A CROSS SECTIONAL STUDY INVESTIGATING THE FUNCTIONAL MOVEMENT SCREEN SCORE AND INJURY STATUS OF TRIATHLETES

Rodger Lawrence Trent
Student number 0607161A

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

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Declaration

I, Rodger Lawrence Trent, declare that this research report is my own work. It is being submitted in partial fulfillment of the degree of Master of Science in Medicine in the field of Biokinetics at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

(Signature of candidate)

25 July 2017

ABSTRACT

Introduction: The popularity of triathlon as a multi-event sport is growing, however injuries can hinder the performance and delay the training regimen of those who participate in the sport. A screening tool such as the functional movement screen (FMS) may assist with early detection of these injuries. Therefore the main purpose of this study was to determine the relationship of injury status with FMS score in a group of South African triathletes.

Methods: Sixty triathletes with a mean age of 38.8 ± 8.5 years volunteered and consented to participate in the study. Both male (n=28) and female (n=32) participants completed a history of injury questionnaire and performed the FMS. The questionnaire consisted of establishing number, site and cause of injury for each participant. The FMS is several fundamental movement patterns, scored on an ordinal of 3 to identify functional limitations or asymmetries.

Results: Forty-nine of the participants reported sustaining injuries in the past six months. Twenty-four of these participants sustained more than one injury, with 31.7% (19.5%-43.8%) being acute injuries, while 48.3% (35.3%-61.3%) were overuse (or chronic) injuries. The majority of injuries sustained took place while running (for males it was 68%, and 74% for females). The mean FMS composite score for all participants was 14.5 ± 2.7. No relationships were found between the FMS scores of triathletes and injury (chronic or acute), (Chi (2)= 0.38; p=0.54). There were no significant statistical relationships found between the FMS score and injured versus non-injured groups, (Chi (2)=0.23, p=0.64).

Conclusion: Previous injury of triathletes revealed a high prevalence of injury and a low overall average FMS score. However, no relationships were found between the FMS and previous injury, therefore the FMS cannot be used in isolation for determining injury incidence.

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Definition of terms

Acute injury: An injury to a person resulting from a specific or sudden onset of short duration, resulting from a single identifiable event or mechanism. [24]

Composite Functional Movement Screen Score: Refers to the total score after completing the Functional Movements screening and is scored out of 21.

Functional movement screen: A screening tool made up of seven specific movements (Deep squat, Inline lunge, ASLR, Hurdle step, Stability push-up, Shoulder mobility and Rotational stability), which can be used to assess an individual's overall functional movement patterns and predict injury. [5]

Ilio Tibial Band friction syndrome: This is an overuse injury most typically seen in runners and cyclists and is caused by excessive friction between the iliotibial band and the lateral femoral condyle. [26]

Overuse/chronic injuries: An injury caused by repeated micro trauma without a single identifiable event responsible for the current injury. [9]

Patella Tendinitis: Frequently occurs from repetitive running which overloads the extensor mechanism and may cause micro tearing and inflammation of either the suprapatellar or infrapatellar. [26]

Plantar Fasciitis: Inflammation of the plantar fascia and is most commonly seen in athletes with poor foot alignment and is precipitated by overuse. [26]

Proprioception: Awareness of position or movement of the body or a body segment. [26]

Abbreviations

- **ASLR:** Active straight leg raise
- **FMS:** Functional Movement Screen
- **IOC:** International Olympic Committee
- **ITBS:** Ilio tibial band syndrome
- **PPE:** Pre-participation Screening
- **TRIPP:** Translating Research into Injury Prevention Practice

CHAPTER 1 - INTRODUCTION

Triathlon is an endurance sport, which includes the three disciplines of swimming, cycling and running and is one of the fastest growing sports in the world.[22] Due to the growing rate of triathlon participation in South Africa and the rest of the world, the prevalence of injuries amongst athletes has increased. [1, 29]

Most evidence regarding physiological parameters and injury prevalence are limited to the individual disciplines of triathlon.[6, 23] However, the data suggests that combining these disciplines into one sporting event can present external stressors, such as different race distances, weather conditions, training techniques and muscular imbalances, which may lead to injury in the athletes.[22]

Due to overuse injuries, many triathletes do not partake in training or competition. [1, 11] A review of the injuries sustained by athletes reported that the prevalence of overuse injuries ranges between 45% - 75%. [6] Pre-participation screening is the primary means of avoiding the risk of overuse injuries in triathletes, however it is not common practice. [6]

Functional Movement Screen (FMS) is a method that has been used in the individual disciplines of triathlon to identify dysfunctional movement patterns in athletes.[17] The FMS battery of tests are used to assess athlete pain, muscle strength, joint stability, flexibility and balance.[17] The use of FMS screening in collision sports is popular, with one study showing the value of the FMS in predicting injury risk of American footballers (or Gridiron). [14] The findings of this study identified a score of <15 as a greater risk of injury, both acute and overuse.[14] Another study similarly showed that a score of ≤14 determined injury in a group of 874 marine officers. [19] These studies demonstrate that there may be value in using the FMS in other settings, and in triathletes the risk of overuse injuries could be reduced during the training season.[5] Further, the rationale for screening triathletes using the FMS was to determine whether triathletes who have better dynamic stability and mobility, with less compensatory movement patterns, are less prone to injuries.[4]

1.1 Problem statement

There is currently no evidence on the utilization of a screening tool to assess athletes who participate in multi-sports such as triathletes. An understanding of the relationship between the FMS score and previous injury can aid in correcting irregular movement patterns and identify weaknesses to reduce the risk of injury in triathletes.

1.2 Aim

To determine the relationship between FMS score and previous injury status of triathletes based in Johannesburg, South Africa.

1.3 Objectives

1. To determine the recent injury status (defined ≤ 6 months) of a selected group of Johannesburg-based triathletes
2. To describe the FMS scores in these triathletes
3. To determine the relationship of FMS scores with injury status in these athletes

CHAPTER 2 - LITERATURE REVIEW

2.1 Introduction

Triathlon is an endurance sport and includes the three disciplines of swimming, cycling and running.[22] Over the past ten years, racing, training parameters, injury occurrence and physiological adaptations have been researched within the individual sports of swimming, cycling and running.[6, 23] Combining these three sports into one sporting event presents a number of challenges, such as exposure to different environmental factors, differing training techniques, and potential muscular imbalances.[22] With an increase in triathlon participation, the increase in the number of injuries seen by health practitioners has become more prevalent.[3] This is accompanied by research papers reporting a high number of overuse and acute injuries sustained by triathletes.[2, 29]

In comparison to triathletes, athletes who only participate in individual sport, spend less hours training per week and have a lower prevalence of injury.[18] Therefore, the physical demands and amount of hours spent training can cause triathletes to be at higher risk of overuse injuries compared with single sport athletes.[3, 29]

2.2 Triathlon

Due to the differing distances of triathlon events; such as Ironman distance, (3.9km swim, 180km bike, 42km run), Half-Ironman distance, (1.9km swim, 90km bike, 21km run), and Olympic distance, (1.5km swim, 40km bike, 10km run), varying amounts of training is required to complete each event. [3,21,25]

Due to the three events, swimming, cycling and running, the amount of hours spent training and the various distances of the races, triathletes have been found to sustain overuse injuries mainly in the running and cycling disciplines during triathlon.[3, 21,25] These overuse injuries were mainly related to the lower limbs and lower lumbar region of the back.[3] Swimming injuries had no or very little influence on overuse injuries due to the short duration and lower impact of the swimming segment of triathlon.[2]

2.3 Overuse and Acute injuries in Triathlon

Injury in triathletes can be defined as, "any injury or medical condition which either prevents an athlete from participating in training or racing, or during training or a racing event prevents the athlete from continuing or finishing'.[24] There has been an increase in the prevalence of overuse injuries in triathlon.[1, 29] In contrast, the prevalence of acute injuries are lower than the overuse injuries.[1]

Along with many other endurance sports, triathlon has shown to have a high prevalence of overuse injuries and accounted for 68-87% of all injuries experienced by triathletes.[1, 3,21,31] Acute injuries were sustained 0.97 injuries per 1000 hours of training and 1.02 injuries per 1000 hours of competition by triathletes.[1]

2.4 Extrinsic causes of injuries in Triathlon

The etiology of triathlon injury comprises many interrelated and varying factors. There are a number of factors, which could contribute to the onset of overuse injuries in triathletes, including intrinsic and extrinsic variables.[29]

2.4.1 Triathlon experience

Triathlon experience, defined as the number of years the athlete has trained and participated in triathlon, is a possible contributing factor to overuse injuries.[3, 12,29] A greater incidence of overuse injury has been found in inexperienced and elite competitors due to longer training profiles.[12] The hours of training by elite and experienced triathletes, and the greater number of years competing in triathlon may elicit a stress effect on the body, which may result in a higher number of overuse injuries.[6] This is in contrast to inexperienced athletes whose injuries could be caused by either not training enough or overtraining when physically preparing for triathlon events.[12]

Triathletes at greater risk of injury during triathlon training and in competition come from the running and cycling components of training.[22] This may suggest that experienced runners starting triathlon are less likely to experience overuse injuries in the running portion of triathlon training and competition.[22] Furthermore, there is no association between age and increased injury occurrence across the age spectrum.[11, 29]

2.4.2 Competition

As triathlon competition has many different race variations, the distance covered during a race and the volume of training varies for each event. The race specific injuries were found to be highest in Ironman and 'fun competition', triathletes.[1, 7,12,29]

Triathletes participating in the Ironman competition have a high degree of exposure to overuse injuries because of the physical preparation involved for longer distances during competition compared with the shorter sprint triathlons.[1] On the other hand, 'recreational' triathletes have a high injury incidence due to inexperience and lower training volume for competitions. [1, 13,22,29] In comparison, Olympic distance triathletes were found to have the least injuries and injury incidence due to the shorter length of the race and the lower training volume demand compared with Ironman training.[1, 7,12,29]

2.4.3 Training

It can be speculated that the amount of training a triathlete performs per week to prepare for a race is proportional to the performance the athlete wishes to produce in competition. Excessive or lack of training hours per week is not related to injuries sustained in triathlon competition.[7] The number of hours spent training per week in the preseason and in competition phases were very similar to those athletes who were injured and those who were not.[3]

However, the number of hours spent training per week may be representative of injuries sustained in training.[3] It was found that training a total of 8-14 hours a week predicted lower chance of sustaining an overuse injury.[25] However, the minimum amount of hours trained per week, up to seven hours and the maximum hours trained per week, 15 hours plus showed a significant increase and risk of sustaining an injury. [25] This suggests that the optimal amount of training should fall within 8-14 hours to prevent the onset of overuse injuries.

2.4.4 Warming-up and Cooling-down

Warming up and cooling down has not yielded any significant outcomes associated with sustaining an injury.[11] Athletes who occasionally perform a warm up and cool down were more likely to report pre-season injuries compared to athletes who claimed to always warm up and cool down pre and post training and racing.[3] Distinguishing what constitutes warming up and cooling down was not identified and lacks a definition for the triathlon context for training or competition. The effectiveness of warming-up and cooling down, in training and competition, in reducing injuries within triathlon is yet to be researched in depth.

2.5 Incidence of areas of injury in Triathlon

2.5.1 Upper limb injuries

The shoulder area is commonly known in triathlon to be susceptible to injury as a result of swimming training load in triathlon.[2] Poor swimming technique, inadequate stretching and inadequate warm up are all factors, which contribute to shoulder injuries.[2] Shoulder injury incidences range from 19-42%. [1,11,21,29]

Neck or cervical injuries were the least reported and were grouped alongside thoracic and lumbar injuries. In one study, a group of triathletes had a lifetime incidence of neck pain of 48.3% compared to the reported neck injuries sustained (3.8%). [21,28] Neck pain associated with triathlon was found to be acute in nature and lasted less than seven days.[28] Chronic neck pain only affected a small number of triathletes, and was found to be due to compromised intervertebral discs. [28]

2.5.2 Back injuries

Lower and upper back injuries ranked third on the most common injuries sustained by triathletes.[11, 31] Lower back pain accounted for 67.8% of lifetime incidence.[28] Lower and upper back injuries in triathletes ranged from 14% to 72% in various studies.[3,11,28,31] Lower back pain can be caused by cycling, due to poor stability or flexibility, resulting in pain, leading to an overuse injury at specific sites in the back.[28] There is a positive correlation between lower back pain with total number of years participating in sport, number of triathlons competed in, and previous injuries sustained to the lower back.[28]

2.5.3 Lower limb Injuries

The lower limb comprising of the hip, knee, thigh, ankle, foot and toes has the highest reported number of injuries ranging from 30-85%.[1,3,11,12,21,31] The cycle and running components of triathlon take up the most time and are the greatest distance aspects of the race. Therefore, it can be deduced that the lower limb would be stressed more and would sustain greater overuse injuries.

The incidence of hip injuries was low (5%), while the incidence of knee and thigh injuries ranged from 13.6% to 63% in triathletes.[1,3,11,12,21,31] Running was the most common mechanism accounting for the highest number of injuries to the lower limb.[3] Poor running technique, hard running surface, inadequate stretching and lack of warming-up could increase an athlete's susceptibility to lower limb injuries.[3, 31]

Ankle, toe and foot injuries included in the lower limb injuries were the second highest reported and ranged from 9-50% of reported incidents by triathletes.[1, 3,11,12,31] Thirty-five percent of ankle and foot injuries reported involved a strain, tendinitis or a tear.[31]

2.5.4 Muscle, ligament, tendon and bone injuries

Muscle and tendon injuries ranged from 10-55% of respondents from triathlons.[1, 7,11,12,15] Ligament and joint injuries accounted for 6-29% of injuries sustained in triathlons.[7,11,15] Fractures that were related mainly due to running and cycling crashes constituted between 2-11% reported by triathletes.[1, 7,12,15]

2.5.5 Mechanism of injury

Mechanism of injury due to acute twist/turning motion 12%, contact or collision 10% and overstretching 9% was reported by triathletes.[15] Injuries caused by swimming accounted for 12-16% of triathletes and was the least common cause of injury.[12, 15,31] Muscle and tendon injuries were caused by swimming in 14% of reported cases.[7]

Cycling caused 16-32% of injuries during training and racing.[12,15,31] Fractures relating to cycling were apparent 75.8% of the time, contusions and abrasions 82.2% and muscle and tendon injuries 14.4%.[7] Seventy-four percent of triathletes related cycling to cause back pain.[21]

Running is the most common and apparent cause of overuse and acute injuries.[12] As mentioned above, this may be due to overtraining, poor running technique, inadequate stretching or hard surface.[21] In triathlon events, running injuries are a result of fracture (12.1%) and muscle and tendon injuries (65.9%).[7]

The time spent cycling and time spent running were significantly associated with the occurrence of triathlete injuries, but swimming injuries were not related to total time spent swimming.[25] The most serious injuries were the result of cycling and running falls.[7, 22]

Another aspect of triathlon training which caused injury in triathletes, was resistance training injuries of 22%, which were responsible for lower back pain 45% of the time in triathletes.[1, 21] The least likely and least reported association and cause of injury among triathletes was circuit training at 19% of all resistance training exercises.[21]

2.5.6 Competition and training injury occurrence

Large volumes and distances covered in training may be related to injury occurrence during training. In addition, injury occurrence during competition could be related to the intensity placed on the triathlete. As races for triathlons vary in length, the significance in injury accumulation changes. This is shown, where Olympic distance triathletes are 1.65 times more likely to sustain an injury than sprint distance athletes.[12] In conjunction with previous data, recreational or fun race athletes had a reduced risk of injury due to the relaxed nature of racing.[12]

Over the sprint distance race, contusions, abrasions, grazers and blisters were the most prevalent injuries sustained by triathletes, while in the half ironman distance races, dehydration followed by muscle cramps occurred 36.1% of the time.[30] Injuries occurring from overuse or gradual-onset were the most common form of injury, occurring in thrice the number of athletes compared to acute injuries.[30] Sixty eight percent of injuries accounted for overuse etiology in preseason training and 78% during competition for triathletes.[3]

In-season and pre-season training during the summer months of the year were found to have the highest injury occurrence and accounted for between 50.4-83% of all injuries occurring during the year.[3, 7,11,31] The injury rate per 1000 hours of training varied from 0.7-2.5 injuries.[3]

Competition or racing injuries were reported far less and only had an incidence percentage relating from 8-37.5%. [3,7,11,31] However the injury rate per 1000 hours of racing reported was far higher than training and was measured at 4.6-17.4 injuries.[3, 11]

Individual race events produced 15.7 injuries in Olympic distance races, 24.3 injuries in fun distance races and 20.4 injuries in sprint distance races per 1000 hours of racing.[12] This may be an indication that injury may be linked to intensity when training for and competing in shorter duration triathlon events.

2.5.7 Degree of injury sustained

The degree to which triathletes are injured and what medical treatment is sought represents a greater need for clarification of injuries and their reoccurrence. Just over half of athletes, fifty-five percent sought medical treatment more than once a year and claims of 65.3% of athletes seek professional medical help after an injury.[7, 31] Athletes sought help from physicians (51.4%) and physical therapists (41.5%), which accounted for the majority of medical help.[31] Many triathletes continue with training without seeking professional help while still injured.[31]

Time spent off work, off training or racing as a triathlete may represent the severity to which the athlete is injured. Injuries severe enough to take time off work ranged from 15-56%. [21] Stopping triathlon training ranged from 4-20% of athletes.[11, 15] Injuries severe enough to stop swim training were reported by 17-21% of athletes. [11, 15]

Whereas cycling and running injuries ranged between 26-75% and 42-67% in triathletes, respectively.[11, 15] Stopping (17%) and not participating (33%) in a race were reported by triathletes as a result of injury.[11, 15]

2.6 The Functional Movement Screen

The Functional movement Screen (FMS) can be used to assess an individual's overall functional movement patterns and predict injury.[17, 19] It may be possible to prevent injuries in triathlon as a result of FMS screening. In order to prepare an athlete for a wide variety of activities, fundamental movements should be assessed. As discussed, the discipline of running has been identified as the most common cause of lower limb injuries in triathletes.[3, 15,22,25] Research conducted on runners have set normative scores of the FMS to compare against other runners and assist in predicting injury.[20]

The FMS has been found to be a reliable indicator for baseline functional testing in long-distance runners.[20] The FMS screen was also found to help strength and conditioning professionals in designing programs, to prescribe corrective exercises to alleviate further injury, and correct biomechanics.[20] A further finding was the lack of balance and low scores of the over forty age group, which may indicate higher risk of injury.[20]

Prediction of injury by means of the FMS has been utilized in American football and the results of the FMS have been used for corrective exercises and preventative measures.[14] Two hundred and thirty eight American professional football players were measured for motor control of fundamental movement patterns.[14] FMS scores less than or equal to 14, significantly increased the likelihood of attaining an injury; this was established in the testing of American football players.[14] This was confirmed in military personal.[19] Functional movement scores were obtained before the start of the training camp. Football players with one asymmetry or poor movement pattern found on the FMS test, exhibited a relative risk of 1.87, (CI_{95} 1.20-2.96), and were more likely to attain an injury leading to time loss in training and competition.[14] This was significant as a player found to have 1 asymmetry and score less than the threshold score was highly specific for an injury.[14] The FMS could be used in any field or clinical setting and could predict those who will suffer an injury which could prevent training or competition.[14]

2.7 Triathlon injury prevention

The increase of triathlon participation over the past 45 years has given rise to the number of research papers reporting triathlon related overuse injuries.[11] FMS screening is therefore important for establishing the weaknesses of the triathlete in terms of low muscle strength and imbalances. [16] Sports injuries can be prevented by means of strength training, proprioception exercises, stretching activities and in combination, essentially accessible to everyone and requires limited medical staff assistance.[16] Due to the short history and duration of triathlon, it is very difficult to evaluate or even predict the long-term physical effects on triathletes.[21] It is still unknown whether resistance training exercise has any benefits for prevention of overuse injuries.

At the 2011 International Olympic Committee world conference on the prevention of injury and illness in Olympic sport, there was said to be a shift towards increased quality of research design in injury prevention and to persuade sport policy makers to support the translation of research into practice and provide practical guidelines for each sport on injury.[30] Although there is essentially evidence to support interventions in general health practice, there is little attention paid to sport science and sport injury prevention.[8]

Sport injury prevention literature has been widely published and thus the presumption that these findings and conclusions have been used for consensus on injury prevention must be questioned.[8] For an intervention program to be successful and have long lasting effects, the program has to be sustained and the desired behavior change and structural systems to support this.[8] In essence the first step to preventing further injury occurrences in triathlon is to present a consensus statement on the definition and reporting of both first-time recurrent injury.[9,10,24,27]

Challenges relating to injury prevention research are consistent among review papers and highlight some of the issues to be accounted for in this research. These challenges include inconsistencies in the definition and recording of injury, inadequate differentiation of study subjects and specialization of race distances.[30] Limitations of the research involve the self-reporting of injuries, as it is the most viable and quantifiable way of collecting data of a vast amount of athletes within a given time frame. Self-reporting however, carries with it the risk of recall bias.[3] Injury interpretation and injury site may vary between athletes.[3]

The size and scope of the triathlon injury problem and its physical health burden is relatively unknown.[30] There is a vast knowledge gap in the incidence, profile and evidence for the prevention of injuries in triathlon.[11]

2.8 Summary of the key literature and research gaps

This exercise in reviewing the pertinent literature confirms that the data regarding the prevalence of triathlon injury is limited, particularly in the South African context, and is usually postulated from injuries sustained within the individual sports.[29] To date there are no specific studies regarding the usage of FMS in a triathlon setting in South Africa. Describing FMS scores within the group of triathletes could further improve the understanding of technical ability in swimming, cycling and running. [22] Since the majority of overuse injuries occur in the lower limbs, due to cycling and running, a prevention strategy is needed to alleviate these.[1, 29] The FMS could be an effective, but underutilized tool in establishing the risk of injury in triathletes. [14, 17]

CHAPTER 3 - METHODS

3.1 Study design

A cross-sectional study design was used for the purposes of this study.

3.2 Ethics

Ethical clearance was applied for and granted by the Human Ethics Research Committee (Medical) (ethical clearance number: M150527 [see appendix E). The data was kept in a secure location and were analysed as a group and not individually to ensure confidentiality. No personal information was captured during the research process.

3.3 Participants

An invite was extended to the relevant triathlon clubs, and a sample of triathletes volunteered as participants from the Johannesburg area. The inclusion criteria included any triathlete actively training towards or competing in triathlons, aged 18-75 years old, who has been involved in triathlon competition greater than six months. The sample population included a convenient sample of 60 triathletes, with ages ranging from 25 to 57 years old. Potential participants were excluded if they had recent competition or training debilitating injuries, which did not allow them to train or race.

3.4 Procedures and Instrumentation

Data was collected over three separate testing sessions with 20 triathletes assessed per session during the South African triathlon season. Not all the participants could make one day to do the testing, so the testing was broken up into 3 separate testing' "sessions", to accommodate the participants. The South African triathlon competitive season starts in September each year and ends in April the following year. In order to ascertain the most reliable results for the FMS, the athlete needed to be actively engaged in all three disciplines of the triathlon. The pilot study showed that testing procedure did not result in excessive fatigue, however the participants were asked to refrain from usual training before testing. A questionnaire was used to determine injury status. An informed consent and information sheet of the testing procedure was filled out and signed by each participant prior to testing. (see appendix C and D). Any questions or concerns relating to the testing procedure were answered. The data collection procedure began with the athlete answering the injury questionnaire, and thereafter completing the FMS.

3.4.1 History of Injury Questionnaire

An adapted questionnaire from Burns et al.[3] was used to determine injury status (in the last six months), however validity and reliability was tested in this study, [see appendix A]. It has been used in previous research and is reliable and valid for use with triathletes.[3] The injury questionnaire also elicited the mechanism of injury for acute injuries.

3.4.2 Functional movement screen (FMS)

The FMS involves several physical tests, (see appendix B), which comprises of movements designed to test an individual's quality of fundamental movement patterns and identify functional limitations or asymmetries.[5]

The FMS includes the overhead squat, hurdle step, forward lunge, shoulder mobility, active straight leg raise (ASLR), push-up, and rotary stability.[16] Each FMS test is scored by a medical practitioner on an ordinal scale of 0-3. A score of three indicates a perfect score for the individual test, showing that the subject was able to perform the movement correctly and without pain. A score of 2 indicates that the subject could complete the movement without pain but with some level of compensation. A score of 1 is given when the subject is unable to complete the movement as instructed. A score of 0 is recorded if the subject experiences pain with any portion of the movement. A total score of 21 may be achieved in the FMS. A score of ≤14 has been shown in literature to be the point at which an athlete is vulnerable to injury.[6] Each movement was explained to the participant prior to being scored, so as to gain a full understanding of what is required. Each movement was attempted three times each, to allow the tester to observe movement pattern asymmetry's and the worst score counted.[16] A pilot study of five participants was conducted for training purposes to perform the FMS with the participants, and to streamline the research procedures (coefficient of variance for the FMS was 6.89). The FMS has shown a likelihood ratio to predict an injury in National football League players, (NFL), of 5.8 (95% CI: 2.0,18.4). A relatively high specificity (0.9; 95% CI: 0.8, 1.0) was found, but a low sensitivity was found (0.5; 95% CI:0. 3, 0.7). [14] In a group of running athletes, the interrater reliability (ICC 3,1) for the composite score was 0.928, showing excellent reliability.[20]

3.4.3 Data Analysis

Data was captured and analyzed in Microsoft Excel using Statplus Pro (USA). Descriptive, continuous data was presented as mean ± SD, while categorical data were presented as percentage. The relationship between injury (acute and chronic) and FMS was determined using Chi-square test for 2 x 2 contingency tables. Differences between male and female were tested using Student's t-test. Statistical significance will be accepted at $p < 0.05$.

CHAPTER 4 - RESULTS

4.1 Sample characteristics

The sample of participants tested comprised of 60 triathletes; the mean age of the sample was 38.8 ± 8.5 years (Table 1).

Table 1. Triathlon experience and training volume for male and female participants (n = 60)

	Total group (n = 60)	**Male (n = 28)**	**Female (n = 32)**	**P-value**
Age (years)	38.8 ± 8.54	38.0 ± 9.68	39.2 ± 7.61	0.610
Triathlon experience (years)	3.8 ± 3.10	4.0 ± 3.18	3.6 ± 3.12	0.610
Training volume per week (hours)	11.3 ± 4.68	10.5 ± 4.67	11.9 ± 4.74	0.249
Swimming (hours)	2.2 ± 1.28	2.1 ± 1.26	2.4 ± 1.30	0.284
Cycling (hours)	5.4 ± 2.65	5.0 ± 2.88	5.7 ± 2.46	0.280
Running (hours)	3.6 ± 2.16	3.4 ± 2.10	3.8 ± 1.88	0.550

Data presented as mean ± SD

4.2 Recent injury status of a selected group of Johannesburg-based triathletes

The majority of the sample reported having an injury in the previous six months (78.3% (67.6%-89.1%)). Of those that reported injuries, 31.7% (19.5%-43.8%) were acute injuries, while 48.3% (35.3%-61.3%) were overuse/chronic injuries. The figures above represent ranges of acute and chronic injuries as a percentage of male and female participants. Table 2 represents the reported number of acute and chronic injuries by the participants and the mechanism of acute injury. The majority of injuries both acute and chronic reported were sustained while running (male = 68%; female = 74%). Twenty-four of the 49 participants who sustained an injury, did sustain more than one injury during the six-month period.

Table 2. Distribution of acute and chronic injuries for male and female participants

Variable	Total group ✝81.7%	Male *51%	Female *49%	P-value
Chronic	43	21	22	0.561
Acute	30	15	15	1.000
Twist/turn	15	7	8	0.398
Collision/impact	11	5	6	0.382
Overstretch	4	3	1	0.841
Total	73	36	37	0.453

✝% of total population who reported injuries
* % of the total population with injuries
Data presented as total (acute and chronic) participants who sustained an injury in the 6 month period

Table 3. shows the distribution of injuries across the disciplines of triathlon. The majority of injuries sustained by the participants were related to running injuries. "Other" injuries were related to any activity unrelated to triathlon or as stipulated in table 3. Resistance training injuries were all experienced inside a gymnasium environment. "Other activity", injuries were also noted, however no significant values were found comparing to the group.

Table 3.Distribution of triathlon injuries among male and female participants

Cause of injury	Total (n = 49)	Male (*n = 25)	Female (*n = 24)	P-value
Cycling	13	8	5	0.797
Running	39	19	20	0.436
Resistance Training	3	2	1	0.718
Other Activity	6	4	2	0.792

Data presented as number of injuries sustained by participants during activities
* No. of the total population with injuries

Table 4. shows the distribution of injuries within the specific body location, between male and female triathletes. Total injuries were included as representation of injuries attained during the six-month period. “Other “, injuries as shown in the table applied to areas of the body not specified in table 4.

Table 4. Prevalence of injuries by body region in male versus female participants

Location of Injury	Total (n = 49)	Male (n = *25)	Female (n = *24)	p-value
Knee	14	6	8	0.297
Lower leg	11	5	6	0.382
Upper leg	10	4	6	0.264
Back	10	7	3	0.897
Hip	8	4	4	1.000
Foot	8	4	4	1.000
Ankle	6	3	3	1.000
Other injuries	6	3	3	1.000

Data presented as actual number of injuries sustained to each body part
* No. of the total population with injuries

Injuries constituted 61% of lower limb injuries sustained by male participants, and consequently female participants shared a similar lower limb injury count at 73%. Hip, back and upper limb injuries accounted for 22% of injuries in males and 27% in female participants. The most common injury for males was the back, followed by the knee. The most common injuries sustained by female participants was the knee, followed by the upper and lower leg.

4.2.1 Training hours

During the six-month period, the male participants who sustained an injury had a mean of 10.1 ± 4.8 training hours while those who did not sustain injury, 13.5 ± 2.1

hours, and there was no difference found (*p* = 0.197). Female participants who sustained injuries trained 11.9 ± 4.9 hours versus 12 ± 4.2 hours of those female participants who did not sustain an injury (*p* = 0.113).

4.3 Description of the FMS scores in these triathletes

The total scores for the FMS test are represented in Table 5. The mean composite score for all participants was 14.5 ± 2.7. The cut-off point established in literature for participants not attaining an injury is <14.

TABLE 5. Total FMS scores of the male and female participants

Variable	**Total** (n = 60)	**Male** (n = *28)	**Female** (n = *32)	**p-value**
Mean ± SD	14.5 ± 2.7	14.6 ± 2.3	14.5 ± 3.0	0.507

* No. of the total population tested
Data presented mean± SD as FMS scores

Each individual movement of the FMS is presented in Table 6. and compared between the male and female participants.

Table 6. FMS scores of male and female participants

FMS Movement	**Male (n = *28)**	**Female (n = *32)**	**p-value**
Deep squat	2.1±0.5	1.9±0.5	0.041†
Hurdle Step	1.8±0.6	2.0±0.4	0.128
Inline Lunge	2.2±0.7	2.0±0.9	0.320
Shoulder mobility	2.1±0.8	2.4±0.9	0.198
ASLR	2.3±0.8	2.5±0.8	0.212
Push-up	2.1±0.9	1.7±1.0	0.076
Rotary stability	1.9±0.6	2.0±0.5	0.372

* No. of the total population tested; ASLR = Active straight leg raise
Data presented as mean ±SD, of each FMS score for each movement
† Indicates a statistically significant difference between male and female participants

Table 7 displays the FMS scores by gender. The relationship between FMS and gender was not significant (Chi (2)= 0.38; p=0.54). Similarly, Table 8 shows that FMS score and injury are not related (Chi (2)=0.23, p=0.64).

Table 7. FMS scores above, below or equal to the injury risk threshold of 14

Variable	Total	Female	Male
Total Score >14	17	24 (55.8)	19 (44.2)
Total Score ≤14	43	8 (47.1)	9 (52.9)

*FMS = f nctional movement screen
Data presented as participants who participated in the study

4.4 Determination of the relationship of FMS scores with injury status in these athletes

Table 8. 2 x 2 contingency table for FMS scores and previous injury

	Total	Non-injured	Injured
FMS<14	17 (28.3%)	3 (17.7 %)	14 (82.4%)
FMS≥14	43 (71.7%)	10 (23.3 %)	33 (76.7%)

Data presented as count with percentage of total row counts in parentheses

CHAPTER 5 - DISCUSSION

5.1 Summary of the key findings

This study has described the prevalence of injuries in triathletes and the components of FMS scores. All three disciplines of triathlon seem to predispose the athletes to injury.[3] The long distance, time of the triathlon competition and the long duration of prior training needed to complete triathlon events, the majority of injuries were characteristically overuse. FMS did not seem to have a relationship with injury status in the study population.

5.2 The injury prevalence of a group of Johannesburg-based triathletes

The injury prevalence of the study population was 81%, sustaining an injury at an injury rate of 1.2 injuries per injured triathlete. This is higher than previous studies, with 50.4% of triathletes reporting injuries in the study by Burns et al. [3] and 47% in the study by Korkia et al. [15] Similarly Egermann et al.[7] showed that 74.8% of the triathletes tested had at any one time during the study sustained an overuse injury. The present study therefore confirms that the prevalence of injury in triathlon is high, however this is in contrast to the lay knowledge which perceives that the sport has a low prevalence of injury due to cross training which supposedly reduces the risk.[7] Nevertheless, it should be noted that the means of attaining the injury status from these various studies differed. The questionnaires of the research articles above were e-mailed to or distributed by the testers with no allowance for participants to ask questions about what was included in the questionnaire.[3, 7, 15] However the current study attempted to reduce recall bias by allowing the participant to ask questions while answering the questionnaire, explaining each injury if not understood.

The present study showed that there were differences in injury according to region. Injuries sustained to the lower limbs and reported by participants were similar to those reported by Burns et al.[3] (75%) and Gosling et al.[12] (59.5%). In the present study, knee injuries were reported by most (19%), followed by the lower leg (15%), upper leg (14%), and back (14%). Knee and lower leg injuries were the most common injury sustained by male and female participants. This is supported by other studies, reporting that the knee was the most commonly injured site in triathletes.[7, 29] Lower limb injuries were more common than upper body injuries, which may be a consequence of the higher number of injuries sustained whilst running and cycling training.

The majority of the injuries sustained were due to running, which is similar to other studies and has shown that the high prevalence of injuries sustained during running was related to the long duration of training time. [3,7,29] In the current study male and female participants sustained similar numbers of injuries while running. Running injuries can be attributed to the repetitive trauma of the lower limbs on the surface of the road, poor foot wear, biomechanical deficiencies and poor movement patterns. These are examples of extrinsic factors and may lead to overuse injuries, such as patella tendonitis, ITBS and plantar fasciitis. Burns et al. [3] confirms this information for both male and female participants as these injuries are attributed to greater training hours during running in training and competition. In comparison to the running-related injuries, cycling and weight training were associated with a lower number of injuries. Cycling injuries in triathlon are generally caused by crashes, acute injury, or lower back pain due to poor set-up and sustaining a misaligned position for long periods.[1, 7] Swimming similarly does not seem to result in injury in triathletes. Of the acute injuries sustained most of the participants either had a twist or turn incident (19%), or a collision/impact incident (15%). Male and female injury characteristics had similar variances in acute versus chronic injuries. Many of these acute incidences were due to bike mishandling and crashes.

5.3 Description of the FMS scores of a group of Johannesburg triathletes

There are no known studies performed using triathletes and the FMS. To date, FMS studies have involved the military, NFL players, runners and physically active students. [14, 17, 19, 20] The results show, that a low composite score for the triathletes was attained compared to other studies.[14] Lower composite scores (of less than 14) are associated with serious injury in football players and predispose, athletes to injury. [14] Other studies such as by Letafatkar et al. [17] observed a composite score of 16.5 for physically active students and Kiesel et al. [14] reported a composite score of 16.9 for American football players. Loudon et al. [20] tested a group of runners, which is closely linked to triathlon, and reported a composite score of 16.4. Loudon et al. [20]

attributed a low composite score for running due to the age of the athletes, stating that runners over the age of 40 were more likely to sustain an injury while running, due to the tests requiring a certain level of balance and strength.

The study by Loudon et al. [20] in runners was the most similar in triathlete related training, and established that although their cohort was injury free prior to testing, 30% of their participants scored below the FMS score of 14. In the current study, similar scores were observed (48% of participants scored below or equal to an FMS score of 14). A number of the participants received a score of 14 or less for the FMS, which may indicate a higher risk of injury. Letafatkar et al. [17] reported that 27% of physically active students, Kiesel et al. [14] 22% of NFL players and 30% found by Loudon et al. [20] in runners scored less than 14 on the FMS test.

A significant difference was noted between male and female participants carrying out the deep squat of the FMS test in this study. This finding differed from other literature. Letafatkar et al. [17] found that, male participants on average scored worse at the deep squat, yet was not statistically significant. Letafatkar et al. [17] reported that males scored higher for trunk stability push-up, rotary stability and inline lunge score and lower for the deep squat, hurdle step, shoulder mobility and ASLR score than females. Loudon et al. [20] had similar findings where female runners scored higher than male runners in the mobility and flexibility tests as shown in the current study. This may be due to female participants eliciting better scores during the flexibility and mobility test components. Loudon et al. [20] confirm these findings in research done on a group of running athletes. In contrast, Letafatkar et al. [17] showed significant differences between scores for male and female participants in the shoulder mobility, ASLR, trunk stability push-up and rotary stability components.

5.4 The relationship of FMS scores with previous injury of a group of Johannesburg triathletes

There are no known published findings to substantiate previous injury with FMS scores of triathletes. It was the hypothesis of this study that there is a relationship between FMS and injury. However, no relationships were found between the FMS scores of triathletes and previous injury. In the current study, there were no statistical significances found between the FMS score and injured versus non-injured groups. Age may have an impact on the current study and could be a confounding factor, as the varying age range of the participants was 38.8 ±8.5 years. In contrast, Letafatkar et al. [17] found a statistical difference between pre-season FMS scores of the injured and non-injured groups. This could be attributed to the nature of the sports in which the study was carried out which involved short bursts of speed and cutting or side stepping movements.[17] Letafatkar et al.'s findings are also in contrast to the current study. This may be due to the longer running distances at moderate speeds that the participant's of this study incorporate in their training. Research studies have found that high weekly training loads for running specifically, increases the risk of attaining an overuse injury.[1, 6- 7] Kiesel et al. [14] established that National Football League football players, with dysfunctional movement patterns and/or pattern asymmetry are more likely to suffer an injury resulting in the player not being able to participate in training or competition.

Knapik et al. [19] state that injury risk is greater for both male and female Coast Guard Cadets with lower FMS scores. The training done by the Coast Guard Cadets involves short duration, high intensity bouts of exercise, again differing from the time intensive long duration training of triathletes in the current study.[19] Tee et al. [27] found in a group of rugby players that the FMS composite score was predictive of severe non-contact injury, but did not relate to the current study due to the nature of training and training regimes. Rugby union is a full-contact sport with intermittent bouts of short duration, high intensity efforts in which players collide at high speed.[27]

5.5 Limitations

This study has a few limitations worth describing. Firstly, there is a difficulty of self-reporting of injuries and thus the questionnaire aimed to limit the options of recall bias. Interpretation of injury site and injury specification may vary between participants although the research provided information on participant requirements around injury feedback.[3, 7] Secondly, the cross-sectional nature of the study and collecting data could not allow for an observable change in triathlete behavior regarding injury status or improvement. This was due to a single day testing with no follow-up of the participants post-testing.

5.6 Conclusion

In the present study, injury prevalence was high, and the participants had FMS scores above and below the cut off point of 14. However, no relationships were found between injury and composite FMS score. This suggests that FMS in isolation is not a good predictor of injury in triathletes, however in combination with other diagnostic tools, FMS may prove to be useful. Further investigations into the use of other accessible tools are necessary before any conclusive decisions around prevention of injuries can be determined in the triathlete population.

5.7 Future Research Recommendations

- Although the sample used in this study is representative of triathletes in Gauteng, further study should include triathletes from other South African regions to understand the relationship of injury with FMS in a representative South African population.
- Pre-season and in-season injury status needs to be distinguished in order to understand the differences in hours trained and different strains put on the body.
- The relatively low FMS scores of the study population in the present study could not be compared with other athletic populations. Therefore, further studies of FMS in other South African sporting populations are needed for comparison across sporting populations.

5.8 Clinical implications

The FMS has up until now been used to establish injury risk in other sporting codes and disciplines, and could be used in endurance sports such as triathlon to ascertain movement pattern weaknesses in the prevention of injury. The current study has found that the FMS cannot be used in isolation for testing triathletes, in determining injury incidence. The FMS could be used to determine movement pattern weaknesses, which could be aligned with the minimal score required for not attaining an injury.

References:

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

2. Bales, J. and Bales, K. (2012). Swimming overuse injuries associated with triathlon training, *Sports Medicine and Arthroscopy Review*, 20(4): 196–199.

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

4. Conlon, J.K., (2013). The Relationship Between the Functional Movement Screen™ and Countermovement Jump Height, *University of Wisconsin Milwaukee Digital Commons*, pp. 213: 1-157

5. Cook, G., Burton, L. and Hoogenboom, B. (2006). 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.

6. Doma, K. and Deakin, G.B. (2012). The acute effects intensity and volume of strength training on running performance, *European Journal of Sport Science*, 14(2): 1–9.

7. Egermann, M., Brocai, D., Lill, C., et al. (2003). Analysis of injuries in long-distance triathletes, *International Journal of Sports Medicine*, 24(4): 271–276.

8. Finch, C.F. (2011). No longer lost in translation: the art and science of sports injury prevention implementation research, *British Journal of Sports Medicine*, 45(16): 1253–1257.

9. Fuller, C.W., Molloy, M.G., Bagate, C., et al. (2007). Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union, *British Journal of Sports Medicine*, 41(5): 328–331.

10. Fuller, C.W., Ekstrand, J., Junge, A., et al. (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries, *Scandinavian Journal of Medicine & Science in Sports*, 16(2): 83–92.

11. 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.

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

13. Gulbin, J. and Gaffney, P.T. (1999). Ultra endurance triathlon participation: typical race preparation of lower level triathletes, *The Journal of Sports Medicine and Physical Fitness*, 39(1): 12–15.

14. Kiesel, K.B., Butler, R.J. and Plisky, P.J. (2014). Prediction of injury by limited and asymmetrical fundamental movement patterns in American football players, *Journal of Sport Rehabilitation*, 23(2): 88-94.

15. 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.

16. Lauersen, J.B., Bertelsen, D.M. and Andersen, L.B. (2013). The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials, *British Journal of Sports Medicine*. 48(11): 871-7.

17. Letafatkar, A., Hadadnezhad, M., Shojaedin, S., et al. (2014). Relationship between functional movement screening score and history of injury, *International Journal of Sports Physical Therapy*, 9(1): 21-27.

18. Levy, C., Kolin, E. and Berson, B. (1986). The effect of cross training on injury incidence, duration, and severity (part 2), *Sports Medicine Clinic Forum*, 3(2): 1–8.

19. Lisman, P., O'Connor, F.G., Deuster, P.A., et al. (2013). Functional movement screen and aerobic fitness predict injuries in military training, *Medicine and Science in Sports and Exercise*, 45(4): 636–643.

20. Loudon, J.K., Parkerson-Mitchell, A.J., Hildebrand, L.D., et al. (2014). Functional Movement Screen Scores in a Group of Running Athletes, *The Journal of Strength & Conditioning Research*, 28(4): 909–913.

21. Manninen, J. and Kallinen, M. (1996). Low back pain and other overuse injuries in a group of Japanese triathletes, *British Journal of Sports Medicine*, 30(2): 134–139.

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

23. Morouço, P.G., Marinho, D.A., Amaro, N.M., et al. (2012). Effects of dry-land strength training on swimming performance: a brief review, *Journal of Human Sport & Exercise*, 7(2): 553-559.

24. Orchard, J.W., Newman, D., Stretch, R., et al. (2005). Methods for injury surveillance in international cricket, *British Journal of Sports Medicine*, 39(4): 22–22.

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

26. Perrin, D.H., Shultz, S.J., Houglum, P.A., et al. (2005). Examination of Musculoskeletal athletic injuries (athletic training education series), *2nd edn. Champaign, IL: Human Kinetics Publishers*, pp. 653-672

27. Tee, J.C., Klingbiel, J.F.G., Collins, R., et al. (2016). Preseason functional movement screen component tests predict severe contact injuries in professional rugby union players, *The Journal of Strength and Conditioning Research*, 30(11): 3194-3203

28. van Mechelen, W., Hlobil, H. and Kemper, H.C. (1992). Incidence, severity, etiology and prevention of sports injuries, *Sports Medicine*, 14(2): 82–99.

29. Villavicencio, A.T., Burneikienë, S., Hernández, T.D., et al. (2006). Back and neck pain in triathletes, *Neurosurgical Focus*, 21(4): 1–7.

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

31. Vleck, V., Millet, G.P. and Alves, F.B. (2013). Triathlon Injury-An update. *Schweizerische Zeitschrift für Sportmedizin & Sporttraumatologie*, 61(3): 10-16.

32. Wilk, B.R., Fisher, K.L. and Rangelli, D. (1995). The incidence of musculoskeletal injuries in an amateur triathlete racing club, *Journal of Orthopaedic & Sports Physical Therapy*, 22(3): 108–112.

APPENDICES

Appendix A:

History of injury questionnaire

Questionnaire initial Date: Subject no: _______

Name__________________________

Age __________

Gender_________

Years in Triathlon____________

On average, how many hours per week do you train? Running ____________

Cycling ____________

Swimming ____________

Number of injuries in the past 6 months? _____________

Injury is defined as any bone or soft tissue problem causing rest from usual training in any of the three disciplines of triathlon for at least one day, a decrease in training distance, taking of medicine or seeking medical aid.

Where was the injury/injuries located?

Foot	□	number: _______
Ankle	□	number: _______
Lower leg	□	number: _______
Knee	□	number: _______
Upper leg	□	number: _______
Hip	□	number: _______
Back	□	number: _______
Other	□	number: _______

What sport did the injury occur in?

Running	□	Injury site: ____________
Cycling	□	Injury site: ____________
Swimming	□	Injury site: ____________
Weights	□	Injury site: ____________
Other	□	Injury site: ____________

How did the injury occur?

Acute:	Twist/turn	□
	Collision/impact	□
	Overstretch	□
Chronic: Overuse		□

Do you warm up/cool down? Always/occasionally/never

Appendix B:

Several physical tests of the Functional Movement Screen


1A: Deep squat

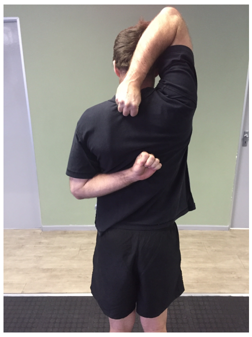

1B: Deep Squat


2A: Hurdle Step


2B: Hurdle Step


3A: Inline Lunge


3B: Inline Lunge


4A:Shoulder Mobility


5A: ASLR


5B: ASLR


6A: Push-up


6B: Push-up


7A: Rotary Stability


7B: Rotary Stability

Appendix C:

Information Sheet

Good day, my name is Rodger Trent. I am a Biokinetics masters student at the University of the Witwatersrand. We are currently undertaking a study to investigate the functional movement screen score and injury status of Johannesburg triathletes. I would like to invite you to participate in this research study. Your participation is voluntary, and you are free to withdraw from the study at any stage.

The aim of this project is to conduct a seven stage Functional Movement Screen in order to establish fundamental movement pattern scores, and a questionnaire pertaining to previous injury history within triathlon. The testing involves a questionnaire to ask you about your history of injury. We will then perform the Functional movement screen, which is 7 movements, which are scored out of a maximum of 3 units depending on correct form.

The testing session should take approximately 30-45 minutes. Testing will take place at the Centre for Exercise Science and Sports Medicine, Wits Education Campus, or at your local triathlon club.

There are no direct benefits to participating in this project. However, if you were to attain a low score on the FMS, notification may be given to the athlete regarding the issue to make safe decisions regarding your triathlon training. If you are currently injured, and cannot complete the FMS you will be excluded from the study. There are no risks to participating in the study.

The results of the study will be used for research purposes, however all your data will remain anonymous and all information provided to us will be confidential.

For further information regarding the ethics approval for this study or feel that your rights have been violated, please contact the HREC chairman Professor Peter Cleaton-Jones on 011 717 2635 or email peter.cleaton-jones@wits.ac.za

For further information regarding the study, or if you have any questions, please feel free to contact me on 011 792 3994 or email me at rodgertentbio@gmail.com

Appendix D:

Research Informed Consent

I____________________, volunteer to participate in a research project conducted by Rodger Trent from The University of the Witwatersrand. I understand that the research is designed to gather information about past injury incidence and test the participant using the FMS protocol. I will be one of approximately 60 people being questioned and tested for the research.

1. My participation in this project is voluntary. I understand that I will not be paid for my participation. I may withdraw and discontinue participation at any time without penalty.

2. Participation involves filling out a questionnaire on previous 6-month injury occurrence during racing and training. Being tested using the FMS protocol by two researchers registered as Biokineticists with HPCSA and that have undergone training on order to become proficient in utilising and effecting the FMS. The questionnaire and FMS testing will last approximately 30-45 minutes. Results will be documented during the FMS testing procedure.

3. I understand that this research study has been reviewed and approved by the ethics committee of The University of the Witwatersrand for Studies Involving Human Subjects: Therapeutic Sciences Committee at The University of the Witwatersrand. For research problems or questions regarding subjects, the Institutional Review Board may be contacted through the Therapeutic Sciences School.

4. I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.

5. I understand that the researcher will not identify me by name in any reports using information obtained from this, and that my confidentiality as a participant in this study will remain secure. Subsequent uses of records and data will be subject to standard data use policies which protect the anonymity of individuals and institutions.

6. I further agree that I or any of my relatives, executor, administrator or legal representative will not impose any claim against the researcher or the University of Witwatersrand except in case of negligence or malpractice by the researcher.

I, ____________________ understand all the questions of the questionnaire and accept FMS protocol. I hereby give my permission and consent to be evaluated by the questionnaire and agree to be tested using the FMS protocol.

Remember the following:

1. *Participation is voluntary.*
2. *Ask questions during the evaluation to eliminate any misunderstandings concerning the procedures, possible risk factors, factors that can cause discomfort, any possible benefits or side effects that can occur during the assessment and the exercise programme.*
3. *Please inform the researcher immediately if you are experiencing any pain and discomfort during the evaluation.*

PARTICIPANT:

Printed Name Signature / Mark or Thumbprint Date and Time

RESEARCHER:
I herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

Printed Name **Signature** **Date and Time**

Appendix E:

Ethical clearance certificate

R14/49 Rodger Trent

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M150527

NAME: (Principal Investigator)	Rodger Trent
DEPARTMENT:	Centre for Exercise and Sports medicine Triahlon Club
PROJECT TITLE:	Cross Sectional Study Investigating the Functional Movement Screen Score and Injury Status of Triathletes
DATE CONSIDERED:	29 May 2015
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Marc Booysen
APPROVED BY:	Professor P Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	06/07/2015

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

DECLARATION OF INVESTIGATORS

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

Principal ~~Investigator~~ Signature   Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES