen athletes before they begin CrossFit, and compare their scores to this value as a reference. Additionally, to assess if the athlete has any risk for developing injuries, as comparison to these normative values may give an indication of each athlete's level of functional movement compared to other CrossFit athletes (Teyhen 2012). In addition, CrossFit instructors can use this information for athletes interested in joining a CrossFit box to recognise any risks of injury before starting training; if these risks are identified and corrected beforehand, the risk of an injury occurring could reduce. Through these efforts the rate of injury in CrossFit athletes may be reduced (Peate *et al* 2007). The health benefits of practising CrossFit may therefore outweigh the risk of injury in athletes. The information from the FMS™ may also allow athletes to be more aware of their bodies' possible limitations, and allow them to be more proactive in achieving all-round fitness and correct functional movement. Furthermore, the results from this research will add value to the knowledge in the use of the FMS™ and improve further accuracies in the reliability when using this screen as a predictor for injury.

## **1.7 LIMITATIONS**

The limitations related to this study are that of the athlete's commitment to report to the researcher with injuries sustained. This research relies on the honesty and reliability of the athletes, which is an inherent bias in any research of this nature (Mounton 2006).

## **1.8 CONCLUSION**

Based on the overall literature of CrossFit injury rates from previous studies conducted, (Chachula *et al* 2016; Da Silva 2015; Hak 2013; Mehrab *et al* 2017; Montalvo *et al* 2017; Sprey *et al* 2016; Weisenthal *et al* 2014), there is still a need to determine the risk factors for these injuries. In addition to the latter, a reliable investigation into determining what the normative values for FMS™ are in relation to CrossFit needs to be investigated; as well as whether the use of the FMS™ as a predictor for injury in CrossFit athletes. This research was conducted in order to find the normative values for CrossFit athletes in the eThekweni municipality and to use these values as a potential predictor of injury.

# **CHAPTER TWO**

## **LITERATURE REVIEW**

### **2.1 INTRODUCTION**

This chapter allows for a greater understanding into the various aspects of this research, including CrossFit and the related rates and types of injury sustained during training. The injuries are also discussed in terms of risk factors and the use of pre-participation studies to predict injury. Finally, the Functional Movement Screen™ (FMS™) is discussed in detail to further the understanding of its use as a pre-participation screen in injury prediction.

### **2.2 CROSSFIT**

#### **2.2.1 CrossFit principles**

CrossFit is a sport established in 2000 (Glassman 2010). It undertakes a different approach to fitness as it includes high intensity interval training (HIIT). It incorporates a multitude of functional movements performed at high intensity and high frequency to attain a generalised aerobic fitness. This ensures that the body is adequately prepared for all daily activities (Glassman 2007). The programme focuses on conditioning training and core strength, which prepares athletes for physical contingency. There is a collection of a wide variety of different exercises performed during CrossFit, including weight lifting (to improve explosive power, controlling objects and to gain control of important motor recruitment pathways), power lifting and gymnastics (from simple to advanced movements which improve strength to weight ratio and flexibility). The programme is said to focus on neuroendocrine responses, power development, training of multiple modalities, functional movement training and diet strategies (Glassman 2010). The dietary strategies follow a Paleolithic diet where fresh fruit, vegetables, meat, seeds and nuts are primarily consumed (Kuhn 2013).

### 2.2.2 CrossFit workout programmes

Within the CrossFit community the CrossFit gyms are referred to as 'boxes'. These boxes must be registered and licensed, thus an affiliated box is a term for a registered and licensed CrossFit gym (Tao 2012). The workout programme consists of the integration of combining various different types of exercises simultaneously for each day, called the Work Out of the Day (WOD). In addition to the WOD, a CrossFit workout programme always begins with a warm-up exercise, followed by strength or skill development training (Paine *et al* 2010). As described by Smith *et al* (2013) a WOD is given at each training session where an assortment of random multiple joint exercises are given to be completed at a high speed and high resistance. An example of a WOD would be to complete as many rounds of 10 push presses, 20 air squats and 30 pull-ups as possible in 10 minutes (Kuhn 2013). There is an incorporation of strength, power, metabolic conditioning and endurance into each workout (Waryasz *et al* 2016). These workout programmes are repetitive, rapid activities performed at a high resistance. Additionally, the WOD is to be completed with very little recovery time (Weisenthal *et al* 2014).

The types of exercises include activities such as jumping, throwing, pushing, pulling, squatting, rowing, running and lifting (Kuhn 2013). The exercise programmes work on altering simple activities into functional movements, which are done at high intensity intervals. For example, a lateral raise will become a push press, leg extensions will be replaced with squats. All workouts conducted in CrossFit are continuously changing and in demand with a high intensity, load, frequency, tempo and volume (Gerhart 2013). The exercise programmes that stem from other sports include the clean, jerk and snatch from Olympic weight lifting, muscle-ups and the handstand walk from gymnastics, and the deadlift and squat from powerlifting (Montalvo *et al* 2017). There are three standard foundations on which CrossFit is based. The first standard includes assessing and improving on competency levels with the 10 main categories of fitness. These categories are: cardiovascular and respiratory endurance, stamina, increasing strength, improving in flexibility, speed, co-ordination, balance, accuracy and agility. The second standard focuses on improving athletes' broad range of physical activities performed. The last standard of CrossFit is to have athletes performing well across the phosphagen, oxidative and glycolytic metabolic pathways. These pathways are responsible for producing energy for the human body (Glassman 2010).

## **2.3 THE UNITED WE STAND CROSSFIT GAMES**

### **2.3.1 Description of the United We Stand CrossFit Games**

The “United We Stand (UWS) CrossFit Games” was initiated in 2011 and take place in Durban, South Africa. The competition is currently one of the biggest CrossFit team competitions in South Africa (Rader 2017) and allows for athletes around South Africa to compete against each other.

The first “UWS Games” only consisted of teams of four taking part in the event, with two males and two females in each team, and consisted of five events over two days. At the initial “UWS Games” athletes could take part in the event regardless of whether they belonged to an affiliated CrossFit gym or not.

The “UWS Games” were created to promote CrossFit to the public and create greater exposure. The competition’s growth over the years has been exponential (Da Silva 2015), and it currently allows teams of six to enter, each consisting of four males and two females. There are also seven events that span over a period of three days, described below.

### **2.3.2 “UWS Games 2017” events**

#### **Event one:**

- 13km trail run

#### **Event two:**

- Overhead Squat: Three repetitions at maximum weight (18 minute limit).

#### **Event three:**

- Three rounds of Hang to Overhead (30kg for female/40kg for male), increasing to 35kg/50kg and 40kg/60kg, as well as 50 pullups in 10 minutes.

**Event four:**

- Female athletes: 10 toe to bars, 14 hand release burpee box jump overs, 14 toe to bars and 10 hand release burpee box jump overs. Once completed, clean squats with 50kg to failure.
- Males: 10 toe to bars, 14 hand release burpee box jump overs, 14 toe to bars and 10 hand release burpee box jump overs (11 minute limit). Once completed, clean squats with 80kg to failure.

**Event five:**

The following must be done in pairs for six minutes each with a 20 minute limit.

- 20 front squats @ 60kg/40kg (male/female) and 50 double under skips
- 20 shoulder to overhead @ 60kg/40kg and 50 double under skips
- 20 snatches @ 60kg/40kg and 50 double under skips

**Event six:**

- As many repetitions as possible (AMRAP) of deadlifts (at 120kg for males and 90kg for females) and medicine ball cleans (at 50kg for males and 30kg for female).
- Two lengths of handstand walks per round.

**Event seven (the final):**

- Male 1: 21, 15, 9 thrusters at 40kg and pull ups
- Female 1: 21, 15, 9 thrusters at 30kg and pull ups
- Male 2: 15, 12, 9 thrusters at 50kg and chin to bar pull ups
- Female 2: 15, 12, 9 thrusters at 35kg and chin to bar pull ups
- Male 3: 9, 6, 3 thrusters at 60kg and bar muscle ups
- Female 1: 9, 6, 3 thrusters at 40kg and bar muscle ups
- Time limit of 25 minutes



## 2.4 CROSSFIT INJURY

CrossFit is performed at a high intensity and resistance resulting in an increased risk for injury occurrence (Weisenthal *et al* 2014). The repetitive use of technical exercises performed at a high intensity rate may leave athletes susceptible to high injury rates (Bergeron *et al* 2011). The repetitive activities can cause micro trauma within the body in overuse chronic type injuries. Technique may be compromised due to the speed and intensity at which these exercises are performed (Da Silva 2015). An injury profile of CrossFit compiled by Weisenthal *et al* (2014) exhibited a 20% injury occurrence. Moreover, the most common type of injuries in this study included the knees, shoulders and lower back, which were mostly acute in nature. The injuries were similar in nature to gymnastics, Olympic weight lifting and powerlifting injuries (Caine and Nassar 2005; Calhoon and Fry 1999; Raske and Norlin 2002). There have only been a handful of studies related to the rate of injury occurrence in CrossFit. Nonetheless, the studies have indicated the significant relationship between CrossFit and injury (Weisenthal *et al* 2014).

Hak *et al* (2013) were the first to conduct an injury prevalence and incidence study of CrossFit by using an online questionnaire to record injuries that had been sustained during CrossFit. The results showed that 73.5% of the respondents developed an injury while doing CrossFit. However, there were limitations, such as the count of athletes that visited the site and did not respond. The most common injuries were that of the spine and shoulder, though not enough evidence was produced with regards to rhabdomyolysis and musculoskeletal injury (Larsen and Jenson 2014, Drum *et al* 2017). The study concluded that further investigation needed to be done for the latter (Hak *et al* 2013).

Da Silva (2015) conducted a CrossFit injury profile at the United We Stand CrossFit Games 2013. This study brought further insight into the nature of CrossFit injuries sustained during competition participation. The region of the lower back, hand and wrist were the most prevalent injuries sustained. Additionally, more than a quarter of the participants had at least two main complaints, which revealed that CrossFit injuries affected more than one body part at a time. The main exercises that caused the injuries were running and overuse mechanisms. The majority of the injuries were acute and muscular in nature. However, it was concluded that further studies into injury occurrence with CrossFit should be conducted (Da Silva 2015).

Chachula *et al* (2016) investigated the characteristics of CrossFit athletes and whether these characteristics played a role in the occurrence of new joint injury developing during training. From the results, it was concluded that athletes with previous injury were 3.75 times more susceptible to sustain an injury during CrossFit. These results gave further insight into the nature of CrossFit injuries, nevertheless further investigations into the type, severity and rehabilitation of CrossFit injuries needs to be conducted (Chachula *et al* 2016, Claudino *et al* 2018).

Montalvo *et al* (2017) conducted a study to identify CrossFit injury rate and risk factors over a six-month observation period. There were a reported 26% of 191 athletes injured. Of these injuries the most common injuries areas were the shoulder, knee and lower back. Further findings suggested that in order to reduce injury, particularly that of the shoulder, athletes should improve flexibility, strength and skill. An injury profile study conducted on Dutch CrossFit athletes, also reveals that the most common areas of injury were the shoulder, knee and lower back. Furthermore, of the Dutch athletes involved in this study, 56.1% sustained injury. This study also included that athletes who had been participating in CrossFit for more than six months were more likely to sustain one of these injuries (Mehrab *et al* 2017). It was also found that the unusual manner in which different CrossFit exercises are combined and performed in different orders decreases the focus on technique (Montalvo *et al* 2017). With regards to the identified risk factors for injury, it was found that taller and heavier athletes were more susceptible to injury: this may be due to taller athletes having larger biomechanical moments and placing extra loads on the musculoskeletal systems during training (Faude *et al* 2006). Athletes were less susceptible to injury with increased time spent training: this may be due to athletes gaining better skills and techniques over time (Montalvo *et al* 2017).

A study was conducted by Sprey *et al* (2016) where by injury rates were recorded and compared to athlete's profiles, training routine and sports history. It was discovered that 31% of athletes sustained injuries. The athletes that were more likely to sustain injuries were those who took part in CrossFit for more than six months and who were training for competitions. This may be due to more advanced, complex and intense work out programmes being implemented for more experienced athletes. This contradicts the above findings as to whether the duration spent training has an impact on injury development. Either a longer training duration decreases injury rates due to an increased skill level, or a longer duration training increases the risk for

injury due to athletes attempting more advanced techniques and more intense work out programmes.

The exercise routines are presented to the athletes with the help of CrossFit instructors, whose role is to present and demonstrate each WOD, as well as the warm-up and skill exercises. These instructors emphasise the teaching of basic movements first. Once these have been perfected they allow athletes to attempt advanced techniques and lifts. CrossFit offers different levels of CrossFit trainer courses to all instructors. This is to allow for adequate understanding in each aspect of the exercises offered and for the safety and optimum performance of athletes. However, due to the various channels available to become an instructor, there is doubt as to whether their training background and involvement in workouts may have an influence on injury in the sport (Waryasz *et al* 2016). It was also found that an increased training load given to athletes from the instructor was a risk factor for injury in CrossFit athletes. The research conducted by Weisenthal *et al* (2014) revealed a significant decrease in injury when instructors were involved in workouts. This research supports CrossFit instructors credibility in having adequate skills to guide athletes in such a manner that injury is avoided. The two conflicting pieces of research leaves reason for doubt as to whether CrossFit instructors play a role in injury rates.

In the above-mentioned studies, it was found that the most prevalent area injured was the shoulder. A study was conducted specifically to assess shoulder injuries in CrossFit athletes. It was found that 23.5% of the group experienced shoulder injuries within a time frame of six months. Of these injured athletes 38.6% reported that the shoulder injury was related to previous CrossFit injuries. The most common causative factors for shoulder injuries in the athletes were improper form and previous injury (Summitt 2016). This indicates that when athletes have a history of injury, there are lingering biomechanical abnormalities. When complex movements are attempted and the shoulder is placed in a hyper flexed, abducted and internally rotated positions due to the repetitive overhead CrossFit movements, these abnormalities place increased strain on the surrounding structures. This may in turn develop into an injury.

The common types of CrossFit injuries previously described have similarities to studies that investigated injury in gymnastics, weight lifting and power lifting (Caine and Nassar 2005; Calhoun and Fry 1999; Raske and Norlin 2002). In a gymnastics injury profile study conducted by Caine and Nassar (2005), it was revealed that the shoulder, knee, lower back, elbow and

wrist were the most common types of injuries sustained. Research into the injury rates of competitive weight lifters revealed that shoulder, knees and the lower back were the most common types of injuries (Calhoon and Fry 1999). Lastly, the injury incidence and occurrence of elite power lifters and weight lifters was investigated and revealed that shoulder and lower back injuries were the most prevalent (Raske and Norlin 2002). With the information that these studies yield one can see why the characteristics of CrossFit might injury appear to be a combination of the injury characteristics of the component sports on which it is based.

In conclusion of the numerous research done with regards to CrossFit injury, it can be said there is a high incidence of injury. The most common injured areas amongst the athletes were the shoulder, knee and lower back. The risk factors that are most likely associated with injury in CrossFit are athletes that are taller, coaching method discrepancies, longer duration of CrossFit participation, previous injury and improper form and technique when executing CrossFit activities. Multiple studies have suggest that further investigation into the nature of CrossFit injuries needs to be looked at, as well as the risk factors for these injuries.

## **2.4.1 Injury risk factors**

### **2.4.1.1 Intrinsic risk factors**

Intrinsic risk factors in athletes are inclusive of internal factors uniquely related to the athletes, which may contribute to injury. These include age, gender, physical fitness, skill level, flexibility, previous injury and body composition (Bahr and Krosshaug 2005). The risk of injury has always been associated with physical activity, even though activity brings so many benefits that reduce morbidity and mortality (McBain *et al* 2014).

In a study conducted by Steffen *et al* (2008) risk factors for injury in young female soccer players were assessed, and previous injury, old age, longer career duration, joint laxity, lower extremity strength, muscle imbalances, inadequate rehabilitation and functional and mechanical instability were all found to be risk factors for injury. Although soccer differs from CrossFit in a sense that it is a predominantly lower limb sport that includes contact injuries, they are similar in terms of both having a high intensity nature. Both sports require athletes to prepare for unpredictable circumstances. These similarities allow for relating these finds to be CrossFit.

Previous injury has been known to be a risk factor for injury recurrence. This has been concluded in a study where the history of previous injury was hypothesised to be a predictor for injury in soccer players. The results of this research concluded that athletes with previous injury were twice as likely to be injured than athletes with no previous injury (Kucera *et al* 2005). In a recent study conducted by Haggland (2006) data was collected from a team of football players regarding any previous injury they had sustained during a selected season. During the following season injuries sustained were recorded in the same team of football players. The two sets of data were compared to see if there was a correlation between athletes with injury from the previous season and whether they were more likely to sustain injury in the current season. The results revealed that those athletes with previous injury were at a greater risk of sustaining injury in the season that followed. Specifically, athletes with hamstring, knee and groin injuries were three times more like to sustain exactly the same type of injury in the season that followed, but this was not the case for ankle sprains (Hagglund *et al* 2016). It was suggested by Ostenbery (2000) that previous injury was a risk factor for injury based on the principle that deficits to the anatomical and physiological systems occurred, and consequently there was decreased neuromuscular control, strength and joint laxity. Joint laxity is often a result of previous injury; therefore, joint laxity is a risk factor for injury (Faude *et al* 2006). The study conducted by (Chachula *et al* 2016) revealed that athletes with previous injury were 3.75 times more susceptible to sustain an injury during CrossFit.

Certain age categories are more susceptible to injury than others (Fukuchi *et al* 2013). In strength training, the age categories most likely to sustain injury were those that were master's athletes and skeletally mature athletes (Lavallee and Balam 2010). The risk factors for injury in football players were investigated and athlete age, body composition, height, weight, leg extension power, jump height, peak oxygen uptake, joint stability and previous injury data was collected. From this collected data any injury sustained during the competitive football season was compared to the previous data collected for any significant correlation, and it was found that older athletes were more at risk for sustaining injuries (Arnason *et al* 2004). Athletes over 25 are more susceptible to sustaining injuries (Otenberg and Roos 2000), because of possible degenerative joint disease and chronic conditions which have a large influence over injury rates (Lavallee and Balam 2010). Further reasons for higher injury rates in older athletes are due to reduced output of muscle force and decreased joint flexibility (Fukuchi *et al* 2013).

Body composition such as height, weight, body mass index (BMI) and body fat content have been evaluated as risks factors for injury. With regards to height and BMI, taller athletes and

athletes with higher BMI levels are more susceptible to injury. This is due to the increased forces on the musculoskeletal structures when participating in activity. Taller athletes have greater moments for movement and are subject to greater forces in neuromuscular control to stabilise joints, therefore increasing risk for injury (Faude *et al* 2006).

Gender is described as an intrinsic risk factor for injury, but there is conflicting evidence as to whether or not males or females are more likely to sustain injury. Research observing powerlifting athletes revealed that male athletes had reported marginally higher injury rates than females, which included chest and thigh injuries (Keogh *et al* 2006). Contradictory to these findings, athletes examined in a study conducted by (Taunton *et al* 2002) found that female runners had higher injury rates. There are, however, findings of different types of injuries occurring in different gender categories. For instance, females are more likely to sustain lower extremity injuries such as ankle and knee sprains, whereas male athletes are more likely to sustain upper extremity injuries. These findings were similar to weightlifting athletes, where higher rates of lower extremity injuries were seen in females and higher rates of sprains and strains were seen in males (Quatman *et al* 2009). This may be due to the different types of equipment used in training (Lund and Myklebust 2011). Injury rates and risk factors were assessed by (Moran *et al* 2013), and it was found that male athletes were more susceptible to injury during CrossFit training than female athletes.

Levels of aerobic fitness can impact the risk factor for injury. This is based on the principle that when an athlete is fatigued there is an alteration in muscle recruitment patterns, which will unevenly distribute forces across the musculoskeletal structures and result in injury. This was found to be the case in male soccer players where athletes with poor physical condition were more at risk for injury (Faude *et al* 2006). In a study conducted on army trainees, aerobic fitness was considered in relation to injury risk factors. Aerobic fitness levels were also tested using the performance of one-mile runs and then compared to injury rates. It was found that for both males and females, poor aerobic fitness injury prevalence was greater (Bell *et al* 2000).

#### **2.4.1.2 Extrinsic risk factors**

Extrinsic risk factors are inclusive of all external and environmental factors that predispose an athlete to injury. This includes the nature of coaching and rules, repetition and intensity of exercises, randomly selected exercises and competition demands.

The study on the influence that instructors have in CrossFit injury rates was conducted by Waryasz *et al* (2016). The study concluded that there were various training and educational channels for instructors to be allowed to supervise CrossFit activities. These training differences influenced the injury in CrossFit athletes (Weisenthal *et al* 2014). CrossFit exercises are extremely technical and difficult to execute and if there is poor supervision and teaching when these exercises are executed, injury will most likely occur (Bergeron *et al* 2011; Hak 2013). The CrossFit training load which the instructor dictates for the athletes has been found to have an effect on injury susceptibility. It was found that an increased or large training load given to the athletes may increase the chance of injury occurrence during training (Claudino *et al* 2018).

CrossFit exercises are frequently performed at high intensity levels and are often repetitive (Cook *et al* 2006). These factors are the proposed reason for injury development in CrossFit athletes. For example, CrossFit exercises often place the shoulder in a hyper flexed, abducted and internally rotated position, due to the repetitive overhead movements. As stated previously in the literature, the shoulder is the most frequently injured area in CrossFit athletes (Hak 2013). The emphasis on speed and achieving as many repetitions as possible when performing exercises places the musculoskeletal structures under more stress as opposed to Olympic weight lifters, where the focus is on one lift of maximum load. Furthermore, high intensity causes fatigue of structures in the body, which results in poor form, and this in turn places uneven loads on structures, which leads to injury susceptibility (Hak 2013).

As described previously in this literature review (section 2.2.2 *CrossFit work out programmes*) the WOD is an assortment of random multiple joint exercises given to be completed at a high speed, resistance and intensity against the quickest time possible (Smith *et al* 2013). These exercises, performed under great levels of stress, have the ability to increase the risk of injury (Waller *et al* 2007). The higher risk for injury with this randomly chosen exercise method allows for a lack in correct form when performing complex lifts, as opposed to the precise manner and skill in which powerlifting and weightlifting athletes perform (Hak 2013).

There is a greater demand placed on athletes when training and participating in a competition setting, due to athletes desiring greater results. The increase in demand on athletes in these conditions places strain on the musculoskeletal structures in the body (Smith *et al* 2013). In a literature review compiled by Murphy *et al* (2003) on the injury risk factors for lower extremities, it was found that the incidence of injury is greater during the period of competitions (Murphy *et al* 2003).

#### **2.4.2 Recording of sports injury**

The importance of injury surveillance is vital for epidemiological information, its effect on changing injury frequency and prevention of injury. The creation of scientifically sound and concise injury surveillance has been developed by a group of researchers (Jungle *et al* 2008), who found that in order to attain accurate injury surveillance there needs to be a comprehensive injury definition, and injury reports must be a daily, detailed, single-page report written up by the physician responsible for the athlete. The report should include details of the injury such as the date and time, sporting event, injury type and area and the causative mechanism of injury (Jungle *et al* 2008).

The efficiency and accuracy of self-reported injuries were analysed in a study conducted by Gabbe *et al* (2003), which compared retrospective data collection versus prospective data collection of injury frequency and location. It was found that through retrospectively collected data, which relied on self-reporting of injury in football athletes, there was an inaccurate report of injury. The football athletes had difficulty recalling description of injuries sustained such as number of injuries, areas involved and specific diagnosis. The athletes also had difficulty recalling injury when the data collection period was longer than one year, furthermore older persons were less likely to recall past injury than younger participants. The athletes did, however, not have difficulty in reporting that an injury had occurred. It was concluded that any future researchers wanting to use a retrospective data collection approach to assess previous injury as a risk factor for subsequent injury should consider the outcomes of this validity research (Gabbe *et al* 2003).

Factors influencing the accuracy of self-reporting injury include the memory of athletes and the reliance on the accuracy of athlete recalling injury. This may lead to biased reports (Mouton 1996). Subsequently, this may lead to incorrect data collection in epidemiology studies of sport injuries and the relationship between previous and subsequent injury. To minimise bias



reporting from athletes, the definition of injury provided for athletes' understanding should be comprehensive and standardised. This may improve athlete's memories and reduce biased reporting. Another means to reduce biased injury reporting is by reducing the length of time in which athletes must recall their injuries. The longer the time of data collection, the less accurate the reports, which Mouton (1996) calls memory decay. Numerous researchers concluded that self-reported data collection of injury should be done within 12 months at most, to maintain accuracy in reporting (Gabbe *et al* 2003; Gosling *et al* 2008). Data collection past the one year mark, suggested that athletes became very broad and lacking in detail about their injuries (Twellaar *et al* 1996). When a comparison between retrospective and prospective data collection of injury in gymnastic athletes was conducted, it was found that more injury data was collected when a prospective approach was used (Kolt and Kirkby 1999).

Injury data collection is also unreliable for a number of other reasons: self-reported injuries don't match with appropriate medical diagnosis, there is an inability to differentiate between injuries during training or competition, athletes tend to be biased when reporting on injury, there is an exclusion of traumatic injuries, there are small sample sizes or incomplete response rates and athletes don't use standardised injury definitions (Gosling *et al* 2008).

The understanding of how injury data is collected and the limitations associated with recording and reporting of injury need to be thoroughly undertaken in order for accurate injury prevention to occur. Researchers need to direct efforts into building accurate evidence-based data for their effectiveness and efficacy of interventions by understanding any factors that might limit the accuracy of the data collection (Finch *et al* 2006).

## **2.5 CROSSFIT BENEFITS**

CrossFit is recognised as high intensity power training (HIPT), which is a type of training that maximises aerobic fitness levels and decreases body fat percentage (Smith *et al* 2013). HIPT differs from high intensity interval training (HIIT) as there is an emphasis on high levels of power output, multi-joint activities and rest periods throughout training (Waryasz *et al* 2016). The benefits of high intensity training were researched, and it was found that fast twitch muscle fibers were activated in this type of training and the stored glucose in the fibers was released. The released glucose is then consumed and used up as opposed to remaining in a place of fat storage, therefore resulting in weight loss (Paton and Hopkins 2004). Further benefits of high intensity training were researched by Paton and Hopkins (2004) where it was

discovered that it produced greater endurance benefits than low intensity training, as well as submaximal benefits (Paton and Hopkins 2004).

The fitness programme incorporates metabolic conditioning with both aerobic and anaerobic training styles which are alternated in the workout programme (Waryasz *et al* 2016). Aerobic training targets the cardiovascular system and aims at improving heart function, which allows for an increase in oxygen intake. Maximum oxygen intake and utilisation (VO<sub>2</sub> max) is the greatest amount of oxygen that can be used for the whole body at a cellular level (Gerhart 2013). Evidence of aerobic fitness benefits in CrossFit athletes has been shown in a study that focused on CrossFit as a HIPT and how the exercises affected the body by incorporating body fat percentage and the aerobic capacity (VO<sub>2</sub> max). It was concluded that there were improvements shown in metabolic capacity, maximal aerobic fitness and body compositions in all fitness types and in all sexes participating in CrossFit (Smith *et al* 2013).

The benefits of CrossFit have been researched to produce quantitative data supporting the physical fitness benefits in athletes. A study was carried out to see if the fitness levels of military combat students improved during an eight-week CrossFit training programme. The results were significant in that each athlete had an increased work capacity, which was measured by an increase of 20% power output. The conclusion of this research was that the combination of constantly varied high intensity exercises allowed for above average gains in athletes' work capacity (Paine *et al* 2010).

## **2.6 THE FUNCTIONAL MOVEMENT SCREEN™**

### **2.6.1 Introduction of the FMS™**

The FMS™ was developed to assess an athlete's functional movement patterns, to evaluate any biomechanical abnormalities or deficits, movement asymmetries and to incorporate these findings into predictive values for injury (Dossa *et al* 2014). This tool evaluates athletes before they exercise; thus is classified as a pre-participation tool (Glover *et al* 1999). The main aim of the FMS™ is to assess functional movement patterns for any deficits and to use this information to determine the risk for injury. Therefore, the FMS™ is used to predict injury based on this assessment and thereafter implement corrective exercises which may reduce the risk of injury

(Cook *et al* 2006). Functional movements of athletes should be assessed to understand athletes' physical capabilities during activities and rehabilitation. It is important for health professionals to understand the physical requirements of athletic activities and to further recognise athletes' movement function with respect to these activities (Cook *et al* 2006).

### **2.6.2 Principles of the FMS™**

The FMS™ was developed to identify, assess, rate and rank a person's fundamental movement patterns. According to Cook *et al* (2006) *fundamental movement* is the action of a human body changing its position using its own power. These fundamental movement patterns are the basis for complex movement patterns, such as sports-specific activities. Therefore, when discrepancies are found in the fundamental movement patterns, it strongly suggests that there is risk for injury when an athlete is placed in a situation of complex movements in specific sport activities. It is more beneficial to assess for limitations at fundamental movement pattern stages, rather than at complex movement pattern stages (Cook *et al* 2006). Fundamental movement patterns establish a neurological foundation which is vital for complex skills and advanced activities to be performed.

Dysfunctional movement, which is identified using the FMS™, is likely to be caused by muscle imbalances, incorrect training methods, habitual asymmetrical movements and inadequate recovery time after injury (Etzel 2012). The test comprises of seven specific functional movements that test athletes' balance, mobility and stability: the FMS™ places the athlete in various positions where weaknesses and imbalances can be identified. The functional movements of this test must be correctly and precisely executed. If there are errors in performing the exercises the athlete may be using compensatory movements and will be scored poorly. If these compensations are not corrected, then the biomechanics will be weakened due to the incorrect movement patterns leading to micro-trauma and subsequent macro-trauma. Compensation mechanisms can result in additional energy requirements during competition which may lead to early fatigue. Fatigued muscles that are placed under stress are at risk for injury (Etzel 2012). These incorrect movement patterns become habitual and are made subconsciously every time a movement is executed. This repetition of poor movement, along with improper technique, may exacerbate the problem and lead to injury (Cook *et al* 2006). If a FMS™ is carried out correctly and adequately identifies functional movement pattern problems, it may suggest a level of injury susceptibility for future participation (Etzel 2012).

To complete the FMS™ correctly there needs to be full functionality of muscle strength, range of motion, flexibility, balance, co-ordination and proprioception. If there are discrepancies in these fields the athlete may be at risk for musculoskeletal injury (Bock and Orr 2015). As Cook *et al* (2006) asserted, the FMS™ movements are based on proprioception and kinesiology principles, therefore if the athletes have a deficit with either of these two principles there will be a failure to perform the FMS™ movements correctly. The FMS™ incorporates all aspects of the kinematic chain, namely the connecting joints and muscles that work together to achieve functional movement (Schneiders 2011).

The screening of athletes using the FMS™ is carried out prior to the commencement of a sporting season or prior to the training period leading up to a particular event, as this is a pre-participation screen. The screen grades the athlete's ability to perform the seven functional tests of the FMS™, as described in the next section. These tests identify any fundamental movement pattern abnormalities which are represented by the score given to the athlete by the researcher. A lower score is correlated with a greater number of biomechanical issues. These scores are recorded and the mean is calculated to create the normative values of the FMS™ for the sport. Thereafter, the athletes are tracked and any injuries sustained during the training and participation in the sport are recorded. The scores of the FMS™ are then compared to the injuries sustained by the athletes and an investigation into the association between the two variables is made. Based on the principles of the FMS™ a low score is a predictor for injury, therefore the association made is to identify whether athletes with a lower score had sustained higher injury rates as opposed to those with a higher score. Once an association is made between athletes with low FMS™ scores and high injury incidence, those figures may be used as predictive values for injury in athletes for future reference (Cook *et al* 2006).

### **2.6.3 Components of the FMS™**

The seven movement patterns that are assessed are (Teyhen *et al* 2002):

- The Deep Squat test
- The Inline Lunge test
- The Hurdle Step test
- Shoulder Mobility test
- The Active Straight Leg Raise test

- The Trunk Stability Push-Up test
- The Quadraped Rotatory Stability test

### **2.6.3.1 The Deep Squat**

The deep squat is the first of the seven functional movements the athletes performed. First, the athlete must initiate the squat in the correct position: feet are placed shoulder width apart with the toes facing forward within the sagittal plane. The athlete must then hold the dowel above the head with the elbows in a 90-degree position. Next, the athlete must extend the elbows and push the dowel further overhead, allowing the shoulder position to be abducted and flexed. Hereafter, the athlete must lower themselves into the squat position. The correct position for the deep squat is when both heels are firmly planted on the floor, the head and chest are facing forward and the dowel is in the maximum overhead position. If the athlete cannot perform this movement, they are able to repeat the movement with the aid of a 15.5cm x 147.5cm wooden board under their heels (Cook *et al* 2006). The scoring criteria for the deep squat can be seen in Appendix I.



(Liu 2009)

**FIGURE 1: THE DEEP SQUAT**

### **2.6.3.2 The Hurdle Step**

When performing the hurdle step the athlete must start by placing their feet together and in contact with the base of the hurdle, which is made up of two vertical beams (59.5cm) and a rubber band. Once the athlete assumes this position, the researcher then adjusts the height of the hurdle level with their tibial tuberosity. The dowel is then held and rested behind the neck and on top of the shoulders. The athlete must now perform the hurdle step by stepping over the hurdle with one limb, the stepping limb, and contacting the ground with their heel on the other side of the hurdle. The stance leg must remain in an extended and unchanging position throughout the hurdle. The athlete must then return the stepping limb back to the original position. The test is then repeated with the opposite limb. Throughout the hurdle step the athlete must maintain a stabilised torso and the stance leg should be extended but not fully locked. The test is done for both left and right sides, with the lower score of the two sides recorded. The scoring criteria for the hurdle step can be seen in Appendix I.



(Liu 2009)

**FIGURE 2: THE HURDLE STEP**

### **2.6.3.3 The In-line Lunge**

The in-line lunge is started off by measuring the length of the athlete's tibia. This is done while the athlete is standing and the researcher uses a tape measure to measure the length between the tibial tuberosity and the floor. The athlete must then begin the test in the correct starting position. This is done by the athlete placing their back foot, the planted foot, on the edge of the board (15.5cm wide and 147.5cm long) that is closest to the athlete. The distance of the previously measured tibial length is then measured out from the edge of the planted foot's toes and a mark is made. The athlete then holds the dowel (135.5cm in length) behind them, allowing the dowel to contact the athletes head, thoracic spine and the sacrum. The dowel is held on top with the hand that is opposite to the front leg of the lunge and the other hand will hold the dowel further down. The athlete then performs the lunge by placing the heel of the front foot on the marked point. The athlete must lower their back knee down to contact the surface behind the front heel and then return the knee back to the normal starting position. Throughout the in-line lunge the athlete must maintain contact with the dowel against the head, thoracic spine, as well as the sacrum. The front heel must remain in contact with the ground and maintain all-round balance throughout the test. The test is done for both left and right sides, with the lower score of the two sides used. The scoring criteria for the in-line lunge can be seen in Appendix I.



(Liu 2009)

**FIGURE 3: THE IN-LINE LUNGE**

### **2.6.3.4 Shoulder Mobility**

The researcher must initially measure the length of the hand by measuring the distance between the distal wrist crease and the tip of the third digit. The athlete must then make fists with their thumbs placed inside their hands. Following this they must adduct, internally rotate and extend one shoulder maximumly; and the opposite shoulder must be abducted, externally rotated and flexed maximumly. Throughout these movements the athlete's fists should be kept tight and they should be in contact with the spine. The distance between the two fists is then measured. The correct distance, revealing proper mobility, between the fists should be at least the length of the initially measured hand length. Any measurement more than the hand length reveals poor mobility. The test is done for both left and right sides, with the lower score of the two sides used. The scoring criteria for the shoulder mobility test can be seen in Appendix I.



(Liu 2009)

**FIGURE 4: SHOULDER MOBILITY**



### **2.6.3.5 Active Straight Leg Raise**

For this test the athlete must initially lie supine on the ground with the arms placed in the anatomical position and the head rested in contact with the ground. Once in this position the researcher must locate the midpoint between the anterior superior iliac spine (ASIS) and the mid patellar point. At this midpoint, the researcher places the dowel perpendicular to the ground. The athlete must then perform the active straight leg raise by lifting the leg while the knee is extended and the ankle is dorsiflexed. The athlete must perform this while the opposite leg maintains contact with the ground. The researcher then compares the position of the medial malleolus of the raised limb with the dowel. The position revealing proper mobility would be if the medial malleolus is beyond the dowel and over the ASIS. When the athlete cannot move the medial malleolus past the dowel then it reflects poor mobility. The scoring criteria for the active straight leg raise can be seen in Appendix I.

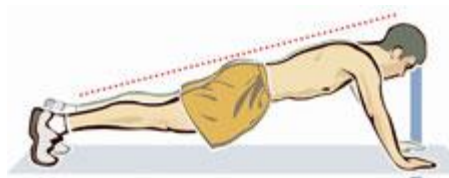


(Liu 2009)

**FIGURE 5: ACTIVE STRAIGHT LEG RAISE**

#### **2.6.3.6 The Trunk Stability Push-Up**

Initially the athlete must assume the starting position, this is when the athlete is prone with the feet next to one another, the hands are placed shoulder width apart, the knees are fully extended and the ankles are in a dorsiflexed position. The athlete must then perform a push-up and the correct movement when performing the push-up is when the body lifts together as a whole and a straight lower back is maintained. If the athlete cannot perform this push-up, then an adjustment must be made by allowing the athlete to lower the thumbs to the level of the clavicle. The scoring criteria for the trunk stability push up test can be seen in Appendix I.



(Liu 2009)

**FIGURE 6: THE TRUNK STABILITY PUSH UP**

### **2.6.3.7 The Rotatory Stability**

The athlete must first assume the starting position in a quadruped position with the hips and the shoulders at 90-degree angles. The ankles should be in a dorsiflexed position with the knees resting on the ground at 90-degrees. The athlete must then perform the test by flexing the shoulder and lifting the arm out in front of the them on one side, and extending the hip and knee behind the athlete on the same side. The arm and lower limb should be raised up from the ground by about 15cm. The shoulder of the raised arm must then be extended and the elbow of the same arm must be flexed, additionally the raised knee must be flexed in order to allow for the elbow and knee to make contact on the same side. If the athlete is unable to perform this movement then they may be allowed to repeat the test using a diagonal pattern using the opposite shoulder and hip. Proper movement of this alternative method would allow the knee and opposite elbow touching without any compensation. The test is done for both left and right sides, with the lower score of the two sides used. The scoring criteria for the rotatory stability test can be seen in Appendix I.



(Liu 2009)

**FIGURE 7: THE ROTATORY STABILITY**

### 2.6.3.8 Clearing Tests

There are three clearing tests incorporated in the FMS™. Each of these clearing tests is linked to one of the seven tests mentioned above. The tests are performed alongside the specific FMS™ components, and when the athlete is scored with a zero for the clearing test then the athlete will automatically receive a zero for the related FMS™ test, regardless of how the athlete performed the actual test.

**Shoulder mobility clearing test:** This test should be performed after the shoulder mobility test. The clearance test is performed when the athlete places a hand on the opposite shoulder and then moves the elbow upwards while maintaining contact between the hand and the shoulder. If the athlete experiences any pain with this movement then a zero is awarded for the clearing test, and therefore a zero is given for the shoulder mobility test as well.

**Extension clearing test:** This test is performed after the trunk stability push-up test. The clearance test is performed by extending the spine in the push-up position as described previously. The athlete is awarded zero if there is any pain experience by the athlete in this position. They will then score zero for the FMS™ test as well.

**The flexion clearing test:** This test is performed after the rotary stability test. The clearance test is performed through flexing the spine when in the quadruped position and then allowing the buttock to fall back and rest on the heels, at the same time resting the abdomen on the anterior thighs and the hands should be stretched out in front of the body as far as possible. Any pain experienced by the athlete in this movement will result in a score of zero for the clearance test, and thus for the rotatory stability test as well.

These seven tests also include related clearance tests which are connected to specific movements in the FMS™. The purpose of the clearance tests is to assess the athletes for pain when conducting the FMS™. The shoulder mobility test has a clearance test that assesses for shoulder impingement. The trunk stability push-up test has a clearance test to assess for any back pain. And lastly the rotatory stability test also assesses the athletes for any back pain during the assessment. If there is pain felt on either one of these clearance tests, the athletes will be given a zero score for the related FMS™ test (Appendix I) (Cook *et al* 2006).

The scoring for the FMS™ tests works on a numerical system where each test is given a score out of three, zero being the lowest score and three being the highest. The overall total score

for the seven tests is 21. On a scale of three for each of the seven movements, a score of zero out of three in any one test indicates that the athlete experiences pain during the performance of that component test of the FMS™. On a scale of three, a score of one indicates that the athlete is unable to complete that component test of the FMS™. A score of two out of three indicates that the athlete uses compensatory mechanisms to complete the test for the FMS™. A score of three indicates that the athlete can perform the FMS™ component test accurately without pain or compensation. The left and right-hand sides are both tested and scored, and the lower score of the two is recorded and added toward the total score (Appendix I) (Cook *et al* 2006).

#### **2.6.4 The FMS™ as a predictor for injury**

It has been suggested by Cook *et al* (2006) that the FMS™ can be used to predict injury by finding a link between a low FMS™ score (which would indicate weakness, asymmetry, poor movement patterns and decreased proprioception) and injury occurrence. If this link is significant then protocols can be put in to place to improve an athlete's movement abnormalities; this will possibly reduce the risk of injury occurrence (Cook *et al* 2006). The FMS™ assesses multiple movement factors and asymmetry to predict the susceptibility of musculoskeletal injuries (Teyhen *et al* 2002). However, evidence supporting the use of the FMS™ as an injury predictor has not been well established and therefore needs to be investigated further (Jooste 2014). Studies on whether injury prediction is possible for athletes has been conducted (Bock and Orr 2015; Cuson 2010; Kiesel *et al* 2007; Lafontaine and Serenko 2017; Lisman *et al* 2013; Schneiders 2011).

Teyhen *et al* (2002) discovered, when testing the FMS™ for reliability, that scores of below 14 out of 21 were more likely to predict injury than scores above 14. Kiestel *et al* (2007) used the FMS™ to predict injury in professional football players, and the results showed that football players with FMS™ scores less than 14 were more likely to suffer from injury during the season. This value was not the mean score for the sample, but rather a cut-off point that was found and used to most likely predict injury. This study's outcome of proving that the FMS™ is a predictor of injury encouraged athletes from other sporting backgrounds to use the score of 14 as a standard value to predict injury (Kiestel *et al* 2007). This did not yield functioning results as each sport is unique and challenges various aspects of the body in different ways. Each sport

requires unique predictive values for that specific sport (Etzel 2012). Furthermore, the study done by (Kiestel *et al* 2007), only assessed a fraction of the general population, professional football players. The nature of football injuries are most likely to be contact injuries, however no differentiation was made between contact and non-contact injuries, these injuries are therefore most likely to be classified as traumatic. Traumatic injuries are a variation from the idea that injury develops from inadequate fundamental movement patterns when using the FMS™, unless there is restricted movement and flexibility which reduces chances of avoiding contact. Therefore, specific FMS™ testing needs to be done for each type of sport to establish specific normative values and predictive values for injury (Etzel 2012).

Chorba *et al* (2010) investigated the compensatory movement patterns of female collegiate athletes, participating in basketball, soccer and volleyball, and the predisposition for injury using the FMS™. The results concluded that athletes with score lower than 14 were four times more likely to sustain injuries than those with scores higher than 14. The score of 14 is the same as the study conducted by Kiestel *et al* (2007), however, there are many significant differences between the two studies that do not justify a proper comparison. There were different definitions of injury used as well as different sample size number and type; one study used only female athletes as opposed to the other study using both genders. If these variables were kept the same it would have allowed for the possibility that the score of 14 could be used as a standard predictive value for the general sporting world. Further investigation of the FMS™ conducted by Bock and Orr (2015) concluded that the FMS™ is a reliable tool to predict injury in firefighters, the military and police officers. The study strongly suggested that low FMS™ scores were predictors for injury development (Bock and Orr 2015). Research on the FMS™ scores and injury predictions of Marine Corps Officer candidates was conducted. The results concluded that the mean FMS™ score for the cohort was 16.6 out of 21. And from these scores the athletes that scored less than 14 demonstrated higher risk of injury (O'Connor *et al* 2011).

A short independent research report published late in 2017 investigated the correlation between the FMS™ and increased risk for injury in CrossFit athletes in America. The report studied 24 CrossFit athletes in a single box between the ages of 20 and 49 years of age. The researchers were unable to find any significant results and reported that the limitations of the report were that the sample size was too small, all athletes came from a single box, retrospective self-reported data collection methods were used and there was inconsistent understanding of injury amongst athletes (Lafontaine and Serenko 2017).

Murphy *et al* (2003) investigated whether the FMS™ could identify history of previous musculoskeletal injury. The study assessed both male and female athletes taking part in various different types of sport including cheerleading, basketball, soccer, softball, tennis, football and athletics. The FMS™ was performed on the athletes who were thereafter questioned as to what previous injuries they had sustained within the past three years. The results of the study concluded that using the FMS™ to identify previous injury in athletes proved unsuccessful (Murphy *et al* 2003). It was suggested by Ostenbery (2000) that previous injury was a risk factor for injury based on the principle that deficits to the anatomical and physiological systems occurred, and consequently there was decreased neuromuscular control, strength and joint laxity. These all in turn effect the normal fundamental movement patterns. Using the of FMS™ to successfully predict previous injury has not yet been proven.

Peate *et al* (2007) conducted the FMS™ on 433 firefighters to assess whether the intervention of trunk stabilisers and core strength could be improved to reduce injury. The scores had a significant correlation for injuries sustained, and thereafter an intervention to improve trunk stability and core strength was conducted over a 12-month period. They found that the intervention reduced the number of injuries sustained by 42% and further reduced the time lost due to injury presence by 62%. These findings suggest that through the means of the FMS™ assessment and through improving functional movement, injuries may be prevented (Peate *et al* 2007).

## **2.7 CONCLUSION**

Based on the above studies it is clear there is a high injury occurrence in CrossFit and furthermore, athletes that are taller, coaching method discrepancies, longer duration of CrossFit participation, previous injury and improper form and technique when executing CrossFit activities increases the likelihood of injury occurrence in CrossFit athletes. CrossFit is a high intensity programme done in a the quickest time possible, this results in poor form and uneven loads on structures. This may either result in injury, or interfere with normal biomechanical functioning. The use of a pre-participation tool, such as the FMS™, may be an appropriate tool to use in this study as it will detect biomechanical abnormalities in the body caused by either previous injury or incorrect movement patterns from training. Reliable

normative values are still to be determined for CrossFit and may aid as a screening tool for athletes to predict injury. There has been literature to suggest that CrossFit may be a beneficial sport and its popularity is continuing to grow, however investigation into injury prevention needs to be conducted (Claudino *et al* 2018). The FMS™ can be used as an appropriate tool in this study due to the similar movements in both CrossFit and the FMS™. The utilization of the FMS™ as an injury prevention tool holds the potential to be highly beneficial not only for CrossFit but many other sports, and needs to be further investigated.



## **CHAPTER THREE:**

### **METHODOLOGY**

#### **3.1 INTRODUCTION**

This chapter includes the research design, sampling method, research procedure, measurement tools and lastly the statistical analysis. These allow for an understanding of how the normative values for the Functional Movement Screen™ (FMS™) in CrossFit athletes are attained.

#### **3.2 RESEARCH DESIGN**

The study design for this research was a quantitative paradigm that incorporated the statistical measurements of the FMS™ scores and injury occurrence. Secondly, a descriptive cohort design was used; because a uniquely selected group was investigated. It was a descriptive design, as no intervention took place, but rather a study to provide information about the selected group. The design used prospective data collection from the selected CrossFit athletes, who were observed using the FMS™ and an injury profile study during the training and participation of the “United We Stand (UWS) CrossFit Games 2017”.

The study design mentioned above was approved by the Faculty of Health Sciences Research and Ethics Committee of the Durban University of Technology (Appendix G) on 16 September 2017. This approval meets the standards of the requirements of the Declarations of Belmont, Nuremberg and Helsinki of 1975 (Johnson, 2005).

### **3.3 SAMPLING**

#### **3.3.1 Participation recruitment/permissions**

Ethical clearance was attained by the Institutional Research Ethics Committee of Durban University of Technology (Appendix G) to conduct this research.

The letter of information and consent (Appendix A) that was needed from the CrossFit box supervisor was granted, as seen in Appendix H, in order to gain permission to conduct the FMS™. Thereafter, each athlete participating in the research signed and accepted the terms of the letter of information and consent (Appendix B) and therefore became eligible to take part in the study.

#### **3.3.2 Sampling size**

There were 162 athletes registered to take part in the “UWS Games 2017” in the eThekweni municipality. The sample size worked out by the statistician was a minimum of 59 athletes (Appendix F) (Singh 2017).

#### **3.3.3 Inclusion criteria**

The inclusion criteria were as follows:

- Athletes had to be over the age of 18 years.
- Only registered athletes with the “UWS Games 2017” were included.
- Athletes had to fully complete the Injury Profile Questionnaire (Appendix D).
- Both male and female athletes were included as the study was heterogeneous.

### **3.3.4 Exclusion criteria**

The exclusion criteria were as follows:

- Athletes with severe injury prohibiting any participating in the training period leading up to the “UWS Games 2017” were excluded.
- Athletes who were under the age of 18 years.
- Athletes who left the box after the FMS™ was conducted.
- Athletes who did not agree to the signed the Letter of Information and Consent (Appendix B).
- Athletes who were not registered to compete in the “UWS Games 2017” were excluded.

## **3.4 PROCEDURE**

### **3.4.1 Research procedure**

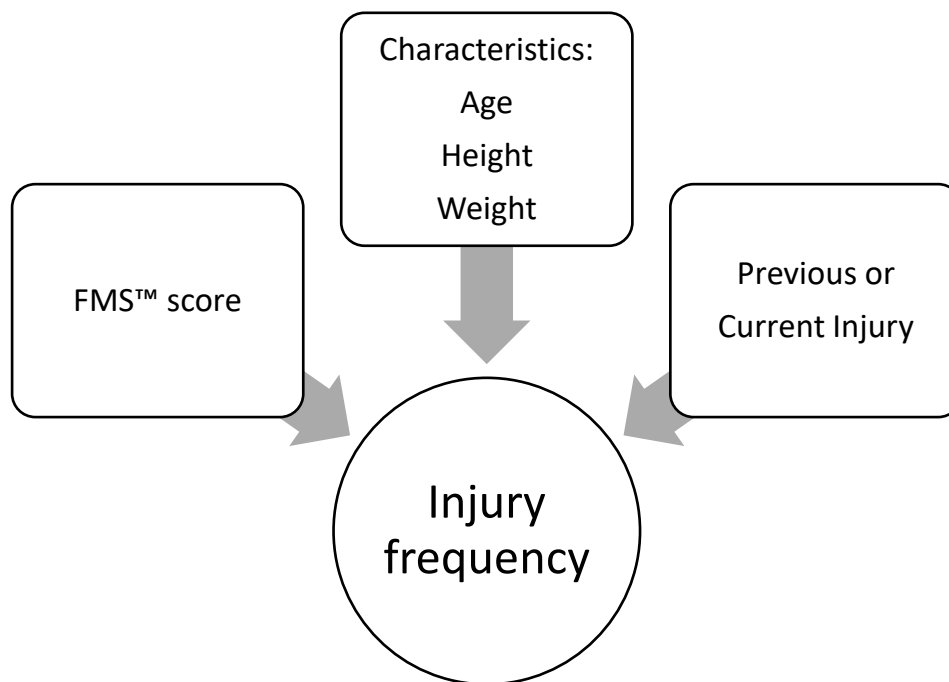
- The researcher contacted a box supervisor for permission to conduct the research (Appendix A) as well as to have access to CrossFit athletes.
- The researcher then approached each participating athlete in the research within the box and obtained written permission from them, using the letter of information and consent (Appendix B) prior to the commencement of the FMS™.
- The FMS™ was then set up at the box within a closed room, prior to the commencement of the athletes' set training programme building up to the "UWS Games 2017".
- The athletes completed the Athlete Questionnaire (Appendix D), before performing the FMS™, to determine any previous injuries that had occurred during CrossFit, as well as the amount of time practising CrossFit and general demographic information.
- Each athlete then performed the FMS™ as accurately as possible by following the specific instructions of the researcher, doing each of the seven functional movements. The researcher graded each test with a score of zero to three (Cuson 2010).
- The researcher recorded each athlete's score (Cuson 2010). These scores assessed their precise strength and weaknesses occurring with each test. The scores were calculated by the researcher and recorded in Appendix C.
- After the FMS™ and Athlete Questionnaire were completed, the athletes began the training programme set for the "UWS Games 2017".
- During this one month training period, building up to the "UWS Games 2017", any injury incurred by the athletes was recorded in the injury profile sheet (Appendix E). The researcher visited the athletes on a regular basis during the training programme and visited on the days of the event, to keep records of any injuries sustained.
- Once the FMS™ was completed and the "UWS Games 2017" was over, the researcher and statistician attempted to find an association between the athletes' FMS™ scores and injury occurrence to see if a reliable pre-participation screen could be conducted.

### 3.4.2 Athlete questionnaire

The Athlete Questionnaire (Appendix D) was completed prior to the commencement of the FMS™ in order to gather information including the following:

- The athlete's characteristics; such as name, age, weight and height.
- The name of the CrossFit box that the athlete was registered with.
- The duration of time in which the athlete had been practising CrossFit.
- Any previous or current injury that was CrossFit related.

The purpose of gathering this information from the questionnaire was to identify any risk factors that might influence the frequency of injury, other than that of the FMS™ score. The purpose of this research is to hypothesise whether or not a low FMS™ score is an indicator for injury, but there is also a need to identify other risk factors associated with each athlete, as this could have an influence in the development of an injury during CrossFit.



**FIGURE 8: RISK FACTORS INFLUENCING THE FREQUENCY OF INJURY IN CROSSFIT**

### **3.4.3 The Functional Movement Screen™**

Athletes are to execute the seven FMS™ tests including the deep squat test, the inline lunge test, the hurdle step test, shoulder mobility test, the active straight leg raise test, the trunk stability push-up test and the quadruped rotatory stability test as described in *Chapter two: 2.6.3 Components of the FMS™*.

#### **3.4.3.1 The Scoring System**

There are three possible scores that can be given for a FMS™ test. The scores range from zero to three. A score of zero indicates that the athlete experiences pain during the performance of the test. A score of one indicates that the athlete is unable to complete the test. A score of two indicates that the athlete uses compensatory mechanisms to complete the test. A score of three indicates that the athlete can perform the test accurately without pain or compensation. The left and right-hand sides are both tested and scored and the lower score of the two sides is recorded and added towards the total score. Furthermore, the scores must all be tallied and recorded; the highest possible score is 21 and the lowest is zero.

### **3.4.4 Injury profile sheet**

The injury profile sheet records any injury after the performance of the FMS™ that the athletes may sustain from the time directly after the FMS™ has been conducted up to the “UWS Games 2017”, as well as any injuries that occur at the “UWS Games 2017” themselves. The researcher visited the athletes on a regular basis and contacted the boxes regularly to encourage athletes to contact the researcher if any injury occurs.

When an injury did occur, it was recorded in the injury profile sheet (Appendix E) which included the details of the injury such as: the athlete’s name, the date, the diagnosis, the severity of the injury, the time lost in training, the mechanism of injury and if the athlete received any treatment for the injury.

### **3.5 MEASUREMENT TOOLS**

The FMS™ kit includes the following:

- One hurdle, which is made up of two vertical beams (59.5cm) and a rubber band.
- One wooden dowel which is 135.5cm in length.
- One wooden board which is 15.5cm wide and 147.5cm long.
- One measuring tape.

### **3.6 STATISTICAL ANALYSIS**

The data collected by the researcher was analysed using the statistical software SPSS version 25. The quantitative data was analysed using descriptive statistics which included the use of frequency tables and various graphs and charts to represent the data with minimum, maximum, mean and standard deviation. The researcher tested the assumptions underlying the parametric tests (including that of the homogeneity of variance using Levene's and tests for normality through the use of the Kolmogorov-Smirnov and Shapiro-Wilk) and where these assumptions were met, parametric tests such as ANOVA and Pearson's Correlations were used. Subsequent to where these tests were violated, non-parametric equivalents such as Kruskal Wallis, Mann-Whitney and Spearman's ranked Rho were used. Statistical significance was considered when the  $p$  value was less than 0.05 (Upton 2017).

## **CHAPTER FOUR:**

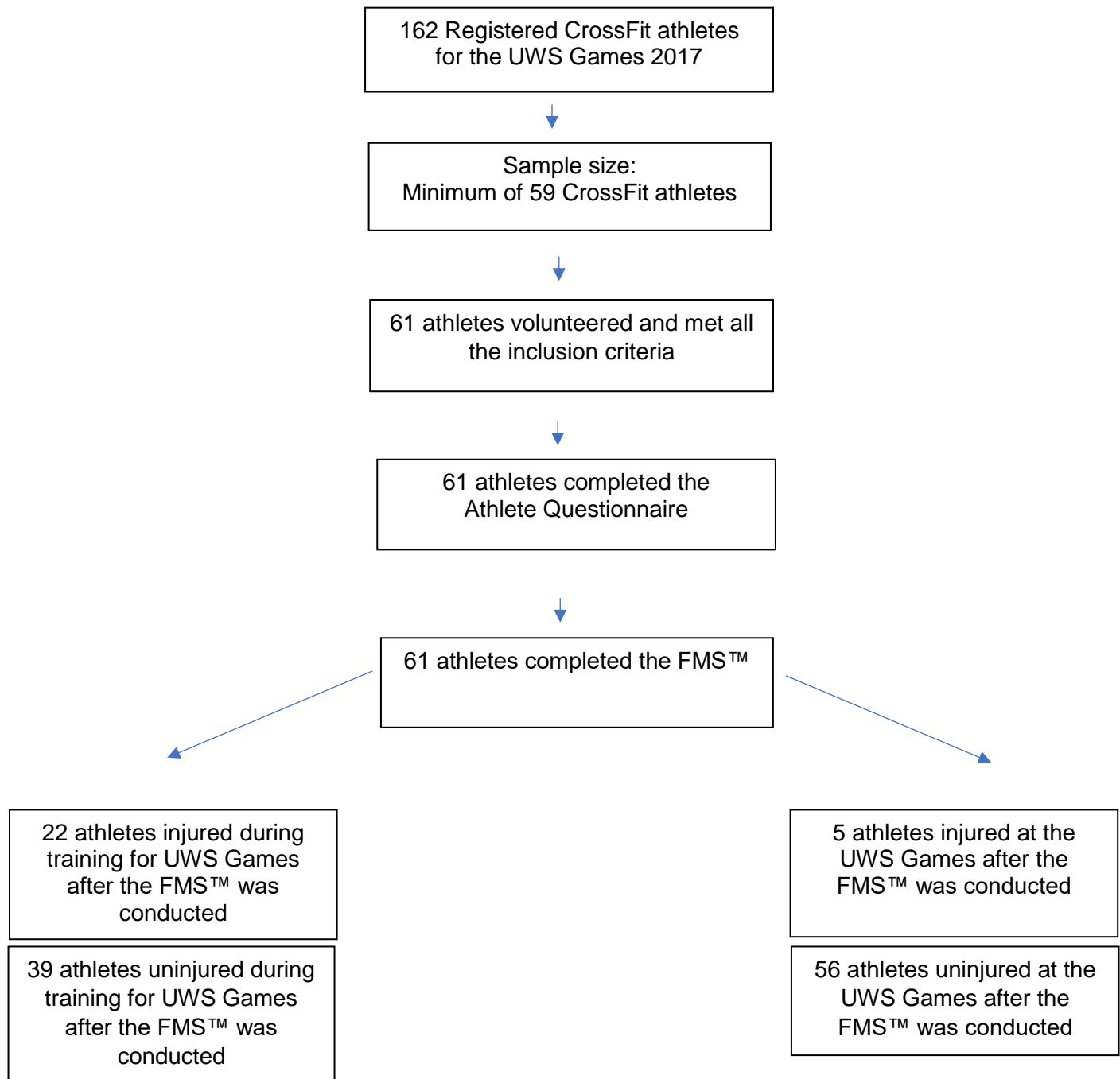
### **RESULTS**

#### **4.1 INTRODUCTION**

This chapter presents the results of the research followed by the discussions related to each finding in Chapter five. Results were obtained from the data collected to establish the normative values of the Functional Movement Screen™ (FMS™), risk factors and demographic data from the Athlete Questionnaire (Appendix D) and injuries sustained throughout athletic training for and participation at the “United We Stand CrossFit Games 2017”. An association was also made between the FMS™ and injury susceptibility in CrossFit athletes in the eThekweni municipality. In order to answer the research question and achieve the research objectives a primary analysis was conducted using SPSS 25.0 to produce descriptive and inferential statistics. These results were discussed further to gain understanding as to why they occurred in Chapter five. The chapter will be presented in form tables or graphical representation with a brief analysis of the data findings.



## 4.2 METHODOLOGICAL FLOW



**FIGURE 9: METHODOLOGICAL FLOW DIAGRAM**

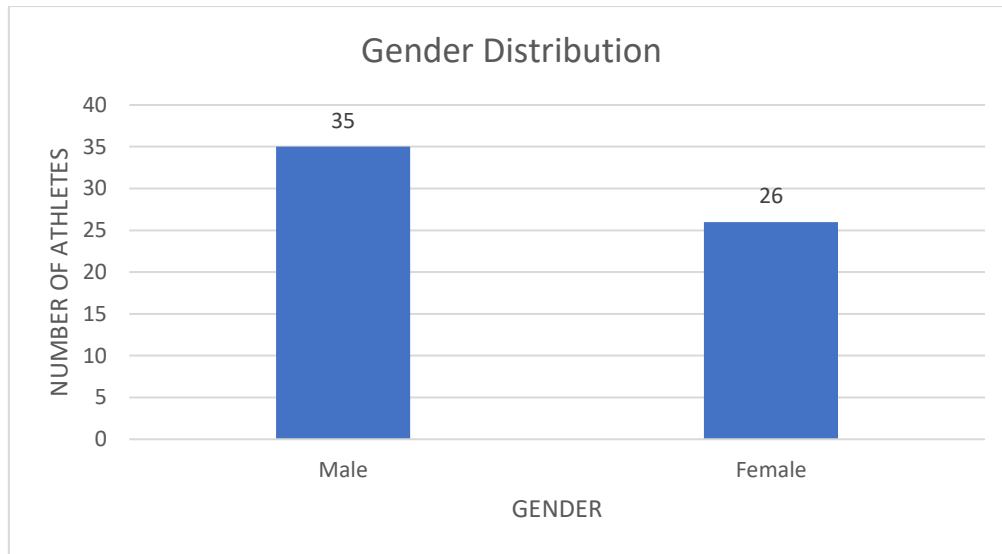
## 4.3 RESPONSE RATE

TABLE 1: RESPONSE RATE

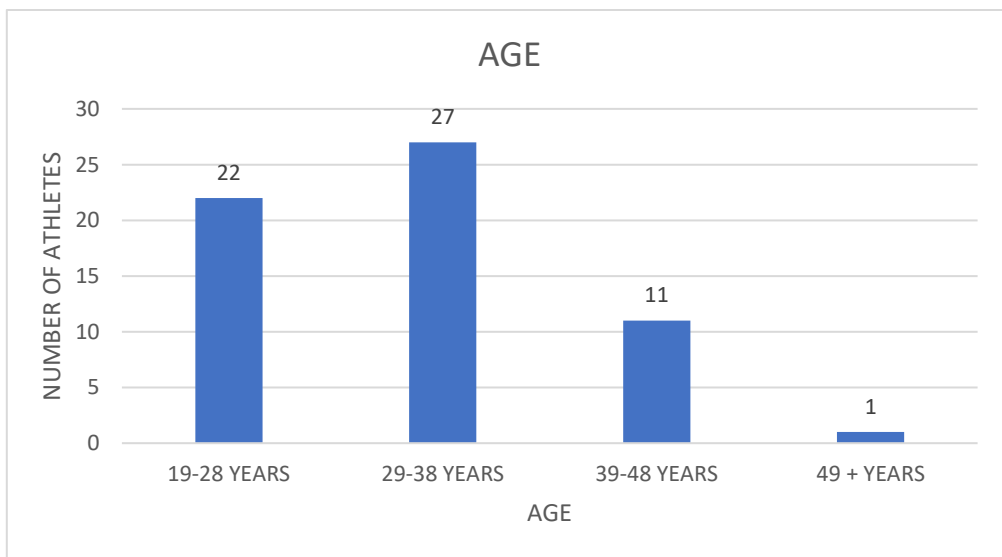
TOTAL POPULATION	162
SAMPLE AVAILABLE FOR RESEARCH	162
MINIMUM SAMPLE SIZE	59
TOTAL RESPONSES	61
USABLE RESPONSE RATE	37.65%

## 4.4 DEMOGRAPHIC DATA

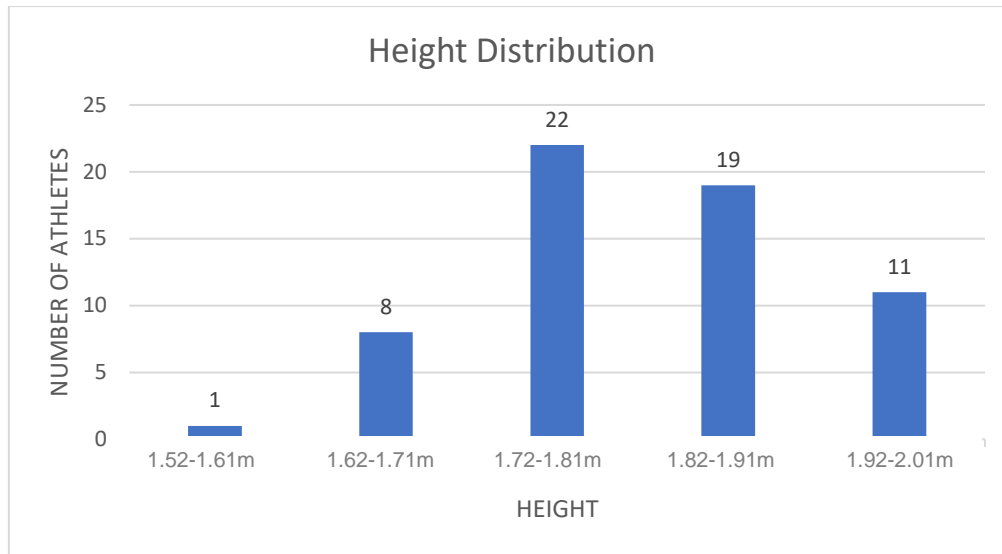
The total sample of athletes that participated in the research was 61 ( $n = 61$ ). Of this total sample, 35 athletes were male (57.40%) and 26 athletes were female (42.60%). The age of the observed CrossFit athletes ranged between 19 to 49 years and the mean age was 32.07 years of age. With regards to the selected athletes' height, the sample range was between 1.52 metres (m) and 1.91m and the mean height was 1.73m. The range of the weight of the sample ranged between 54 kilograms (kg) and 113kg and the mean weight was 77.50kg. An analysis of the athletes' body mass index (BMI) was also carried out and revealed a range of 20.05 kilograms per metre squared ( $\text{kg/m}^2$ ) and 35.66  $\text{kg/m}^2$  and the mean BMI was 25.84  $\text{kg/m}^2$ . The aforementioned data is reflected in the figures below, including the distribution of athletes in their registered boxes.



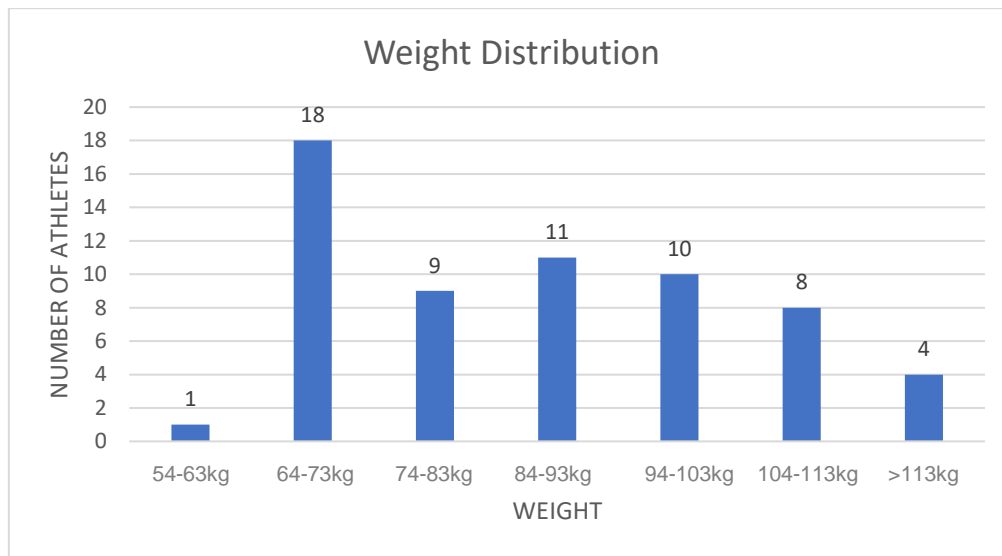
**FIGURE 10: GENDER DISTRIBUTION OF ATHLETES**



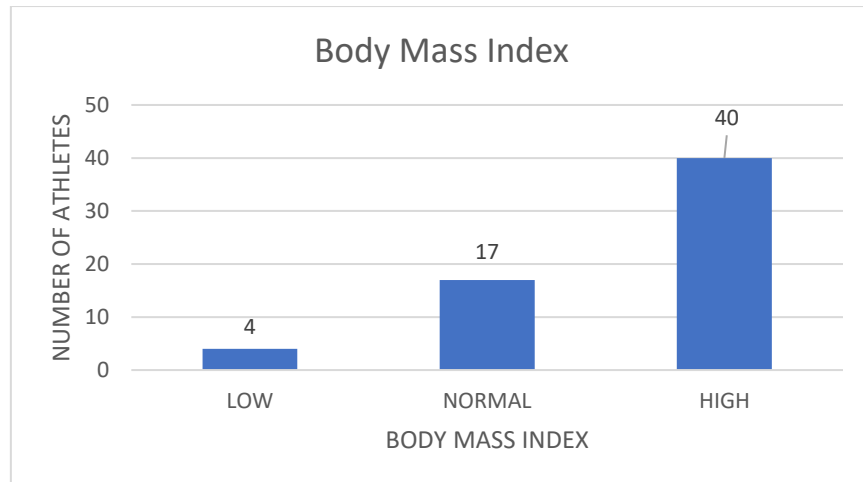
**FIGURE 11: AGE DISTRIBUTION OF ATHLETES**



**FIGURE 12: HEIGHT DISTRIBUTION OF ATHLETES**

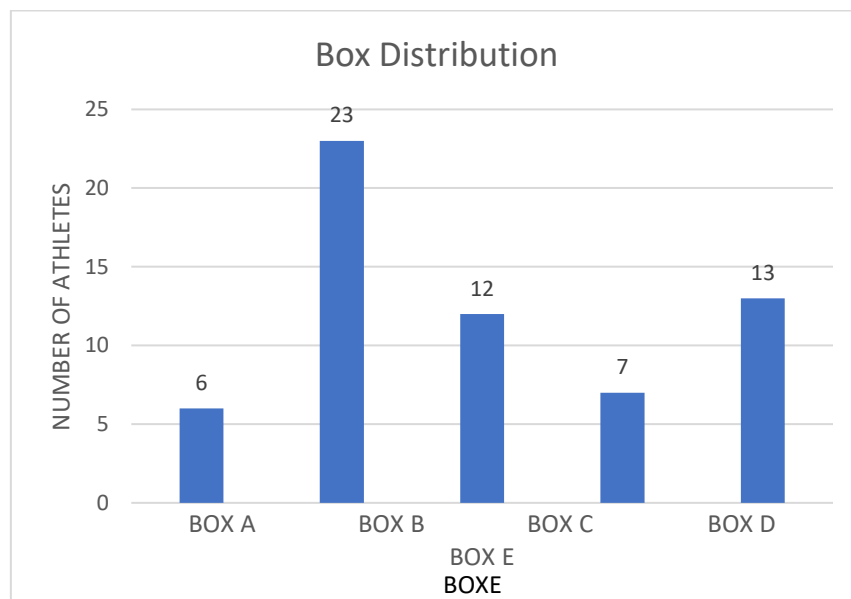


**FIGURE 13: WEIGHT DISTRIBUTION OF ATHLETES**



**FIGURE 14: BMI DISTRIBUTION OF ATHLETES**

The athletes ( $n = 61$ ) that participated in this research were registered with five CrossFit boxes in the eThekweni municipality. Of the five different boxes that the athletes were affiliated with, the majority of them were affiliated with Box B, with 23 athletes (37.70%). There were 13 athletes affiliated with Box E, 12 athletes with Box C, seven athletes with Box D and six athletes with Box A.



**FIGURE 15: BOX DISTRIBUTION OF ATHLETES**

## 4.5 THE FMS™ SCORES

### 4.5.1 The normative values of the FMS™ scores in CrossFit athletes

The FMS™ was conducted prior to the training for the “UWS Games 2017” on athletes (n = 61) from the eThekweni municipality. The scores were recorded and represented in terms of mean, median, range and standard deviation, as seen below in Table 2. The mean allowed for understanding of what the central tendency of the data was, and referred to the average overall score. The mode allowed for further understanding of the central tendency whereby the most frequently occurring score is represented. The median was calculated to represent the middle score of the data. The discrete values were represented with the median and mode. Whereas the continuous data was represented with the mean value (Smith 2017). The range of scores were between 11 and 21 out of 21. The mean score was 17.73 out of 21, with a standard deviation of 2.46. The highest frequency, mode, of the FMS™ scores was 20 out of 21 and the middle score of the total data was 18 out of 21.

**TABLE 2: THE NORMATIVE VALUES OF THE FMS™ SCORES IN CROSSFIT ATHLETES**

<b>SAMPLE CHARACTERISTIC</b>	<b>VALUE</b>
<b>Total sample size</b>	61
<b>Range of FMS™ scores</b>	11 - 21
<b>Mean FMS™ score</b>	17.73
<b>Median FMS™ score</b>	18
<b>Mode of FMS™ score</b>	20
<b>Standard deviation</b>	2.46

## **4.6 INJURY PROFILE**

This section includes the description of previous injuries before the FMS™ was conducted, current injuries experienced while doing the FMS™, as well as injury after the FMS™ was conducted, during training for the “UWS Games 2017” and injury sustained at the “UWS Games 2017”. The type of injuries that were recorded during data collection were described in the broad categories of type of tissue injured and the location of the injury, as listed below. The different types of injury seen were muscle strain, joint dysfunction, hernia, bone fracture and nerve damage. The injury locations found were general areas, back, neck, shoulder, elbow, arm, wrist, abdomen, buttock, hip, groin, thigh, knee, leg, ankle and foot.

### **4.6.1 Previous CrossFit related injury**

The Athlete Questionnaire (Appendix D) recorded information regarding previous injuries that were sustained during CrossFit training. From the total sample (n = 61) 63.93% of athletes had previous injuries prior to the FMS™ and 36.07% of athletes had no history of previous injury.

The most common type of previous injury sustained by athletes was joint dysfunction at 31.1%. Following this was muscle strain with 27.9% of athletes sustaining this type of injury. There were an 1.6% of athletes who sustained injuries of a hernia, bone fracture and nerve damage.

With regards to the location of injuries sustained, the shoulder was the most frequently injured area of the body, in 33.3% of the sample. Thereafter, 23.1% of athletes sustained injuries in the area of the back, 7.7% of the knee, 5.1% of general, hip, groin, ankle and neck, 2.6% of buttock, leg, foot and arm areas of injury.

The frequency of previously sustained injuries in terms of type of injury and location is described in Tables 3 and 4.

**TABLE 3: PREVIOUS TYPE OF CROSSFIT RELATED INJURY**

		NUMBER OF ATHLETES	VALID PERCENT (%)
<b>VALID</b>	Joint dysfunction	19	31.1
	Muscle strain	17	27.9
	Hernia	1	1.6
	Bone fracture	1	1.6
	Nerve damage	1	1.6
	<b>None</b>	<b>22</b>	<b>36.1</b>
	Total	61	100.0

**TABLE 4: PREVIOUS LOCATION OF CROSSFIT RELATED INJURY**

		NUMBER OF ATHLETES	VALID PERCENT (%)
<b>VALID</b>	Shoulder	13	21.3
	Back	9	14.8
	Knee	3	4.9
	General	2	3.3
	Hip	2	3.3
	Groin	2	3.3
	Ankle	2	3.3
	Neck	2	3.3
	Buttock	1	1.6
	Leg	1	1.6
	Foot	1	1.6
	Arm	1	1.6
	<b>None</b>	<b>22</b>	<b>36.1</b>
	<b>TOTAL</b>	61	100.0



#### 4.6.2 Current CrossFit related Injury

Athletes who had injuries present on the day of the FMS™ assessment had been recorded in the Athlete Questionnaire (Appendix D). It was discovered that 16.39% of the sample had injuries present when the FMS™ was conducted and 83.61% had no current injury.

The most common type of current injury that was sustained during CrossFit training was joint dysfunction, in 11.5% of the sample, followed by 3.3% with muscle strain injuries and 1.6% with bone fractures.

The most common location of current injuries was the shoulder, with 4.9% of athletes injured. There were 3.3% of athletes with ankle injuries and 1.6% of hip, knee, arm, back and thigh injuries.

**TABLE 5: CURRENT TYPE OF INJURY SUSTAINED BY ATHLETES**

		NUMBER OF ATHLETES	VALID PERCENT (%)
VALID	Joint dysfunction	7	11.5
	Muscle strain	2	3.3
	Bone fracture	1	1.6
	<b>None</b>	<b>51</b>	<b>83.6</b>
	<b>Total</b>	<b>61</b>	<b>100.0</b>

**TABLE 6: CURRENT LOCATION OF INJURY SUSTAINED BY ATHLETES**

		NUMBER OF ATHLETES	VALID PERCENT (%)
VALID	Shoulder	3	4.9
	Ankle	2	3.3
	Hip	1	1.6
	Knee	1	1.6
	Back	1	1.6
	Arm	1	1.6
	Thigh	1	1.6
	<b>None</b>	<b>51</b>	<b>83.6</b>
	<b>TOTAL</b>	<b>61</b>	<b>100.0</b>

#### 4.6.3 INJURIES SUSTAINED DURNING TRAINING FOR “UWS GAMES 2017”

During the training for the “UWS Games 2017” 36.10% of the sample (n = 61) were injured and 63.90% were not injured. The types and locations of injuries sustained during training are represented in the tables and charts below. Many athletes sustained more than one injury during the training period, therefore the first injury that the athlete sustained was recorded as ‘first recorded injury’ and thereafter if a second injury was sustained it was recorded as ‘second recorded injury’. The most common type of first recorded injury sustained by athletes was joint dysfunction of 24.6% followed by muscle strain of 11.5%. The most common type of second recorded injury was similar to the first recorded injury as joint dysfunction was most common at 13.1% and muscle strain the second most common, at 6.6% of the athletes.

With regards to the location of injuries sustained, the shoulder was the most frequently injured area of the body for the first recorded injury, affecting 9.8% of the sample. Thereafter, 4.9% of athletes sustained injuries in the area of the knee, ankle and back. And lastly the least injured areas accounted for 1.6% of the sample and included areas of the leg, hip, neck, arm, thigh, abdomen and wrist.

**TABLE 7: TYPE OF INJURY SUSTAINED DURING TRAINING**

		NUMBER OF ATHLETES	VALID PERCENT (%)
<b>FIRST INJURY SUSTAINED</b>	Joint dysfunction	15	24.6
	Muscle strain	7	11.5
	<b>None</b>	<b>39</b>	<b>63.9</b>
	Total	61	100.0
<b>SECOND INJURY SUSTAINED</b>	Joint dysfunction	8	13.1
	Muscle strain	4	6.6
	<b>None</b>	<b>49</b>	<b>80.3</b>
	Total	61	100.0

**TABLE 8: LOCATION OF INJURY SUSTAINED DURING TRAINING**

		<b>NUMBER OF ATHLETES</b>	<b>VALID PERCENT (%)</b>
<b>FIRST INJURY SUSTAINED</b>	Shoulder	6	9.8
	Knee	3	4.9
	Ankle	3	4.9
	Back	3	4.9
	Leg	1	1.6
	Hip	1	1.6
	Neck	1	1.6
	Arm	1	1.6
	Thigh	1	1.6
	Abdomen	1	1.6
	Wrist	1	1.6
	<b>None</b>	<b>39</b>	<b>63.9</b>
	Total	61	100.0
<b>SECOND INJURY SUSTAINED</b>	Shoulder	3	4.9
	Hip	3	4.9
	Knee	3	4.9
	Buttock	1	1.6
	Back	1	1.6
	Elbow	1	1.6
	<b>None</b>	<b>49</b>	<b>80.3</b>
	Total	61	100.0

#### 4.6.4 INJURIES SUSTAINED AT THE “UWS GAMES 2017”

Athletes that were injured at the “UWS Games 2017” while participating, made up for 8.20% of the sample. The location and type of injury is represented in the tables below.

The types of injuries sustained at the “UWS Games 2017” were muscle strain and joint dysfunction. The majority of the injuries were muscle strains, affecting 4.9% of the total sample. The least number of injuries was found in joint dysfunction, with 3.3% of the athletes sustaining this type of injury.

The location of injuries sustained at the “UWS Games 2017” included the shoulder and back, which were the most sustained areas of injury, affecting 3.3% of the total sample. The least injured area at the “UWS Games 2017” was the knee, which affected 1.6% of athletes.

**TABLE 9: TYPE OF INJURY SUSTAINED AT THE “UWS GAMES 2017”**

		NUMBER OF ATHLETES	VALID PERCENT
<b>FIRST INJURY SUSTAINED</b>	Muscle strain	3	4.9
	Joint dysfunction	2	3.3
	<b>None</b>	<b>56</b>	<b>91.8</b>
	Total	61	100.0

**TABLE 10: LOCATION OF INJURIES SUSTAINED AT THE “UWS GAMES 2017”**

		FREQUENCY	VALID PERCENT (%)
<b>FIRST INJURY SUSTAINED</b>	Shoulder	2	3.3
	Back	2	3.3
	Knee	1	1.6
	<b>None</b>	<b>56</b>	<b>91.8</b>
	Total	61	100.0

## 4.7 ASSOCIATIONS WITH THE FMS™ SCORES

### 4.7.1 Injury and the FMS™ scores

A correlation between the total FMS™ scores and injury in CrossFit athletes was hypothesised in this research. The results of this hypothesis were tested below by comparing FMS™ scores and injuries sustained using T-Tests, Mann-Whitney U test, Fisher's exact Chi-Square and One-way Analysis of Variance (ANOVA) tests.

With regards to previously sustained CrossFit injury the use of the T-Test made a comparison between athletes who sustained previous CrossFit related injuries and the total FMS™ scores. The data revealed that 39 of the total sample who had previous injuries had a mean total FMS™ score of 17.64 (SD 2.45) out of 21. Furthermore, the 22 athletes who did not have previous injuries, had a mean total FMS™ score of 17.90 (SD 2.50). The corresponding two-tailed  $p$  value is  $t(59) = -0.41$ ,  $p = 0.69$  which concludes that this comparison is not significant as the value is more than 0.05. However, a difference is seen between scores of injured and uninjured athletes.

The use of the T-Test made a comparison between athletes sustaining injuries during training and the total FMS™ scores. The data revealed that 22 athletes who sustained injuries had a mean total FMS™ score of 17.68 (SD 2.80) out of 21. Additionally, there were 39 athletes who did not sustain any injuries during training, and had a mean FMS™ score of 17.97 (SD 1.98). The corresponding two-tailed  $p$  value is  $t(56) = -0.46$ ,  $p = 0.65$  which concludes that this comparison is not significant as the value is more than 0.05. However, a difference is seen between scores of injured and uninjured athletes.

The injuries sustained at the "UWS Games 2017" and the total FMS™ scores were compared using the T-Test. The data revealed that 5 athletes of the total sample that did sustain injuries had a mean total FMS™ score of 17.60 (SD 2.88) out of 21. Additionally, there were 56 athletes of the total sample that did not sustain any injuries during competition and had a mean total FMS™ score of 17.73 (SD 2.44). The corresponding two-tailed  $p$  value  $t(59) = -0.13$ ,  $p = 0.90$  which concludes that this comparison was not significant as the value is more than 0.05. However, a difference was seen between scores of injured and uninjured athletes. These findings will be discussed in Chapter five.

#### **4.7.2 Injury and the different components of the FMS™**

Each score of the components of the FMS™ is compared with the injuries sustained to find any significance between a specific FMS™ component (excluding the clearance tests) and injury either during training for the “UWS Games 2017” or with injury sustained at the “UWS Games 2017”. Each FMS™ component is listed below:

- The Deep Squat test
- The In-line Lunge test
- The Hurdle Step test
- Shoulder Mobility test
- The Active Straight Leg Raise test
- The Trunk Stability Push-Up test
- The Quadruped Rotatory Stability test

As seen in Table 11 below, the non-parametric correlation was violated when the Chi-Square test was used to find an association between the shoulder mobility test of the FMS™ and type of previous injury. The results revealed that the  $p$  value is ( $\chi^2(15) = 33.28$ ,  $p < 0.004$ ) and this indicated that athletes with previous injury negatively influenced the outcome of the shoulder mobility test. These findings will be discussed in Chapter five.

**TABLE 11: ASSOCIATION BETWEEN SHOULDER MOBILITY TEST AND TYPE OF PREVIOUS INJURY**

CROSSTAB

		0 UNABLE	1 DO IT BUT PAIN	2 DO IT WITH COMPENSATION	3 FULLY ABLE	Total
<b>PERVIOUS INJURY</b>	1 Muscle	3	1	4	9	17
	2 Joint	7	0	2	10	19
	3 Hernia	0	0	0	1	1
	4 Bone	0	1	0	0	1
	5 Nerve	0	0	0	1	1
	99 None	1	1	10	10	22
<b>TOTAL</b>		11	3	16	31	61

CHI-SQUARE TESTS

	Value	df	Asymptotic Significance (2-sided)
<b>PEARSON CHI-SQUARE</b>	33.275 <sup>a</sup>	15	0.004
<b>LIKELIHOOD RATIO</b>	21.730	15	0.115
<b>LINEAR-BY-LINEAR ASSOCIATION</b>	1.287	1	0.257
<b>N OF VALID CASES</b>	61		

**A. 20 CELLS (83.3%) HAVE EXPECTED COUNT LESS THAN 5. THE MINIMUM EXPECTED COUNT IS .05.**

There was a significant finding using the Chi-Square test to find an association between the trunk stability test and injury during training, represented in Table 12 below. The  $p$  value is ( $\chi^2(2) = 7.06$ ,  $p < 0.029$ ), therefore indicates a significant association. This indicates that a low score for the trunk stability test was a predictor for injury during training for the “UWS Games 2017”. These findings will be discussed in Chapter five.

**TABLE 12: ASSOCIATION BETWEEN TRUNK STABILITY TEST AND TYPE OF INJURY DURING TRAINING**

**CROSSTAB**

		2 DO IT WITH COMPENSATION	3 FULLY ABLE	TOTAL
<b>INJURY DURING TRAINING</b>	Muscle	4	3	7
	Joint	2	13	15
	None	6	33	39
<b>TOTAL</b>		12	49	61

**CHI-SQUARE TESTS**

	Value	df	Asymptotic Significance (2-sided)
<b>PEARSON CHI-SQUARE</b>	7.055 <sup>a</sup>	2	0.029
<b>LIKELIHOOD RATIO</b>	5.662	2	0.059
<b>LINEAR-BY-LINEAR ASSOCIATION</b>	1.269	1	0.260
<b>N OF VALID CASES</b>	61		

**A. 2 CELLS (33.3%) HAVE EXPECTED COUNT LESS THAN 5. THE MINIMUM EXPECTED COUNT IS 1.38.**



There was an additional significant finding using the Pearson Chi-Square test to an association between the trunk stability test and injury during participation of the “UWS Games 2017”. The  $p$  value revealed a significant association of ( $\chi^2(2) = 8.98, p < 0.011$ ), indicating that a low score for the trunk stability test was a predictor for injury during participation at the “UWS Games 2017”. These findings will be discussed in Chapter five.

#### **4.7.3 Athlete Age and the FMS™ Scores**

An association between the age of athletes and FMS™ scores was made using the One-way Analysis of Variance (ANOVA) test. Age has been noted as a risk factor for injury and thus has been selected to make a comparison with the FMS™ scores in order to see if age can influence the FMS™ scores, and therefore influence injury susceptibility. There were no significant findings based on this test as the  $p$  value  $t(3, 57) = 0.624$ , value = 0.60, which is not less than  $p = 0.05$ , which indicates no statistical significance. These findings will be discussed in Chapter five.

#### **4.7.4 Body Mass Index and FMS™ Scores**

An association was made between the FMS™ scores of the athletes and their BMI. The BMI was calculated using the height squared divided by the athlete’s weight. The reason for the BMI being compared to the FMS™ scores is because BMI may be seen as a risk factor for injury. The one-way ANOVA test was used to compare this association and based on this test as the  $p$  value  $t(1, 59) = 5.09$ , value = 0.028, and this reveals significance, as seen in Table 13 below. These findings will be discussed in Chapter five.

**TABLE 13: CORRELATION BETWEEN THE FMS™ SCORES AND BMI**ANOVA<sup>A</sup>

MODEL	Sum of Squares	df	Mean Square	F	Sig.
Regression	28.71	1	28.71	5.09	.028 <sup>b</sup>
Residual	333.10	59	5.65		
Total	361.80	60			

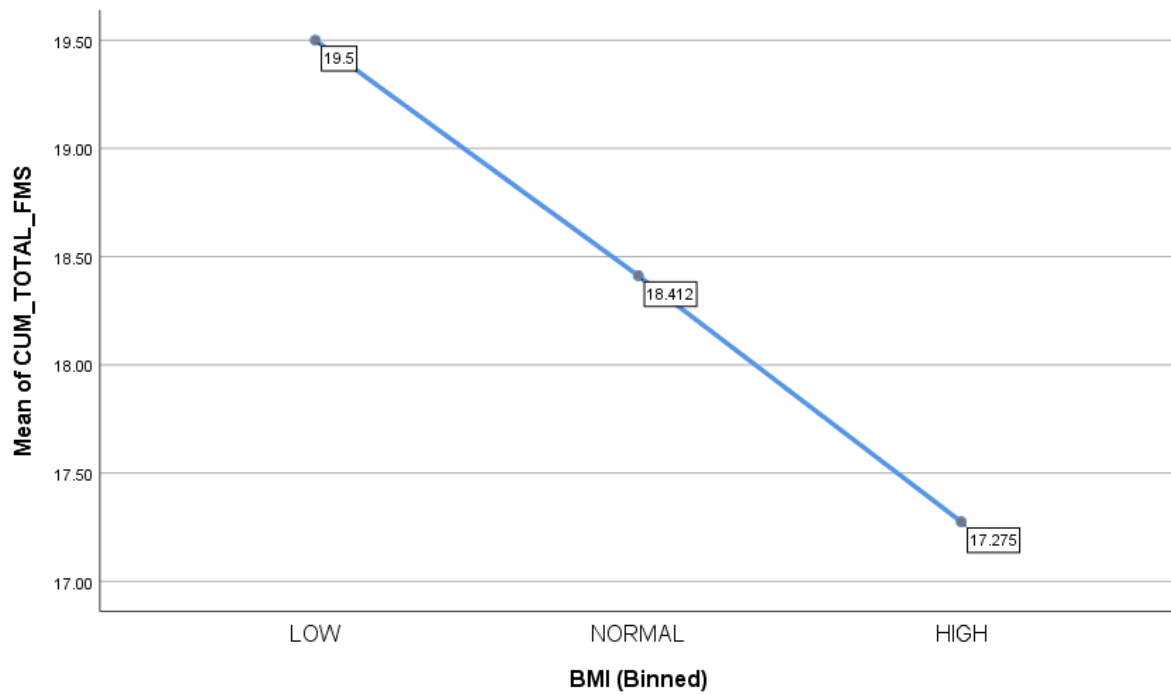
To further prove this significant finding, the non-parametric equivalent (Kruskal-Wallis) was run and the equality of means was violated. There is a significant difference in an athlete's BMI and total FMS™ score ( $H(2) = 41.781$ ,  $n = 61$ ,  $p < 0.001$ ).

There was a further significant, negative, moderate correlation between BMI and total FMS™ score ( $r = -0.44$ ,  $n = 61$ ,  $p$  was 0.00 and was therefore  $< 0.001$ ) when the Pearson's correlation test was used, as seen in the table below. This finding allowed for the understanding that the higher the BMI of the athletes, the lower the athletes would score in the FMS™. These findings will be discussed in Chapter five.

**TABLE 14: BMI RANGES LINKED TO WEIGHT GROUPS**

BMI	WEIGHT GROUP
< 18.50	Underweight
18.5 – 24.90	Normal
25.00 – 29.9	Overweight
> 30.0	Obese

The graph in Figure 16 represents the negative correlation between BMI and FMS™ scores. A low BMI is linked to a high FMS™ score and a high BMI is linked to a low FMS™ score. Furthermore, a low BMI score indicates underweight athletes, normal BMI indicates normal weight groups and high BMI will relate to overweight and obese athletes (Rantanen 2000). A high BMI may not only indicate obesity, as a higher BMI may indicate high muscle percentage. Some athletes may have a high BMI due to a high fat percentage or a high muscle mass, both scenarios may attribute to a low FMS™ score. These findings will be discussed in Chapter five.



**FIGURE 16: CORRELATION BETWEEN FMS™ SCORES AND BMI**

#### **4.7.5 CrossFit Duration and FMS™ Scores**

An association between the number of months an athlete has participated in CrossFit for and the FMS™ scores was conducted. There was no significant finding when the one-way ANOVA test was conducted as the  $p$  value  $t(11, 49) = 0.73$ , value = 0.71, which did show any significance. These findings will be discussed in Chapter five.

#### **4.7.6 Box and FMS™ Scores**

An association between the box with which athletes are affiliated with and the FMS™ scores was conducted. A significant association was found as the  $p$  value was value  $t(4, 56) = 0.262$ , value = 0.04. As seen in the Table 15 below with the use of the ANOVA. A further association between the affiliated box and FMS™ scores using robust tests of equality and there were further significant findings found where the  $p$  value = 0.032 as seen in Table 16. The correlation reveals that the box the athletes are affiliated with will influence the outcome of the FMS™ score. Figure 17 represents these findings and reveals that there are significantly higher mean FMS™ scores seen in box A (20.17), followed by box E (18.23), box C had the third highest scores of 13.92 and two boxes with the lowest scores were box D (17.14) and box B (16.91). These findings will be discussed in Chapter five.

**TABLE 15: CORRELATION BETWEEN FMS™ SCORES AND BOXES**

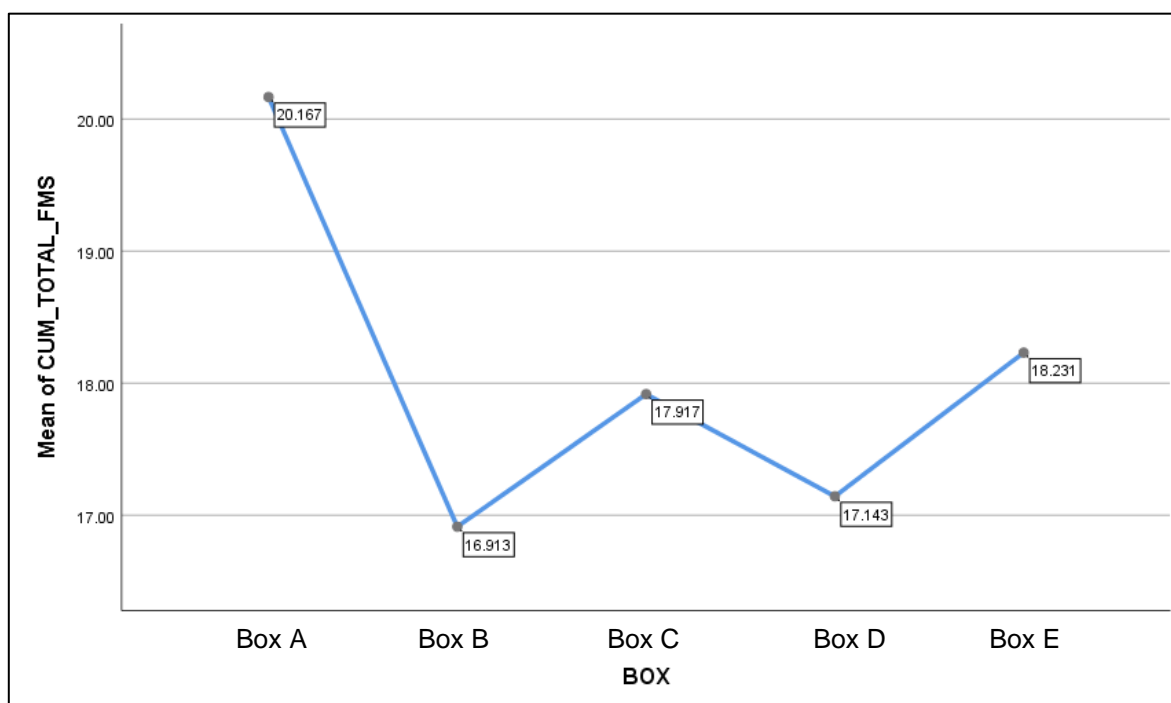
ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
<b>BETWEEN GROUPS</b>	57.062	4	14.266	2.621	0.044
<b>WITHIN GROUPS</b>	304.741	56	5.442		
<b>TOTAL</b>	361.803	60			

**TABLE 16: CORRELATION BETWEEN FMS™ SCORES AND BOXES**

ROBUST TESTS OF EQUALITY OF MEANS

	Statistic	df1	df2	Sig.
<b>BROWN-FORSYTHE</b>	2.947	4	38.036	0.032
A. ASYMPTOTICALLY F DISTRIBUTED.				



**FIGURE 17: CORRELATION BETWEEN FMS™ SCORES AND AFFILIATED BOXES**

## **CHAPTER FIVE:**

### **DISCUSSION**

#### **5.1 INTRODUCTION**

This Chapter expands the data presented in Chapter four and discusses it with relation to other information. The discussions will cover the objectives of the research as well as use literature from Chapter two, to support these discussions.

#### **5.2 OBJECTIVE A**

The first object was to evaluate the scores of the FMS™ in CrossFit athlete's pre-participation and to determine the normative values of the FMS™ as a predictor of injury.

##### **5.2.1 The normative values of the FMS™ scores in CrossFit athletes**

The average FMS™ score which was calculated from the total athletes ( $n = 61$ ) was 17.73 out of 21. These results indicated that the athletes had an overall above average grading of the FMS™ tests. The value is higher than most other already established normative values where the FMS™ was used. This can be expected as the aim of CrossFit is to incorporate a multitude of functional movements performed at a high intensity and high frequency to attain a generalised and comprehensive level of fitness. These conditions allow athletes to be in an above average fitness and functional category, which may explain the higher FMS™ scores (Glassman 2010). When these values were compared with other values from different sports including, hockey, football, cheerleading, basketball, softball, tennis and athletics; it was found that the CrossFit normative values were higher than the other sports (Kiestel *et al* 2007, Chorba *et al* 2010, Murphy *et al* 2003). As previously mentioned, CrossFit is a type of sport that allows athletes to take part in various functional activities, thus the latter could be true considering this. CrossFit was developed to achieve optimal and all round fitness to prepare athletes for

unpredictable circumstances. Whereas, other sporting activities involve similar and repetitive functional movement to achieve its goal.

The results from this current study regarding the normative values of the FMS™, differed to various studies where the mean scores of 14 out of 21 were used to predict injury (Kiesel *et al* 2007; Chorba *et al* 2010). One of these studies observed a group of professional football players, and although the sport has similar characteristics, such as the high intensity nature, the football players were at a level of advanced skill. One can therefore see why the athletes have lower scores than the athletes from the current study, which observed all levels of competition ranging from beginners to advanced. Athletes that compete at a higher and more advanced skill level may work at a higher level of intensity than athletes of a lower skill level and therefore increase their risk of injury. This may result in a lower FMS™ score (Kiesel *et al* 2007; Smith *et al* 2013; Murphy *et al* 2003). Another study with an average score of 14 observed 38 female student athletes participating in soccer, volleyball and basketball (Chorba *et al* 2010). The difference in scores from the female student athletes and CrossFit athletes of this current study can be as a result of the different sample sizes, as a smaller and only female group of athletes were observed, compared to the heterogeneous study conducted in the current research. A study revealed that when comparing FMS™ scores between males and females, females scored significantly lower than males (Anderson *et al* 2015).

The definition of injury used in research related to the FMS™ is a variable which may have a serious effect on the outcomes. The definition used for this current research was: acute injury is an injury which occurs suddenly because of macro-trauma or aggravation of a chronic complaint; and chronic injury is a repetitive micro-trauma to soft tissue structures - improper healing of these structures may result in pain for a prolonged period. This definition was used to allow the participants to obtain a greater understanding of what injury is, aiding them in reporting their injuries more accurately. This definition varies from the different definitions used in other research (Kiesel *et al* 2007, Chorba *et al* 2010). If participants in the FMS™ have different understandings of what injury is, there will be different reports on what injury is sustained. This will result in different predictive values for injury, which is seen in this current research.

There were studies which had very similar normative values to the current study. These included the normative values for military and tactical officers. Specifically, the results can be compared to a study carried out by O'Connor *et al* (2011) who recorded a mean FMS™ score of 16.60 for a sample of a military troop, whom had additional similarities to the current study.

This similarity may be due to the nature of training that military members take part in, which resembles the generalised fitness training protocol CrossFit undertakes. Ricks (2014) stated that soldiers were using CrossFit training techniques to develop a more inclusive and generalised fitness protocol. A study conducted on a group of active students yielded normative values of 17 (Letafatkar *et al* 2014) which is similar to the current study. The active students participated in many various sporting activities and were not limited to participating in one sport (Letafatkar *et al* 2014). This similarity may be due to the active athletes achieving a generalized fitness through the participation in numerous sports at one time which is similar to the generalized fitness which CrossFit aims to achieve.

## **5.3 OBJECTIVE B**

The second objective was to determine demographic data and additional risk factors which might predispose athletes to injury occurrence pre-participation such as: previous injury, age, height, weight and duration one has taken part in CrossFit, through the use of the Athlete Questionnaire (Appendix D). The risk factors were compared to the FMS™ scores to see if there was an association between the different factors.

### **5.3.1 Demographic data**

The comparisons of the demographics of this data can be made with the study done by *Da Silva* (2015); the studies had similarities with regards to the sample groups used. Both studies used CrossFit athletes at the “UWS Games 2017”. There were also similarities in the gender of the total samples, as both studies had a majority of male participants. There were similarities noticed in the age distribution of athletes as the study done by *Da Silva* (2015) had an age distribution of 18 and 43 years, as compared to this research where the age ranged from 19 to 49 years.

The similarities in the comparison of these studies were allowed based on the common demographic factors that these two studies shared. An explanation for the vast range of athlete ages in the sample is most likely due to the “UWS Games 2017” entry form requiring any athlete aged over 18 years to participate, with no maximum age stated. This allowed for a greater range of data collection from vast ages, however both studies did not look at athletes under the



age of 18 years. This could have provided additional information on CrossFit injuries and should be looked at for further studies.

### **5.3.2 Age**

When age was compared to the FMS™ scores, no significance was noted. This meant that age did not influence athlete performance of the FMS™. Researchers like Lavalley and Balam (2010) found that in strength training the ages most likely to sustain injury were master's athletes and skeletally mature athletes. However, Hagglund *et al* (2016) found that age was not a risk factor for injury when looking at football players. The research done on how age influences injury risk does not clearly depict which age category has more risk of injury, Therefore, since CrossFit incorporates certain aspects of both of the sports mentioned above, (Hak 2015), it is understandable why the FMS™ scores and age had no significance when compared. Age related changes to the musculoskeletal system that occur over time can result in decreased flexibility, decreased range of motion and weakness. These changes are accelerated when living a sedentary lifestyle (Loeser 2010). Further reasons for higher injury rates in older athletes are due to reduced output of muscle force and decreased joint flexibility (Fukuchi *et al* 2013). However, CrossFit athletes are continuously engaging in a multitude of functional movements performed at high intensity and high frequency which may slow down the effects of aging on the musculoskeletal system. Therefore, one can see how with CrossFit athletes age has not affect the outcome of the FMS™.

### **5.3.3 Height and weight**

In this research the height and weight of each athlete was used to calculate the BMI of the athletes. The BMI was then compared to the FMS™ scores. There was a significant link found between the two variables. It was found that the higher the athlete's BMI, the lower their FMS™ score. It has been found that higher BMI levels are a risk factor for injury. The FMS™ assesses mobility and stability and the functionality of muscle strength, range of motion, flexibility, balance, co-ordination and proprioception (Bock and Orr 2015). The FMS™ incorporates all aspects of the kinematic chain, which are the connecting joints and muscles that work together to achieve functional movement (Schneiders 2011). Therefore, a higher BMI score places increased load on the kinematic chain, which affects an athlete's performance when performing the FMS™. Athletes with a higher fat content often have weaker core strength and trunk stability, and therefore impeding the accuracy at which the functional movements are executed

(AlAbdulwahab and Kachanathu 2016). Often, athletes with a higher muscle content train isolated muscles for the purpose of looking muscular rather than training for functional form and strength. The athlete's core can also be weaker than other reliant muscles, thus negatively impacting their functional movements and causing an imbalance in musculoskeletal strength. It can also be suggested that larger athletes train using heavier weights and more resistance, which can directly increase the risk of injury on the musculoskeletal system (Montalvo *et al* 2017). A larger BMI indicates that athletes are typically heavier, due to either increased fat and/or muscle content in the body. Athletes that are carrying a larger amount of weight require more energy and applied force to execute adequate fundamental movements. This extra energy required may cause the athlete to fatigue quicker, therefore there is an alteration in muscle recruitment patterns. This can unevenly distribute forces across the musculoskeletal structures and may result in injury (Mitchell *et al* 2015). Based on the above one can deduce that there is a near direct relationship between an athlete's BMI, FMS™ score and consequently, injury.

#### **5.3.4 Duration practising CrossFit**

When the monthly duration each athlete had been practising in CrossFit for was compared to the FMS™ scores there was no significant correlation. It was found in a previous study that athletes that were more likely to sustain injuries were those who took part in CrossFit for more than six months and who were training for competitions, Sprey *et al* (2016). Another study done by Montalvo *et al* (2017) found that the longer duration of CrossFit reduced the rate of injury, which seems to contradict the latter. Therefore, either a longer period of training decreases injury rates due to an increased skill level, or a longer period of training increases the risk for injury due to athletes attempting more advanced techniques and more intense work out programmes. Due to conflicting studies which suggest different outcomes it is difficult to conclude anything, especially since no correlation was found between the duration and FMS™ scores in this current study. More finite research needs to be done in order to accurately conclude which factors actually influence injury in CrossFit athletes; more specifically with regards to the duration that athletes have been taking part in the sport..

### **5.3.5 Different affiliated boxes**

A significant correlation was found when comparing which box the athletes were affiliated with and the FMS™ scores. These findings may be due to different levels of training that CrossFit instructors receive, which means that instructors who have undergone different types of training will supervise boxes differently (Waryasz *et al* 2016). CrossFit exercises are extremely technical and difficult to execute. When there is poor supervision and teaching in CrossFit boxes, injury will most likely occur. These instructors should strictly implement the teaching of basic movements first before they allow athletes to attempt advanced techniques and lifts. Failure of adequate supervision in this process could result in injury from athletes attempting advanced techniques without the knowledge of how to execute them. It was also found that an increased training load given to athletes from the instructor was a risk factor for injury in CrossFit athletes. Therefore, if instructors are increasing workload beyond the capabilities of the athletes, they may over exert themselves and cause injury (Bergeron *et al* 2011; Hak 2013). An injury profile study conducted on CrossFit athletes found that instructor supervision during training was directly related to injury (Weisenthal *et al* 2014). These factors may explain why athletes from different affiliated boxes have different FMS™ scores. The different instructors in each affiliated box that are instructing these athletes, may have an effect on the risk of injury placed on the athletes and therefore affect their FMS™ scores.

## **5.4 OBJECTIVE C**

The third objective was to compile an injury profile of the athletes during the training period before and during the “United We Stand CrossFit Games 2017”.

### **5.4.1 Injuries sustained**

From the total sample, 36.10% of CrossFit athletes sustained injuries during the training period of one month leading up to the “UWS Games 2017”. This percentage is slightly high compared to some injury profile studies done on CrossFit athletes. An online injury profile study revealed that 20% of CrossFit athletes sustained injuries through the data collection using an online retrospective method (Weisenthal *et al* 2014). The athletes that were tracked in the

retrospective injury profile conducted by Chachula *et al* (2016) found that 22% of athletes sustained injury. An online retrospective epidemiological study done on CrossFit athletes in Brazil revealed a total of 31% athletes sustaining injury (Sprey *et al* 2016). As stated in *Chapter 2: 2.4.2 Recording of Sports Injury* the use of a retrospective data collection with self-reported injuries decreases the accuracy and number of injuries reported. Therefore, due to the current study's approach of prospective data collection, more injury occurrences were reported (Gabbe *et al* 2003). Another reason for the current study's injury rates being higher than other injury profiles is possibly due to the study sample training under more strenuous circumstances. This current study collected data over a period where the athletes were training for the "UWS Games 2017". When athletes are performing in a competitive setting it has been found that injury rates are higher due to the increase in demand on athletes, which places strain on the musculoskeletal structures in the body (Smith *et al* 2013; Murphy *et al* 2003; Sprey *et al* 2016).

From the overall data collection, the most common type of injuries sustained were joint dysfunction and muscle strains. From the overall injuries sustained it was found that the most frequently injured areas were primarily the shoulder, followed by the knee and lower back. CrossFit is an all-inclusive fitness programme which targets all areas of the body (Glassman 2010). This may explain why the most common areas of injury were distributed evenly throughout the body. The injuries were found in the upper limbs (shoulder), the trunk (lower back) and the lower limb (knees). These findings are consistent with numerous findings in previous injury profile studies conducted (Montalvo *et al* 2017; Weisenthal *et al* 2014; Mehrab *et al* 2017; Chachula *et al* 2016; Hak 2013). A study conducted by Montalvo *et al* (2017) discovered shoulder injury to be the most prevalent injury sustained during CrossFit, followed by areas of the knee and lower back. Additionally, Weisenthal *et al* (2014) and Mehrab *et al* (2017) found the exact same areas to be the most common areas of injury in CrossFit athletes. In the injury profile study conducted by Chachula *et al* (2016) 27.5% of athletes sustained back injuries and 22.5% of athletes sustained shoulder injuries. It was also found that athletes' back pain was aggravated by certain exercises performed during CrossFit, such as dead lifts and kettle bell swings. Shoulder pain was reported to be aggravated by ring dips.

Possible reasoning for these areas commonly sustaining injuries may be due to the structures being placed under high levels of stress at a high frequency and repetition. There are many overhead exercises performed during CrossFit, which are often at high loads and have many technical aspects to the movements. The structures in the shoulder are therefore especially placed under strain as a repetitive hyperflexed, abducted and internally rotated position is

assumed. The structures eventually fatigue and result in a lack of technique and form, which may result in injury (Hak 2013). Knowing which areas are most commonly injured during training, athletes need to be aware of the risks and strive to maintain form during training (Weisenthal *et al* 2014).

## **5.5 OBJECTIVE D**

The fourth objective was to determine any association between low FMS™ scores and injury occurrence. The total FMS™ score, as well as each specific FMS™ component was compared to the injury data collected.

### **5.5.1 Discussion of the associations with the total FMS™ scores**

The total FMS™ scores were compared to the previous injury rates, injury rates during training for the “UWS Games 2017” and injuries sustained during participation at the “UWS Games 2017”. Although there were no statistically significant findings for the total FMS™ score and injury, there was a weak association found between low FMS™ scores and injury susceptibility. There are numerous published research papers on the use of the FMS™ as a successful predictor of injury; many of these studies found that athletes with scores of less than 14 out of 21 were more likely to sustain injuries than athletes with scores higher than 14 out of 21 (Bock and Orr 2015; Kiesel *et al* 2007; Chorba *et al* 2010; Schneiders 2011). The scores used for the current research were higher in comparison to previous studies, however, these scores were specific to the normative values for the FMS™ in CrossFit athletes. This differs from the previous studies which used a cut-off score of 14 to predict injury, and did not use normative values. This study did not use a generalized cut-off point to predict injury, but rather a unique score which is specific to CrossFit, as previously discussed in the current study where a generalized cut-off point was not an accurate indicator. Using the normative value score to predict injury in CrossFit athletes, was not statistically significant enough to be accurately used as a predictor for injury of these athletes.

In this current research, more athletes sustained injury when awarded a score of less than 17.73 out of 21. Additionally, more athletes remained uninjured when awarded a score or more than 17.73. This proves that there is a link between the normative values of the FMS™ and CrossFit, but not at a 95% level of confidence. In a study conducted on basketball players, the FMS™ scores were calculated and it was found that athletes with a score of 16.25 were less

likely to sustain injury, whereas athletes with scores of 15.24 were more likely to sustain injury (Cuson 2010). These finding can be compared to this research as the values were also higher than the previously stated score of 14 being a more likely score to determine injury. The fast and unpredictable manner in which basketball is played is similar to that in which the CrossFit exercises are performed. This may add to the understanding of why these two sports resulted in higher FMS™ scores as indicators for injury (Fader 2016).

In a study that analysed the use of the FMS™ as a predictor of injury in the training of active students, it was found that the students with a score less than 17 were more likely to sustain a lower extremity injury. The selected group of active students took part in sports such as basketball, soccer and handball (Letafatkar *et al* 2014). All three of these sports are of a high intensity nature and the athletes were exposed to a generalized fitness, which agrees with the nature of CrossFit training (Czuba *et al* 2013; Howard and Stavrianeas 2017; Buchheit 2018).

Lafontaine and Serenko (2017) conducted a research report that attempted to find a link between the FMS™ and injury in CrossFit athletes. A link could not be found based on limitations stated in the research report including, the sample size was too small, all athletes came from a single box, retrospective self-reported data collection methods were used and there was inconsistent understanding of injury amongst athletes. In opposition to Lafontaine and Serenko's (2017) research report, this current research found a weak link between the FMS™ scores and injury susceptibility. The reasons for this is that this research overcame the limitations mentioned in the research report. This study's sample size was three times the size, athletes from this research were affiliated to numerous different boxes, a prospective data collection of method was used to track injury and the definition of injury was repeatedly explained and defined for the sample (Gabbe *et al* 2003). It has been found that prospective data collection for injury related studies is more reliable than that of retrospective data collection (Gabbe *et al* 2003; Kolt and Kirkby 1999; Twellaar *et al* 1996).

Additional reasons for this current study not successfully predicting injury in CrossFit athletes could, firstly, be due to varying understandings of what athletes define an injury to be. The definition of injury provided for athletes' understanding should be comprehensive and standardised, in turn, this may improve athlete's memories and reduce biased reporting (Finch *et al* 2006). The possibility of the effect that the definition of injury has, may have impacted the current study. Secondly, the lack of successful injury predictability in this study may have been due to the use of the normative values for CrossFit athletes. Previous research used a cut-off point of 14 out of 21 to investigate injury predictability (Bock and Orr 2015; Kiesel *et al* 2007;

Chorba *et al* 2010; Schneiders 2011). The researcher used the normative value of 17.73 in hopes to use a predictive value that was unique to CrossFit, as opposed to a generalized cut-off point used previously. However, it may be possible that the use of the 14 cut-off score would have been a better injury predictor than that of 17.73, as it proved successful for other studies (Etzel 2012).

### **5.5.2 Discussion of the associations with the different FMS™ components**

The separate components of the FMS™ were also compared to the injury data. This comparison was suggested by Chorba *et al* (2010) following a study done on female collegiate athletes. It was found that there was a significant finding when the shoulder mobility test was compared to previous injury. This finding meant that athletes with previous injury were more likely to score lower in the shoulder mobility test. Previous injury has been found to be a risk factor for injury occurrence (Hagglund *et al* 2016; Kucera *et al* 2005; Otenberg and Roos 2000; Faude *et al* 2006). Murphy *et al* (2003) investigated whether the FMS™ could identify history of previous musculoskeletal injury, but the results of the study concluded that using the FMS™ to identify previous injury in athletes was unsuccessful. This current study proves that the FMS™ can predict previous injury in athletes specific for shoulder mobility.

Another component of the FMS™ significantly related to injuries sustained during training was the trunk stability test. Peate *et al* (2007) conducted the FMS™ on firefighters in order to assess whether the intervention of trunk stabilisers and core strength could be improved in order to reduce injury. It was found that there were 43% less injuries after the trunk stability and core strength exercises were conducted over a period of one year. The findings between the two studies are that trunk stabilisers and core strength can positively influence the rate of injury following then FMS™ and that the trunk stability test can predict injury. From these findings it can be said the this component of the FMS™ is an accurate predictor of injury. This explains why the trunk stability test in the FMS™ is a predictor of injury, because when trunk stability is strengthened, less injury occurs (Peate *et al* 2007).

## **5.6 CONCLUSION**

The results from this research concluded that all the objectives were met. The first objective was to evaluate the normative values of the FMS™ in CrossFit athlete's pre-participation to the training and participation at the "UWS Games 2017". The FMS™ scores were recorded and analysed and revealed that the mean FMS™ score for the total sample of CrossFit athletes was 17.73 out of 21, with a standard deviation of 2.46.

The second objective was to determine any risk factors which might contribute to the susceptibility to injury. The risk factors were compared to the FMS™ scores, and the comparisons showed significant findings. When BMI was compared to the FMS™ scores, the equality of means was violated. There was a negative correlation between the two values: as the FMS™ scores increase, the BMI value decreases. There was a second significant correlation found between the affiliated box and the FMS™ scores. This correlation noted a significant difference between the scores and which box the athletes were affiliated with.

The third objective was to compile an injury profile study for the CrossFit athletes building up to the "UWS Games 2017". The results showed that during the training and participation at the "UWS Games 2017" the most common types of injury were joint dysfunction and muscle strains. The most common locations for injury during the training and participation at the "UWS Games 2017" were the shoulder, back and knee.

The last objective of this research sought to discover the normative values for the FMS™ and its association to injury in CrossFit athletes in the eThekweni municipality. This objective is related to the hypothesis for this research which was that a low score on the total FMS™ score is a predictor for injury in CrossFit athletes in the eThekweni municipality. The results from this research indicated that the total FMS™ scores were not a predictor for injury, as there were no statistical significant findings, however, a weak link was found. From the total sample of athletes that participated in training for the "UWS Games 2017", 22 athletes sustained injury with a mean FMS™ score of 17.68, and the athletes who were not injured had a score of 17.97. This indicated that the athletes who did not sustain injuries had a higher FMS™ score than those athletes that were recorded as injured. This finding is also true for the injuries sustained at the event of the "UWS Games 2017". At the "UWS Games 2017" five athletes were injured and from these athletes they received a mean score of 17.60. This score was lower than the score of the athletes that did not sustain any injury at the "UWS Games 2017" (56 uninjured athletes with a score of 17.73). However, these differences were not enough to be statistically significant, as they did not violate the equality of means. Therefore, the result is a null



hypothesis, which indicates that a low score is not a predictor for injury in CrossFit athletes in the eThekweni municipality.

When the specific components of the FMS™ were compared to injury rates there were significant findings. A low trunk stability test score increased the likelihood of sustaining injury, and therefore establishing that the test is a predictor of injury in CrossFit athletes. Additionally, it was found that previous injury negatively impacted the shoulder mobility test, and therefore the shoulder mobility test could test for past injury.

## **CHAPTER SIX:**

### **CONCLUSIONS AND RECOMMENDATIONS**

#### **6.1 INTRODUCTION**

This chapter concludes the research and presents the overall significant and relevant findings from the data collected. Additionally, the recommendations are described for future studies based on the limitations encountered.

#### **6.2 CONCLUSIONS**

This research determined that the normative values for the FMS™ in CrossFit athletes in the eThekweni municipality is 17.73 out of 21. There was a link found between the athletes' average FMS™ scores and injury susceptibility, however it was not statistically significant. Further studies are therefore recommended, as the link of using the FMS™ to predict injury in CrossFit athletes has been found, but needs further investigation to find a stronger link that can prove to be statistically significant. There were statistically significant findings between previous injury and the shoulder mobility test, as well as between the trunk stability test and injuries sustained during training. There were aspects of the demographic and anthropometric risk factors that influenced the outcome of the FMS™ scores, including BMI and box affiliation. This outcome revealed that the FMS™ scores to be a dependent metric that is affected by various injury risk factors.

The overall percentage of athletes that sustained injuries during training was 36.10% and at the "UWS Games 2017" was 8.20% of athletes. Of the athletes injured, the most common types of injuries recorded were joint dysfunction and muscle strain. The most common locations of injury were the shoulder, knee and lower back.

## 6.3 LIMITATIONS

- a) The limitations found in this research include that even with the use of a prospective method of data collection for injury, it was required that the athletes notify the researcher if they sustained an injury. Reliability and honesty were concerns when collecting data from the sample (Gabbe *et al* 2003).
- b) Diagnosis of injury was based on a combination of athlete description and clinical observation made by the researcher, and therefore the diagnosis is limited by the researcher's scope and athlete perception.

## 6.4 RECOMMENDATIONS

Recommendations for future studies should consider the following:

- a) A more in-depth rating of injury should be included to gain insight into the severity of injuries.
- b) The use of injury definition needs to be promoted in more regular intervals throughout the period of data collection to allow athletes to report accurately on injuries sustained (Finch *et al* 2006).
- c) A follow-up study is recommended with a larger sample size. CrossFit athletes separated into their different rankings, ranging from beginners to elite athletes, and CrossFit athletes from all over South Africa could be investigated, rather than being limited to one city. A longer time period of data collection could also be incorporated into future studies.
- d) Further investigation into the reasons behind the shoulder, knee and lower back being highly susceptible to injury is required.
- e) Further investigation into the specific testing of each FMS™ component may be done to allow for greater accuracy in understanding and using the FMS™ as a predictor on

injury, specifically, that of the shoulder mobility test, trunk stability test and the in-line lunge.

- f) Further investigations could investigate and compare athletes of different races in CrossFit and the FMS™ to see if ethical differences could affect performance.
- g) Further investigations could investigate and compare athletes different types of diets and the possible affects on6 performance (Bell *et al* 2000).

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## APPENDIXES

### Appendix A



### LETTER OF INFORMATION

Dear Participant

Thank you for considering this letter and taking the time to read it.

**Title of the Proposed Research Study:**

An investigation into the use of the normative values of the Functional Movement Screen™ as a predictor of injury in CrossFit athletes in a selected gym in the eThekweni municipality.

**Principal Investigator:** Michelle Richardson (DUT Chiropractic Student M Tech)

**Co-Investigator:** Dr G Haswell (M. Tech: Chiropractic; B COM)

**Brief Introduction and Purpose of the Study:**

**Outline of the Procedures:**

A pre-participation tool assessing athlete's functional movement will be used to assess the CrossFit athletes in this study. The aim is to use the pre-participation tool, the Functional Movement Screen™ (FMS™), to assess CrossFit athletes to detect any biomechanical abnormalities, with the use of seven movement tests, which may predict injury occurrence with the use of its normative values. Once the FMS™ scores are calculated, an attempt will be made to find a link between FMS™ scores and injury occurrence in CrossFit athletes.

The FMS™ will be set up within a closed room prior to the commencement of the set training programme building up to the United We Stand CrossFit Games 2017.

You must complete the Athlete Questionnaire, before performing the FMS™, to determine any previous injuries that have occurred while doing CrossFit, the amount of time practicing CrossFit, as well as general personal information.

You must perform the FMS™ accurately by following the specific instructions of the researcher, doing each of the seven functional movements. The researcher grades each exercise with a score of zero to three. A score of three indicates that you can execute the movement perfectly. A score of two indicates that you can complete the movement but there are compensatory movements present. A score of one is given if you are unable to complete the movement. And lastly a score of zero is given if you feel pain at any point during the movement.

During this period of training building up to the "UWS Games 2017" any injury incurred by the athletes will be recorded in the injury profile sheet. The researcher will visit on a regular basis during the training programme to keep record of any injury occurrence.

**Risks or Discomforts to the Subject:**

There is minimal chance of risk involved in this research. As per the instructions of the FMS™™, if you experiences any pain during a test, the test is stopped and a score of zero is given. Therefore, you will not be placed in any harmful situations.

**Benefits:**

The CrossFit sport will benefit from this research by learning its normative values associated with the FMS™™ which can predict injury. Therefore, if this study is successful the normative values will be a means to which injury can be predicted in CrossFit athletes, thus reducing the rate of injury in the athletes. You yourself will benefit by gaining knowledge about any biomechanical abnormalities present based on the FMS™™ tests.

**Reason/s why the Player May Be Withdrawn from the Study:**

Any illness or injury that you may have incurred over the duration of the research not related to CrossFit will be withdrawn.

You may withdraw at any time during the study and there will be no penalty.

**Remuneration:**

You will not receive payment for participation in the study.

**Costs of the Study:**

No costs to you will be involved.

**Confidentiality:**

Your information will be kept confidential at all times and will remain anonymous in the reporting of the study.

**Research-related Injury:**

There are no anticipated research related injuries expected. As noted above, should you experience pain when doing the tests, these tests will be stopped to avoid any injury.

**Persons to Contact in the Event of Any Problems or Queries:**

Dr Charmaine Korporaal:

M. Tech: Chiropractic, CCFC, CCSP, ICSSD

Senior lecturer and Clinic Director: Department of Chiropractic and Somatology

Durban University of Technology

P.O. Box 1334 Durban 4000 / 11 Ritson Road

Tel: 27 (0) 31 373 2611 Cell: 27 (0) 832463562

E-mail: [charmak@dut.ac.za](mailto:charmak@dut.ac.za)

Dr A Docrat

M. Tech: Chiropractic

Acting Head of Chiropractic Department, Durban University of Technology

P.O. Box 1334 Durban 4000 / 11 Ritson Road

Tel: 031 373 2589 or 031 202 3632 Email: [AadiID@dut.ac.za](mailto:AadiID@dut.ac.za)

Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support, Prof S Moyo on 031 373 2577 or [moyos@dut.ac.za](mailto:moyos@dut.ac.za)

## Appendix B



### LETTER OF INFORMATION

**Dear Participant**

**Thank you for considering this letter and taking the time to read it.**

**Title of the Proposed Research Study:**

An investigation into the use of the normative values of the Functional Movement Screen™ as a predictor of injury in CrossFit athletes in a selected gym in the eThekweni municipality.

**Principal Investigator:** Michelle Richardson (DUT Chiropractic Student M Tech)

**Co-Investigator:** Dr G Haswell (M. Tech: Chiropractic; B COM)

**Brief Introduction and Purpose of the Study:**

**Outline of the Procedures:**

A pre-participation tool assessing athlete's functional movement will be used to assess the CrossFit athletes in this study. The aim is to use the pre-participation tool, the Functional Movement Screen™



(FMS™), to assess CrossFit athletes to detect any biomechanical abnormalities, with the use of seven movement tests, which may predict injury occurrence with the use of its normative values. Once the FMS™ scores are calculated, an attempt will be made to find a link between FMS™ scores and injury occurrence in CrossFit athletes.

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During this period of training building up to the “UWS Games 2017” any injury incurred by the athletes will be recorded in the injury profile sheet. The researcher will visit on a regular basis during the training programme to keep record of any injury occurrence.

#### **Risks or Discomforts to the Subject:**

There is minimal chance of risk involved in this research. As per the instructions of the FM™, if you experiences any pain during a test, the test is stopped and a score of zero is given. Therefore, you will not be placed in any harmful situations.

#### **Benefits:**

The CrossFit sport will benefit from this research by learning its normative values associated with the FMS™ which can predict injury. Therefore, if this study is successful the normative values will be a means to which injury can be predicted in CrossFit athletes, thus reducing the rate of injury in the athletes. You yourself will benefit by gaining knowledge about any biomechanical abnormalities present based on the FMS™ tests.

**Reason/s why the Player May Be Withdrawn from the Study:**

Any illness or injury that you may have incurred over the duration of the research not related to CrossFit will be withdrawn.

You may withdraw at any time during the study and there will be no penalty.

**Remuneration:**

You will not receive payment for participation in the study.

**Costs of the Study:**

No costs to you will be involved.

**Confidentiality:**

Your information will be kept confidential at all times and will remain anonymous in the reporting of the study.

**Research-related Injury:**

There are no anticipated research related injuries expected. As noted above, should you experience pain when doing the tests, these tests will be stopped to avoid any injury.

**Persons to Contact in the Event of Any Problems or Queries:**

Dr Charmaine Korporaal:

M. Tech: Chiropractic, CCFC, CCSP, ICSSD

Senior lecturer and Clinic Director: Department of Chiropractic and Somatology

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Dr A Docrat

M. Tech: Chiropractic

Acting Head of Chiropractic Department, Durban University of Technology

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Tel: 031 373 2589 or 031 202 3632 Email: [AadiD@dut.ac.za](mailto:AadiD@dut.ac.za)

Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the  
Director: Research and Postgraduate Support, Prof S Moyo on 031 373 2577 or [moyos@dut.ac.za](mailto:moyos@dut.ac.za)



## CONSENT

### Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, \_\_\_\_\_ (name of researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: \_\_\_\_\_.
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

\_\_\_\_\_  
Full Name of Participant

\_\_\_\_\_  
Date

\_\_\_\_\_  
Time

\_\_\_\_\_  
Signature / Right Thumbprint

I, \_\_\_\_\_ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

\_\_\_\_\_  
Full Name of Researcher

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Full Name of Witness

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature

# Appendix C

Athlete name: \_\_\_\_\_

Appendix C

Test	Raw Score		Final Score	Comment:
Deep Squat				
Hurdle Step	L			
	R			
In-Line Lunge	L			
	R			
Active straight leg raiser	L			
	R			
Shoulder mobility test	L			
	R			
Shoulder mobility clearing test	L			
	R			
Trunk stability Push-up				
Extension clearing test				
Quadruped Rotary stability test	L			
	R			
Flexion clearing test				
<b>Total score:</b>				

\*For tests that are scored for both the right and left sides, the lower score is used when calculating the Functional Movement Screen™ composite score.

## Appendix D

### **Athlete Questionnaire:**

This questionnaire is related to the research, *An investigation into the use of the normative values of the Functional Movement Screen™ as a predictor of injury in CrossFit athletes in a selected gym in the eThekweni municipality.*

Please fill out the following information for the researcher to gather knowledge about each participant within the study.

1. Gym Name:

2. Athletes name:

3. Athletes age:

4. Athletes gender:

5. Number of years/months doing CrossFit:

6. Height:

7. Weight:

8. Previous injury:

(CrossFit related) E.g.

- Muscle strain?
- Joint sprain?
- Fracture?

9. Current injury:

(CrossFit related) E.g.

- Muscle strain?
- Joint sprain?
- Fracture?

Appendix E

**Injury Profile Sheet**

**Date:**

**Athletes name:** \_\_\_\_\_

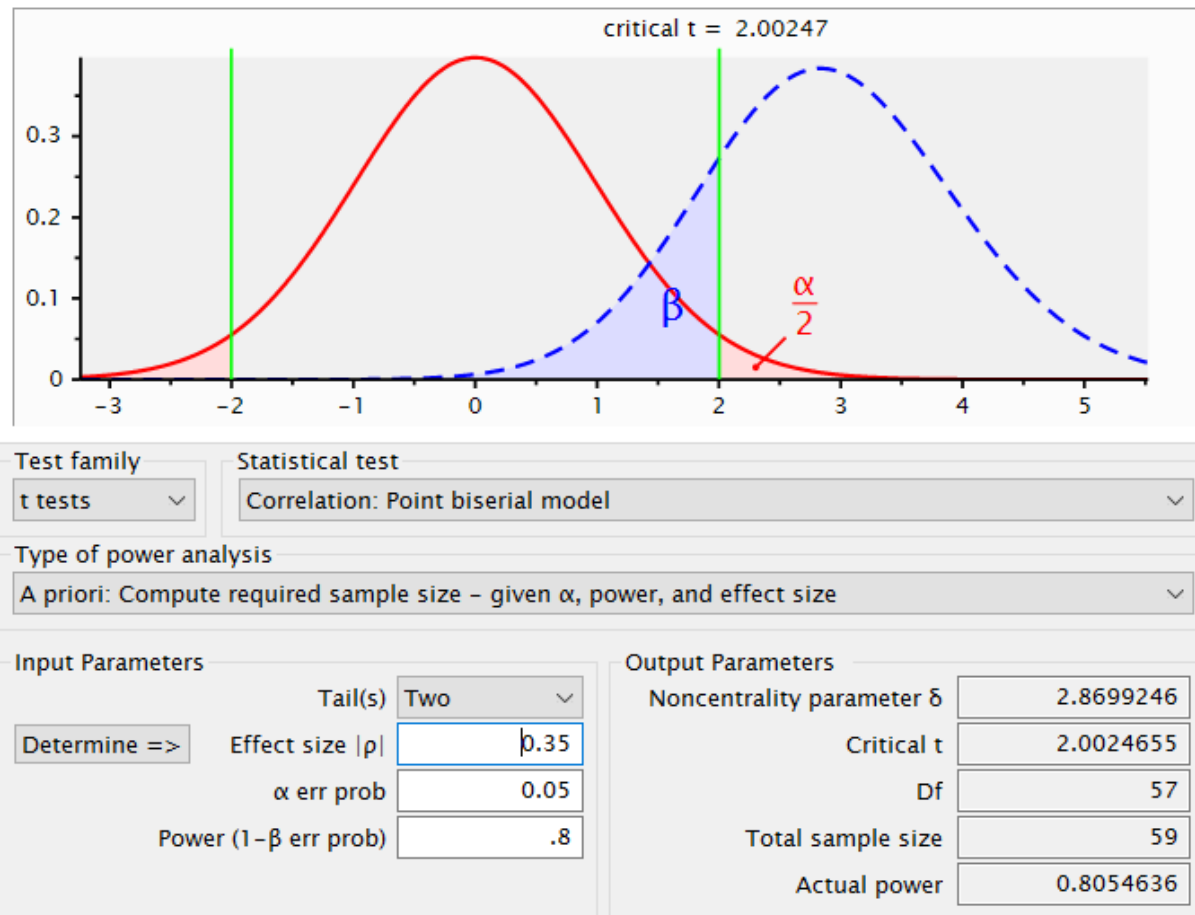
<b>Athletes gym:</b> _____ <b>To be completed by researcher or Intern</b>
1. Diagnosis:
2. **Severity: (mild, moderate, severe)
3. Date of injury:
4. Time lost:
5. Mechanism of injury:
6. Treatment (if any)

\*\*Severity description bellow (Jooste 2014)

Rating descriptor table Rating	Descriptor
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	-
7	Very hard
8	-
9	-
10	Maximal



## Appendix F



Power analysis for a chi-square test was conducted in G-POWER to determine a sufficient sample size using an alpha of 0.05, power of 0.80, a large effect size ( $w = 0.5$ ) and 4 degrees of freedom (Faul et al., 2013). Based on the aforementioned assumptions, the desired sample size is 59.

## Appendix G



6 September 2017

IREC Reference Number: **REC 65/17**

Ms M Richardson  
7 Bexmore Place  
Glenwood  
Durban  
4001

Dear Ms Richardson

**An investigation into the use of the normative values of the Functional Movement Screen™ as a predictor of injury in CrossFit athletes in a selected gym in the eThekweni municipal area.**

The Institutional Research Ethics Committee acknowledges receipt of your gatekeeper permission letter.

Please note that Full Approval is granted to your research proposal. You may proceed with data collection.

Yours Sincerely,



Professor J. R. Adam  
Chairperson: IREC





24/8/2017

Michelle Richardson  
[chellerichardson123@gmail.com](mailto:chellerichardson123@gmail.com)  
Telephone number: 0833959105  
M Tech Chiropractic student at Durban University of Technology

---

**Request for Permission to Conduct Research**

---

Dear Russel,

My name is Michelle Richardson, a M-Tech Chiropractic student at the Durban University of Technology. The research I wish to conduct for my Masters dissertation involves, **An investigation into the use of the normative values of the Functional Movement Screen™ as a predictor of injury in CrossFit athletes in a selected gym in the eThekweni municipal area.**

I am hereby seeking your consent to utilize CrossFit Shumba.

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/ or assent forms to be used in the research process, as well as a copy of the approval letter which I received from the Institutional Research Ethics Committee (IREC).

If you require any further information, please do not hesitate to contact me on 0833959105. Thank you for your time and consideration in this matter.

[Redacted signature area]

Name and surname

[Redacted signature area]

Sign

24/8/17

Date

---

## FMS SCORING CRITERIA

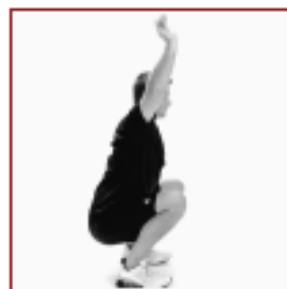
---

### DEEP SQUAT

---



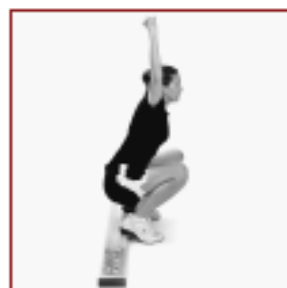
3



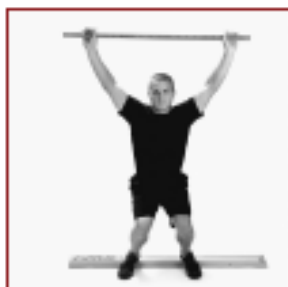
Upper torso is parallel with tibia or toward vertical | Femur below horizontal  
Knees are aligned over feet | Dowel aligned over feet



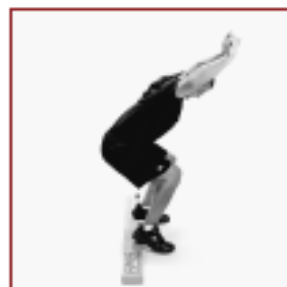
2



Upper torso is parallel with tibia or toward vertical | Femur is below horizontal  
Knees are aligned over feet | Dowel is aligned over feet | Heels are elevated



1



Tibia and upper torso are not parallel | Femur is not below horizontal  
Knees are not aligned over feet | Lumbar flexion is noted

The athlete receives a score of zero if pain is associated with any portion of this test.  
A medical professional should perform a thorough evaluation of the painful area.

## HURDLE STEP



3



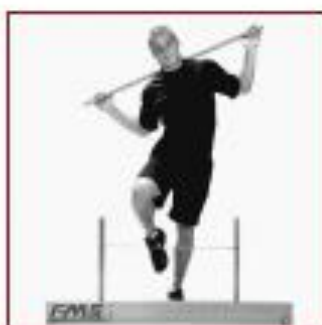
Hips, knees and ankles remain aligned in the sagittal plane  
Minimal to no movement is noted in lumbar spine | Dowel and hurdle remain parallel



2



Alignment is lost between hips, knees and ankles | Movement is noted in lumbar spine  
Dowel and hurdle do not remain parallel



1

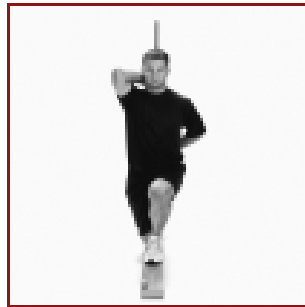


Contact between foot and hurdle occurs | Loss of balance is noted

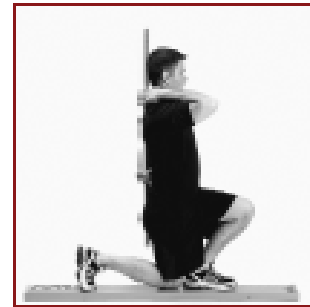
The athlete receives a score of zero if pain is associated with any portion of this test.  
A medical professional should perform a thorough evaluation of the painful area.

## INLINE LUNGE

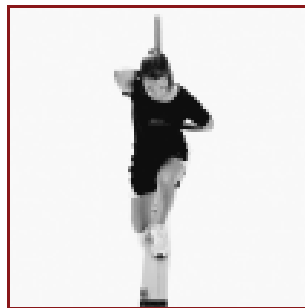
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3



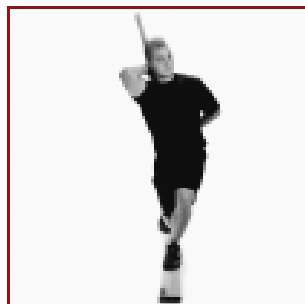
Dowel contacts maintained | Dowel remains vertical | No torso movement noted  
Dowel and feet remain in sagittal plane | Knee touches board behind heel of front foot



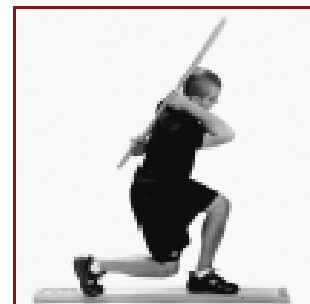
2



Dowel contacts not maintained | Dowel does not remain vertical | Movement noted in torso  
Dowel and feet do not remain in sagittal plane | Knee does not touch behind heel of front foot



1



Loss of balance is noted

The athlete receives a score of zero if pain is associated with any portion of this test.  
A medical professional should perform a thorough evaluation of the painful area.

## SHOULDER MOBILITY

---

3



Fists are within one hand length

2



Fists are within one-and-a-half hand lengths

1



Fists are not within one and half hand lengths

The athlete will receive a score of zero if pain is associated with any portion of this test.

A medical professional should perform a thorough evaluation of the painful area.



### CLEARING TEST

Perform this clearing test bilaterally. If the individual does receive a positive score, document both scores for future reference. If there is pain associated with this movement, give a score of zero and perform a thorough evaluation of the shoulder or refer out.



## ACTIVE STRAIGHT-LEG RAISE

---

3



Vertical line of the malleolus resides between mid-thigh and ASIS  
The non-moving limb remains in neutral position

2



Vertical line of the malleolus resides between mid-thigh and joint line  
The non-moving limb remains in neutral position

1



Vertical line of the malleolus resides below joint line  
The non-moving limb remains in neutral position

The athlete will receive a score of zero if pain is associated with any portion of this test.  
A medical professional should perform a thorough evaluation of the painful area.



## TRUNK STABILITY PUSHUP

3

The body lifts as a unit with no lag in the spine



Men perform a repetition with thumbs aligned with the top of the head  
Women perform a repetition with thumbs aligned with the chin



2



The body lifts as a unit with no lag in the spine  
Men perform a repetition with thumbs aligned with the chin | Women with thumbs aligned with the clavicle

1

Men are unable to perform a repetition  
with hands aligned with the chin

Women unable with thumbs aligned with the clavicle



The athlete receives a score of zero if pain is associated with any portion of this test.  
A medical professional should perform a thorough evaluation of the painful area.



### SPINAL EXTENSION CLEARING TEST

Spinal extension is cleared by performing a press-up in the pushup position. If there is pain associated with this motion, give a zero and perform a more thorough evaluation or refer out. If the individual does receive a positive score, document both scores for future reference.

## ROTARY STABILITY

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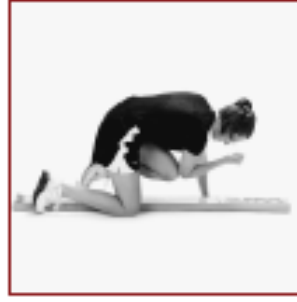
3



Performs a correct unilateral repetition



2



Performs a correct diagonal repetition

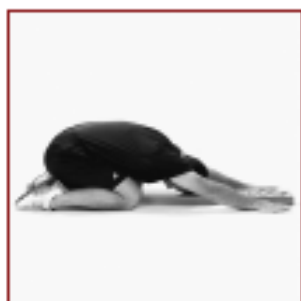


1



Inability to perform a diagonal repetition

The athlete receives a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.



### SPINAL FLEXION CLEARING TEST

Spinal flexion can be cleared by first assuming a quadrupedal position, then rocking back and touching the buttocks to the heels and the chest to the thighs. The hands should remain in front of the body, reaching out as far as possible. If there is pain associated with this motion, give a zero and perform a more thorough evaluation or refer out. If the individual receives a positive score, document both scores for future reference.