Determining Functional Movement Screen™ normative values as a predictor of injury in triathletes in the eThekwini municipal area

By

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The work is submitted in partial compliance with the requirements for the Master's Degree in Technology: Chiropractic at the Durban University of Technology.

I, Izanne Jacobs, do declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate the contrary)

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Dedication

I dedicate this dissertation to my Lord and Saviour, Jesus Christ. This would never have happened without His guidance, His love and His grace. For Your glory, Lord.

To my parents, Strauss and Este Jacobs. You have walked and prayed with me through every page of this dissertation. Thank you for your unconditional love, support and encouragement. Words can never describe my gratitude for everything that you have done for me. I am so grateful and I love you.

Trust in the Lord completely, and do not rely on your own opinions. With all your heart rely on him to guide you, and he will lead you in every decision you make. Become intimate with him in whatever you do, and he will lead you wherever you go.

Proverbs 3: 5-6 NKJV

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Abstract

Background: Triathlon is a multidisciplinary sport that comprises of swimming, cycling and running. Triathlon events are classified as sprint distance, Olympic distance and Ironman or long course triathlons. Triathlon is considered to be one of the fastest growing sports globally and, despite this, there is insufficient data relating to injuries and injury prevention in the South African context. The Functional Movement Screen™ is a pre-participation screening tool that evaluates fundamental movement patterns to determine potential injury risk and to predict injury.

Aim: This study aims to determine the normative values for the FMS™ in triathletes and its ability to identify possible injury risks in triathletes.

Methods: The research evaluated the FMS™ score in triathletes in the eThekwini municipal area prior to the commencement of a training session and then tracked the incidence, frequency and distribution of injuries that were sustained during a six-week follow-up period. Two triathlon training groups were approached, and triathletes voluntarily participated provided that they fitted the inclusion criteria. The triathletes were required to fill out an athlete questionnaire which was followed by performing the seven FMS™ tests. In total 24 triathletes between the ages of 18 and 35 were assessed. IBM SPSS version 27 was used in the data analysis to test for statistical significance of the results.

Results: The research sample revealed that the normative value for the FMS™ score for triathletes was 14.25 out of 21, with a standard deviation of 2.15. The male triathletes (14.32), on average, had a higher FMS™ score than the female triathletes (14.00). The participants did not report any injuries during the six weeks after completing the FMS™, therefore, this research shows that no association can be made between a low score on the Functional Movement Screen ™ and injury susceptibility. There was, however, noted that triathletes who reported current injuries scored lower on the FMS™ (13.25) than triathletes who did not report current injuries (14.45). However, this finding was not statistically significant ($p=0.319$). Further findings suggested that the most common injuries amongst triathletes were lower extremity muscle strains.

Conclusion: The results concur with previous research. However, this study adds insight into injury occurrence and prevention strategies in triathlon. The most common injuries require investigation to develop preventative interventions to reduce injuries in triathletes. Health professionals require education about triathlon-related injuries to improve preventative and curative interventions.

Key words: Triathlon, musculoskeletal injuries, injury profile, pre-participation screen, predictive values, Functional Movement Screen™

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List of abbreviations

ASIS

Anterior superior iliac spine

BMI

Body Mass Index

FMS™

Functional Movement Screen™

IBS SPSS

Software package used for statistical analysis

IREC

Institutional Research and Ethics Committee

Kg

Kilograms

M

Metres

N

Sample number

p

Significant value

Definitions

Acute injury

For the purposes of this research an acute injury is defined as an injury which occurs suddenly as a result of macro-trauma (Richardson 2018).

Amateur

For the purpose of this study, an amateur is defined as an athlete who engages in a pursuit, especially a sport, on an unpaid basis (Coetzee 2013).

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.* 2014a).

Injury

Based on Chorba *et al.* (2010) injury definition and for this research, injury was defined as: any acute or chronic injury that prevents an athlete from playing 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.

Overuse injury

An injury that did not occur from an acute traumatic event such as a twist or turn, collision or impact, or overstretch (Burns, Keenan and Redmond 2003).

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.

Triathlete

A triathlete is an athlete who participates in a triathlon.

Triathlon

Triathlon an athletic contest consisting of three different events, typically swimming, cycling, and running

Triathlon training group

A training group with a qualified coaches that focus on swimming, running and cycling. Triathletes from two training groups, namely Team Just-In and Triathlon Training Academy participated in this study.

Chapter One

Introduction

1.1 Introduction

Triathlon is an uninterrupted multidisciplinary sport that consists of three disciplines: swimming, cycling, and running that are completed sequentially in one event (Gosling, Gabbe and Forbes 2008; Knechtle *et al.* 2015). Triathlon was first included in the 2000 Summer Olympic Games and has since grown significantly as both a recreational and professional sport (Gosling, Gabbe and Forbes 2008). McHardy, Pollard and Fernandez (2006) stated that the variety of disciplines and distances covered within the sport is what led to its popularity.

In South Africa, several different triathlon events exist within the sport, and they are classified according to distance. The three classifications are sprint distance, Olympic distance, and long course triathlons (Triathlon South Africa 2018). Sprint distance triathlons are very popular amongst recreational triathletes and commonly consist of a 750-metre (m) swim, a 21-kilometre (km) cycle, and a 5-kilometre run. The Olympic distance triathlon is used at the Commonwealth Games, Olympic Games, National and World Championships. The distances for Olympic distance triathlons include a 1500m swim, a 40km cycle, and a 10 km run (Triathlon South Africa 2018). Long course triathlons can be divided into two categories, Ironman 70.3 and Ironman triathlon. Ironman 70.3 consists of a 1900m swim, 90 km cycle, and a 21.1 km run, whereas an Ironman triathlon is double that of an Ironman 70.3, which includes a 3600 m swim, 180 km cycle, and 42.2 km run (Anon 2019).

Due to triathlon being a multi-disciplinary sport, triathletes must transition from one discipline to the following during a race. The time spent in transition is added to the triathlete's overall time for the race, therefore triathletes spend time training not only for the swimming, running, or cycling leg of the race, but also to master the transition. The first transition is the transition from swimming to cycling, and the second from cycling to running (Gosling *et al.* 2010).

As a result, a triathlete can compete for any duration of time, from an hour up to ten hours depending on the distance of the race. Additionally, due to the wide variety of and often unpredictable conditions in which triathletes compete, and the high physiological demand due to the great distances covered, the variety and severity of injuries within triathlon differ greatly (Dallam, Jonas and Miller 2005).

Table 1: Triathlon event distances

Event	**Swim**	**Bike**	**Run**
Super sprint	400m	10km	2.5km
Sprint	750m	20km	5km
Olympic	1.5km	40km	10km
Half-Ironman	1,9km	90km	21.1km
Ironman	3,9km	180km	42.2km
Mixed relay	300m	8km	2km

(Walsh 2019)

1.2 Aim

This study aims to determine the normative values for the FMS™ in triathletes and its ability to identify possible injury risks in triathletes.

1.3 Objectives

1. To determine the normative values of the FMS™ for triathletes.
2. To determine the injury history in triathletes.
3. To identify an association between a low FMS™ score and possible occurrence of injury.

1.4 Hypothesis

Hypothesis: a low score on the FMS™ is a predictor of injury in triathletes in the eThekwini municipal area.

Null Hypothesis: a low score on the FMS™ is not a predictor of injury in triathletes in the eThekwini municipal area.

1.5 Rationale

Triathlon has proven to be a popular and highly beneficial sport that presents a unique challenge as the sport consists of three disciplines. The growth in popularity has led to an increase in the number of participants and the level of competition amongst triathletes. Triathletes are wanting to compete more often and at higher levels, therefore the need to keep triathletes injury free to sustain these competition levels has gained importance amongst health care professionals, such as chiropractors, physiotherapists and biokineticists who treat musculoskeletal injuries (Lalonde *et al.* 2020).

Current literature on injuries in triathletes mainly include the characteristics and prevalence of injuries and not injury risk or prevention methods (Kienstra *et al.* 2017). According to Sanders, Blackburn and Boucher (2013) all sports physicians must prioritize the use of an evidence-based approach to reduce injury amongst athletes. Being able to identify athletes that are at risk of injury and then developing preventative strategies can aid in reducing injury occurrence. The main objective of a pre-participation screening tool is to identify athletes at risk of injury, prevent re-injury and to use the information to enhance performance and promote health and safety in athletes (Sanders, Blackburn and Boucher 2013).

According to (Dossa *et al.* 2014), the FMS™ is a method for assessing fundamental movement patterns in an individual and therefore to identifying biomechanical irregularities in athletes and incorporating these findings into injury prediction values. The FMS™ consists of seven fundamental movement tests that requires mobility and stability. Through assessment of these movement patterns any form of compensatory movement, that includes asymmetry, instability, or abnormal mobility (hyper/hypo), can be noted as risk factors that can contribute to injury (Cook *et al.* 2014a, 2014b). Previous research has shown that the FMS™ can be used to identify injury risk in football, basketball, and soccer players, however, further research is required to validate the use of the FMS™ as a pre-participation screening tool in other sports (Schneiders *et al.* 2011).

To contribute to the existing body of research regarding the FMS™, this study focuses on triathletes since triathlon continues to grow as both a professional and recreational sport.

1.6 Benefits

Information provided by the FMS™ can be utilized by coaches and managers to identify athletes at risk of injury before or at the early stages of training for a triathlon event. Therefore, to reduce injury, when athletes at risk are identified the information can be used to develop injury preventative strategies. This has the potential to lower the number of injuries in the sport.

Triathlon's evolution as a safe sport will be aided by injury prevention, and the health advantages of triathlon will outweigh the risk of injury. Triathletes will be more aware of their physical limitations as a consequence of the FMS™ results, allowing them to be more proactive in obtaining all-round fitness and optimal functional movement. This study will also add to the body of information on the FMS™ by determining whether it can be used as an injury prediction tool in triathletes.

1.7 Limitations

The limitations related to this study are that of the accuracy of reporting by the participants. The researcher had to rely on the players recall and honesty when they completed the questionnaire and when reporting injuries after they had been screened.

1.8 Conclusion

This chapter aims to provide an introduction to the research study by discussing the sport of triathlon and what it constitutes, as well as the aims, objectives, benefits and limitations of the study.

The second chapter expands on the current literature in this topic, allowing the reader to gain a better understanding of the study's rationale.

Chapter three outlines the study design by providing the materials and methods used to conduct the research. Based on the lack of research regarding the use of the FMS™ in the sport of triathlon, this research aims to determine the normative value of the FMS™ in triathletes and to determine if there is an association between a triathlete's FMS™ score and injury. This chapter further outlines the various injuries that triathletes sustain and therefore also the necessity to determine the usefulness of a pre-participation screening tool to prevent injuries.

In chapter four provides the results of the study and the discussion thereof in relation to the current literature on the relevant topics. The results and discussion of the results were combined into one chapter for ease of reading and to show the results and discussion of the results in a logical order.

Chapter five details the conclusion of this study, as well as recommendations for other studies.

Chapter Two

Literature review

2.1 Introduction

Chapter two aims to provide the reader with an overview of the current literature to allow for a greater understanding of the rationale behind studying triathlon and the related training programs, events, and types of injuries. Triathlon injuries are further discussed in terms of intrinsic and extrinsic risk factors, as well as the use of pre-participation screening tools to predict injury in general. Finally, this chapter also reviews the Functional Movement Screen (FMS™) to enhance the reader's understanding of its use as a pre-participation screening tool to predict injury.

2.2 Triathlon

2.2.1 Triathlon even format

Several different racing formats exist within the sport of triathlon over which the International Triathlon Union (ITU) presides. These include individual and relay races that occur over a wide range of distances, from the sprint distance, lasting an hour, to the full Ironman, taking about 8-9 hours to complete at elite level (Etxebarria, Mujika and Pyne 2019). It can generally be categorized as short-course, Olympic distance, or long-course. The different distances in triathlon events each place a unique demand on the athletes.

The first Ironman triathlon was held in Hawaii in 1978 and had 50 participants. Since then, the triathlon World Championship is held in Hawaii every year and is considered one of the world's toughest endurance races (Knechtle *et al.* 2015). Currently more than 50,000 athletes compete in Ironman distance races across the globe annually (Kienstra *et al.* 2017).

In contrast to the long course Ironman, the World Triathlon Series, which consisted of eight Olympic distance events in 2019, requires a high level of performance throughout the season as the most consistent athlete is awarded the World Champion title (Etxebarria, Mujika and Pyne 2019).

The most recent addition to the Tokyo Olympics is the mixed relay race. It is a sprint triathlon where a team of two female and two male athletes each complete a 300m swim, 6.6km bike and 1km run before tagging off a teammate.

Within the different triathlon races athletes are ranked as either elite/pro-athletes or amateurs, also referred to as age-groupers. In South Africa triathletes start by competing as age groupers/amateurs. Triathletes obtain elite status once they finish in the top 5% of the South African male and 8% of South African female triathletes at the South African National Triathlon Championships or any other selected event (Triathlon South Africa 2018). In 2015 Half-Ironman events attracted 120,000 participants, of which 1% were elite athletes and the other 99% raced in the age-group categories (Sellés-Pérez *et al.* 2019). The age group most represented is the 40-49 year-olds (Vleck *et al.* 2010).

2.2.2 Triathlon training

The primary aim of training is to prepare triathletes for maximum competitiveness and peak performances at the correct intervals during the season. The complexity of triathlon reaches further than the multidisciplinary nature of the sport, affecting not only the triathlete's physical health but also mental well-being, dietary plans, recovery strategies, physiological health and training monitoring (Etxebarria, Mujika and Pyne 2019).

On average triathletes train 15 to 20 hours per week (Etxebarria, Mujika and Pyne 2019). It takes approximately six months to prepare for an Ironman race and the majority of triathletes remain active throughout the entire year (Kandel, Baeyens and Clarys 2014). Elite triathletes rest for 21 full days over a 50-week Olympic season and have, on average, 16 training sessions per week. Due to the unique nature of triathlon, training for three disciplines simultaneously, the training volume, frequency and intensity of training for a triathlon event is usually higher than athletes who compete in a single sport (Kienstra *et al.* 2017). Triathletes spend a significant time training; therefore, it is important to find a balance between overtraining, which can lead to injury, and maintaining a training load which will not cause injury but rather improve performance. Thoughtful planning of a large number of training sessions weekly is required to achieve goals while limiting over training, excessive fatigue, illness or injury (Kienstra *et al.* 2017; Etxebarria, Mujika and Pyne 2019)

Distance covered or time spent training is most used by endurance athletes to determine training volume (Kienstra *et al.* 2017). Other measurement tools include power output, measured in watts during cycling, rating of perceived exertion (RPE), heart rate (HR), blood lactate and oxygen consumption. Due to the unique nature of triathlon training, there is a lack of scientific evidence to support specific training recommendations, with training intensity distribution (time of exercise spent at the different zones of training intensity) being one of the variables around which uncertainty exists (Sellés-Pérez *et al.* 2019).The incidence of injury and illness can be increased by large volumes of training, but recent advances in research on different training techniques can be used to maximize performance while limiting injury risk (Etxebarria, Mujika and Pyne 2019).

2.2.3 Training strategies

2.2.3.1 The ten percent rule

One of the most popular training strategies is the 10% rule (Kienstra *et al.* 2017). The 10% rule means training load/intensity must be increased at a maximum rate of 10% per week (Kienstra *et al.* 2017). However, according to Nielsen *et al.* (2014) only when novice runners increased their training program by 30% or more did the risk of overuse injuries increase. Two previous studies investigated the use of the 10% rule in novice runners, however, very little is known about training load progression in professional endurance athletes (Nielsen *et al.* 2014). With triathletes doing training for three disciplines simultaneously it is even more difficult to determine the correct ratio of training progression (Kienstra *et al.* 2017).

2.2.3.2 Periodization

Periodization is another popular training strategy. According to this training principle performance goals are met by dividing a year training cycle into smaller cycles (preparatory, competitive and transition periods), to be able to compete and recover adequately (Kienstra *et al.* 2017).

Periodization aims to distribute training intensity and volume effectively throughout the different training cycles to achieve maximum results. The traditional periodization strategy involves starting with high-volume and low-intensity training while progressively increasing training intensity and at the same time decreasing training volume throughout the different cycles (Clemente-Suárez and Ramos-Campo 2019). As with many other sports, top performances in triathlon are often preceded by a period of intense training followed by a period of tapering (a decrease in training load a few days prior to a race) (Etxebarria, Mujika and Pyne 2019)

Over the years periodization has been modified significantly, however, little evidence exists to support the effect of this training principle on injury prevention. A recent modification is the concept of integrated periodization. A concept where multiple training components (physical and psychological training, nutrition, recovery, and racing skills) are coordinated according to the training phase of the triathlete’s program.

2.2.3.3 Reverse periodization

In contrast to periodization, a new model of periodization emerged, namely reverse periodization. According to this model triathletes start with high-intensity, low-volume training and then gradually decrease the training intensity while simultaneously increasing training volume (Clemente-Suárez and Ramos-Campo 2019). Research has shown that reverse periodization increases strength, muscle endurance and endurance performance (Clemente-Suárez and Ramos-Campo 2019). Reverse periodization is a time-efficient and highly effective training strategy, as athletes get the same or higher adaptations as with periodization, but less training time is required (Clemente-Suárez and Ramos-Campo 2019).

2.2.3.4 Polarized

Another training approach, focused on training intensity is polarized training/intensity distribution, a format focused on training at a low to moderate intensity (below lactate threshold), while devoting the remainder of training time to targeting the athlete's maximum intensity. Polarized training can be divided into three training zones based on ventilatory threshold. Zone 1 is found under the first ventilatory threshold, zone 2 between the first and second ventilatory threshold and zone 3 above the second ventilatory threshold. Ventilatory threshold is defined to be the point where pulmonary ventilation becomes disproportionately high in comparison to oxygen intake during training. It is thought to indicate the onset of lactate build-up. It should be mentioned that there are two ventilatory thresholds that arise during exercise with increasing intensity: the first appears at a lower body load of 50-60 percent VO2max, and the second appears at 70-90 percent VO2max (Zych *et al.* 2017).

For example, an athlete could spend 80% in zone 1, 5% in zone 2 and 15% in zone 3 (Sellés-Pérez *et al.* 2019). Polarized training intensity offers maximum physiological adaptation (Etxebarria, Mujika and Pyne 2019). Additionally, low to moderate intensity training is associated with improved Ironman performances.

2.2.3.5 Pyramidal

In contrast to polarized training, pyramidal training is characterized by spending a higher percentage of training time in zone 2 (15-20%) and less in zone 3, but as in the case of polarized training the highest percentage of training time still takes place in zone 1. Scientific research supports that 70-90% of training time spent in zone 1 has a higher impact on athletic performance. A higher percentage of time spent in zone 3 can lead to overtraining or a higher incidence of injuries (Sellés-Pérez *et al.* 2019).

2.2.3.6 Strength training

In addition to the various training formats, strength training combined with aerobic endurance training (i.e., concurrent training) allows for maximum competition performance, long term athlete development and decreased injury risk (Etxebarria, Mujika and Pyne 2019). In a study done by Lalonde *et al.* (2020) it was found that strength and conditioning was the part of the triathlon training program with the lowest compliance and is often the first part of training to be neglected by triathletes.

In a study done by Sellés-Pérez *et al.* (2019) it was found that performance variables improved in triathletes after a period of following a triathlon training program. According to this study the majority of the participants improved their body composition values, which includes a decrease in body fat percentage and weight. Almost all the participants also increased their VO2max values for cycling.

Coaches are expected to structure training programs for triathletes that would help properly prepare a triathlete for a race while limiting injury risk (Kienstra *et al.* 2017). Training for three different endurance sporting disciplines simultaneously demands thoughtful planning (Etxebarria, Mujika and Pyne 2019). Following a structured program is necessary as a balance between total training load, adequate changes in training volume and appropriate recovery is needed to avoid over-training and minimize injury risk in triathletes while improving fitness and performance (Kienstra *et al.* 2017).

2.3 Triathlon injuries

2.3.1 Mechanism of injury in triathlon

A strong anatomical structure combined with over-all health, appropriate training loads, healthy diet and adequate recovery strategies is the foundation needed for improved training and competitive performance (Etxebarria, Mujika and Pyne 2019). However, according to Zwingenberger *et al.* (2014), at some stage during a competitive season most high-performing triathletes will experience one or more health issues significant enough to affect training progress.

Swimming, running, and cycling consecutively places a unique physiological strain on the body (Kienstra *et al.* 2017). Therefore, in the sport of triathlon, injuries can occur as a result of either swimming, cycling, or running or due to triathlon being an uninterrupted combination of the three disciplines.

There is no association between recreational and elite athletes and injury incidence, nor is there between competitive distance and injury incidence (Kienstra *et al.* 2017). This study by Kienstra *et al.* (2017) also reported that over an 8-week study period there was no association between the number of workouts per week, the total weekly training time, or training distance and injury incidence. Lalonde *et al.* (2020), found that injury risk in Ironman triathletes were not associated with average training pace or training time, and also not with training distance per week.

However, research shows that triathletes train, on average, 16 times per week to allow the necessary training within each discipline. This is greater than the amount of training sessions done by double discipline athletes such as Nordic skiers (11 sessions per week) or marathon runners (12-13 sessions per week) (Kennedy *et al.* 2020). This is an indication as to why triathletes have significantly more overuse injuries compared to other types of endurance sports. In order to improve performance an increase in training loads is necessary, however, when not done appropriately an increase in training load can be a possible risk factor for injury.

When the load applied exceeds the capacity of the body tissues to maintain integrity injury occurs (Kienstra *et al.* 2017). According to Strock, Cottrell and Lohman (2006) overuse and fatigue attributes to many of the musculoskeletal injuries experienced by triathletes.

Fatigue can be defined as a reduced performance caused by failure to maintain the necessary force output (Walsh 2019) and therefore leads to changes in biomechanics (Kienstra *et al.* 2017). According to Strohrmann *et al.* (2012) twenty-one runners displayed an increase in time of foot contact with the ground, an increased load transmission to the upper body and a decrease in heel lift after an exhausting 45-minute run, therefore there is a link between fatigue and changes in running mechanics which results in injury.

Previous studies have identified the fatigue caused during triathlon races and analysed the blood markers of muscle damage to demonstrate that following an Ironman or Half Ironman triathlon, indicators of muscle damage increased significantly (Strohrmann *et al.* 2012). During an Ironman triathlon jump height and rate of force development decreases, which indicates a decrease in musculoskeletal function (Knechtle *et al.* 2015). The jump height measured during a countermovement jump as well as the isometric strength of the flexor/extensor of the leg decreased after completing a long-distance triathlon race (Olcina *et al.* 2018). A significant decrease of 12% was reported in the strength and vertical height of jumping during a countermovement jump, these findings indicate that muscle fatigue occurs after competing in a triathlon race.

As increased risk of acute and overuse injury can be contributed to by extreme fatigue, triathletes need to find a balance between training and recovery. The inability to do so will lead to the breakdown of tissue repair mechanisms, and ultimately to injury (Cosca and Navazio 2007).

2.3.2 Most common injuries

As a result of the complexity of triathlon, various musculoskeletal injuries can occur at a wide variety of anatomical sites. According to Kienstra *et al.* (2017) the neck, shoulder, low back, knee, ankle, Achilles tendon, and foot are the anatomical locations most frequently injured in triathletes.

However, Andersen *et al.* (2013) further reported that the lower extremity is the most common site of injury in triathletes. The knee (32.39%), low back (16.9%), and ankle/foot (15.49%) were reported to be the most commonly injured sites amongst 43 Kwa-Zulu Natal triathletes (Ellapen *et al.* 2011), with the knee being the most prevalent lower extremity site of injury amongst these triathlete (Vleck and Garbutt 1998; Andersen *et al.* 2013). Even though studies on triathletes report significant deviations in injury rates, the low back and knee are predominantly found to be the most commonly injured sites (Vleck and Garbutt 1998; McHardy, Pollard and Fernandez 2006; Vleck *et al.* 2010; Ellapen *et al.* 2011).

Although the prevalence of upper extremity injury is less prevalent than the lower extremity, the shoulder is the most commonly reported upper extremity region, with injury with tendonitis or impingements being the most frequent injuries caused by swimming (Strock, Cottrell and Lohman 2006). Due to overuse or poor swimming technique elbow injuries can also occur during swimming, but Gosling *et al.* (2010) found that as few as 6% of all triathlon injuries are related to the elbow.

2.3.3 Acute injuries

Vleck *et al.* (2010) found that acute musculoskeletal injuries are rare in triathletes, and most are reported to be minor. Acute injuries such as contusions, abrasions, and blisters are among the most common race-day injuries and are most often caused by falls during cycling (Gosling *et al.* 2010; Migliorini 2011). On the bike, technical errors, judgment errors on the triathlete's part, or accidents can lead to these falls (Migliorini 2011). The most reported acute injuries include blisters, abrasions, and contusions. Acute Injuries have been reported to occur three times less than overuse injuries (Vleck, Millet and Alves 2014).

2.3.4 Overuse injuries

According to Kienstra *et al.* (2017), the majority of injuries in triathletes are overuse injuries as opposed to acute injuries therefore overuse and fatigue are the most common causes of musculoskeletal complaints in triathletes. Due to the intensity and repetitive nature of triathlon training, triathletes are predisposed to overuse and/or chronic injuries (Shaw *et al.* 2004).

In the literature, the incidence of injuries in triathletes varies from 37% to 91% (McHardy, Pollard and Fernandez 2006). In a study by Ansell, Rivett and Callister (2012), a large majority (86.1%) of the 1250 triathletes that competed in the Australian Ironman triathlon reported overuse injuries. In a retrospective injury analysis study done by (Vleck *et al.* 2010) 72.2% of the British National Squad sustained overuse injuries. In another retrospective study of 656 participants in the European Ironman 75% of the triathletes reported a minimum of one chronic injury since starting triathlon.

However, in a prospective study of 174 triathletes, it was found that 87% suffered from an overuse injury over a training period of 26 weeks (Andersen *et al.* 2013). A comparison between retrospective and prospective injury rates showed that 2.1 times more injuries were reported prospectively, of which the rate of overuse injuries were 2.4 times higher.

As a result of training for three endurance disciplines, it is more common to be affected by the same injuries and complaints than each of these individual sports poses (Strock, Cottrell and Lohman 2006). Therefore, according to Ansell, Rivett and Callister (2012), further research is needed to better prevent and manage injuries in triathletes. The mechanism of injury and the discipline of triathlon at the time of injury is important information that may be used for the development of the necessary preventative measures (Gosling, Gabbe and Forbes 2008).

2.3.5 Common injuries within the disciplines of triathlon

2.3.5.1 Swimming

In a study done by Zwingenberger *et al.* (2014) it was found that cycling and running have injury rates of 43% and 50%, respectively, whereas swimming has an injury rate of 7%. The most commonly injured site during swimming is the shoulder and is usually a form of tendonitis or impingement. Factors that contribute to the cause of injury include inadequate stretching, poor swimming technique and inadequate warm up. Shoulder injury incidences range from 19-42% (Gosling *et al.* 2010). Muscle and tendon injuries were caused by swimming in 14% of reported cases (Egermann *et al.* 2003).

The swim cycle transition presents with some difficulty, one of which is blood pooling in the arms as the triathlete transitions from a supine predominant upper body movement to an upright predominant lower body movement (Walsh 2019).

2.3.5.2 Cycling

Cycling injuries are relatively uncommon compared to running even though Gosling *et al.* (2010) reported injuries from cycling as 3.5 times greater than from swimming. Egermann *et al.* (2003) found that the most injuries reported during an Ironman was from cycling, but in this study no distinction was made between acute and overuse injuries. According to Vleck, Millet and Alves (2014), an association between speed cycling and low back injury can be made. These results indicate that triathletes should focus more on moderate pace training instead of speed work close to a race. Inexperienced triathletes, with a seat that is too low, commonly report iliotibial band syndrome. This is due to inflammation caused by repetitive friction of the iliotibial band over the lateral epicondyle of the femur (Flato *et al.* 2017).

2.3.5.3 Running

Running appears to be the discipline most frequently associated with musculoskeletal overuse injuries (Kienstra *et al.* 2017). Anterior knee pain is the most frequently experienced pain during running (Tuite 2010). Approximately 70% of injuries sustained during training and competing in triathlon are related to running. Within a triathlon race, musculoskeletal injuries can occur at any stage, where it is either one of the three disciples or one of the two transitions.

2.3.5.4 Transition

The second transition, between cycling and running, is where the difference between professional and recreational athletes is most evident. This is due to the difference in mechanics and the ability of an athlete to adapt to the difference between cycling and running (Millet and Vleck 2000). After cycling, the running discipline is the last leg of the triathlon race and altered muscle recruitment patterns when running directly after the cycling discipline have also been reported to cause injury (McHardy, Pollard and Fernandez 2006). It has been proposed in some studies that the transition between cycling and running might be a risk factor for low back and knee injuries (Vleck *et al.* 2010). Amongst triathletes subjective descriptions of perceived incoordination are commonly reported during the cycle-run transition. Success in triathlon is largely dependent on the athlete's ability to efficiently transition from cycling to running. Current research shows that cycling negatively affects the running performance of some elite triathletes as it reduces running economy, changes stride pattern, and increases variation in muscle recruitment patterns (Walsh 2019).

2.4 Injury risk factors

2.4.1 Intrinsic risk factors

Risk factors that are unique to an individual athlete that can lead to injury are referred to as intrinsic risk factors. Age, gender, prior injury, body composition, triathlon experience, physical health, ability level and endurance are all factors to consider. (McBain *et al.* 2012). In another study conducted by Steffen *et al.* (2008) previous injury, age, joint laxity, lower extremity strength, muscle imbalances, poor recovery and functional and mechanical instability were all found to be risk factor for injury in young female soccer players.

Even though physical activity has so many benefits that minimize morbidity and mortality, the risk of injury has always been correlated with it (McBain *et al.* 2012).

The following intrinsic risk factors will be discussed further:

- Age
- Gender
- Previous injury
- Body composition

Research has shown that specific age categories are more prone to injury than other. Decreased joint flexibility and a reduced muscle output force are reasons for higher rates of injury in older athletes (Fukuchi *et al.* 2014). According to Dallinga, Benjaminse and Lemmink (2012) increased age can be a risk factor for ankle sprains and hamstring strains.

Due to female sex hormones and the affect thereof, women are more prone to sports injuries than men. Progesterone and oestrogen increases ligament laxity and decreases muscular relaxation, strength and motor co-ordination (Jooste 2015).

A history of injury has long been thought to be a warning factor for recurrence of injury. In a study on football players data pertaining to previous injury was recorded as well as current injuries. The two sets of data were compared to see if there was a connection between athletes who had been injured the previous season and their likelihood of being injured this season. It was found that athletes who had previously sustained an injury were more likely to suffer an injury in the following season. Athletes who suffered hamstring, knee, or groin injuries were three times more likely to have the same form of injury the next season, but this was not the case for ankle sprains (Hägglund, Waldén and Ekstrand 2006). Based on the principal that injury decreases neuromuscular control, joint laxity, and strength it was suggested that previous injury is a risk factor for re-injury (Nessler 2013).

An athlete’s Body Mass Index (BMI) can be calculated based on the individuals body weight and height. BMI can range from 18.5-24 for normal individuals, under 18.5 for underweight individuals, over 25 for overweight individuals and a score of 30 and over is classified as obese. BMI can predispose an athlete to injury as a high BMI can result in altered biomechanics (Micheli 2010).

2.4.2 Extrinsic risk factors

In contrast to intrinsic risk factors, extrinsic risk factors are external (environmental) factors that can lead to injury. Extrinsic factors include training hours per week, training distance per week, training sessions per week, training intensity, training load increases, presence or absence of a coach and medical care, running service, strength training, athletic status, triathlon competition distance and participation in other activities (Gosling, Gabbe and Forbes 2008).

Environmental factors that cannot be managed are examples of extrinsic non-modifiable risk factors. Rain, humidity, wind, fog, and extreme cold/heat will put athletes at risk for injury because they can affect an athlete's physical condition as well as the surface on which the athlete train or compete (Jooste 2015).

Modifiable extrinsic risk factors can be changed through preventative strategies to reduce injury occurrence. The modifiable extrinsic risk factors, like the non-modifiable risk factors, carry an inherent risk of injury (Nessler 2013). Usage of specific sports equipment (types of shoes, tri-suits) and protective equipment (helmets, goggles) are examples of modifiable extrinsic risk factors. The use of these different protective agents can either protect or injure a player, depending on the equipment used.

Coaching can also be viewed as a modifiable extrinsic risk factor, as proper coaching can minimize the number of injuries sustained by a player, while incorrect coaching can increase the number of injuries sustained by a player (Jooste 2015). Identification of intrinsic and extrinsic risk factors aids in developing injury preventative strategies (Coetzee 2013).

2.5 Pre-participation screens

Pre-participation screenings, also known as pre-participation evaluations or sport screening tests, usually include pre-participation medicals as well as performance assessments (Cook, Burton and Hoogenboom 2006b; Sanders, Blackburn and Boucher 2013). A pre-participation screen's major purpose is to promote health and safety in athletes during training and competition, as well as to identify athletes who are at risk of injury (Sanders, Blackburn and Boucher 2013) .

Screenings should be conducted before an athlete's engagement in sport (Sanders, Blackburn and Boucher 2013), they should be simple to perform during practices, standardized, rapid, and economical (Dallinga, Benjaminse and Lemmink 2012). They should be founded on evidence and specialized to a given sport, with adequate inter-rater and intra-rater reliability. Screens should be capable of predicting injury so that they may be utilized to develop injury prevention methods in the future (Cook, Burton and Hoogenboom 2006a; Sanders, Blackburn and Boucher 2013).

Most performance tests are only used to identify a minimal level of ability to determine if an athlete is ready to compete or needs to be omitted. In general, performance testing does not evaluate movement efficiency or effect (Cook, Burton and Hoogenboom 2006b). For example, two athletes could attain the same result on the performance test if one athlete used ideal movement patterns while the other used compensating movement patterns (Cook, Burton and Hoogenboom 2006a; Sanders, Blackburn and Boucher 2013).As a result, it's critical to analyse basic movement patterns before evaluating performance, as compensatory movement patterns might lead to damage (Cook, Burton and Hoogenboom 2006b).

Cook *et al.* (2014a) developed a screening tool named the Functional Movement Screen in response to the demand for a simple and effective assessment that coaches and administrators could use to evaluate fundamental movement patterns.

The information around triathletes' injury prevalence and profiles point to the possible suggestions for injury preventive measures (Gosling, Gabbe and Forbes 2008). Gosling, Gabbe and Forbes (2008) stated that treatment, management, and prevention of triathlon-related musculoskeletal injuries would improve if the association between injury prevalence and clinical characteristics (diagnosis, location and severity) could be determined. The nature of each discipline differs and therefore each discipline has its normative values linked to the different forms of injury.

The FMS™ tests require a balance of stability and mobility, as it places athletes in extreme positions where imbalances and weaknesses can be observed. It has been found that if athletes who compete at high levels cannot perform these fundamental movements, this is an indication that these athletes use compensatory movement patterns during their activities. When these compensatory movement patterns are reinforced and repeated, biomechanical abnormalities occur that can lead to injury (Cook *et al.* 2014b).

Compensatory movements are identified using the FMS™ by comparing the athlete's left and right side for imbalances. The FMS™, a movement based assessment, aims to identify movement deficits (Kiesel, Plisky and Voight 2007). The FMS™ can be used to prevent injury by finding a link between a low FMS™ score (which would indicate weakness, asymmetry, poor movement patterns, and decreased proprioception) and injury occurrence.

The use of the FMS™ has not been well established as an injury preventative tool in triathlon and therefore further investigation is needed (Jooste 2015).

2.6 The Functional Movement Screen™

2.6.1 Introduction of the FMS™

In the 1990s the term "functional training" became popular as it referred to training built around movements that occur naturally, therefore enhancing training effectiveness (Kraus *et al.* 2014). Stability, flexibility, balance, and strength are all important components of a training program, subsequently the FMS™ aims to assess functional mobility and postural stability.

The Functional Movement Screen™ (FMS™) is a pre-participation examination tool in which athletes perform seven specific functional movements to identify any compensations, asymmetry, instability, and mobility changes, such as hypermobility and hypomobility (Cook, Burton and Hoogenboom 2006a). The FMS™, as described by Dossa *et al.* (2014), is a method used to identify any biomechanical abnormalities in athletes and to incorporate these findings into predictive values for injury. The FMS™ has a sensitivity of 24, 7%, and specificity of 85, 7% (Dorrel *et al.* 2015). It is a pre-participation tool because it evaluates an individual before participating in a sporting event. By using the tool before engaging in training it may be used as an injury preventative strategy as abnormalities can be identified and corrected to prevent injury and/or re-injury (Cook, Burton and Hoogenboom 2006b).

Research shows that current pre-participation screens are not sport-specific or standardized and cannot reliably identify athletes at risk for injury (Jooste 2015). Sanders, Blackburn and Boucher (2013) stated that reducing injuries must be a priority for all sports physicians and that there is a need for an evidence-based screening tool to be used by physicians. The FMS™ is used to assess an athlete’s physical condition prior to participating in sport. The information obtained from the FMS™ can be utilized to identify possible performance limitations that might be the cause of injuries in athletes. It was created to identify functional limitations in the kinematic chain to prevent possible injury.

2.6.2 Principles of the FMS™

The Functional Movement Screen is an example of a pre-participation tool that is being used to assess the risk of injury in an athlete based on physical imbalance, asymmetry or abnormal moving patterns (Chimera, Smith and Warren 2015). More specifically, the seven tests are used to assess flexion, internal and external rotation of the hip, core stability as well as abduction and adduction of the shoulder joint (Kraus *et al.* 2014). The functional movements in this test must be performed correctly and precisely; if the exercises are not performed correctly, the athlete will resort to compensatory movements.

If these compensations are not reversed, the biomechanics will be compromised due to incorrect movement patterns, which will result in micro-trauma and then macro-trauma. Any time a movement is performed, these incorrect movement patterns become subconsciously habitual. This pattern of poor movement, combined with poor technique, could aggravate the problem and result in injury (Cook, Burton and Hoogenboom 2006b, 2006a).

Muscle power, range of motion, flexibility, balance, co-ordination, and proprioception must all be fully functional to complete the FMS™ correctly; if any of these fields are off, the athlete is at risk of musculoskeletal injury (Bock and Orr 2015). The FMS™ movements are based on proprioception and kinesiology concepts, according to Cook, Burton and Hoogenboom (2006b), so if the athletes have a deficit in one of these two principles, they would be unable to execute the FMS™ movements correctly. Both aspects of the kinematic chain, including the linking joints and muscles that work together to achieve functional movement, are included in the FMS™ (Richardson 2018).

2.6.3 The FMS™ as a predictor of injury

By establishing a correlation between a low FMS™ score (which indicates weakness, asymmetry, poor movement patterns, and reduced proprioception) and injury incidence, the FMS™ may be used to avoid injury. If there is a correlation, procedures may be put in place to strengthen an athlete's weaknesses prior to exercise, thus reducing the risk of injury (Cook, Burton and Hoogenboom 2006b). Athletes have been the subject of studies to see whether injury prediction is feasible (Kiesel, Plisky and Voight 2007; Schneiders *et al.* 2011; Bock and Orr 2015). Injuries to the knee, anterior cruciate ligament, groin, ankle, and hamstring in athletes involved in team sports is predicted using anthropometric and physical screening test values. The findings showed that screening methods were good predictors of injury in the areas described above (Dallinga, Benjaminse and Lemmink 2012).

The FMS™ was used by (Kiesel, Plisky and Voight 2007) to predict injury in professional football players, and the findings showed that players with low FMS™ ratings, less than 14, were more likely to sustain musculoskeletal injury during the season (Kiesel, Plisky and

Voight 2007). Using the FMS™, Chorba *et al.* (2010) studied the compensatory movement habits of female college athletes and their injury risk. Athletes with a score of less than 14 were four times more likely to suffer injuries than those with a score of more than 14. Schneiders *et al.* (2011) discovered similar results in a study involving active athletes. Bock and Orr (2015) conducted further research on the FMS™ and concluded that it is a reliable method for predicting injury in firefighters, military, and police officers. Low FMS™ scores were found to be good predictors of injury development in the sample (Bock and Orr 2015). Marine Corps Officer candidates' FMS™ scores and injury forecasts were investigated. According to the findings, the cohort's average FMS™ score was 16.6 out of 21. The athletes who scored less than 14 were found to be at a higher risk of injury (O'connor *et al.* 2011).

Research has suggested that the FMS™ can be used to predict injury when the composite score is lower than fourteen out of a possible twenty-one. However, according to Kiesel, Plisky and Voight (2007) the FMS™ sensitivity of 0.91 and specificity of 0.54, two findings that could not be reproduced by Chorba *et al.* (2010) who found sensitivity to be 0.58 and specificity of 0.74.

The triathlon coaches can use the normative values of the FMS™ to screen triathletes at the beginning of a training session, to assess any injury risk factors. If these risk factors are identified and corrected before training starts, the risk of injury occurrence should decrease (Peate *et al.* 2007). The health benefits of doing triathlon will therefore outweigh the risk of injury in triathletes. Triathletes will be able to be more proactive in correcting functional movement imbalances if they are aware of limitations identified by the FMS™. The results of this study will add value to the knowledge in the use of the FMS™.

2.6.4 Relevance of the FMS™

Clinically the FMS™ is being used to adjust training programs to decrease injury risk by identifying athletes at risk of injury (Chimera, Smith and Warren 2015). According to Etzel (2012), relevancy refers to the degree of agreement between what a test measures and what it is ideally designed to assess, as well as the tool's appropriateness. The FMS™ is a management tool designed to detect areas of movement pattern constraint and asymmetry that may predispose a person to injury so that preventative actions can be implemented (Cook *et al.* 2014a). The FMS™ 's relevance is determined by whether the screen can effectively detect dysfunctional movement and asymmetries, as well as whether this may be linked to injury susceptibility (Etzel 2012).

The notion of motion versus movement must be considered when determining if the FMS™ measures dysfunctional movement. Movement is the act of a functional body changing position under its own power from point A to point B, whereas motion measures the range of flexibility within a particular body segment or collection of segments (Cook, Burton and Hoogenboom 2006b). The FMS™ scores a functional body as it changes position under its own power in all seven assessments. As a result, the FMS™ assesses motion rather than movement (Sanders, Blackburn and Boucher 2013). When an athlete is unable to complete the correct movement, they resort to compensating motions, which are scored by raters (Cook, Burton and Hoogenboom 2006b).

To prove the FMS™'s relevance, it must be able to detect asymmetry in participants. The FMS™ test for asymmetry includes five of the seven tests (hurdle step, in-line lunge, shoulder mobility, active straight-leg lift, and quadruped rotary stability). The test's rater evaluates both sides of the athlete's body to see if they have symmetry or not (Cook, Burton and Hoogenboom 2006b). As a result, the FMS™ assesses movement symmetry in order to predict injury risk as a result of symmetry mismatch.

The efficacy of the FMS™ as an indicator of injury risk in athletes is the next most essential factor to consider when determining relevance. This is especially noteworthy because Cook (2010) claims that a poor FMS™ score can be improved with the use of remedial techniques. Kiesel, Plisky and Voight (2007) tested a seven-week offseason intervention program on professional American football players to see if it improved their FMS™ scores. Sixty-two players had their scores taken before and after the intervention.

Prior to the intervention, seven players had a score of 14/21 or higher, while 39 players had a score of 14/21 or higher following the intervention. After the intervention, 41 players were free of asymmetries, compared to 31 before the intervention. An intervention/rehabilitation program, according to Kiesel, Plisky and Butler (2011), can effectively improve dysfunctional mobility. Despite this, (Kiesel, Plisky and Butler 2011) proposed that more research be done to see if injury risk is lowered when a player's score increases following an intervention program.

2.6.5 Validity of FMS™

Validity refers to the “soundness of test score interpretations” or the degree to which a test tests what it claims to measure (Etzel 2012). The validity of the screen must be established before the FMS™ results can be considered relevant (Schneiders *et al.* 2011; Etzel 2012).

The screen must be relevant, dependable, and repeatable in order to be considered legitimate. Since the FMS™, which was first released in 1995, is a relatively new screen, there is little research available to assess its relevance and reliability in particular sporting contexts (Schneiders *et al.* 2011; Etzel 2012).

2.6.6 Reliability of FMS™

The ability of a test to detect consistent and accurate variations between subjects across test occasions is known as reliability. The screen must show both intra-rater and inter-rater reliability (Etzel 2012).

The FMS™ had a high inter-rater reliability, 39 college students were videotaped conducting the FMS™ by Minick *et al.* (2010). The college students were rated by four raters (two professional raters with ten years of experience and two inexperienced raters with two years of experience). The ratio of times the raters approved was calculated using the Kappa statistic. It was adjusted for randomness and the number of times the raters could agree. On 6 of the 17 tests, the inexperienced raters had excellent agreement, substantial agreement on 8 of the 17 tests, and reasonable agreement on 3 of the 17 tests. Excellent agreement was found in 4 of the 17 tests, substantial agreement in 9 of the 17 tests, and moderate agreement in 4 of the 17 tests.

This suggested that the expert raters' scores were more variable than the inexperienced raters'. For 14 of the 17 tests, the beginner and expert raters had outstanding agreement, and for 3 of the tests, they had substantial agreement. The disparity in scores may be attributable to the raters' differing levels of experience or the ambiguous midrange scoring requirements (Minick *et al.* 2010).

Schneiders *et al.* (2011) evaluated 209 active people between the ages of 18 and 40 years old to see whether there was a disparity in scores between males and females, those with a prior history of injury, and the FMS™ real-time inter-rater reliability. The average FMS™ score of the participants in this study was 15.7 out of a possible 21. There was no statistical disparity between males and females, or between participants who had previously been injured.

Schneiders *et al.* (2011) study's inter-rater reliability supported the Minick *et al.* (2010) study's high inter-rater reliability. Schneiders *et al.* (2011) measured a score of 0.971 using the inter-class correlation coefficient, indicating excellent agreement between raters (complete agreement equals 1.0). Raters reached excellent agreement on 12 of the 17 tests (excellent agreement) and substantial agreement on the remaining 5. Both raters in the Schneiders *et al.* (2011) study had the same amount of FMS™ scoring experience and training.

2.7 Conclusion

Injuries can possibly be prevented if triathletes at risk for injury could be identified beforehand. Many athletes are believed to perform high-level activities ineffectively due to incorrect fundamental movement patterns. These individuals unknowingly add fitness to this dysfunction and train around these weaknesses and/or imbalances (Cook *et al.* 2014a). The use of a pre-participation screening tool, such as the Functional Movement Screen™, can therefore assist in identifying incorrect fundamental movement patterns and therefore help in predicting and potentially preventing injuries. The FMS™ has not been used in triathlon to determine a normative value and to determine if there is a possible link between injury in triathletes and a low FMS™ score.

Chapter Three

Methodology

3.1 Introduction

The research methodology provides an understanding of how the FMS™ normative values are attained for triathletes. This chapter includes the research design, the method of sampling, the research procedure, the measurement tools utilized, and the statistical method used to analyse the results of the study.

3.2 Research design

The study design was of a quantitative, descriptive cohort design as it will include statistical measurements of the FMS™ scores and a selected group of athletes will be investigated. It was quantitative as statistical measurements of the FMS™ and injury occurrence was included. It was a descriptive cohort design as a specific group was investigated and descriptive as no intervention took place. The study design used prospective data collection from the selected triathletes, who were observed using the FMS™.

3.3 Sampling

3.3.1 Participation recruitment

Ethical clearance to conduct the study was attained from the Institutional Research Ethics Committee of the Durban University of Technology (Appendix H).

The researcher contacted the coaches of Team Just-In and Triathlon Training Academy via email to explain the proposed research and to request permission to conduct the FMS™ on their athletes. A letter of information and consent was given to and signed by the coaches (Appendix A and C), as well as a letter of Gatekeepers' permission from the coaches to conduct the research at the facility and on their triathletes (Appendix G).

After receiving permission from the above-mentioned coaches, the researcher approached and obtained informed consent from each participant to become eligible to participate in the study (Appendix B and C).

3.3.2 Sampling size

The sample size was calculated using the total number of triathletes in the selected triathlon training group/s in the eThekwini municipal area that follow either the Team Just-In or Triathlon Training Academy training program. Within the two triathlon training groups, 24 athletes trained according to the Team Just-In or Triathlon Training Academy training programs. All 24 of the triathletes participated in the study.

3.3.3 Inclusion criteria

- Only athletes who have completed the letter of information and consent were included.
- Athletes had to be over the age of 18 years to participate, this eliminated having to obtain parental consent.
- Only participants that follow the Team Just-In or Triathlon Training Academy training program on the basis that they train at a high intensity and train at least three times a week.
- Athletes had to fully complete the Injury Profile Questionnaire (Appendix F)
- The study is heterogeneous therefore both male and female participants were be included.

3.3.4 Exclusion criteria

- Athletes that joined the triathlon club after the FMS™ ™ has been conducted.
- Athletes who did not sign the Letter of Information and Consent (Appendix B and C).
- Athletes who did not follow the Team Just-In or Triathlon Training Academy training program, or athletes who trained less than three times a week.
- Athletes who were under the age of 18.
- Athletes who were not able to complete the FMS™ due to current injury.

3.4 Procedure

3.4.1 Research procedure

- Once the two training groups (Team-Just-In and Triathlon Training Academy) were selected for the study, official permission was obtained from the triathlon training group coaches (Appendix A and C)
- The researcher then approached each participating triathlete and obtained written permission using the letter of information and informed consent (Appendix B and C).
- At the start of a training session the researcher set up the FMS™ at the location of training as arranged with the coaches.
- Before performing the FMS™ the athletes completed the Athlete Questionnaire (Appendix D) to identify any previous injuries, calculate the amount of time spent training per week, and have the participant's general personal information.
- Followed by specific instructions from the researcher the athlete then performed the FMS™ by doing each of the seven functional movements. The researcher gave the triathlete a score between zero and three for each exercise depending on how well the movement was executed. The scores were given and recorded by the researcher using the scoring sheet (Appendix E).
- The researcher recorded each athlete's total score out of a possible 21. These scores gave information about each athlete's strengths and weaknesses.
- After completing the FMS™ and the Athlete Questionnaire (Appendix D) the athletes commenced with their usual training program.
- During a six-week period of training after the FMS™ had been completed, the researcher contacted each triathlete telephonically to record any injuries using the injury profile sheet (Appendix F).
- Once the injury data had been collected after the six weeks of training the researcher and statistician analysed the data.
- In keeping with Covid-19 protocol, during data collection the researcher and participants sanitized before and after performing the FMS™, masks were worn at all times and social distancing was maintained.

3.4.2 Athlete questionnaire

Once informed consent was obtained from each participant the triathletes were asked to complete the Athlete Questionnaire (Appendix D). The Athlete Questionnaire (Appendix D) was designed to gather information regarding:

- The athletes' personal descriptors such as name, age, weight, and height.
- The name of the triathlon training group of which the athlete is a member.
- How long the athlete has been participating in triathlon.
- Previous and current triathlon related injuries.

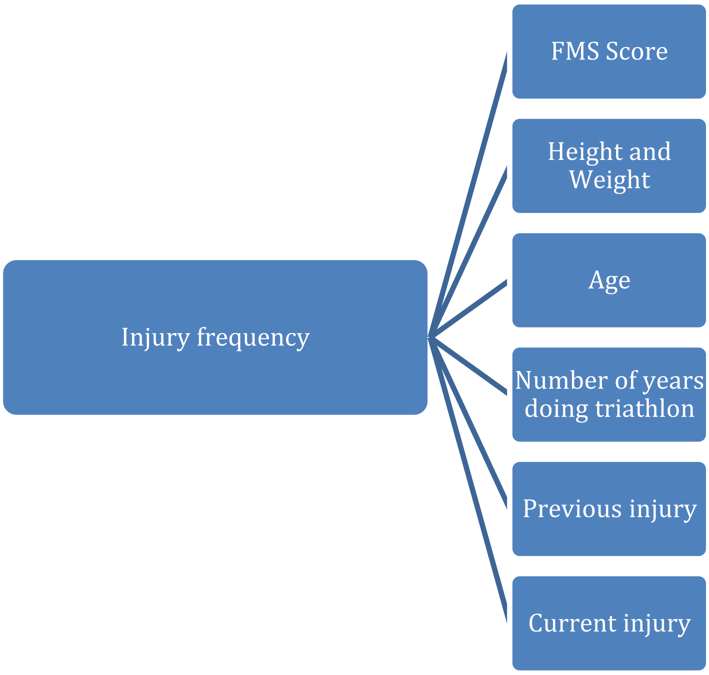


Figure 1: Risk factors influencing injury frequency

3.4.3 The Functional Movement Screen™

During the Functional Movement Screen seven movement patterns are used to evaluate movement performance (Chimera, Smith and Warren 2015).

The seven movement patterns are (Chimera, Smith and Warren 2015):

- The Deep Squat test
- The In-line Lunge test
- The Hurdle Step test

- The Shoulder Mobility test
- The Active Straight Leg Raise test
- The Trunk Stability Push-Up test
- The Rotatory Stability test

Clearance tests are also added to three of the above-mentioned tests. The clearance test for the shoulder mobility test assesses for shoulder impingement; the trunk stability push-up test and the rotatory stability test each have a clearance test for back pain. The clearance tests are utilized to assess the athletes for pain experienced during these tests. If an athlete reports pain on either of these clearance tests, a score of zero is given for the corresponding FMS™ (Cook *et al.* 2014a).

- The shoulder mobility clearing test
- The extension clearing test
- The flexion clearing test

An athlete is given a score out of three for each of the individual tests. If the athlete performs the test successfully without any compensation or pain a score of three is given for the test. A score of two indicates compensatory movements being used to complete the movement and a score of 1 indicates that the athlete is unable to complete the test. If an athlete experiences pain during the test a score of 0 will be awarded. The highest overall score that can be obtained for the FMS™ is 21 and the lowest is 0. For tests that can be done bilaterally, the left and right-hand sides will be tested and scored, and the lowest score between the two sides will count towards the final total (Cook *et al.* 2014a).

Each triathlete's seven scores were recorded on the FMS™ score sheet (Appendix E) and then totalled to assign each triathlete a score out of 21.

3.5 Measurement tools

The FMS™ kit includes the following:

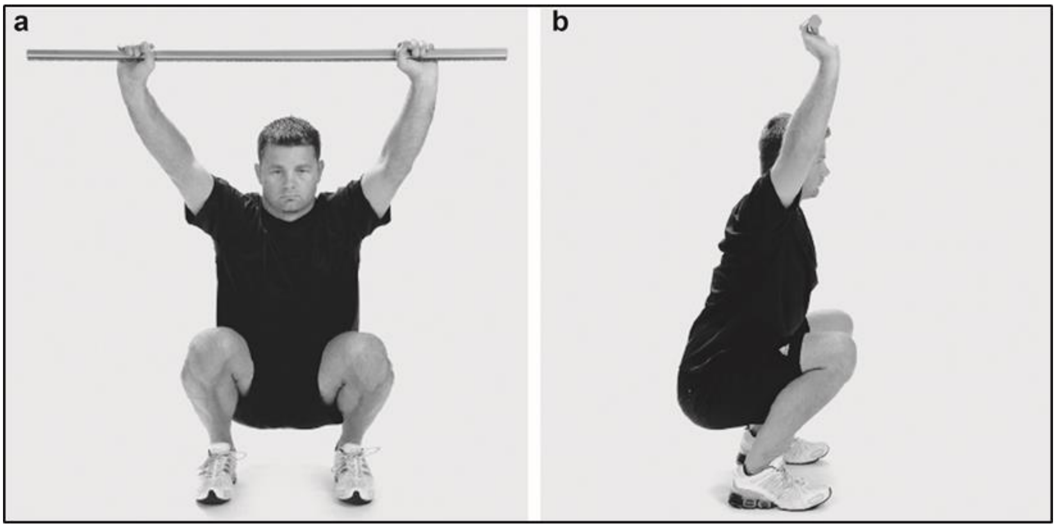
- One hurdle, that is made up of a rubber band connecting two vertical beams (59.5cm).
- One wooden dowel which is 135.5cm in length.
- One wooden board which is 15.5cm wide and 147.5cm long.
- One ruler.

The kit was utilized to complete the FMS™ and to measure outcomes.

3.6 The Functional movement screen tests

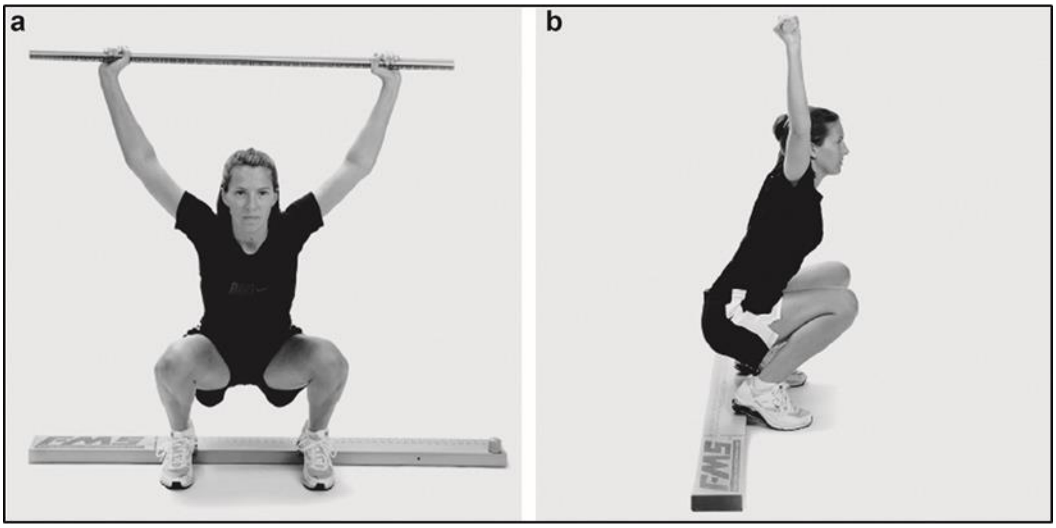
3.6.1 The Deep Squat

Before the start of the squat, the athlete must place his/her feet shoulder-width apart with toes facing forward. With the dowel overhead, the athlete adjusts his/her hands to assume a 90-degree angle of the elbow with the dowel. The athlete is then instructed to slowly perform the squat. In doing so, the athlete’s heels must remain on the floor, the chest and head must face forward, and the dowel must be kept in an overhead position. If the athlete is unable to successfully perform the test, the athlete is asked to repeat the teat with a 15.5cm x 147.5am wooden board under his/her heels (Cook *et al.* 2014a)



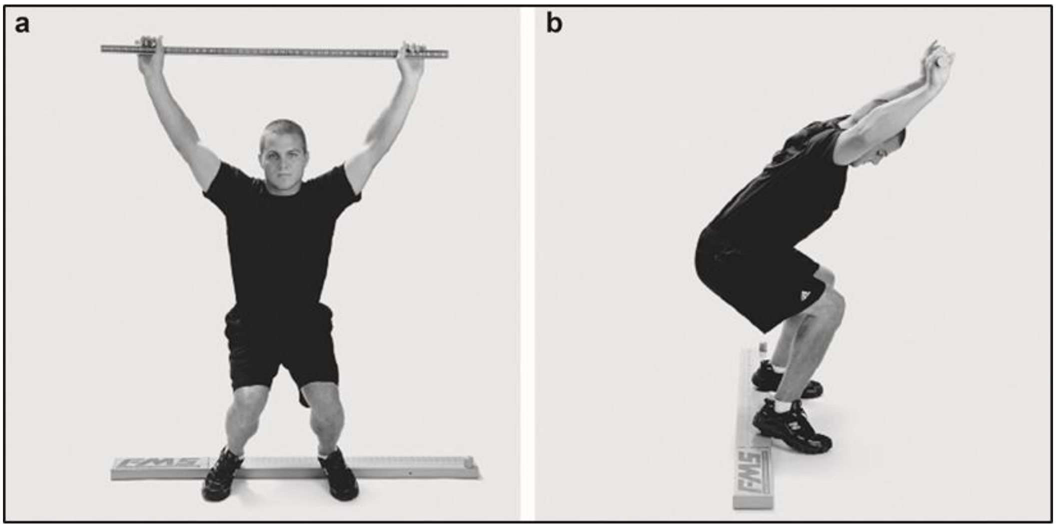
(Cook *et al.* 2014a)

Figure 2: Views from the front (a) and side (b) of the deep squat test, which received a score of 3. The upper body must be parallel with the lower limb, the thigh is below horizontal, the knees and dowel must be aligned over the feet.



(Cook *et al.* 2014a)

Figure 3: Views from the front (a) and side (b) of the deep squat test, which received a score of 2. The upper body is parallel to the lower limb, the thigh is below horizontal, the knees are in front of the feet, the dowel is over the feet, but the heels are elevated on the board.

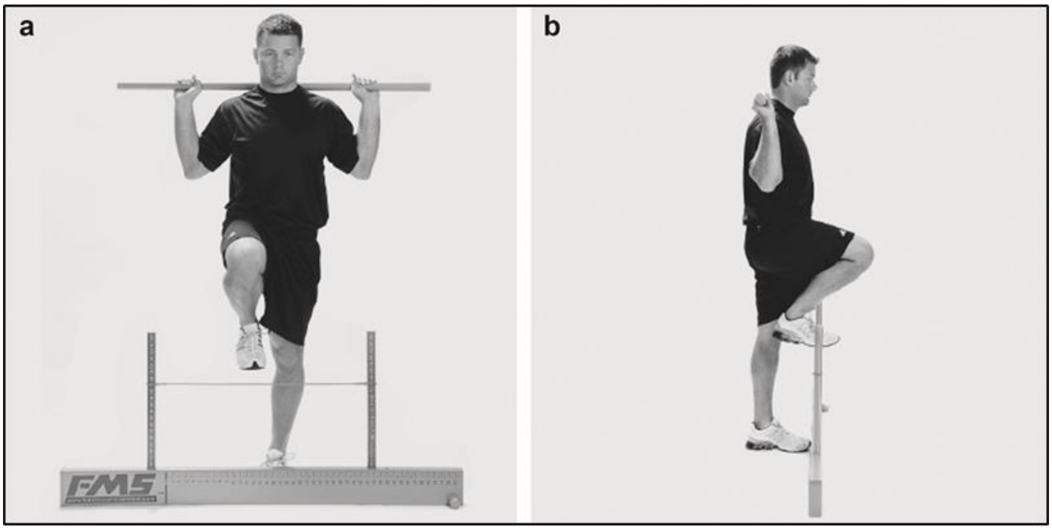


(Cook et al. 2014a)

Figure 4: Views from the front (a) and side (b) of the deep squat test, which received a score of 1: the lower limb and the upper body are not parallel, the thigh is not below horizontal, the knees are not aligned over the feet, and the heels are elevated on a board.

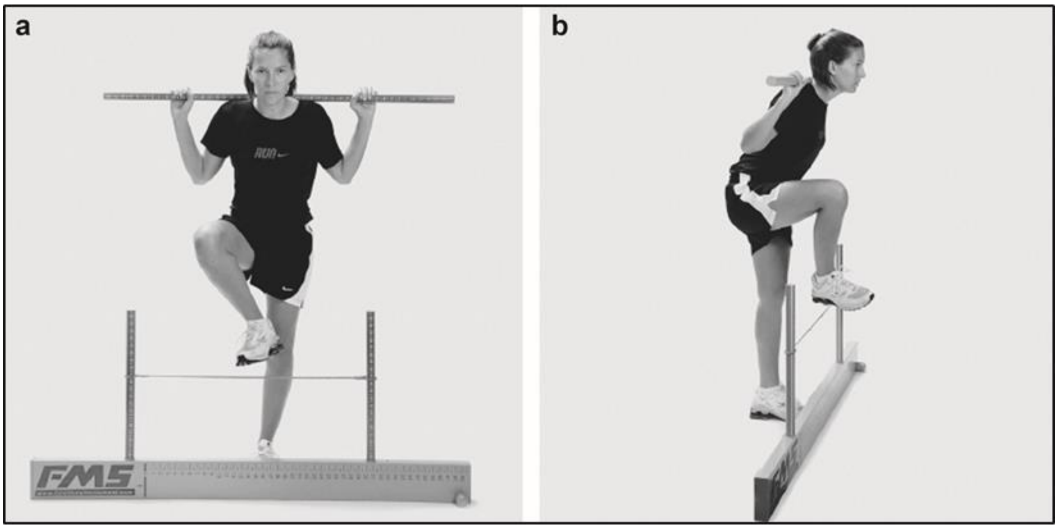
3.6.2 The Hurdle Step

The athletes start with his/her toes touching the base of the hurdle and their feet together. The researcher then adjusts the height of the hurdle to the level of the athlete's tibial tuberosity. The dowel is held at the base of the neck, across the athlete's shoulders. The athlete then steps over the hurdle with one leg. Once the heel touches the floor on the other side, and the stance leg is kept straight, the athlete may then bring the moving leg back to its original position. This test must be done bilaterally (Cook *et al.* 2014a).



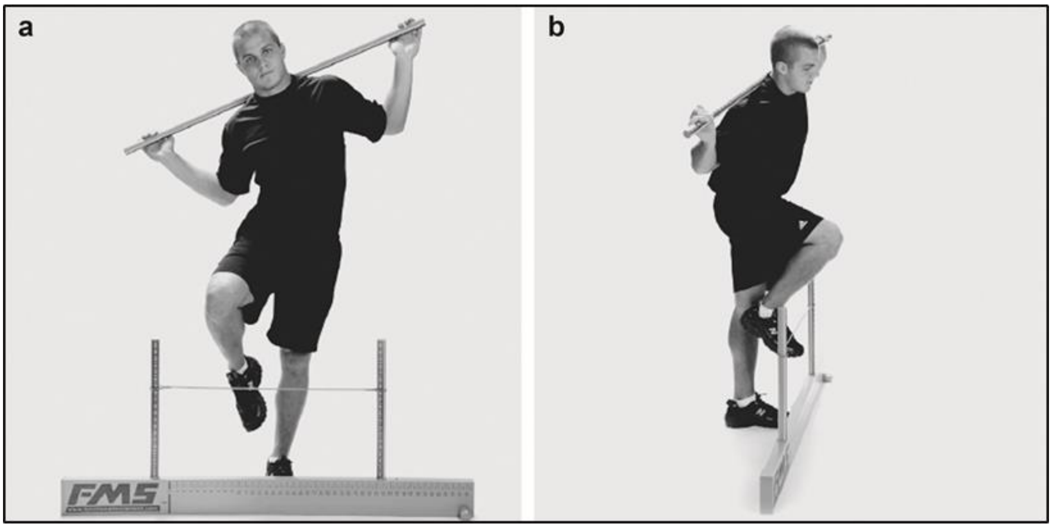
(Cook *et al.* 2014a)

Figure 5: Views from the front (a) and side (b) of the hurdle step test, which received a score of 3. Hips, knees, and ankles are aligned vertically, no movement is noted in the lumbar spine, and the dowel and hurdle remain parallel.



(Cook *et al.* 2014a)

Figure 6: Views from the front (a) and side (b) of the hurdle step test, which received a score of 2: the hips, knees, and ankles are not aligned. Movement is seen in the lumbar spine, or the dowel and hurdle do not remain parallel.

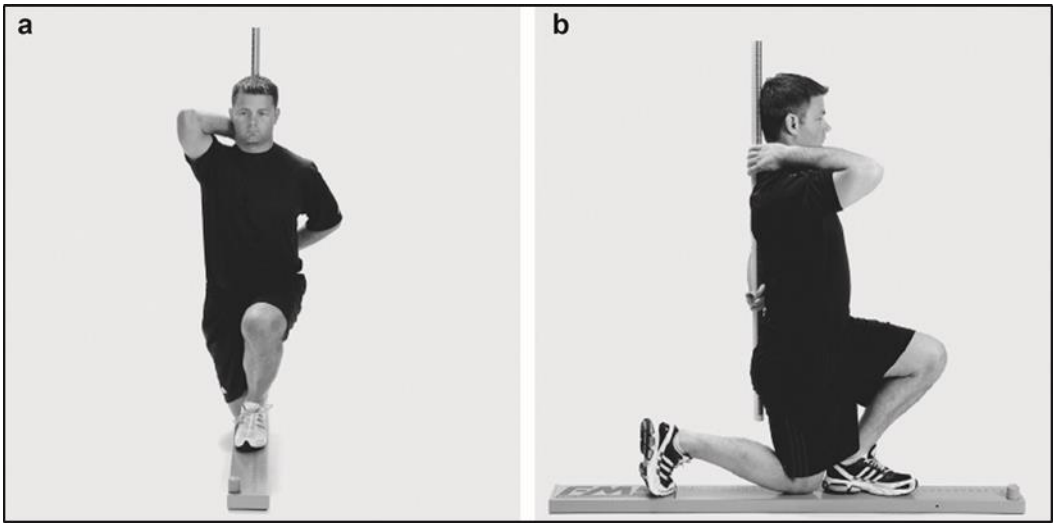


(Cook et al. 2014a)

Figure 7: Views from the front (a) and side (b) of the hurdle step test, which received a score of 1. Loss of balance or contact with the hurdle results in a score of 1.

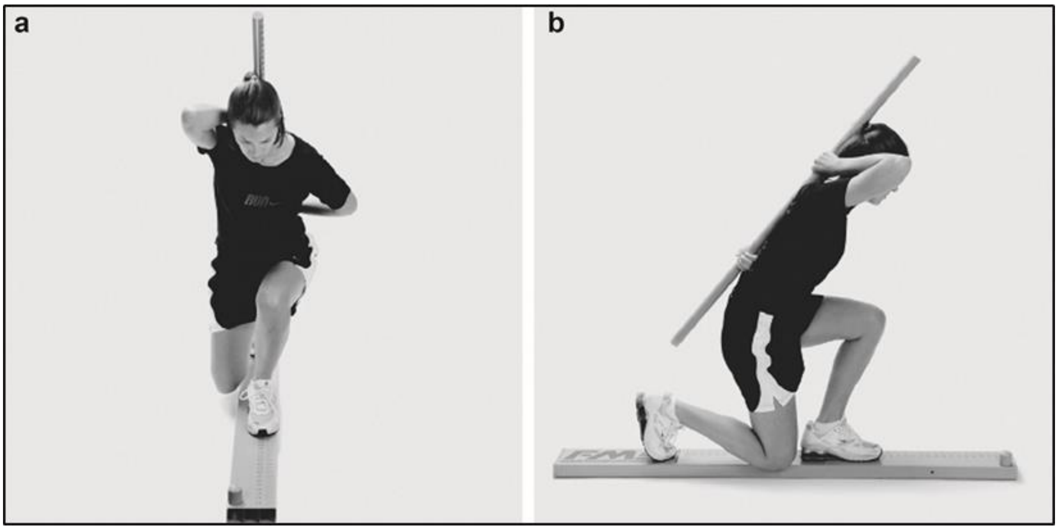
3.6.3 The In-Line Lunge

The researcher first measures the athlete’s tibial length (from the tibial tuberosity to the floor). The athlete then stands with his/her heels at the end of the board, the researcher then uses the tibial measurement (from the toes of the athlete) to make a mark on the board. The dowel is placed behind the researcher's back and he/she must then step forward onto the board placing the heel of the moving leg at the mark. Thereafter the athlete must slowly descend until the back knee touches the board behind the front leg. The athlete must then return to the starting position (Cook *et al.* 2014a).



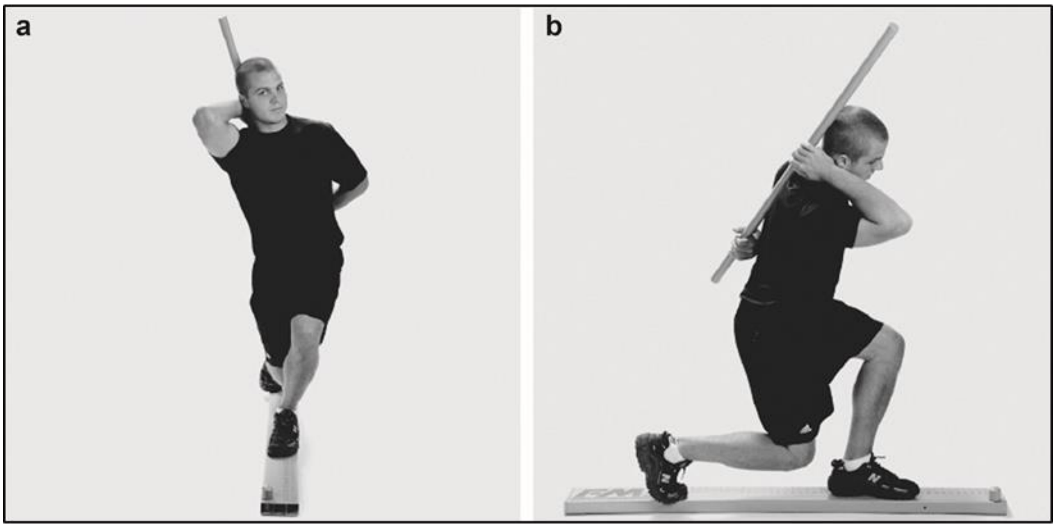
(Cook et al. 2014a)

Figure 8: Views from the front (a) and side (b) of the in-line lunge test, which received a score of 3. No upper body movement is noted, the dowel remains vertical and in contact with the spine. The knee touches the board behind the front foot.



(Cook et al. 2014a)

Figure 9: Views from the front (a) and side (b) of the in-line lunge test, which received a score of 2: the dowel does not remain in contact with the spine, nor does it remain vertical, movement is noted in the upper body, or the knee does not touch the board behind the front foot.



(Cook et al. 2014a)

Figure 10: Views from the front (a) and side (b) of the in-line lunge test, which received a score of 1. If the athlete loses balance a score of 1 is awarded.

3.6.4 Shoulder Mobility

The researcher starts by measuring the distance from the distal wrist crease to the tip of the third digit to determine the hand length. The athlete then makes a fist with each hand. The athlete must then reach up with the test arm, bend his/her elbow, and reach behind his/her back. The other arm must be dropped next to his/her body, bend at the elbow, and reach up to his/her back. The distance between the two closest bony prominences is measured (Cook *et al.* 2014b)

(Cook et al. 2014b)

Figure 11: View from the back of the shoulder mobility test, which received a score of 3. Fists are within one hand length.

(Cook et al. 2014b)

Figure 12: View from the back of the shoulder mobility test, which received a score of 2. Fists are within one and a half hand lengths.

(Cook et al. 2014b)

Figure 13: View from the back of the shoulder mobility test, which received a score of 3: fists are not within one- and one-half hand lengths.

3.6.4.1 Shoulder mobility clearing test

The shoulder mobility clearing test is performed after the shoulder mobility test. This test is only used to evaluate whether the participant experiences pain or not. The presence of a pain response could be indicative of shoulder impingement.

The participant places his/her hand on the opposite shoulder followed by pointing the shoulder upwards. If pain is experienced a score of zero is awarded to the shoulder mobility test (Cook *et al.* 2014b).

(Cook et al. 2014b)

Figure 14: View from in front of the shoulder clearing test. The test is performed bilaterally and a score of zero is given if the athlete experiences any pain.

3.6.5 Active Straight Leg Raiser

The athlete must start by lying on the floor with his/her arms next to the body and palms facing up. The researcher then identifies the three regions:

1. Between the mid-thigh and superior iliac spine of the opposite leg.

2. Between the mid-thigh and knee joint of the opposite lower leg.

3. Below the knee joint on the opposite leg.

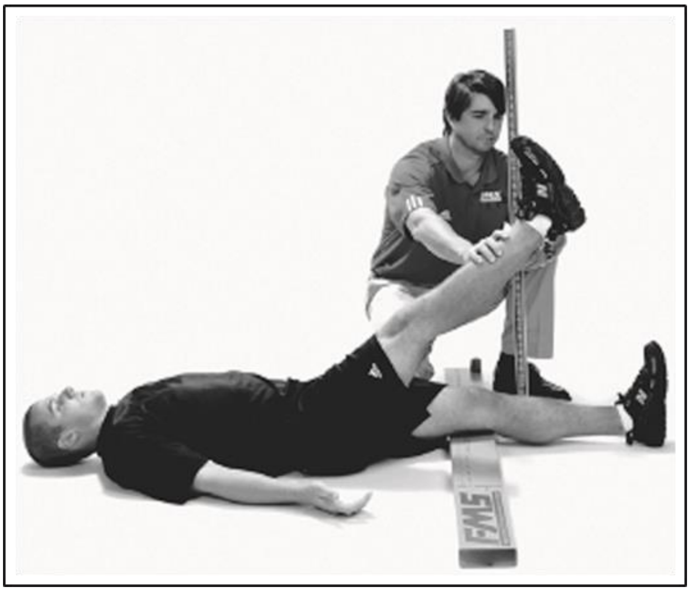
The athlete is asked to lift one leg with his/her ankle dorsiflexed and knee extended. The opposite knee and both hands must stay in contact with the floor, and the toes must point upwards. Once the athlete cannot move the leg further, the researcher will determine which of the regions the malleolus is located. This test must be done bilaterally (Cook *et al.* 2014b).

(Cook et al. 2014b)

Figure 15: Views from the side of the active straight leg raiser test, which received a score of 3. A vertical line from the malleolus of the leg being tested resides between the mid-thigh and the ASIS.

(Cook et al. 2014b)

Figure 16: Views from the side of the active straight leg raiser test, which received a score of 2. A vertical line from the malleolus of the leg being tested resides between the mid-thigh and the knee joint line.

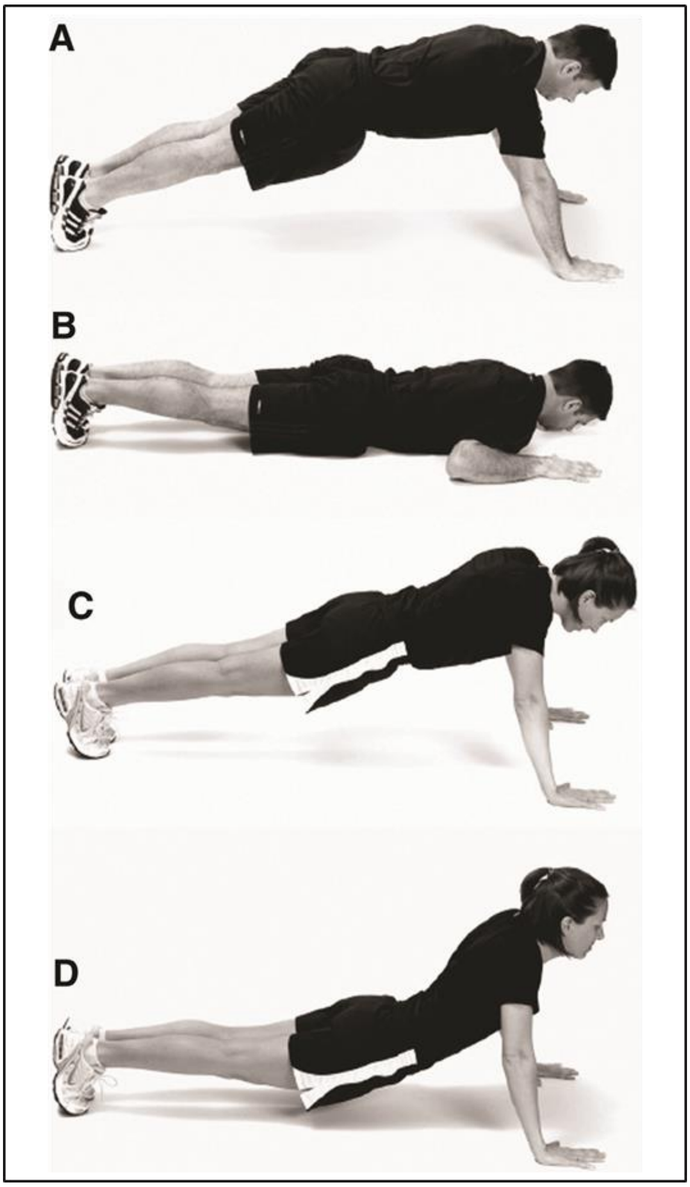


(Cook et al. 2014b)

Figure 17: Views from the side of the active straight leg raiser test, which received a score of 1. A vertical line from the malleolus of the leg being tested resides below the knee joint line.

3.6.6 The Trunk Stability Push Up

The athlete starts by lying on his/her stomach on the floor, feet together. The athlete must then place his/her arms shoulder-width apart. The athlete must then perform a push-up by lifting his/her body from the floor as a unit (Cook *et al.* 2014b)



(Cook et al. 2014b)

Figure 18: View from the side of the trunk stability push up test.

A. To earn a "3", men complete a repetition with their thumbs aligned with the top of their heads, while women perform a repetition with their thumbs aligned with the chin. There is no lag in the spine as the body elevates as a unit.

The body must raise as a unit with no lag in the spine to receive a “2.” B. men must do a repetition with their thumbs aligned with their chin. C. Women repeat with their thumbs aligned with the clavicle.

D. A score of “1” is given if the athlete is not able to perform one repetition with their body lifting as a unit with the hand positions as in picture B.

3.6.6.1 Extension clearing test

After the trunk stability push up test the extension clearing test is performed. Pain can go undetected during movement screens; therefore, this test is simply to identity if the participant experiences pain or not (Cook *et al.* 2014b)

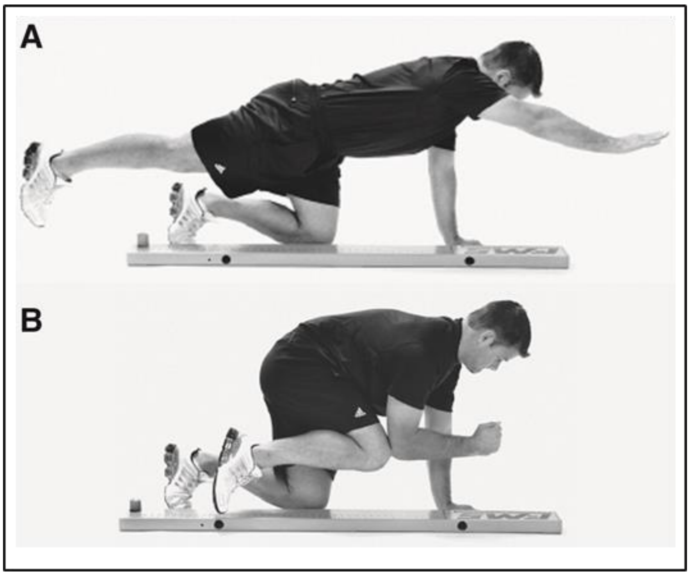
The participant starts on his/her stomach and then pushes up on his/her arms until full elbow extension is reached. In the presence of pain, a score of 0 is given to the trunk stability test.

(Cook et al. 2014b)

Figure 19: Spinal extension clearing test. The athlete performs a press-up with the upper body while the lower body remains in contact with the floor. If there is pain associated with this movement, a score of 0 is given.

3.6.7 The Rotatory Stability

The athlete starts on all fours while keeping his/her shoulders and hips at 90 degrees. The athlete is then asked to reach forward with one arm and straighten the leg on the same side. The hand and leg must only be lifted 15cm off the floor. The same arm and leg must then be bent until the knee and elbow touch each other (Cook *et al.* 2014b).

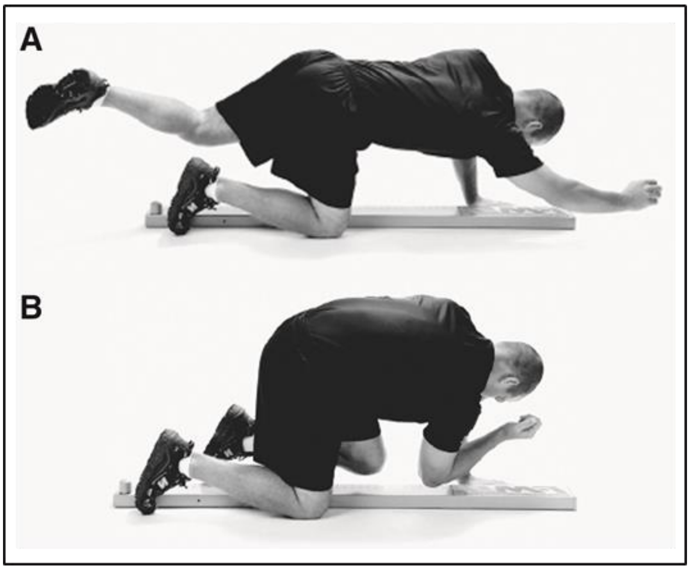


(Cook et al. 2014b)

Figure 20: View from the side of the rotary stability test which received a score of 3. The athlete performs a correct unilateral repetition. A. Extended position. B. Flexed position, elbow and knee must meet.

(Cook et al. 2014b)

Figure 21: View from the side of the rotary stability test which received a score of 2. The athlete performs a correct diagonal repetition. A. Extended position. B. Flexed position, elbow and knee must meet.



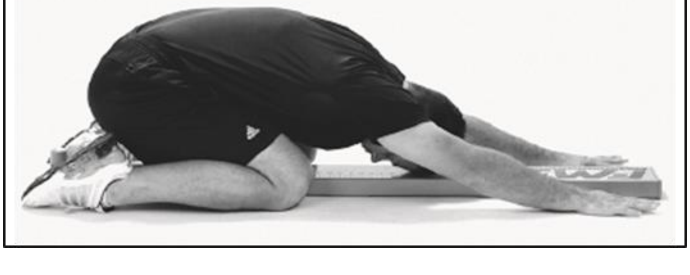
(Cook et al. 2014b)

Figure 22: View from the side of the rotary stability test which received a score of 1. The subject is unable to perform a diagonal repetition. A. Extended position. B. Flexed position.

3.6.7.1 Flexion clearing test

After the quadruped rotary stability test the flexion clearing test is performed. Pain can go undetected during movement screens; therefore, this test is simply to identify if the participant experiences pain or not (Cook *et al.* 2014b).

The participant remains in his/her quadruped position and from there move backwards until the buttock touches the heels. At the same time the participant must move his/her chest toward their thighs, while keeping their arms stretched out in front of them. In the presence of pain, a score of 0 is given to the quadruped rotary stability test (Cook *et al.* 2014b).



(Cook et al. 2014b)

Figure 23: Spinal flexion clearing test. The individual assumes a quadruped pose and then rocks backward, touching the buttocks to the heels and the chest to the thighs, extending out as far as possible with the arms. If there is any discomfort associated with this movement, a score of "0" is given.

3.7 Injury profile sheet

The injury profile sheet (Appendix E) was used to record any injuries the players sustained during the six weeks after the FMS™ was completed. After the triathletes completed the FMS™ tests and the six-week period had past, the researcher contacted each triathlete telephonically to record any injuries that occurred since the participant performed the FMS™.

In the event of an injury the participants were requested to inform the researcher. The researcher then recorded detail pertaining to the injury which included:

- The diagnosis of the injury.
- The severity of the injury (on a scale from zero to ten).
- The date on which it occurred.
- The duration of time unable to train/exercise.
- The mechanism of injury.
- The treatment (if any).

3.8 Statistical analysis

For data analysis IBM SPSS version 27 was used. A p value <0.05 was considered as statistically significant. Demographics were compared between males and females using t-tests. FMS™ Scores were compared between groups using t-tests. Data were summarised using mean, standard deviation, and range.

Chapter Four

Results and Discussion

4.1 Introduction

This study was conducted to determine the normative values for the FMS™ as a predictor of injury in triathletes in the eThekwini municipal area and to determine if there is a link between a low FMS™ score and the occurrence of injury. Thus, this chapter aims to present and discuss all the data collected throughout the duration of the study.

This chapter will present a summary of the sample population characteristics followed by the statistical analysis of the data in the form of graphs and tables. To improve flow and avoid repetition, the results are given per objective and discussed as they occur in this chapter.

4.2 Methodological flow

Twenty-four athletes were in the Team Just-In and Triathlon Training Academy training groups. All 24 athletes participated in the study.

4.3 Response rate

Table 2: Response rate

TOTAL POPULATION	24
SAMPLE AVAILABLE FOR RESEARCH	24
MINIMUM SAMPLE SIZE	24
TOTAL RESPONSES	24
USABLE REPONSE RATE	100%

4.4 Demographic data

The total number of triathletes that participated in the study was 24 (n = 24). Of the total sample, 19 triathletes were male (79.17%), and 5 triathletes were female (20.83%). The demographics by gender are shown in Table 1. There were 24 participants of whom 79% were male.

The triathletes from two triathlon training groups participated in this study. Out of the 24 participants 18 followed the training program of Team Just-In and 6 that of Triathlon Training Academy.

The age of the triathletes ranged between 19 to 59 and the mean age was 41.83 years of age. The range of the height of the sample size ranged from 1.54 to 1.94 metres with the average height being 1.75 metres. Their mean age and number of years were not different between the males and females, but there was a higher mean height and weight in the males compared with the females ($p<0.001$ and $p=0.003$ respectively).

With regards to the selected triathletes' weight, the sample range was between 52 and 108kg with the mean weight being 81.08kg. This information was used to calculate the Body Mass Index (BMI) of the triathletes which ranged from 17.71 to 33.51 with the mean BMI being 26.13. Distribution of training group, age and gender of the sample size are reflected in Figure.

Table 3: Demographic data

		Gender		
		Female	Male	Total
Age	N	5	19	24
	Mean	39	42	42
	Standard Deviation	18	10	12
Number of years doing triathlon	Valid N	5	19	24
	Mean	4.6	3.9	4.0
	Standard Deviation	1.7	3.3	3.0
Height	Valid N	5	19	24
	Mean	1.60	1.80	1.76
	Standard Deviation	.08	.07	.11
Weight	Valid N	5	19	24
	Mean	62	86	81
	Standard Deviation	21	12	17

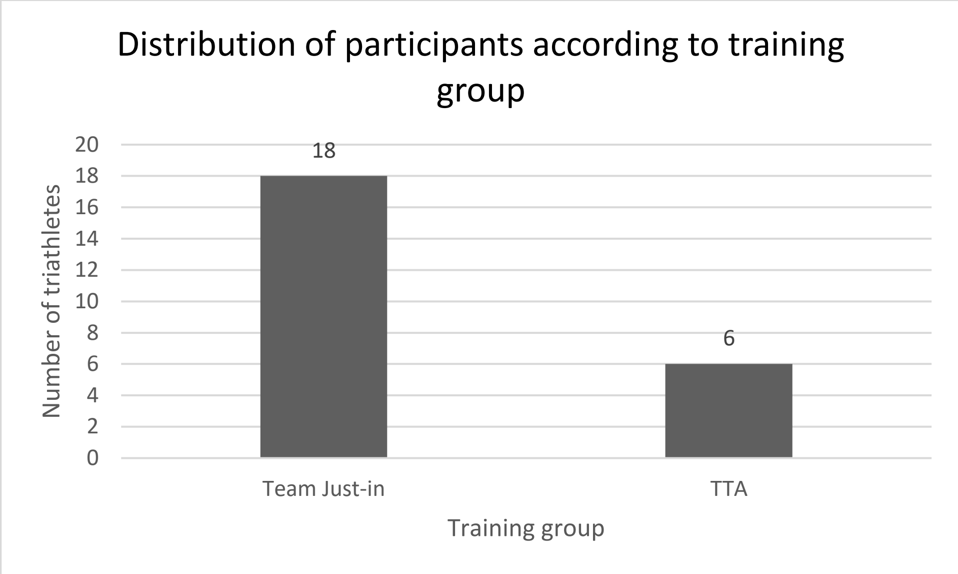


Figure 24: Distribution of participants according to training group

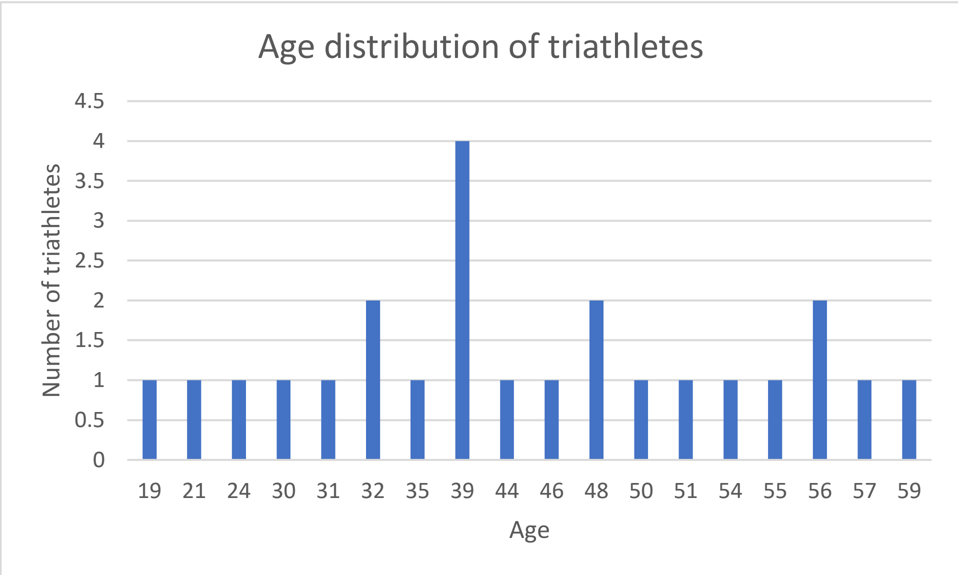


Figure 25: Age distribution of triathletes that participated in the study

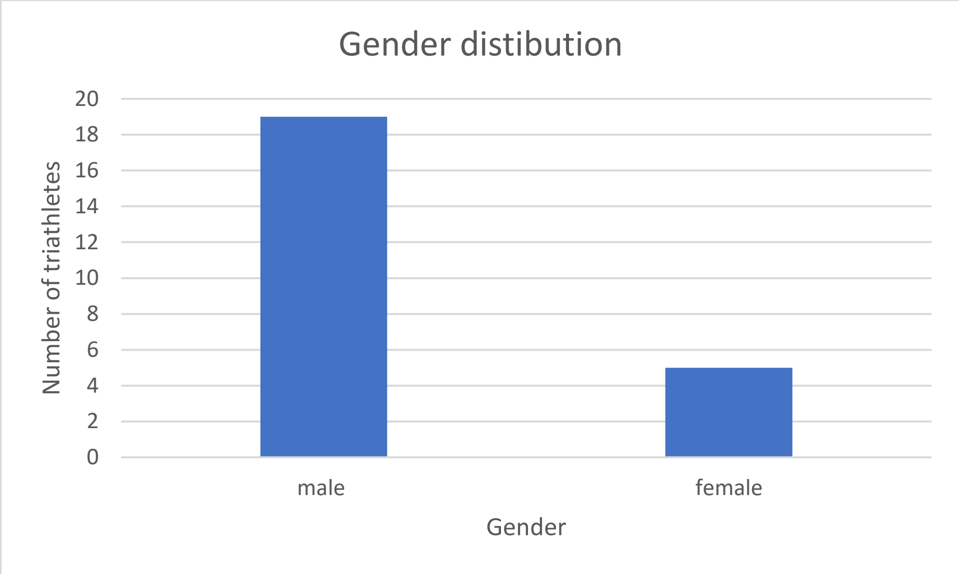


Figure 26: Gender distribution of triathletes that participated in the study

4.4.1 Discussion of demographic data

The demographics of this study can be compared to the findings of Ellapen *et al.* (2011), Coetzee (2013) and Momberg (2019). In terms of sample cohorts employed, the studies were similar in that they used South African triathletes, with Coetzee (2013) using specifically athletes from Kwa-Zulu Natal.

In terms of gender the population was similar to a study done in Australia by Ansell, Rivett and Callister (2012) who found that the greater majority of triathletes were male (76%) and only 24% were female. Further similarities were noted in the local studies done by Coetzee (2013), Ellapen *et al.* (2011) and Momberg (2019). Coetzee (2013) reported that 68% of the population was male and 32% female, Ellapen *et al.* (2011) reported the male population to be 72% compared to the female population being 27% and Momberg (2019) found that 66.2% were male and 33.8% female.

Similarities were noted in the height of the triathletes as the study done by Coetzee (2013) had a mean height of 1.74 metres, as compared to this study where the mean height was found to be 1.75 metres. In study done by Richardson (2018) the FMS™ was conducted on athletes competing in CrossFit. The average height of these athletes was similar to this study and therefore a comparison can be made. The average height of the CrossFit athletes was 1.7 metres, which is similar to the findings of this study where the average height is 1.76 metres.

With regards to age, the range in this study is from 19 to 59, which is similar to the range of 18 to 64 reported by Coetzee (2013) and 18 to 59 reported by Momberg (2019). The range of triathlete ages can likely be attributed to the entry requirements of most triathlon races being a minimum age of 18 years with no maximum age limit. None of the studies included triathletes under the age of 18 years. This could possibly have provided more information on triathlon injuries and should be considered in future studies.

These similarities would allow for comparison between these studies as the demographics of the triathletes were similar.

In contrast to this study with a resultant mean weight of 81 kilograms, the mean weight reported by Coetzee (2013) was reported to be 71 kilograms and Ellapen *et al.* (2011) reported a mean weight of 67.86 kilograms. In previous studies it has been noted that the mean weight for male participants are higher of the mean weight of female participants (Coetzee 2013). This could explain the higher mean weight as the majority of participant in this study were male.

4.5 The FMS™ Scores

4.5.1 The normative values of the FMS™ scores in triathletes

As per the table below the data was recorded and represented in terms of mean, range and standard deviation. FMS™ scores were summarised by gender and overall. The overall mean score was 14.25 with males scoring slightly higher than female triathletes. The standard deviation was 2.15 overall with a range from 10 to 18. The maximum score of 18 out of 21 for male triathletes is also higher than the maximum score of 16 found in female triathletes.

Table 4: The normative values of the FMS™ scores in triathletes

		Gender		
		Female	Male	Total
FMS score	Mean	14.00	14.32	14.25
	Standard Deviation	2.35	2.16	2.15
	Minimum	10	10	10
	Maximum	16	18	18

4.5.2 Discussion of the normative values of the FMS™ ™ scores in triathletes

Lucas *et al.* (2019) compared the normative values between elite and non-elite swimmers and found that elite swimmers scored 17.3 and non-elite swimmers had a score of 14.59, which can be compared to the current study as none of the triathletes compete as elite triathletes, but rather as age-groupers which refers to non-elite triathletes. In a recent study on competitive male runners by Hotta *et al.* (2015) the normative values were found to be 14.1, likewise, a study looking at running athletes found the normative value of the FMS to be 15.4 (Loudon *et al.* 2014). Rannama *et al.* (2017) found that the normative value for cyclists was 14.7. These studies focused on either swimming, cycling, or running therefore a comparison can be made to the current study as triathlon include all three of these disciplines, it is interesting to see comparable findings despite triathlon being a multi-disciplinary sport including all three disciplines.

Other studies with similar normative values include those of Chorba *et al.* (2010) who reported a mean FMS™ score of 14.3 for female collegiate athletes and Jooste (2015) who found the normative value for hockey player to be 14.9.

In contrast to this study where the normative value was found to be 14.25, in a study by Schneiders *et al.* (2011) the FMS™ normative value in a young, active population (18-40 years) was calculated to be 15.7. In another study the normative value in health service members was found to be 16.2 (Teyhen *et al.* 2012). In both the above-mentioned studies it was found that FMS™ score decreased with advancing age and therefore the normative values in these two studies are higher than the current study as the mean age of the participants was lower.

The mean age in the study by Schneiders *et al.* (2011) was 21.9 and that of Teyhen *et al.* (2012) was 25.2. In a study done on professional football players the normative values was found to be 16.9 (Kiesel, Plisky and Voight 2007), an explanation for the higher normative value can be due to the fact that the participants were professional athletes.

In a study done by Anderson, Neumann and Bliven (2015) the FMS™ scores of male and female athletes were compared. They found mean males FMS™ score to be 15.3 and females 13.8. This is similar to this study as the male triathletes also scored higher overall.

In their investigations, Kiesel, Plisky and Voight (2007), Chorba *et al.* (2010) and O'connor *et al.* (2011) found that a score of 14 or less increased a player's risk of injury.

4.6 Injury profile

This segment presents and discusses the previous injuries the triathletes had before the FMS™ was performed, the current injuries the triathletes had at the time of performing the FMS™ and lastly, the injuries that occurred in the six-weeks after the FMS™ had been performed. The injuries that were reported by the triathletes were described in in terms of tissue injured and the injury location.

4.6.1 Previous and current triathlon related injury

4.6.1.1 Previous injuries

The Athlete Questionnaire was used to record information regarding triathlon related injury history. The table below shows that 66.7% of the triathletes had a previous injury and 33.3% of triathletes did not report any previous injuries.

The most frequently reported previous injuries were muscle strain (56.3%) followed by spinal fractures (12.5%) and tibial stress fractures (12.5%). The least commonly reported injuries were low back injuries (6.3%), medial tibial stress syndrome (6.3%), and joint sprains (6.3%). The muscle that was most commonly strained was the gastrocnemius (25%), followed by the iliotibial band (18.8%) and quadriceps muscle (12.5%).

With regards to injury location the lower extremity was the most frequently injured, as no upper extremity injuries were reported. 93.6% of injuries were lower extremity injuries and 6.35% reported low back injuries.

Table 5 describes the frequency of previous injuries and current injuries whereas table 6 describes the types of previous injuries reported by the triathletes.

Table 5: Frequency of previous and current injuries sustained by triathletes

			Gender		
			Female	Male	Total
Previous Injury	No	Count	1	7	8
		Column N %	20.0%	36.8%	33.3%
	Yes	Count	4	12	16
		Column N %	80.0%	63.2%	66.7%
Current injury	No	Count	3	17	20
		Column N %	60.0%	89.5%	83.3%
	yes	Count	2	2	4
		Column N %	40.0%	10.5%	16.7%

Table 6: Location of previous triathlon related injuries

Previous injury		Frequency	Valid Percent
Valid	Ankle sprain	1	6.3
	Muscle strain:	9	56.3
	• Gastrocnemius strain	4	25.0
	• ITB Stain	3	18.8
	• Quadriceps strain	2	12.5
	Low back injury	1	6.3
	Medial tibial stress syndrome	1	6.3
	Spinal fracture	2	12.5
	Tibial stress fracture	2	12.5
	Total	16	100.0

4.6.1.2 Current injuries

The Athlete Questionnaire was used to record any current injuries. At the time of screening 17% of the triathlete had current injuries and 83% of the triathletes did not have current injuries. 50% of the triathletes that had current injuries had medial tibial stress syndrome and 50% had a muscle strain (quadriceps muscle).

The most common area of current injuries was the lower extremity (100%).

Table 7: Location of current triathlon related injuries

Current injury		Frequency	Valid Percent
Valid	Shin splints	1	50.0
	VMO strain (muscle strain)	1	50.0
	Total	2	100.0

4.6.1.3 Discussion of previous and current injuries

According to studies by Andersen *et al.* (2013) and Shaw *et al.* (2004) the lower extremity and lower back were the two most commonly injured areas in triathletes. This is similar to the findings in this study where 93.6% of injuries were lower extremity injuries and 6.35% were lower back injuries. It has been found that the knee is the most commonly injured site in triathletes (5.1%), followed by the lower back (34.1%) (Ansell, Rivett and Callister 2012).

Vleck *et al.* (2010) found that Achilles tendon, gastrocnemius and hamstring were the locations most frequently affected by injury in triathletes. In a study done by Momberg (2019) it was reported that the posterior lower limb was the most common site of injury, this included the gastrocnemius and hamstring muscles. Another study that found muscle strains to be the most common injury amongst triathletes was done by Lalonde *et al.* (2020). It was found that iliotibial band injuries, muscle strains and back pain were the most frequently reported musculoskeletal injuries. These findings can be compared to the current study as the gastrocnemius was found to be the mostly previously injured site.

In this study it was found that females are more prone to injury (80% previous and 40% current injuries) compared to male triathletes (63.2% previous and 10.5% current) which is similar to the finding by Momberg (2019). Momberg (2019) also investigated triathletes from the eThekwini municipal area and found reported that 66.2% of the participants in that study were male and 3.8% were female. However, these findings in the current study were not significant (p=0.777).

In contrast to this study, it has been reported by several other studies that the knee is the most common anatomical site of injury (Egermann *et al.* 2003; Ellapen *et al.* 2011; Ansell, Rivett and Callister 2012; Andersen *et al.* 2013).

4.6.2 Injuries sustained during six-week training period

During the six-week period after completing the FMS™ the triathletes continued training according to their normal training program. During this period there were no injuries reported by the triathletes.

4.6.2.1 Discussion

In previous prospective studies CrossFit athletes and hockey players reported injuries after completing the FMS™ (Jooste 2015; Richardson 2018). The information was used to identify a relationship between a low FMS™ score and possible injury. However, due to the absence of injuries reported in this study after the FMS™ was performed, a comparison between the studies cannot be made.

A reason for no injuries reported in the period after testing in this study could be as a result of the Covid pandemic. This study was conducted during level 4 national lockdown. Restrictions of sporting events could therefore have had an effect on the level and intensity of training. Previous studies found that athletes' injury rates are higher in athletes who train in a competitive setting due to increased demand placed on the musculoskeletal structures (Richardson 2018).

Kienstra *et al.* (2017) compared different studies according to study timelines and the percentage of injuries found:

- In a cross-sectional study it was found that 62% of triathletes sustained an injury in the last 12 months (Shaw *et al.* 2004).
- Egermann *et al.* (2003) reported that 74.8% of triathletes had a minimum of one injury during their time competing in triathlons.
- In a prospective study of 174 triathletes, 87% of the triathletes reported some form of overuse injury over a 26-week period of training (Andersen *et al.* 2013).
- A 10-week prospective study conducted by Burns, Keenan and Redmond (2003) found that 37% of triathletes sustained injuries during the triathlon season. In addition to this a 6-month retrospective study found that 50% of triathletes sustained injuries during the pre-season period.
- In an 8-week study by Korkia, Tunstall-Pedoe and Maffulli (1994) 37% of triathletes reported at least one overuse injury.

As seen above a comparison cannot be made between previous studies and the current studies as the timelines differ significantly. It can be concluded that the longer the study, the greater the percentage of triathletes who sustained injuries. This finding can be due to the fact that the majority of triathlon injuries are overuse injuries and will therefore only present after a longer period of time (Vleck *et al.* 2010; Ansell, Rivett and Callister 2012; Andersen *et al.* 2013). It can be noted that the two 8-week studies reported an injury rate of 37%, compared to the longer studies which reported an injury rate between 50-78% (Burns, Keenan and Redmond 2003; Egermann *et al.* 2003; Shaw *et al.* 2004; Andersen *et al.* 2013).

Another explanation for the absence of injuries reported by the triathletes and the difference in finding between this study and previous studies can be due to the variation among studies with regards to the definition of an injury. It has been proven that different definitions for injury among the same group of triathletes can offer varying results when reporting injury (Kienstra *et al.* 2017).

According to Vleck, Millet and Alves (2014) there is a fine line between the level of training required for peak performance and the level of training that could lead to injury. The use of a qualified coach can aid in achieving the highest level of performance with the least risk of injury. This can be a further explanation as to why triathletes did not report injuries during this study, as all the triathletes followed a structured training program written by the coach of the training group.

4.7 Association between FMS™ scores and injury occurrence

In the absence of any injuries reported during the follow-up time no association can be made between a low FMS™ and possible injury. It was noted that triathletes who reported current injuries scored lower on the FMS™ (13.25) than triathletes who did not report current injuries (14.45). However, this finding was not statistically significant (p=0.319) as the *p* value is more than 0.05. In terms of previous injuries, it was found that triathletes with previous injury scored higher (14.69) in the FMS™ than triathletes who did not report any history of previous injury (13.38). The *p* value was found to be p=0.164, which is more than 0.05, therefore this finding is not statistically significant.

Table 8: Association between FMS™ score and injury occurrence

				Gender		
				Female	Male	Total
Previous Injury	No	FMS™ score	Mean	14.00	13.29	13.38
			Standard Deviation	.	2	2
	Yes	FMS™ score	Mean	14.00	14.92	14.69
			Standard Deviation	3	2	2
Current injury	No	FMS™ score	Mean	14.67	14.41	14.45
			Standard Deviation	1	2	2
	Yes	FMS™ score	Mean	13.00	13.50	13.25
			Standard Deviation	4	1	3

4.7.1 Discussion

Previous studies have shown that a low FMS™ score can be used to predict injury in athletes:

- Kiesel, Plisky and Voight (2007) determined that professional football players are more susceptible to injury if the score is 14 or less.
- In a study by Chorba *et al.* (2010) it was found that female collegiate athletes were in a fourfold increase risk of injury if they scored 14 or less.
- Schneiders *et al.* (2011) found that that a score of 14 or less might indicate a potential higher injury risk.

In contrast to the above studies, the following studies found no association between a low FMS™ and injury susceptibility:

- In a prospective study assessing the FMS™ scores of first division intercollegiate basketball players there was no significant difference between the scores of the injured and non-injured athletes (Cuson 2010).
- Lafontaine and Serenko (2017) attempted to find a link between FMS™ scores and injury susceptibility in CrossFit athletes, however no link could be found due to a small sample size and the fact that all the athletes came from one CrossFit box.

Even though Kiesel, Plisky and Voight (2007), Chorba *et al.* (2010) and Schneiders *et al.* (2011) found a link between FMS™ scores and injury the current study is similar to the finding of Lafontaine and Serenko (2017) and Cuson (2010) as no link could be found between a low FMS™ and injury susceptibility.

This study found that triathletes with current injuries scored lower on the FMS™ (13.25) than triathletes who did not have injuries at the time of completing the FMS™ (14.45). This finding can be attributed to the FMS™ movements aiming to identify weaknesses, imbalances, and asymmetry in athletes. Due to the presence of an injury the triathletes possibly had altered mobility, stability and asymmetric influences which leads to compensatory movement patterns which results in a lower FMS™ score (Cook *et al.* 2014a).

Triathletes with previous injuries had a score of 14.69 in comparison to triathletes who did not report previous injuries that scored 13.38 out of 21. This is in contrast to the studies done by Richardson (2018) who found that CrossFit athletes who did not report previous injury reported a higher FMS™ (17.90) score compared to athletes who reported previous injuries (17.64).

4.8 Conclusion

This research set out to answer the objectives of this study.

The findings indicated that the mean FMS™ score in a sample of triathletes was 14.25 out of 21.

The results revealed that the most common injuries were muscle strains which included lower extremity muscles namely the gastrocnemius, iliotibial band and quadriceps muscle.

No association could be found between a low FMS™ and injury susceptibility. Therefore, with the hypothesis of a low FMS™ score being an injury predictor in triathletes in the eThekwini municipal area; and the resultant null hypothesis indicating that a low FMS™ is not a predictor of injury in triathletes in the eThekwini municipal area. The findings of this study reject this hypothesis.

Chapter Five

Conclusion and recommendations

5.1 Introduction

This chapter draws conclusions based on the results of the primary data obtained. The study's limitations are discussed, as well as recommendations for future research.

5.2 Conclusions

This prospective cross-sectional research determined that the normative value for the FMS™ for triathletes in the eThekwini municipal area is 14.25 out of a possible 21.

It was further determined that 66.7% of the triathletes had previous injuries and 16.7% had current injuries. Previous injuries that were most common were lower extremity muscle strains (56.3%) followed by spinal fractures (12.5%) and tibial stress fractures (12.5%).

However, no link was found between a low FMS™ and injury susceptibility. It was noted that athletes with current injuries scored lower on the FMS™, however, this finding was not statistically significant.

5.3 Limitations

Sufficient data was collected with regards to the normative value for the FMS™ in triathletes as well as the history of injury. However, the lack of injuries occurring in the six-week follow-up period was not sufficient to give statistically significant results.

Due to the self-reporting of injuries by the triathletes in a questionnaire there is a possibility of recall bias (Burns, Keenan and Redmond 2003). This is complicated even more by a triathlete's interpretation of what an injury is and the location of injury (Burns, Keenan and Redmond 2003).

A larger sample size is always an advantage for future research, whether they are regional or national in scope.

5.4 Recommendations

a) A follow-up study is recommended with a larger sample size to further test if any injuries occur in the time period after completion of the FMS™. A larger sample size will amplify the findings to determine if there is an association between a low FMS™ score and injury susceptibility.
b) Further research should change the inclusion criteria to include triathletes under the age of 18, as many triathlon events allow for athletes to compete under the age of 18. This will enlarge the sample size as well as provide a more accurate reflexion of the triathlon population competing in short distance events.
c) Future research should identify a specific triathlon event and incorporate it into the study. As per previous studies the FMS™ must be performed six weeks prior to the event and all injuries sustained up until and during the event must be recorded. This will prove a better representation of injuries sustained by triathletes during the triathlon season.
d) Future research should evaluate an association between intrinsic risk factors and the FMS™ to be able to determine the effect of these factors on FMS™ and if the FMS™ scores can be used independent of other risk factors.
e) Future research should investigate each individual FMS™ test to assess the link between specific tests that are more relevant to a specific sport and possible injury.
f) A follow-up study is recommended with more than two triathlon training groups. This will be more reflective of the triathlon community.
g) Three triathletes sustained injuries after completing the FMS™, however, these injuries did not occur within the six-week period and could therefore not be included in this study to find a possible association between a low FMS™ and injury susceptibility. Therefore, follow-up study with a longer post-test injury reporting period is recommended.

References

Andersen, C. A., Clarsen, B., Johansen, T. V. and Engebretsen, L. 2013. High prevalence of overuse injury among iron-distance triathletes. *British Journal of Sports Medicine*, 47 (13): 857-861.

Anderson, B. E., Neumann, M. L. and Bliven, K. C. 2015. Functional movement screen differences between male and female secondary school athletes. *The Journal of Strength & Conditioning Research*, 29 (4): 1098-1106.

Anon. 2019. *Ironman* Available: https://www.ironman.com/ (Accessed 12 January 2019).

Ansell, W., Rivett, D. and Callister, R. 2012. Characteristics, training loads, injury patterns and stretching habits of Australian Ironman triathletes. *Journal of Science and Medicine in Sport*, 15(suppl. 1): S133.

Bock, C. and Orr, R. M. 2015. Use of the functional movement screen in a tactical population: a review. *Journal of Military and Veterans Health*, 23 (2): 33-42.

Burns, J., Keenan, A. and Redmond, A. C. 2003. Factors associated with triathlon-related overuse injuries. *Journal of Orthopaedic & Sports Physical Therapy*, 33 (4): 177-184.

Chimera, N. J., Smith, C. A. and Warren, M. 2015. Injury history, sex, and performance on the functional movement screen and Y balance test. *Journal of Athletic Training*, 50 (5): 475-485.

Chorba, R. S., Chorba, D. J., Bouillon, L. E., Overmyer, C. A. and Landis, J. A. 2010. Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *North American Journal of Sports Physical Therapy*, 5 (2): 47.

Clemente-Suárez, V. and Ramos-Campo, D. J. 2019. Effectiveness of reverse vs. traditional linear training periodization in triathlon. *International Journal of Environmental Research and Public Health*, 16 (15): 2807.

Coetzee, C. 2013. An injury profile of amateur and semi-professional KwaZulu-Natal triathletes. M.Tech Chiropractic, Durban University of Technology.

Cook, G. 2010. *Movement: Functional movement*. Aptos CA: On Target Publications.

Cook, G., Burton, L. and Hoogenboom, B. 2006a. Pre-participation screening: the use of fundamental movements as an assessment of function-part 1. *North American Journal of Sports Physical Therapy*, 1 (2): 62-72.

Cook, G., Burton, L. and Hoogenboom, B. 2006b. Pre-participation screening: the use of fundamental movements as an assessment of function-part 2. *North American Journal of Sports Physical Therapy*, 1 (3): 132-139.

Cook, G., Burton, L., Hoogenboom, B. J. and Voight, M. 2014a. Functional movement screening: the use of fundamental movements as an assessment of function-part 1. *North American Journal of Sports Physical Therapy*, 9 (3): 396.

Cook, G., Burton, L., Hoogenboom, B. J. and Voight, M. 2014b. Functional movement screening: the use of fundamental movements as an assessment of function-part 2. *North American Journal of Sports Physical Therapy*, 9 (4): 549.

Cosca, D. and Navazio, F. 2007. Common problems in endurance athletes. *American Family Physician*, 76 (2): 237-244.

Cuson, M. 2010. FMS scores as a predictor of acute lower extremity in division 1 intercollegiate basketball players. Exercises Science, University of Toledo.

Dallam, G. M., Jonas, S. and Miller, T. K. 2005. Medical considerations in triathlon competition. *Sports Medicine*, 35 (2): 143-161.

Dallinga, J. M., Benjaminse, A. and Lemmink, K. A. 2012. Which screening tools can predict injury to the lower extremities in team sports? *Sports Medicine*, 42 (9): 791-815.

Dorrel, B. S., Long, T., Shaffer, S. and Myer, G. D. 2015. Evaluation of the functional movement screen as an injury prediction tool among active adult populations: a systematic review and meta-analysis. *Sports Health*, 7 (6): 532-537.

Dossa, K., Cashman, G., Howitt, S., West, B. and Murray, N. 2014. Can injury in major junior hockey players be predicted by a pre-season functional movement screen–a prospective cohort study. *The Journal of the Canadian Chiropractic Association*, 58 (4): 421.

Egermann, M., Brocai, D., Lill, C. and Schmitt, H. 2003. Analysis of injuries in long-distance triathletes. *International Journal of Sports Medicine*, 24 (04): 271-276.

Ellapen, T., Chetty, L., Dorasami, C., Abrahams, S., Narsigan, S., Desai, F. and Van Heerden, H. 2011. Prevalence of triathlon-related musculoskeletal pain among Kwa-Zulu Natal tri-athletes. *African Journal for Physical, Health Education, Recreation & Dance*, 17 (1)

Etxebarria, N., Mujika, I. and Pyne, D. B. 2019. Training and competition readiness in triathlon. *Sports*, 7 (5): 101.

Etzel, C. E. 2012. A literature review of the functional movement screen as a predictor of injury in the sport of basketball. Honors Bachelor of Science, Oregon State University.

Flato, R., Passanante, G. J., Skalski, M. R., Patel, D. B., White, E. A. and Matcuk, G. R. 2017. The iliotibial tract: imaging, anatomy, injuries, and other pathology. *Skeletal radiology*, 46 (5): 605-622.

Fukuchi, R. K., Stefanyshyn, D. J., Stirling, L., Duarte, M. and Ferber, R. 2014. Flexibility, muscle strength and running biomechanical adaptations in older runners. *Clinical Biomechanics*, 29 (3): 304-310.

Gosling, C. M., Forbes, A. B., McGivern, J. and Gabbe, B. J. 2010. A profile of injuries in athletes seeking treatment during a triathlon race series. *The American Journal of Sports Medicine*, 38 (5): 1007-1014.

Gosling, C. M., Gabbe, B. J. and Forbes, A. B. 2008. Triathlon related musculoskeletal injuries: the status of injury prevention knowledge. *Journal of Science and Medicine in Sport*, 11 (4): 396-406.

Hägglund, M., Waldén, M. and Ekstrand, J. 2006. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *British Journal of Sports Medicine*, 40 (9): 767-772.

Hotta, T., Nishiguchi, S., Fukutani, N., Tashiro, Y., Adachi, D., Morino, S., Shirooka, H., Nozaki, Y., Hirata, H. and Yamaguchi, M. 2015. Functional movement screen for predicting running injuries in 18-to 24-year-old competitive male runners. *The Journal of Strength & Conditioning Research*, 29 (10): 2808-2815.

Jooste, A. 2015. An investigation into normative values for the Functional Movement Screen and its association to injury in female premier league hockey players in KwaZulu-Natal. M.Tech Chiropractic Durban University of Technology.

Kandel, M., Baeyens, J. P. and Clarys, P. 2014. Somatotype, training and performance in Ironman athletes. *European Journal of Sport Science*, 14 (4): 301-308.

Kennedy, M. D., Knight, C. J., Neto, J. H. F., Uzzell, K. S. and Szabo, S. W. 2020. Futureproofing triathlon: expert suggestions to improve health and performance in triathletes. *BMC Sports Science, Medicine and Rehabilitation*, 12 (1): 1-12.

Kienstra, C. M., Asken, T. R., Garcia, J. D., Lara, V. and Best, T. M. 2017. Triathlon injuries: Transitioning from prevalence to prediction and prevention. *Current Sports Medicine Reports*, 16 (6): 397-403.

Kiesel, K., Plisky, P. and Butler, R. 2011. Functional movement test scores improve following a standardized off-season intervention program in professional football players. *Scandinavian Journal of Medicine & Science in Sports*, 21 (2): 287-292.

Kiesel, K., Plisky, P. J. and Voight, M. L. 2007. Can serious injury in professional football be predicted by a preseason functional movement screen? *North American Journal of Sports Physical Therapy*, 2 (3): 147.

Knechtle, B., Knechtle, R., Stiefel, M., Zingg, M. A., Rosemann, T. and Rüst, C. A. 2015. Variables that influence Ironman triathlon performance–what changed in the last 35 years? *Open Access Journal of Sports Medicine*, 6: 277.

Korkia, P., Tunstall-Pedoe, D. and Maffulli, N. 1994. An epidemiological investigation of training and injury patterns in British triathletes. *British Journal of Sports Medicine*, 28 (3): 191-196.

Kraus, K., Schutz, E., Taylor, W. R. and Doyscher, R. 2014. Efficacy of the functional movement screen: a review. *Journal of Strength & Conditioning Research*, 28 (12): 3571-3584.

Lafontaine, E. and Serenko, J. 2017. Using functional movement screen (FMS) to predict injury in CrossFit® athletes. Physical Therapy, Florida Gulf Coast University.

Lalonde, F., Martin, S., Boucher, V. G., Gosselin, M., Roch, M. and Comtois, A. S. 2020. Preparation for an half-ironmantm triathlon amongst amateur athletes: Finishing rate and physiological adaptation. *International Journal of Exercise Science*, 13 (6): 766.

Loudon, J. K., Parkerson-Mitchell, A. J., Hildebrand, L. D. and Teague, C. 2014. Functional movement screen scores in a group of running athletes. *The Journal of Strength & Conditioning Research*, 28 (4): 909-913.

Lucas, D. A., Duarte-Mendes, P., Marinho, D. A., Rolo, I. V. and Neiva, H. P. 2019. Functional movement screen evaluation: comparison between elite and non-elite juvenile swimmers. *Sport Psychology Notebooks* vol. 21, no. 2, 163–173.

McBain, K., Shrier, I., Shultz, R., Meeuwisse, W. H., Klügl, M., Garza, D. and Matheson, G. O. 2012. Prevention of sports injury I: a systematic review of applied biomechanics and physiology outcomes research. *British Journal of Sports Medicine*, 46 (3): 169-173.

McHardy, A., Pollard, H. and Fernandez, M. 2006. Triathlon injuries: A review of the literature and discussion of potential injury mechanisms. *Clinical Chiropractic*, 9 (3): 129-138.

Micheli, L. J. 2010. *Encyclopedia of sports medicine*. USA: Sage Publications.

Migliorini, S. 2011. Risk factors and injury mechanism in Triathlon. *Journal of Human Sport and Exercise*, 6 (2): 309-314.

Millet, G. P. and Vleck, V. E. 2000. Physiological and biomechanical adaptations to the cycle to run transition in Olympic triathlon: review and practical recommendations for training. *British Journal of Sports Medicine*, 34 (5): 384-390.

Minick, K. I., Kiesel, K. B., Burton, L., Taylor, A., Plisky, P. and Butler, R. J. 2010. Interrater reliability of the functional movement screen. *The Journal of Strength & Conditioning Research*, 24 (2): 479-486.

Momberg, C. D. 2019. A retrospective profile of musculoskeletal injuries of ultra-endurance triathletes in South Africa. M.Tech Chiropractic, Durban University of Technology.

Nessler, T. 2013. Using movement assessment to improve performance and reduce injury risk. *International Journal of Athletic Therapy and Training*, 18 (2): 8-12.

Nielsen, R. Ø., Parner, E. T., Nohr, E. A., Sørensen, H., Lind, M. and Rasmussen, S. 2014. Excessive progression in weekly running distance and risk of running-related injuries: an association which varies according to type of injury. *Journal of Orthopaedic & Sports Physical Therapy*, 44 (10): 739-747.

O'connor, F. G., Deuster, P. A., Davis, J., Pappas, C. G. and Knapik, J. J. 2011. Functional movement screening: predicting injuries in officer candidates. *Medicine and Science in Sports and Exercise*, 43 (12): 2224-2230.

Olcina, G., Timón, R., Brazo-Sayavera, J., Martínez-Guardado, I., Marcos-Serrano, M. and Crespo, C. 2018. Changes in physiological and performance variables in non-professional triathletes after taking part in an Olympic distance triathlon. *Research in Sports Medicine*, 26 (3): 323-331.

Peate, W., Bates, G., Lunda, K., Francis, S. and Bellamy, K. 2007. Core strength: a new model for injury prediction and prevention. *Journal of Occupational Medicine and Toxicology*, 2 (1): 1-9.

Rannama, I., Pedak, K., Bazanov, B. and Port, K. 2017. Cycling specific postural stability during incremental exercise. The relationship with cyclists functional movement screen score. *Journal of Human Sport and Exercise*, 12 (1): 83-95.

Richardson, M. 2018. An investigation into the use of the Functional Movement Screen as a predictor of injury in CrossFit athletes in the eThekwini municipality. M.Tech Chiropractic, Durban University of Technology.

Sanders, B., Blackburn, T. A. and Boucher, B. 2013. Preparticipation screening–the sports physical therapy perspective. *International Journal of Sports Physical Therapy*, 8 (2): 180.

Schneiders, A. G., Davidsson, Å., Hörman, E. and Sullivan, S. J. 2011. Functional movement screenTM normative values in a young, active population. *International Journal of Sports Physical Therapy*, 6 (2): 75.

Sellés-Pérez, S., Fernández-Sáez, J., Férriz-Valero, A., Esteve-Lanao, J. and Cejuela, R. 2019. Changes in triathletes' performance and body composition during a specific training period for a Half-Ironman race. *Journal of Human Kinetics*, 67: 185.

Shaw, T., Howat, P., Trainor, M. and Maycock, B. 2004. Training patterns and sports injuries in triathletes. *Journal of Science and Medicine in Sport*, 7 (4): 446-450.

Steffen, K., Myklebust, G., Andersen, T. E., Holme, I. and Bahr, R. 2008. Self-reported injury history and lower limb function as risk factors for injuries in female youth soccer. *The American Journal of Sports Medicine*, 36 (4): 700-708.

Strock, G. A., Cottrell, E. R. and Lohman, J. M. 2006. Triathlon. *Physical Medicine and Rehabilitation Clinics*, 17 (3): 553-564.

Strohrmann, C., Harms, H., Kappeler-Setz, C. and Troster, G. 2012. Monitoring kinematic changes with fatigue in running using body-worn sensors. *IEEE Transactions on Information Technology in Biomedicine*, 16 (5): 983-990.

Teyhen, D. S., Shaffer, S. W., Lorenson, C. L., Halfpap, J. P., Donofry, D. F., Walker, M. J., Dugan, J. L. and Childs, J. D. 2012. The Functional Movement Screen: a reliability study. *Journal of Orthopaedic & Sports Physical Therapy*, 42 (6): 530-540.

Triathlon South Africa. 2018. *Triathlon South Africa* Available: https://triathlonsa.co.za/ (Accessed 8 April 2020).

Tuite, M. J. 2010. Imaging of triathlon injuries. *Radiologic Clinics of North America*, 48 (6): 1125-1135.

Vleck, V., Millet, G. P. and Alves, F. B. 2014. The impact of triathlon training and racing on athletes' general health. *Sports Medicine*, 44 (12): 1659-1692.

Vleck, V. E., Bentley, D. J., Millet, G. P. and Cochrane, T. 2010. Triathlon event distance specialization: training and injury effects. *The Journal of Strength & Conditioning Research*, 24 (1): 30-36.

Vleck, V. E. and Garbutt, G. 1998. Injury and training characteristics of male elite, development squad, and club triathletes. *International Journal of Sports Medicine*, 19 (01): 38-42.

Walsh, J. A. 2019. The rise of elite short-course triathlon re-emphasises the necessity to transition efficiently from cycling to running. *Sports*, 7 (5): 99.

Zwingenberger, S., Valladares, R. D., Walther, A., Beck, H., Stiehler, M., Kirschner, S., Engelhardt, M. and Kasten, P. 2014. An epidemiological investigation of training and injury patterns in triathletes. *Journal of Sports Sciences*, 32 (6): 583-590.

Zych, M., Stec, K., Pilis, A., Pilis, W., Michalski, C., Pilis, K. and Kosiński, D. 2017. Approaches to describe ventilatory threshold in professional sports. *Physical Activity Review*, 5: 113-123.

Appendices

Appendix A: Letter of Information (coaches)

LETTER OF INFORMATION

Title of the Research Study: Determining functional movement screen normative values as a predictor of injury in triathletes in the eThekwini municipal area.

Principal Investigator/s/researcher: Izanne Jacobs (DUT Chiropractic Student M Tech)

Co-Investigator/s/supervisor/s: Dr. G Matkovich (M. Tech: Chiropractic)

Brief Introduction and Purpose of the Study:

Dear Coach

My name is Izanne Jacobs. I am a MTech Chiropractic student at the Durban University of Technology. The research I wish to conduct for my Masters dissertation involves determining functional movement screen normative values as a predictor of injury in triathletes in the eThekwini municipal area.

I would like to invite the athletes from Team Just-In and Triathlon Training Academy to participate in this study.

Generally, research is the systematic and organised method of seeking answers to questions. It is systematic because it is a process broken up into clear steps that lead to conclusions. Research is organised because there is a planned structure or method used to reach the conclusion. Development research is focussed on relevant, useful and important questions. If there are no questions, there can be no research.
If government, business, institutions, organisations and society in general are to function efficiently and effectively, it is important that the decisions they make are based on valid and reliable information and thorough analysis. The search for this information is referred to as the research process.

As indicated above, the primary purpose of research is to find answers to questions. Research allows us to find the right solutions to key issues in our communities by:

- providing facts that will help us to analyse the problem;
- testing the feasibility and the impact of programmes; and
- finding better solutions to the challenges.

Outline of the Procedures: A pre-participation tool assessing an athlete's functional movement will be used to assess the athletes in this study. The aim is to use the pre-participation tool, the Functional Movement Screen™ (FMS™), to assess triathletes 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 triathletes.

The FMS™ will be set up within a closed room prior to the commencement of the set training program.
Each participant must complete the Athlete Questionnaire, before performing the FMS™, to determine any previous injuries that have occurred while doing a triathlon, the amount of time practicing triathlon, as well as general personal information.

Each participant 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, any injury incurred by the athletes will be recorded in the injury profile sheet. The researcher will visit regularly during the training program to keep a record of any injury occurrence.

Risks or Discomforts to the Participant: There is minimal chance of risk involved in this research. As per the instructions of the FMS™, if you experience 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.

Reasons the participants may be withdraw from the Study:

- The athlete will be withdrawn from the study if they leave the triathlon training group after the FMS™ has been conducted.
- The athlete will be withdrawn if they suffer any injury that is not sustained while doing triathlon specific training.
- The athlete will be withdrawn in they suffer from any illness that prevents them from training during the six-week period.
- The athlete or coach may withdraw at any time during the study and there will be no penalty.

Benefits: The triathlon 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 triathletes, thus reducing the rate of injury in the athletes. You will benefit by gaining knowledge about any biomechanical abnormalities present based on the FMS™™ tests.

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.

Results: (Explain how the researcher plans to disseminate the results of the research. Explain if any significant new findings developed during the course of the research how it will be conveyed to the participant.)

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.

Storage of all electronic and hard copies including tape recordings: All the research data, both electronic and hard copies, will be kept at the Durban University of Technology for five years and thereafter will be destroyed as per protocol. All research data will be recorded by the participant's allocated number to endure confidentiality.

Persons to contact in the Event of Any Problems or Queries:

Dr G Matkovich:
M. Tech: Chiropractic
Tel: 082 5683 980 E-mail: grantmatko@mweb.co.za

Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support Dr L Linganiso on 031 373 2577 or researchdirector@dut.ac.za.

Appendix B: Letter of Information (participants)

LETTER OF INFORMATION

Title of the Research Study: Determining functional movement screen normative values as a predictor of injury in triathletes in the eThekwini municipal area.

Principal Investigator/s/researcher: Izanne Jacobs (DUT Chiropractic Student M Tech)

Co-Investigator/s/supervisor/s: Dr. G Matkovich (M. Tech: Chiropractic)

Brief Introduction and Purpose of the Study:

Dear Participant,

My name is Izanne Jacobs. I am a MTech Chiropractic student at the Durban University of Technology. The research I wish to conduct for my Masters dissertation involves determining functional movement screen normative values as a predictor of injury in triathletes in the eThekwini municipal area.

I would like to invite the athletes from Team Just-In and Triathlon Training Academy to participate in this study.

Generally, research is the systematic and organised method of seeking answers to questions. It is systematic because it is a process broken up into clear steps that lead to conclusions. Research is organised because there is a planned structure or method used to reach the conclusion. Development research is focussed on relevant, useful and important questions. If there are no questions, there can be no research.
If government, business, institutions, organisations and society in general are to function efficiently and effectively, it is important that the decisions they make are based on valid and reliable information and thorough analysis. The search for this information is referred to as the research process.

As indicated above, the primary purpose of research is to find answers to questions. Research allows us to find the right solutions to key issues in our communities by:

- providing facts that will help us to analyse the problem;
- testing the feasibility and the impact of programmes; and
- finding better solutions to the challenges.

Outline of the Procedures: A pre-participation tool assessing an athlete's functional movement will be used to assess the athletes in this study. The aim is to use the pre-participation tool, the Functional Movement Screen™ (FMS™), to assess triathletes 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 triathletes.

The FMS™ will be set up within a closed room prior to the commencement of the set training program.
Each participant must complete the Athlete Questionnaire, before performing the FMS™, to determine any previous injuries that have occurred while doing a triathlon, the amount of time practicing triathlon, as well as general personal information.
Each participant 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, any injury incurred by the athletes will be recorded in the injury profile sheet. The researcher will visit regularly during the training program to keep a record of any injury occurrence.

Risks or Discomforts to the Participant: There is minimal chance of risk involved in this research. As per the instructions of the FMS™, if you experience 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.

Reasons the participants may be withdraw from the Study:

- The athlete will be withdrawn from the study if they leave the triathlon training group after the FMS™ has been conducted.
- The athlete will be withdrawn if they suffer any injury that is not sustained while doing triathlon specific training.
- The athlete will be withdrawn in they suffer from any illness that prevents them from training during the six-week period.
- The athlete or coach may withdraw at any time during the study and there will be no penalty.

Benefits: The triathlon 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 triathletes, thus reducing the rate of injury in the athletes. You will benefit by gaining knowledge about any biomechanical abnormalities present based on the FMS™™ tests.

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.

Results: (Explain how the researcher plans to disseminate the results of the research. Explain if any significant new findings developed during the course of the research how it will be conveyed to the participant.)

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.

Storage of all electronic and hard copies including tape recordings: All the research data, both electronic and hard copies, will be kept at the Durban University of Technology for five years and thereafter will be destroyed as per protocol. All research data will be recorded by the participant's allocated number to endure confidentiality.

Persons to contact in the Event of Any Problems or Queries:
Dr G Matkovich:
M. Tech: Chiropractic
Tel: 082 5683 980 E-mail: grantmatko@mweb.co.za

Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support Dr L Linganiso on 031 373 2577 or researchdirector@dut.ac.za.

Appendix C: Consent

CONSENT

Full Title of the Study: Determining functional movement screen normative values as a predictor of injury in triathletes in the eThekwini municipal area.

Names of Researcher/s: Izanne Jacobs (DUT Chiropractic Student M Tech)

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 D: Athlete Questionnaire

Athlete Questionnaire: This questionnaire is related to the research, *Determining functional movement screen normative values as a predictor of injury in triathletes in the eThekwini municipal area*. Please fill out the following information for the researcher to gather knowledge about each participant within the study.
1. Name of training group:
2. Athlete's name:
3. Athlete's age:
4. Athlete's gender:
5. Number of years/months doing Triathlon:
6. Height:
7. Weight:
8. Previous injury: (Triathlon related) E.g. Muscle strain, Joint sprain, Fracture?
9. Current injury: (Triathlon related) E.g. Muscle strain, Joint sprain, Fracture?

Appendix E: Score sheet

Athlete name: …………………………..

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				
<u>Total score:</u>				

*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 F: Injury profile questionnaire

Injury Profile Sheet **Date:**

Athlete's name: _____________________________________

Athletes Training group: _____________________________________   ***To be completed by the researcher***
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 G: Gatekeepers' permission

June 2020

Request for Permission to Conduct Research

Dear Mr. Hand and Mr de Swardt,

My name is Izanne Jacobs, a MTech Chiropractic student at the Durban University of Technology. The research I wish to conduct for my Masters dissertation involves determining functional movement screen normative values as a predictor of injury in triathletes in the eThekwini municipal area.

I am hereby seeking your consent to approach the members of your training group to take part in the study.

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 at 079 233 2944 or izannej@gmail.com Thank you for your time and consideration in this matter.

Yours sincerely,

Izanne Jacobs

Durban University of Technology

Appendix H: Ethical Clearance

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

5 May 2021

Ms I Jacobs
567 Currie Road
Morningside
Durban
4001

Dear Ms Jacobs

Determining Functional Movement Screen ™ normative values as a predictor of injury in triathletes in the eThekwini municipal area
Ethical Clearance number IREC 045/21

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.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

Prof J K Adam
Chairperson: IREC

Appendix I: Signed Gatekeepers' permission from coaches

June 2020

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Yours sincerely,

Izanne Jacobs

Durban Uni[redacted]echnology

June 2020

Request for Permission to Conduct Research

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My name is Izanne Jacobs, a MTech Chiropractic student at the Durban University of Technology. The research I wish to conduct for my Masters dissertation involves determining functional movement screen normative values as a predictor of injury in triathletes in the eThekwini municipal area.

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If you require any further information, please do not hesitate to contact me at 079 233 2944 or izannej@gmail.com Thank you for your time and consideration in this matter.

Yours sincerely,

Izanne Jacobs
Durban University of Technology
[redacted]