

**INJURY RISK ASSESSMENT AND THE INCIDENCE
OF MUSCULO-SKELETAL INJURIES IN RECREATIONAL LONG-
DISTANCE RUNNERS OVER A 3-MONTH TRAINING PERIOD**

by
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DECLARATION

Injury risk assessment and the incidence of musculo-skeletal injuries in recreational long-distance runners over a 3-month training period.

I, **TANYA SMITH**, hereby:

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ABBREVIATIONS

ACLR	Anterior Cruciate Ligament Reconstruction
AE's	Athletic Exposure's
ASLR	Active Straight Leg Raise
BMI	Body Mass Index
cm	Centimetre
DS	Deep Squat
FMS	Functional Movement Screen
FPI	Foot Posture Index
h	Hours
HS	Hurdle Step
ILL	In-line Lunge
kg/m ²	Kilogram per square meter
km	Kilometre
mm	Millimetre
OTP	Observational Training Period
RRI	Running Related Injury
RS	Rotary Stability
SM	Shoulder Mobility
TSPU	Trunk Stability Push-Up
S & R	Sit and Reach
VJ	Vertical Jump

CHAPTER 1

Review of the Literature

1.1 Introduction and Background

Running, as a recreational sport, has grown significantly in the last 50 years (Saragiotto et al., 2014; Fields et al., 2010; Fredericson & Misra, 2007; Paluska, 2005). During the 1960's, most major marathon events around the world had fewer than 1000 competitors, whereas today, more than 30 000 competitors register for popular marathons each year (Fields et al., 2010). Jacobson and Etling, 2016 reported that during 2014, a record high of 550 600 runners completed a marathon in the United States of America. In 2015, 509 000 runners completed a marathon. For the first time in history, this is a decline in the numbers from the previous year. In spite of this decline, this is still a 280% increase from the number of runners completing a marathon in 1980 (Jacobson and Etling, 2016). The steep increase in the number of participants can partially be attributed to the inclusion of female athletes in the field of running. It wasn't until 1972 before women were officially recognized and welcomed into the sport of marathon running. 1973 saw the first women's only marathon in Waldniel, West Germany, starting with less than 40 competitors.

Since the 1970's there has been a significant increase in the number of people participating in running as a recreational sporting activity. Approximately 6% of the English population engage in running at least once per week and 7% of the Dutch population showed interest to take up running as a recreational sport (Hespanhol Jnr et al., 2016) Van Poppel and colleagues (2016) indicated that 36% of the European population between the ages of 15 and 65 years run recreationally. Van Hespén and co-authors (2012) adds to the numbers by reporting that 1.9 million people participated in running activities across the Netherlands in 2012. According to the Danish Institute of

Sports Studies, 31% of the Danish adult population participates in recreational running (Buch & Pilgaard, 2013). South Africa is also known for two of the world's most iconic ultra-marathons, the Two Oceans Marathon (approximately 11 000 participants per year) and the Comrades Marathon (approximately 20 000 participants per year).

In recent years, a large body of evidence has accumulated, providing unequivocal support for the role for increased participation in physical activity in the prevention of premature mortality, disability and the development of early onset cardiovascular and metabolic diseases, and all-cause mortality (Samitz et al., 2011). Health awareness campaigns focusing on chronic disease prevention have led to many people participating in running as a way of maintaining their health and wellbeing (Fields et al., 2010; Koplan et al., 1995; Fredericson & Misra, 2007).

Furthermore, physical activity has been associated with a better quality of life in older adults. Chakravarty and colleagues (2008) found that adults aged 50 years and older who participated in recreational running or who previously spent at least 1 month running consistently, were healthier, stronger and mentally more able than their inactive counterparts. The morbidity and mortality outcomes were also lower in the group of runners compared to the non-runners group at each time measure.

The major challenge with running, as either competitive or recreational sport, is the high rate of musculoskeletal injuries. Most recent statistics reveal that up to 70% of runners are plagued by injuries on a seasonal basis (Malisoux et al., 2013). The current rate of injuries among runners varies greatly. Prevalence's range between 18.2% and 92.4%, and incidence rates of running related injuries (RRI) range between 6.8 to 59

injuries per 1000 hours (h) of running (Saragiotto et al., 2014; Lopes et al., 2012; van Middelkoop et al., 2008; van Gent et al., 2007; Hreljac, 2004; Hreljac, 2005; Hreljac et al., 2000;).

In one study of 1.9 million Dutch citizens engaged in running, 610 000 injuries were reported (van Hespden et al., 2012). This amounts to one injury for every 3 runners. The most recent statistics reported by Malisoux and colleagues (2015) found that injury rates amongst runners were 32.3%, with an over-all injury incidence of 6.68 injuries/1000h of running.

1.2 Rate of Injury Incidence

Running related injury prevalence vary between 1.4% and 94.4% among different study reports (Hespanhol Jnr et al., 2016b). Kluitenberg and co-authors (2015b) use the term incidence density – this refers to the amount of RRIs sustained per 1000 hours of running. By using incidence density as a reporting method, injury incidence can be compared uniformly across studies with different populations and varying follow up times. Vidabæck and colleagues (2015) confirmed the use of injury per 1000h saying it is the most effective method to quantify the incidence of running injuries, since the risk for injury is directly related to the time spent running. Rauh and colleagues (2006) reported running injuries as an incidence per 1000 Athletic Exposures (AEs). This refers to each incidence of injury, reported against the amount of time or hours of either training or competition to which an athlete is exposed. Ryan and colleagues (2006) highlighted this individual methodology wherein Rauh and colleagues (2006) expressed injury incidence as 1000AE's. Ryan and colleagues (2006) reported that no

other reports used the 1000AE's format and expressing injury incidence as a unit per 1000h of running is a more unified expression of injury incidence (Ryan et al., 2006).

Analysing 13 original articles, Vidabæk and colleagues (2015) summarized the range of RRI incidence to 2.5 - 33.0 injuries per 1000h of running among a mixture of runners. Kluitenberg and colleagues (2015b) investigated RRI's and the number of medical-attended-injuries during running events and reported a range of RRI incidence of 3.2% in cross-country runners to 84.9% in novice runners. Kluitenberg and co-authors (2015b) reported a RRI incidence of 10.9% among 1696 novice runners during a 6-week guided training program. The highest injury incidence was reported during week 2 (53.4/1000h) and week 3 (44/1000h) of the training program. The overall injury incidence of 27.5 injuries/1000h of running by Kluitenberg and associates (2015) was lower compared to investigations by Buist and co-authors(2007), Van Ginckel and associates (2009) and Nielsen and colleagues (2013) who found injury incidence among novice runners to be between 16.0% and 53.5%.

Cross-country, marathon and ultra-marathon running groups have all been studied for the incidence of running related injuries. The reported injury incidence rate among these populations is diverse. Rauh and co-authors (2006) reported 316 running related injuries among 162 high school cross-country runners during a 11-week season. The total injury incidence was 17.0 injuries/1000 athletic exposures (AEs). Girls (19.6/1000 AEs) had a much higher injury incidence rate than boys (15.0/1000 AEs). Bennett and colleagues (2012) reported an injury incidence of 44.1% among a group of competitive colleague cross-country runners, with similar frequencies between genders. Reinking and co-authors (2010) reported a lower leg injury incidence of 48% among high school

cross-country runners. Contradictory to other investigations they reported that more men than women cross-country runners were injured.

Longer distances were investigated by van Poppel and colleagues (2016). They compared the injury incidence between half and full marathon runners. Two hundred and nine new injuries were reported from 147 runners after the half marathon compared to 226 new injuries from 1000 runners after the full marathon. The overall injury rates among recreational half-marathon runners was 23.1% and among full-marathon runners 22.7%, suggesting no significant difference.

Fallon (1996) investigated the incidence of RRIs in ultramarathon runners during the 1990 Sydney to Melbourne run, covering 1005km over 8.5 days. Thirty-two runners started the race but only 19 finished within the cut-off time. Twenty-nine runners reported 64 injuries over the course of the race. Seventy two percent of runners sustained at least one injury that was severe enough to have a significant effect on their performance.

Kluitenberg and associates (2015) concludes that literature on recreational running and the factors that influence the incidence of injury are scarce, although recreational runners are continually described as the largest pooled group of runners, globally. A large variation exists in the methods and follow-up time used to express injury incidence. This variation contributes to the difficulty of combining and comparing injury rates across studies suggestive of evidence indicating running related injury incidence (van Gent et al., 2007; Vidabæck et al., 2015; Kluitenberg et al., 2015; Saragiotto et al., 2014; Lopes et al., 2012).

1.3 Type of Running Related Injuries

There have been several attempts to summarise the literature on the types of running-related injuries (RRI). Malisoux and colleagues (2015) assign the presence of RRIs to the accumulation of micro-traumatic injuries through the repetitive nature of running. According to their report recreational runners sustain a greater amount of injuries to the lower limbs in comparison to the upper-body. Medial tibial stress syndrome, Achilles tendinopathy and plantar fasciitis are the highlighted lower limb injuries reported in this investigation. Kluitenberg and co-authors (2015) recently published a systematic review and meta-analysis wherein they discussed the different injury proportions among different running populations. They too had difficulty expressing injury incidence using only one metric, as the available literature makes use of varying units when reporting injury incidence. Nonetheless, they reported site-specific time loss-injury proportions, indicating that track sprinters lost the most training time due to injuries incurred on the upper leg, hip and pelvis.

Novice runners mostly sustained injuries to the lower leg and knee, recreational runners also sustained the most injuries to the knee and lower leg however to a lesser degree than novice runners. Cross-country and marathon runners had a higher incidence of time loss due to lower leg injuries than recreational runners, but experienced less time loss due to knee injuries. Foot injuries were the biggest reason for time loss among marathon runners, but ankle injuries were the highest among cross-country runners. In their concluding statements, they said that among the available literature, there is comparatively less research concerning RRI in recreational runners.

1.3.1 Running Related Injuries in Novice and Recreational Runners

Van der Worp and colleagues (2016) reported the knee joint and thigh as the most affected sites of injury among recreational female runners participating in a 10km distance and the hip, groin and lower leg to be most implicated among those participating in the 5km distance. Kluitenberg and associates (2015) reported the knee (38.4%) as the most frequent injured joint, followed by musculoskeletal injuries to the gastrocnemius (20.0%), shin (13.0%) and the Achilles tendon (13.0%) during a 6 week follow up period among 1696 novice runners. Van Ginckel and co-authors (2009) also found the knee and lower leg to be the most prevalent site of injury among novice runners. Hespanhol and associates (2016) indicated that most of the reported injuries consisted of tendinopathies and muscle injuries, also identifying the knee and lower limb to be the most affected areas. They reported a previous injury prevalence of 55.1% and a new injury prevalence of 27% among their sample group, but went on to say that none of the lower limb characteristics that they investigated could be associated with the injury incidence for running related injuries. Hespanhol Jnr and associates (2016) looked at RRIs over an 18 week follow up among a cohort of 53 runners, participating in an organized running program. They found that overuse injuries were more prominent than acute injuries and that Achilles tendon injuries and knee pain was the most reported injuries among this group of novice runners. Lumbar spine pain, plantar fasciitis and shin splints were also frequently reported.

1.3.2 Running Related Injuries in Marathon and Ultra Marathon Runners

The most frequent injuries during ultra-marathon running have been identified as Achilles tendinopathy, patello-femoral pain syndrome and iliotibial band syndrome (Lopes et al., 2012). Buist and colleagues (2007) found that 50% - 75% of injuries in

runners can be attributed to overuse and found toward the knee and the lower leg. Van Middelkoop and co-authors (2008) reported similar sites as the most prominent area of injury during a marathon, concluding that the calf (33.9%), knee (27.1%) and thigh (17.8%) were the most affected areas among 694 male runners completing a marathon. However, in this study, they not only reported on RRI occurring during an event, but on running related injuries are also sustained through the long bouts of training. One month before the marathon, participants reported injuries to the knee (29.6%), calf (20.4%) and foot (13.9%). The overall injury incidence during the marathon was 3.2 injuries/ 1000h of running.

Data collected during the 1990 Sydney to Melbourne ultramarathon of 1005km revealed that 31.2% of injuries incurred through the course of the event were at the knee, 28.1% of injuries at the ankle, 14.0% on the lower leg and 10.9% on the upper leg. In spite of the different regional distribution of injuries – 43.7% of all the diagnosed injuries were tendinitis and 15.6% were retropatellar pain syndrome (Fallon, 1996). This author contributed the high incidence of tendinitis to the gait change in the runners over the course of the event, saying that most runners changed their stride pattern into a shuffle as the distance progressed. The smaller range of plantar- and dorsiflexion in the ankle contributed to a smaller range of movement for the tendons in the ankle and the calf complex, exposing sections of the tendons to greater volume of constant friction over the time of the event.

1.3.3 Acute Injuries vs Recurring and Chronic injuries

Acute running injuries are believed to be of lesser frequency but often greater severity when they occur. Compared to overuse injuries-long distance running is considered one

of the most incidental sports. The high rate of overuse injuries among runners are often attributed to a healing discrepancy of the connective tissue and the exposure to running volumes (van der Worp et al., 2015). For Example, Malisoux and colleagues (2015) found that 13.8% of injuries reported were acute muscle tears. From all the injuries sustained, 32.9% of the injuries were recurrent. Muscles (44.9%) and tendons (41.9%) were the most affected anatomical structures by RRIs and these were mainly present on the lower leg (22.7%), knee (22.2%) and thigh (20.9%). Van Poppel and colleagues (2016) contribute to these findings, as they had similar results during a study wherein 570 athletes completed either a half- or full-marathon. 18.7% of all the newly reported injuries involved the knee joint.

Ristolainen and colleagues (2010) reported that more than half of the elite Finnish long-distance runners reported injuries to the lower limbs. Twenty nine percent were acute injuries that accumulated to the foot, ankle and knee. Fifty nine percent of the injuries were overuse injuries sustained to the foot and ankle. Van Middelkoop and others (2008) reported that there was an acute injury incidence of 18.2% during the Rotterdam Marathon Study (2008). Van Poppel and colleagues (2014) investigated the incidence and cause of injury among recreational runners competing in a 5km, 10km, 15km and 21km running race. There were a total of 575 participants who participated in the study. One hundred and eight athletes reported sustaining at least one injury during the event, 45 of these injuries were sustained for the first time, accounting for an acute injury incidence of 7.8%, while recurring injuries accounted for 10.9% of the injuries sustained during the event. They found that the sites of most injuries differed between the shorter and longer distances. Injury to the knee (18.5%), calf (16.3%) and Achilles tendon was mostly reported by participants in the 5km and 10km distances, while

runners completing 15km and 21km distances reported injury to the knee (19.7%), hip (15.2%) and thigh (13.6%) as most prevalent. During a 12 week follow-up period Van der Worp and co-authors (2016) investigated running related injuries among female runners completing a 5km and 10km running race. There was a total injury incidence of 26.1 % (109 injuries from 417 runners), 25.4% (48) of the injuries were reported by the 5km runners (n=189). Six runners (12.5%) reported 2 injuries, but only 4 (66.7%) of the six runners reported a recurring injury. Of the total of 184 runners who completed the 10km race, 49 (26.6%) reported a running related injury. Twenty percent (10) of the 10km runners reported 2 injuries, but only 3 (30.0%) of the 10 runners reported a recurring injury. Hespanhol Junior and associates (2016) reported 85.4% overuse injuries and 14.6% acute injuries among novice runners participating in an 18-week follow-up training program.

From these studies, we can conclude that acute injuries are not uncommon among recreational runners participating in an event. Care should be taken to interpret a secondary injury as a new injury. Runners often mistake old injuries as new ones, due to a behavioural tendency of underestimating the degree of the initial injury and describing it as insignificant but adapting their training regime for a few weeks to mask the discomfort. However, when they participate in an event and the discomfort or pain, similar to the previous injury returns – this is sometimes reported as a new injury.

1.4 Risk Factors for Developing Running Related Injuries

Risk factors related to running injuries have been well researched in the past, but the heterogeneity of the previously cited studies adds to a complex body of evidence. Thus, there is no clear overview on what are currently the most important risk factors related

to running injuries (van Poppel et al., 2016). To date the only risk factor that has consensus among researchers for future injury, is previous injury within the last 12 months (Saragiotto et al., 2014; Pileggi et al., 2010; Buist et al., 2009; Lun et al., 2004; Fields et al., 1990). Malisoux and colleagues (2015) argue that purely identifying injury risk factors will not contribute to the prevention of injury unless the underlying cause of the risk has been addressed. Characteristics such as an increased age, increased BMI ($>25\text{kg.m}^2$) or the incidence of previous injury are the most prominent risk factors. The same study determined that modifiable risk factors, namely, weekly volume ($<2\text{h}$) and frequency (<2 x per week) contributed to increased risk of injury.

Other studies contradicted the latter finding by suggesting that increased volume and frequency of running has a protective effect against injuries (Rasmussen et al., 2013). However, some of the earlier research reported that excessive weekly mileage ($> 64\text{km}$) is an increased risk for lower extremity injuries (Macera et al., 1989). Van Gent and colleagues (2014) suggested that age, body mass index, interchangeable use of running shoes and type of running surfaces are all possible risk factors for RRI's. It is clear that the identification of the most important risk factors for RRI's are still debatable.

1.4.1 Internal Risk Factors

Internal risk factors are intrinsic characteristics that increase susceptibility for injury. Windt and Gabbett (2016) differentiate between modifiable and non-modifiable internal risk factors. They address modifiable risk factors as those physical characteristics that can change due to the adaptation and conditioning of physical exercise e.g. body composition and non-modifiable risk factors are characteristics which we cannot change e.g. age and gender.

1.4.1.1 Body Composition

Body composition is still a highly debated potential risk factor among long distance runners. Body Mass Index (BMI) and fat percentage values are universally used as metric units to compare runner's body composition. Novice and recreational runners are often of heavier weight as these groups of runners may only be starting out running or competing in running races as a social event. Irrespective of this, body composition still affects the participants. BMI as an overall risk factor for sustaining a RRI injury has been discounted in some studies (van der Worp et al., 2015) but found to be a potential risk factor, for example, in sustaining lower back injuries among female runners (Wen et al., 1997).

1.4.1.2 Age

There is conflicting evidence regarding the contribution of age as a risk factor for sustaining a running related injury. Van der Worp and co-authors (2015) found that a younger age is protective for overall overuse injuries and that older age place runners at a greater risk of sustaining, for example, injuries to the hamstrings and mid-portion Achilles tendinopathy. However, they suggest that the available research is of poor quality and therefore, should be interpreted with caution. Confirmatory evidence was reported by Mclean and colleagues (2006) in a study in which master runners (≥ 40 years of age) had a significantly higher injury incidence rate than younger runners, and that the injuries varied greatly from one another. Master runners mostly reported fasciitis and tendinopathies, whereas younger runners reported Iliotibial Band Syndrome, some fasciitis and Medial Tibial Stress Syndrome.

1.4.1.3 Gender

Van Der Worp and co-authors (2015) indicated that the risk profiles for running related injuries are different for male and female runners. There is limited evidence for this as there are only a few published studies investigating only female runners. Studies support the notion that recreational female runners have a different injury risk profile than their male counterparts. They have indicated that a higher BMI, greater navicular drop, less running experience and earlier (younger) involvement in activities without axial pressure are factors that contribute to the higher risk of sustaining a RRI among female runners (Buist et al., 2010a; Buist et al., 2010b). Adding to this argument Taunton and colleagues (2003) associated running frequency of once per week, being older than 50 years of age and using running shoes that are 4 to 6 months old, with greater risk of injury among female runners. Van der Worp and co-authors (2016) found that female recreational runners participating mainly in 5km and 10km races have an increased risk for sustaining a RRI when they run more than 30km a week, have a higher BMI or had a previous injury. However, Malisoux and colleagues (2014) have found these risk factors for RRI, irrespective of gender.

1.4.1.4 Previous Injury

Two recent reviews came to the same conclusion, i.e. previous injury in the last 12 months is the best predictive risk factor for future injury (Saragiotto et al., 2014; Hespanhol Jnr et al., 2013). Saragiotto and associates (2014) published a review article including only prospective cohort studies that investigated risk factors leading to running injuries in general. Previous injury, mostly in the past 12 months, was the most frequently discussed risk factor among the included studies and found to be the main contributing factor playing a role in the development of new running related injuries.

Sixty two percent (5/8) of the articles they reviewed found a positive correlation of previous injury as a risk for future injury. They also referred to the study by Fuller and colleagues (2007); who concluded that among all sporting codes there is a known association between previous injuries and athletes acquiring a new injury or an injury of similar nature, but that tends to have a worse prognosis. Powell and associates (1986) and Rasmussen and co-authors (2013) attribute this association between previous injuries and new injuries to lack of sufficient rehabilitation and healing time for the initial injury. Most running injuries were attributed to overuse, referring to a continual exposure of unmanageable loads, leading to micro-trauma within the musculoskeletal system. If the loads are continually repeated through training, there is a high probability that an already compromised skeletal system will cause a related injury, but which is often reported as new.

1.4.2 External Risk Factors for Running Related Injuries

“Running as an exercise can strengthen the limbs, develop the lungs, exercise the will and promote the circulation of the blood. The clothing should be light, the head bare and the neck uncovered. Care must be taken not to overdo.” – Scientific American, 1883.

There is reason to believe, with research to support – that excessive mileage, done at high speed – relative to each individual – without significant rest days during one week of training, and accumulating to too much running during a year-round cycle, are strong contributing factors that lead to the development of injuries among runners. Unaccustomed interval training, hill sprints, the wrong shoes for a specific foot type

and over exposure to running on concrete also adds to the list of external risk factors that lead to injuries among runners (Fields et al., 2010).

1.4.2.1 Training Variables

Nielsen and co-authors (2012) describe the outcome of their systematic review as inconclusive due to methodological limitations within the available research. A shortage of large scale objective studies to determine the relationship between training variables and running related injuries adds to the confusion. They could identify that running experience and injury threshold are role players in the relationship between emerging injuries and training variables, but that there is a diverse synergy between volume, duration, frequency and intensity of training sessions that was not examined by the majority of the reviewed studies. It is widely believed, and accepted, that a weekly increase of no more than 10% of the previous week's total running distance is a protective factor for the risk of sustaining a running related injury due to excessive load on an un-adapted body. However, Buist and co-authors (2010) compared a weekly distance progression of 10.5% and 23.7%. They determined that there is no difference or increased risk of sustaining a RRI between the higher or lower load progressions, although they did find that a distance progression of 30% increased the risk to sustain a RRI.

Saragiotto and co-authors (2014) reported that 5 prospective studies have investigated the association of weekly training distance in relation to sustaining a RRI on the lower extremity. Two of the five studies came to the conclusion that a weekly volume of more than 64km expose runners to a greater risk of lower extremity injuries (Macera et al., 1989; Walter et al., 1989). Taunton and associates (2003) reported that both extremes

place runners at greater risk of injury. They cited Macera and co-authors (1989) in saying that runners training 7 days a week and female runners only training once per week are both at an increased risk of sustaining an injury, compared to runners who train a moderate amount.

Training characteristics are complex in their association to one another, and difficult to evaluate the effect of any training variable in relation to sustaining a running related injury in isolation. Volume and duration are often measured as independent variables, however the intensity at which runners participate may be dependent on the volume and distance (duration) of the exercise bout (Nielsen et al., 2013).

1.4.2.2 Running Experience

There seems to be contradictory views on the value of less or more running experience as a risk factor for sustaining a running related injury. Van der Worp and associates (2015) concludes that the available information is inconclusive about the value of running experience. Strong evidence suggests that runners with less than one year of running experience are at greater risk of sustaining a running injury. However, running more than 5 years is protective against sustaining a running related injury. Van Poppel and associates (2016) concluded that recreational runners participating in a half-marathon with less than 5 years of running experiences and a shortage of frequent interval training are at higher risk of sustaining a running related injury when compared to other recreational runners who meet these requirements.

1.5 Risk Assessment for Running Related Injuries

Screening tools can be used as evaluations to identify biomechanical and training related risk factors among athletes. With the rise of professional sporting careers there has also been development of highly technical and electronically advanced equipment to test and evaluate athletes to better prepare them for their specific sport and ensure that they stay injury free during any competition season. Most equipment is very expensive and generally only available at universities or sport performance centres. However, there are reliable and low-cost screening tools that can be used in private practice.

1.5.1 Health Par-Q and Injury History Questionnaire

Current evidence reports that a previous injury within the last 12 months is one of the most weighted risk factors to future injury. For this reason, medical and injury history is of importance to any clinician. Previous injury history may provide valuable information during the assessment of an athlete's running-related injury risk profile. However, previous injury is not well defined in the literature. Most of the literature reviews only make use of the term "previous injury", however injury definitions vary between studies and authors (van Gent et al., 2007). Thus, that the impact of a previous injury on subsequent injury may depend on the original definition and the rehabilitation sequelae that followed.

1.5.2 Anthropometric Evaluation

Weight loss and overall health improvement is a well-documented reason for people to start running. Increased body mass index (BMI) has also been indicated as contributing risk factors for sustaining running related injuries among novice and recreational

runners. Buist and associates (2010) reported that a higher BMI (≥ 26) is a predictor of running related injuries among men. They further reported a hazard ratio of 1.14 for every one-unit increase in BMI among the men in their cohort 532 novice runners. However, they found no association between BMI and an increased risk of injury among women in the investigation. Nielsen and co-authors (2013) also reported that an increased BMI was an associated risk factor for sustaining a running related injury. They found that runners with a BMI value of greater than $\geq 30\text{kg/m}^2$ (obese) and women with a BMI below $\leq 20\text{kg/m}^2$ (underweight) had the highest risk of sustaining an injury. Runners with a BMI value of $25 - 30\text{kg/m}^2$ were also at a higher risk than persons with a normal BMI value. In contrast to these reports Malisoux and colleagues (2014) and Murphy (2003) reported that runners with a BMI lower than 25kg/m^2 are at higher risk of sustaining running related injuries. They hypothesized that runners with a normal BMI value have the ability to complete longer bouts of individual training session; therefore, the total load of running placed on the runner increase their risk to injury.

1.5.3 Foot Posture Index

The gold standard for assessing lower limb kinematics and biomechanical movement are laboratory-based objective gait analysis with advanced 3D technology. Within a clinical set-up the equipment and facility to produce high-quality objective data is not always affordable and the process to obtain the data can be overly time-consuming to justify as an effective method for routine patient assessment. Direct angular measures with regards to the calcaneus and arch height have been widely used before the reliability of the techniques were in question, Another type of screening test, i.e. measuring arch height of the static foot and navicular drop have been reported more effective and reliable to assess foot kinematics (Bennett et al., 2012). There was a need

in the clinical and research setup for an assessment tool that was reliable, simplistic in use, quantitative in output of information, yet reflected the complexity of foot function and biomechanics while minimising the subjective input of the assessor and had the proficiency to undertake measures without the use of state of the art equipment.

The Foot Posture Index was developed as an observational scoring system with a six criterion that provide an accurate and efficient assessment of the standing foot posture in multiple planes and segments (Redmond et al., 2006). Neal and co-authors (2014) reported in their systematic review and meta-analysis that a strong association was found between foot posture and the development of medial tibial stress syndrome, determined by the use of the FPI. This association was confirmed through positive navicular drop (defined by magnitude greater than 10mm) and calcaneal eversion assessments (Reinking et al., 2007; Plisky et al., 2007; Bennett et al., 2012). The FPI has been found to be a valid and reliable measuring tool (Neal et al., 2014; Redmond et al., 2006) to predict non-specific lower limb overuse injury.

1.5.4 Functional Movement Screen (FMS)

The FMS is an objective screening tool used to identify biomechanical risk factors associated with internal movement patterns of individuals. The screening test consists of 7 independent movements that extensively evaluate flexibility, mobility, stability and proprioception components. Each movement is scored on a predetermined execution criterion and the deviation of movement patterns within the kinetic chain through comparison of the left and right side. However, Hotta and colleagues (2015) found that the total FMS score was a poor predictor of risk associated with injury. They constructed a shorter version of the FMS, consisting only of the deep squat (DS) and the active straight leg raise (ASLR), illustrating that these tests specifically evaluate

range of motion in the hip, knee and ankle joints which was directly associated with the joints mostly affected by injuries among running populations. Hotta and associates (2015) indicated that the DS and ASLR in the short FMS version had a higher accuracy of identifying injuries among runners. The FMS is a validated field test used among various sporting groups. Loudon and colleagues (2014) and Agresta and co-authors (2014) have explored the normative values of FMS scores for both running athletes and healthy runners respectively. They subsequently reported mean FMS total scores of 13.1 ± 1.8 and 15.4 ± 2.4 . Hotta and colleagues (2015) indicated that these scores portray a reference framework which indicates that athletes scoring below these values are at greater risk of sustaining running related injuries compared to athletes who scored the same values or greater. Earlier research indicated that poor flexibility (Yagi et al., 2013), muscular weakness, muscle imbalance (Niemuth et al., 2005) and insufficient neuromuscular coordination (Renström, 1993) are all risk factors associated with sustaining running related injuries. Cook and colleagues (2006a) and Cook and co-authors (2006b) also reported that poor movement mechanics can be associated with the described factors. Achieving a lower score on the FMS highlights these deficient kinetic chain movement patterns. In contradiction to these reports, Murphy and co-authors (2003) explained that joint laxity has been shown to be a risk factor for all injuries. They also cited Ostenberg and Roos (1973) who indicated that a moderate and higher (4 + / 9) laxity score on the Beighton scale placed athletes at a five times higher risk for sustaining an injury. Murphy et al., (2003) also cited Soderman and associates (2009) who indicated athletes to be at a threefold risk of injury when they scored a value of 5 or higher on the Beighton scale.

1.5.5 Single Leg Hop Test

Difference in limb performance during the course of athletic activity may expose the athlete to increased risk of sustaining lower limb injury. Hewett (2005) and associates reported a secondary injury rate of 44% among athletes who's initial injury was related to asymmetrical limb-to-limb biomechanical deviation. Niemuth and associates (2005) compared a group of injured and uninjured recreational runners. Among the injured athletes the hip flexor and hip abduction strength was significantly worse on the injured limb. They further reported that hip adduction strength was greater in the injured group of runners compared to the uninjured group.

Muscle strength is considered an important factor for the prevention and maintenance of injury free running, however, the difficulty with many investigations is determining whether the muscle imbalance and limb asymmetry is the cause of injury (Almekinders & Temple, 1998; Ryan et al., 2006). Asymmetrical limb loading is possibly affected by side-to-side variation in muscular strength, flexibility and coordination. The interaction of these components are important factors in injury prevention and a shortage of sufficient development in these components place athletes at greater risk for injury (Hickey et al., 2009; Knapik et al., 1991; Myer et al., 2011).

The single leg hop test for distance is a unilateral screening test used within a battery of tests to determine limb symmetry among athletes who have had anterior cruciate ligament reconstruction (ACLR). Myer and co-investigaters (2011) determined that previous bilateral agility and coordination tests used in the battery of return to play screening tests were not significant indicators of asymmetrical differences between injured and uninjured limbs. They attributed the shortage of precise measurement

outcomes among these tests to the athlete's ability to compensate for strength, speed and flexibility with the unaffected limb when exposed to bilateral screening tests. The problem is that the athlete scored a false positive, thus an athlete that is not fully rehabilitated was allowed back to the performing arena, increasing the risk to re-injury right from the start (Mehran et al., 2016). Therefore, the uninjured and injured limbs are tested separately, post rehabilitation. The single leg hop test for distance is described as an isolated single-limb performance task by Lephart and associates (2002) and Myer and colleagues (2008). Using the single leg hop test allows the clinician to test the athlete for functional power, force generation or a shortage thereof (Myer et al., 2008; Myer et al., 2011) and postural stability (Paterno et al., 2007) exposing lower limb performance deficits on the previously injured limb. The single leg hop test was reported to be an easy, valid and reliable, field test (Munro & Herrington, 2011; Myer et al., 2011)

1.5.6 Vertical Jump

The Sargent vertical jump test is a widely used measure of explosive leg strength (Bui et al., 2015; de Salles et al., 2012; Dalui et al., 2014). It is an easy and objective field test. The test is easy to use in clinical practice and valid for reproducibility (de Salles et al., 2012). The Sargent vertical jump test is executed by placing a measuring tape against a wall. The athlete is asked to stand adjacent to the wall, extend the arm closest to the wall to create a baseline standing reach measure. The athlete starts in a comfortable static position and jump as high as possible, marking the wall at the highest possible point. The jump is repeated. The higher measure is taken down for analytical purposes. The difference between the reach and the jump height is determined, and the difference, is the outcome variable for explosive power (de Salles et al., 2012).

In recent years the vertical jump test has evolved and is now being used in collaboration with a force plate and a countermovement jump whereby the pressure that the athlete exerts on the pressure plate is used to determine the explosive leg power. Another method that has come about is the use of video cameras whereby the actual height of the jump is recorded and measured (Bui et al., 2015). According to Bui and co-authors (2015) both force plate and video analysis measure of vertical jump is more accurate than the widely used Sargent vertical jump. These technologically advanced methods have a high cost of implementation and may lose accuracy as the mechanism experiences wear and tear (Bui et al., 2015). On the other hand, the Sargent Vertical Jump test may lead to an under estimation of explosive leg power.

De Salles and co-authors (2012) determined that the over and under range of variation of the Sargent Vertical Jump Test scores were small enough that the test is valid for use as a field test among athletes. The Sargent vertical jump test is still a widely-implemented test among athletes of all nature and sport codes. However, height gain does not directly reflect the athletes power output, which makes comparison between athletes inaccurate. The same elevation between two athletes does not mean that these athletes produced the same explosive leg power. Height, weight and gender differences between athletes affects the direct power output exerted when jumping. To compensate for this error Sayers and his co-authors (1999) developed the most recent mathematical calculation using the elevation gain in cm to determine the power output of the athlete, allowing for comparison between athletes with different stature but similar height gain.

1.5.7 Sit and Reach

The sit and reach test is a widely used objective test for flexibility, assessing both the hamstring and spinal muscle extensibility. A participant is expected to sit with legs straight in front of them – feet placed in a flexed position directly against the flexibility box but underneath the ruler. They place one hand on top of the other then place both hands on top of the ruler and stretch forward as far as possible without bending the knees or lifting the hands from the ruler. The motion should be performed in a controlled fashion and held for 1 second at the final reaching measure. The measure is considered a valid and objective clinical tool for the assessment of combined hamstring and lumbopelvic flexibility. The measure is widely used in pre-season screening of football players and running athletes (Gabbe et al., 2004). It is regarded as simple clinical measure that is easily performed in a clinical or field based situation. It does not require expensive equipment but is regarded as a reliable and valid measure of flexibility for pre-season and injury screening (Gabbe et al., 2004).

1.6 Prevention of running related injuries

Running related injuries have a time loss effect on runner's due to the temporary loss in the ability to exercise and participate in races. There is a significant economic burden that accumulates when sustaining a running related injury. The approximate direct cost of dealing with a RRI is R 792.09 – R 4416.40, depending on the severity (Hespanhol Junior et al., 2016b). Additionally, Hespanhol Junior and associates (2016) reported that the indirect cost of dealing with a RRI accumulates to twice the cost of the direct healthcare utilization, explaining that the ripple effect of a severe injury affects the production of companies. This association impacts societal financial resources. They further reported that acute injuries initially presented with greater severity and that

85.4% of the reported injuries were overuse injuries; the cumulative effect of overuse injuries placed previously injured runners at a greater overall severity of risk when considering the direct and indirect cost and the time-loss effect.

This adds to growing evidence that RRI's are not just affecting participants who regularly partake in the sport, but that they have a much larger effect on overall community wellbeing and therefore, are of great importance. A better understanding of running related injuries are warranted. Current evidence surrounding risk factors that lead to various injury rates among recreational runners is debatable (Saragiotto et al., 2014). The basis of a broader understanding allows clinicians to better diagnose and prevent injuries instead of just managing injuries, thereby adding to the long-term problem of re-injury and chronic overuse injuries among this sporting population. Malisoux and colleagues (2015) state that 50% of all RRI's are preventable and in order to decrease the injury incidence rate and develop more effective injury prevention strategies, a greater body of evidence is needed to identify and understand the risk factors that play a significant role in injury development. It was previously reported that RRI's are related to training errors i.e. training volume and frequency (Fields et al., 2010; Hreljac, 2005). However, a recent systematic review failed to identify that training errors are related to RRI's (Nielsen et al., 2012).

Current evidence reveals that injury types and possible injury risks vary greatly among populations, making it challenging to apply previous findings of previous research to the immediate population that will seek advice from the clinician or sport scientist about injury prevention. Developing effective injury prediction strategies to minimize the onset of RRI's, warrants the investigation of RRI risk factors in the local context. This

study will attempt to address a better strategic approach [by applying the approach by Malisoux and colleagues (2015)] to identify risk factors associated with RRI's in local recreational runners of various local running clubs.

1.7 Problem Statement

The greatest challenge with recreational long distance running is high burden of incidence of running related injuries (RRI) (Lopes et al., 2012). Recent reviews reported the current incidence rate among recreational runners to be up to 84.9% (Ryan et al., 2006; Kluitenberg et al., 2015). A study consisting of a 12-week training programme specifically designed to decrease the risk of injury still had an injury rate of 29.5% (Taunton et al., 2003).

Apart from the high risk for the incidence of injury, different investigators use different reporting methods to quantify injury incidence. Current literature has different reporting strategies which includes: injury per 1000h of running, injury per 1000 athletic exposures, and time- to-event injuries (Windt & Gabbett, 2016). The different follow-up time frame among studies adds to the difficulty to compare study results the incidence of RRI's. Some studies report only on one running event, or have a follow up of 12 months, or follow runners for several years. The diverse reporting strategies complicate the process of comparing results from different studies with one another (Videbæk et al., 2015).

The difficulty with comparing studies investigating the risk for running related injuries is also attributed to the differences among studies in the type of running-related injury investigated. Determining the risk for one specific injury will not necessarily be a risk

for a different running-related injury. Overuse injuries have a much higher incidence rate among recreational long distance runners in comparison with acute musculoskeletal injuries (Lopes et al., 2012). Even though the acute onset of overuse injuries are not as traumatic as those experienced through acute muscle tears and ligament sprains, the time loss effect and the total cost of injury treatment places a significant burden on recreational runners suffering from overuse injuries (Hauswirth & Le Meur, 2011; Kluitenberg et al., 2015).

Another unresolved issue with the current literature is the diverse number of associated risk factors for running injuries e.g. high mileage, high frequency of training sessions (Lopes et al., 2012; Nielsen et al., 2012) and/or the incidence of previous injury (Saragiotto et al., 2014; Ryan et al., 2006).

The large degree of variability in the literature concerning injury definitions, diverse study designs, contrast in the study populations, and different methodology for reporting risk factors limits the evidence of injury risks. Running requires the involvement of the entire kinetic chain and is affected by full body biomechanics to move efficiently and remain injury free. Currently the only agreed risk factor is a history of previous injury (Kluitenberg et al., 2015) within studies investigating different types of running-related injuries. The literature lacks the investigation of general risk factors that may influence running-related injuries in totality regardless of the area of injury. This type of investigations is warranted, for it may lead to conclusive evidence of the most important risk factors for running-related injuries.

Information from screening assessments may be very useful to recreational runners, especially with regards to identifying risk factors that are associated with sustaining a RRI's. However there is a need for more effective methods of rapid clinical assessment protocols in practice, in order for clinicians and therapists alike to better identify the factors that places these recreational runners at a higher risk of injury (Bui et al., 2015). The aim of the study was to address the overall risk factors that generally place recreational long-distance runners at an increased risk to sustain an injury. The study will attempt to determine the internal and external risk factors and the dose-response effect of external load brought on by training variables on incident injury.

The following research questions have been formulated from the problem statement:

1. What proportion of recreational runners will experience a running related injury over a 12-week observational training period?
2. What is the status of the body's functional ability (mobility, stability, balance and power) in the group of recreational runners; and are there significant differences between injured and non-injured recreational runners, retrospectively?
3. Are there significant differences in the internal (physical characteristics and training status) attributes between injured and non-injured recreational runners?
4. Do any of the internal (physical and training status) attributes predict the incidence of injury over the 12-week observational training period?
5. Do any of the external functional outcomes (mobility, stability, balance and power) significantly predict the incidence of injury over the 12-week observational training period?

6. Do any external behavioural factors significantly predict the incidence of injury over the 12-week observational training period?

CHAPTER 2

Injury Risk Assessment and the incidence of Musculo-Skeletal Injuries in Recreational Long-Distance Runners Over a 3-Month Period

2.1 Introduction

Running as a recreational sport, is growing in popularity on an annual basis across the globe (Buist et al., 2010). Unfortunately the high incidence rate of injuries among runners casts a shadow over running among researchers and participants alike (van Poppel et al., 2016) Studies investigating the specific biomechanical and training characteristics, in an effort to explain anatomical and functional deviations as the cause(s) of running related injuries are well documented. In general, researchers associate training overload and poorly managed training programmes as the causes of injury among runners (Saragiotto et al. 2014; Lopes et al., 2012). However, there is a lack of consensus as to the primary cause/s of running related injuries (RRI). The majority of studies concentrated on risk factors relating to a specific injury, e.g. hamstring tear and did not focus on RRI, in general (Lopes et al., 2012).

In the latest literature review on risk factors that are associated with running related injuries, Saragiotto and associates (2014) investigated 60 different risk factors to identify the main risk factors that contribute to sustaining a running related injury. Previous injury, specifically in the previous 12 months was the most consistent and prominent risk factor, that was present in the largest amount of studies. A higher Quadriceps angle measured in relation to the knee joint, total weekly distance and total weekly running frequency were also identified as important risk factors that contribute to sustaining running related injuries. Running more than 64 km per week and completing less than 2 running sessions per week were also associated with a higher risk of sustaining a running related injury. However, they reported that heterogeneity variance in injury definition study design and outcome variables complicate the comparison of different studies with one another.

The human body is a diverse ecosystem that responds to the specific stimuli it is continually exposed to. The body will adapt and increase in strength and performance when it is placed under the necessary load to create adaptation. On the other hand, the body's overall wellbeing will gradually decrease and regress when it is continually exposed to internal and external factors that lead to injury. Due to the integration of training and non-training related factors that affect runners' performance it is important to identify the combination of risk factors that contributes to the injury risk among runners (Drew & Finch, 2016).

The purpose of this study was to add to the current body of evidence concerning general intrinsic, and external functional and exercise-behavioural factors that may influence the occurrence of any RRI in recreational runners. The first aim was to determine the number of injuries sustained by recreational runners over an observational period of 12 weeks. The second aim was to identify possible non-training-related risk factors that may influence the incidence of RRI's in local recreational club runners (e.g. age or BMI). The third aim was to identify the modifiable training-related risk factors measured that may influence the incidence of RRI's in local recreational club runners.

2.2 Methods

2.2.1 Participants

Fifty recreational runners were recruited to take part in this 12-week observational study. Forty-one (mean age 38 ± 10 , years; mean BMI 23.5 ± 3.3 kg/m²) of the fifty participants' data were included in the final data analyses. Nine participants were omitted from the final data analysis due to the following: 1) Three participants did not complete their follow up tests. 2) Three participants did not complete their online

training diary during the 12-week observational training period (OTP). 3) Three participants did not complete their online training diary and did not complete follow up assessments. Thirty nine percent of the study population consisted of men (n = 16).

Flyers were distributed at running club gatherings and posted on social media networks. All the interested participants were contacted telephonically, through email or text messages and invited to attend an information session. The researcher presented the study details and outcome variables in detail. Participants were included in the study if they were between the age of 18 and 65 years of age, had a running history of at least 1 year, ran consistently twice per week for at least 6 months in the previous year, had no current injury or known degenerative disease or on chronic medication. Inclusion criteria also required participants to plan to run at least 1 x 21 km race within six months of the start of the study. All the participants received a full written description of the study protocol and requirements. All the experimental procedures were approved by the Health Sciences Research Ethics Committee (HREC), Faculty of Health Sciences, University of Cape Town (HREC: 149/2016). Participants were enrolled after signing informed, written consent.

2.2.2 Study Design

Volunteer runners who complied with the inclusion criteria were asked to complete the informed consent form, a Health Par-Q, demographics, running and injury history questionnaire at the meeting. Screening tests consisted of anthropometric evaluation measures of weight, height and calculation of BMI. Foot posture was determined by using the Foot Posture Index (Redmond et al., 2006). The foot posture index is a criterion based diagnostic tool, used to quantify standing foot posture. The analysis is

conducted through a six-item criterion, with a set score for each anatomical landmark. This is a validated and affordable clinical diagnostic tool (Redmond et al., 2005). A five-minute treadmill warm-up preceded the functional tests (Functional tests were classified as External Functional Outcomes). The functional tests consisted of a test battery of 4 different tests: The Functional Movement Screen (FMS) was used to determine overall body mobility and stability. The FMS consists of seven individual movements: a deep squat, a hurdle step, an in-line lunge, shoulder mobility test, an active straight leg raise, a trunk stability push-up and a rotary stability test. In addition, the following tests were conducted, including i) the single leg hop test to determine bilateral leg strength, proprioception and balance, ii) a vertical jump test to measure explosive lower limb strength, and iii) the sit and reach test as a measure of lower back and hamstring flexibility. Once screening testing was completed the participants were asked to keep a daily training logbook for the following 12 weeks during the Observational Training Period (OTP).

2.2.3 Observational Training Period

Each participant was expected to keep a weekly online training diary during the 12-week OTP. The training diary was managed electronically through Survey Monkey (<https://www.surveymonkey.com/>). This programme allowed each individual to log their time, distance, frequency and intensity of the various training sessions done in that week. The programme allowed the researcher to monitor which of the participants had not logged their training data for the week. Survey Monkey provided a platform where the required training information could be documented and kept up to date.

If the participant indicated that they had suffered an injury, they were contacted via telephone to gather more information regarding the injury, i.e. occurrence, time, and if

they had medical attention or treatment. An injury was defined as “any physical pain located at the lower limbs or lower back region, sustained during or as a result of running competition or running training and impeding planned activity for at least one day” (Buist et al., 2007). Participants were reminded to complete their training information via telephone if they had not completed the weekly training information within 3 days of the requested weekly due date. Data collection for the study was terminated after 12 weeks of monitoring training in the group of recreational runners. Participants were contacted via telephone to confirm the end of the observational period and they were informed about when and how they would receive their results at the end of the study. All the testing and evaluations were done by the same investigator.

2.2.4 Experimental Procedures

2.2.4.1 Health Par-Q

This is a standard health questionnaire to ensure that all the participants were healthy to participate in physical activity during the study and did not suffer from a chronic disease or were taking chronic medication. Although the latest research suggest that a PAR-Q+ should be used in order to minimise cases where high risk participants need to obtain medical clearance before they can be included in a study, for the purposes of our study the original PAR-Q was adequate as our recruited population consisted of healthy active individuals (Duncan et al., 2016).

2.2.4.2 Running History Questionnaire

The running history questionnaire was developed in-house and was based on specific information needed regarding the participant’s running history; training patterns;

footwear, surface use and injury history. The questionnaire was adapted from a similar questionnaire for previous running injury studies within the research division.

2.2.4.3 Foot Posture Index (FPI)

The foot posture index is a diagnostic tool to quantify excessive supination or pronation using a six-item criterion with a set score for each item. This is a validated and affordable clinical diagnostic tool (Redmond et al., 2005). The test starts with the participant standing barefoot on a solid surface; taking a few steps on the spot to adjust their stance to a comfortable standing position. The participant stood in this position for about 2 min while the Exercise Specialist proceeded with the assessment.

The FPI assessed each of the following structures: talar head position supra- and infra-lateral malleolar curvature, calcaneal frontal plane position, talonavicular joint prominence, medial longitudinal arch congruence and adduction or abduction of the forefoot on the rearfoot. Assessments were conducted with palpation by the clinician. The position of each of these structures was scored according to a standardised scoring system and a total score between -12 (severe supination) and + 12 (severe pronation) was determined at the end to identify the foot's position. Left and right were scored independently.

2.2.4.4 Functional Movement Screen

The Functional Movement Screen (FMS) is a functional and objective screening tool that is used to evaluate movement patterns and determine risk of injury among athletes. The screening tool consists of 7 movements, each rated on a 4-point scale (0 - 3) of correct execution. Loudon and associates (2014) validated the FMS as an objective

injury risk screening tool. Each participant underwent the following measures: deep squat (Cook et al., 2014a; Zazulak et al., 2007), hurdle step (Cook et al., 2014a; Leetun et al., 2004), inline lunge (Cook et al., 2014a; Nadler et al., 2000), shoulder mobility and impingement clearing test (Cook et al., 2014b; McMullen & Uhl, 2000), active straight-leg raise (Cook et al., 2014b; Yagi et al., 2013; Mens et al., 2002), press-up clearing test (Cook et al., 2014b; Cholewicki et al., 2002), rotary stability and posterior rocking clearing test (Cook et al., 2014b; Leetun et al., 2004; Cholewicki et al., 2002).

Each movement was scored on an execution criterion with a maximum value of 3. If the movement is executed correctly the person scores 3. In the case where the movement is executed correctly with partial compensation the person scores a 2 and in the case where there are fundamental parts of the movement that are done incorrectly the person scores a 1. All the scores were recorded on a scoring sheet. At the end of the FMS, a total score was calculated for the athlete, by adding all the individual scores together.

2.2.4.5 Single Leg Hop Test

This is a functional balance test whereby stability and proprioception are measured simultaneously (Daniel et al., 1982). A measuring tape was placed on the floor. The participant stood on one leg and jumped as far as possible while landing safely on the same leg. When landed, the participant was required to maintain their balance for at least 2 seconds. The test was repeated on the other limb. The test was repeated twice for both limbs and the better of the two attempts was used as the outcome variable. This test has been shown to be a reliable and valid test, with minimal risk for pain or injury (Reid et al., 2007).

2.2.4.6 Vertical Jump

The vertical jump test is a validated measure of strength and power among athletes (de Salles et al., 2012). The participant stood, barefoot, sideways next to a wall. Using the hand closest to the wall the participant reached up and made a mark on the wall where the tip of their middle finger reached. The participant had to jump and reach with their arm stretched to maximum to make the highest possible mark on the wall while holding a piece of chalk as marker. The higher distance to the mark of two attempts was used. The standing reach and the jumping height was measured with a measuring tape and recorded. The difference between jumping height and standing reach was used as numerical data for analysis of leg muscle power (de Salles et al., 2012; Dalui et al., 2014).

2.2.4.7 Sit and Reach

The sit and reach test is a lumbar spine flexibility measure. A standardised sit and reach box was used. The participant sat on the floor with bear feet against the bottom of a rigid box. The participant then placed both their hands on-top of the box in line with the ruler marked in centimetre. The participant reached forward as far as they could while keeping their knees flat on the ground and holding the stretch for at least two seconds. The measurement was taken from the top of the middle finger. Athletes reaching their toes indicate a positive measure for the test. The better measure of two attempts was used for data analysis (Gabbe et al., 2004).

2.3 Statistical Analysis

Participants were divided into 2 groups, injured and uninjured, according to the self-report data accumulated from the 12-week observational training period. A statistical

power analysis was performed for sample size estimation, based on FMS (main outcome variable) data from a previous study comparing two independent groups. The effect size in this study was 1.18. Thus, with an alpha level = 0.05 and power = 0.85, the projected sample size needed was approximately 22 participants in total with approximately 11 participants per group for the simplest between-group comparison.

Firstly, comparisons between men and women were made using Independent Student's t-tests (for normal distributed continuous variables), Mann-Whitney U-tests (for non-parametric continuous data), or Chi-Square analyses (χ^2) or Fisher's Exact statistics (for expected frequencies below 5). All continuous variables were tested for normality by the Shapiro-Wilk test. All parametric data were reported as Mean \pm SD and non-parametric data as Median (Interquartile Range). Secondly, differences between injured and uninjured participants were determined by Multifactorial Analysis of Variance (ANOVA). ANOVAs were performed on outcome variables where men and women showed significant differences. This analysis was done to determine if there were any gender and injury interactions that could have influenced the variance of a particular outcome variable. Frequencies not depicted in tables were illustrated in the form of Bar charts, distributions of certain outcome variables between men and women were displayed in horizontal histograms (sample pyramids). Bar charts were used to display data of outcome variables where the gender and the incidence of injury interactions on specific outcome variables were determined.

Outliers were assessed for dependent variables as a value greater than 3 box-lengths from the edge of the box, during Multifactorial ANOVA analysis. Dependent variables in the Multifactorial ANOVAs were assessed by Shapiro-Wilk test for normality.

A binomial logistic regression was performed to ascertain the effects of internal physical and training status characteristics, external functional and performance variables and external training behaviour on the likelihood that participants would have an injury. Firstly, correlation coefficients were calculated among all variables that were identified as factors that may influence the likelihood of incidence of injury within each group of internal, external function and external behavioural factors, separately. Only one of two outcome variables showing significant association was included in the regression model. Secondly, linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure (Box & Tidwell, 1962). A Bonferroni correction was applied using the number of terms (including the constant) in the model resulting in statistical significance being accepted when $P < (\text{number of terms}/0.05)$ (Tabachnick & Fidell, 2013). Based on this assessment, all continuous independent outcome variables were found to be linearly related to the logit of the dependent variable, Studentized residuals were considered normal at ± 3 standard deviations.

Mixed Model analyses were also performed to determine the internal physical predictors, external performance predictors and external behavioural predictors of the incidence of injury. These analyses did not reveal different results from Binomial logistic regressions. The researchers therefore depicted and discussed the results from the Binomial Logistic Regressions. Gender-incidence of injury interaction had no significant effects on any of the predictor variables used in any of the models and was not considered a confounder. All significance levels were accepted at an alpha-Level of < 0.05 . SPSS statistical analysis software (IBM SPSS Statistics 23) were used for data analyses.

2.4 Results

The results of the study are reported in three different sections, i.e. 1) Internal physical characteristics and training status, 2) external functional outcomes and 3) external behavioural outcomes.

2.4.1 Differences in Outcome Variables between Groups

Initial investigation into the differences between men and women revealed that mean/median height, weight, BMI, Vertical Jump, Sit-and-Reach and the Hurdle Step, Active Straight Leg Raise and Trunk Stability Push components of the FMS outcomes were significantly different between the two groups. As such, comparisons of outcome variables between injured participants and uninjured participants, were also tested for significant interactions between gender and the incidence of injury for the specific outcome variables.

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2.4.1.1 Internal Physical Characteristics and Training Status

The mean age of the group of runners was 38.34 ± 10 years (Table 1). The median BMI of the sample was within the normal range ($BMI \leq 18 - 25$) for healthy persons; however, 27% of the runners were classified as overweight or obese, with a BMI value $\geq 25\text{kg/m}^2$. Men presented with a 14% higher median BMI than women ($P = 0.03$). Fifty percent of the men were overweight compared to only 12% of women. Seventy-six percent of women and fifty-six percent of men were distributed between the ages of 18 and 54. Seventy three percent of the injured runners were also distributed within the age range of 18 and 54 years.

The following tables depict the outcome variables for men, women and the total study population, respectively.

Table 1: Descriptive Statistics for normal distributed data (mean \pm SD)

Variables	Men (n=16)	Women (n=25)	Total (n=41)
Age (years)	38.9 \pm 10.7	37.9 \pm 9.7	38.3 \pm 10.0
Height (cm)	181.0 \pm 6.3*	169.0 \pm 5.5	173.9 \pm 8.1
Weight (kg)	84.1 \pm 11.3*	64.6 \pm 8.9	72.2 \pm 13.7
BMI (kg/m ²)	25.2 \pm 3.1	22.3 \pm 2.9	23.4 \pm 3.2

*Men significantly different from women, $P < 0.0001$

**Men significantly different from women, $P < 0.05$

Training characteristics of men and women are presented in Table 2. The cohort of runners had a median (Interquartile range) running experience of 8(12) years and ran 3(1) sessions per week, in the previous 12 months. Women ran one day per week more than men, but this was not a meaningful difference. The group of recreational runners reportedly spent a median (Interquartile range) of 300 min per week running in the previous 12 months. Although there were no statistical differences, women ran 60 min per week more than men, over the same period. They also completed a median (Interquartile range) of 10 (8) races in the 12 months prior to the start of the study.

Table 2: Descriptive statistics for non-parametric data [median (Interquartile range)]

Variables	Men (n=16)		Women (n=25)		Total (n=41)	
Years running	8	(15.5)	8	(12)	8	(12)
Running frequency in the previous 12 months (per /week)	3	(1)	4	(2)	3	(1)
Running time per week in the previous 12 months	240	(165)	300	(210)	300	(240)
Running races per year	10	(12)	10	(8)	10	(8)

2.4.1.2 Comparing injured and uninjured runners for intrinsic factors and training status:

In the cohort of recreational runners' ages and running time per week, over the previous 12 months, were the same between injury groups. Previous running experience, running frequency in the previous 12 months and current running frequency per week were also similar between injury groups. The results are presented in tables 3 and 4.

Table 3: Descriptive statistics for normally-distributed variables between injured and uninjured participants

Variables	Injured (n=26)	Uninjured (n=15)
Age	37.0 ± 9.1	40.6 ± 11.4
Running time per week in the previous 12 months	308.0 ± 126.0	295.0 ± 143.0
Current running frequency per week	2.0 ± 0.9	2.0 ± 0.9

Twenty six of the 41 recreational runners (63%) who participated in the study sustained a new injury during the 12-week Observational Training Period (OTP).

Ten of the 16 men (63%) and 16 of the 25 women (64%) who participated in the study, experienced one or more injuries during the OTP (figure 1). Frequency distributions of injuries obtained during the OTP were similar, $\chi^2 (1) = 0.009$, $P = 0.923$.

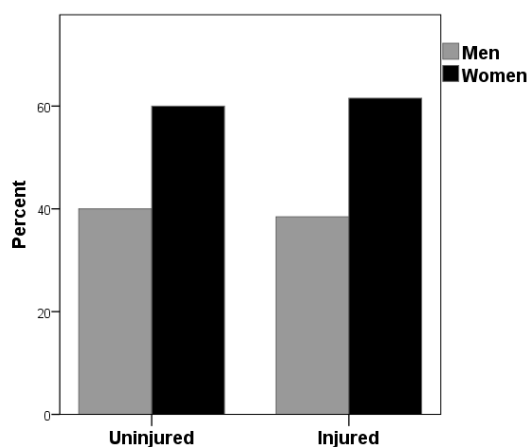


Figure 1: Illustration of percentages of men and women obtaining an injury or no injury during the 12-week OTP.

Multifactorial Analysis of variance (ANOVA) revealed no significant differences between men and women (within-subjects) within each relevant group, therefore only the mean \pm SD for normally-distributed data; and median (Interquartile range) for non-parametric results were reported between injured and uninjured (Table 3 and 4) runners.

Table 4: Descriptive statistics for non – parametric variables between injury and uninjured participants

Variable	Injured (n=26)	Uninjured (n=15)
Years running	8.5 (13.3)	8.0 (9.0)
Running frequency in the previous 12 months (per /week)	3.5 (1.0)	3.0 (1.0)
Running races per year	10.0 (7.0)	12.0 (10.0)

2.4.1.3 Incidence of Previous Injury

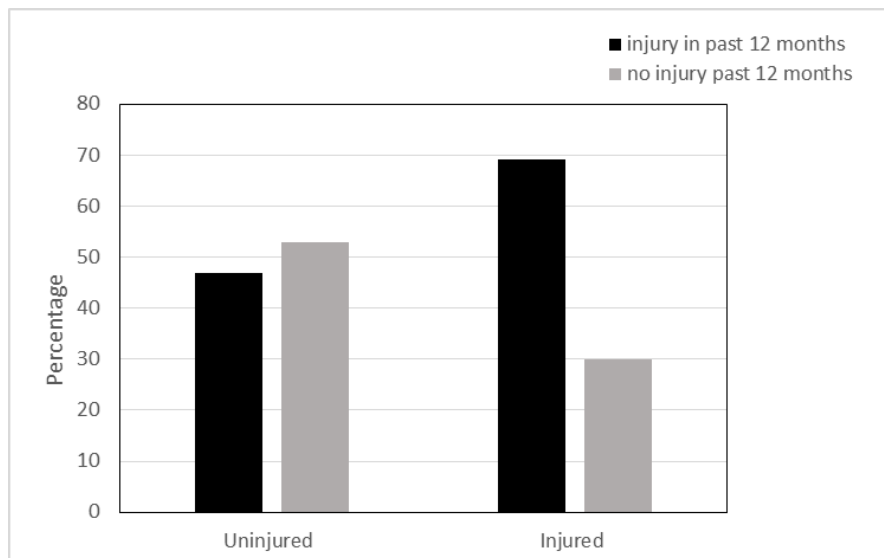


Figure 2: Bar Chart illustrating the frequencies of men and women who reported either an injury or no-injury history (Injury incidence in the past 12 months)

Eighteen of 26 injured runners (69.2%) reported that they experienced a previous injury in the previous 12 months compared to 7 out of 15 uninjured runners (46%). Differences in the frequency distributions of an injury or no injury within the past 12 months were

not significantly different between injured and uninjured participants, $\chi^2 (1) = 2.035$, $P = 0.154$.

There was a statistically significant difference in mean BMI outcome between men and women who were injured over the 12-week OTP, $F (1, 37) = 9.086$; $P = 0.005$, $\eta^2 = 0.197$. Injured men had on average a 2.5 (95% CI, 0.57 to 4.53) kg/m^2 higher BMI compared to injured women ($P = 0.013$).

2.4.1.4 External Functional Outcomes

Each component of the functional movement test battery was coded from a total rating score of 1 to 3, to a nominal variable where 1 indicated “correct execution” and 0 indicated “unable to execute”. The hurdle step was executed successfully by 1.3 times more injured runners than those who remained injury free during the OTP, $\chi^2 (1) = 13.58$, $P \leq 0.001$. The functional movement screen (FMS) total score was recoded into a score ≤ 14 equals 1 and score of > 14 equals 2. Seventy three percent of the injured participants achieved an FMS score higher than 14, compared to 60% of uninjured runners (Fisher exact = 0.492), however, these differences were not significant.

2.4.2 Differences in Functional Outcomes between Men and Women

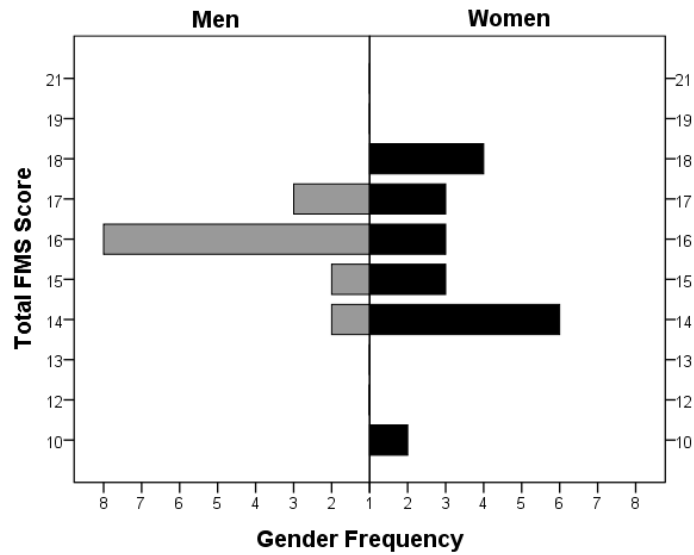
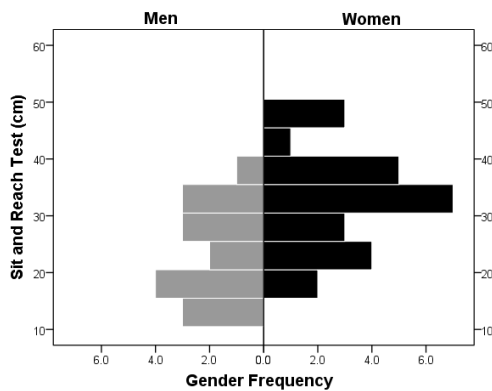


Figure 3: Distributional illustration of the total FMS score between men and women (n = 41)

A Mann-Whitney U test was performed to determine if there were differences in the total FMS scores between men and women. Distributions of the FMS scores among men and women were not normally distributed, as assessed by visual inspection (Figure 4) and the Shapiro-Wilk test for normality ($p = 0.005$). There were no statistically significant differences in total FMS scores between men (mean rank = 21.5) and women (mean rank = 20.7), Mann-Whitney U = 192; $z = -0.217$, $P = 0.843$.

A



B

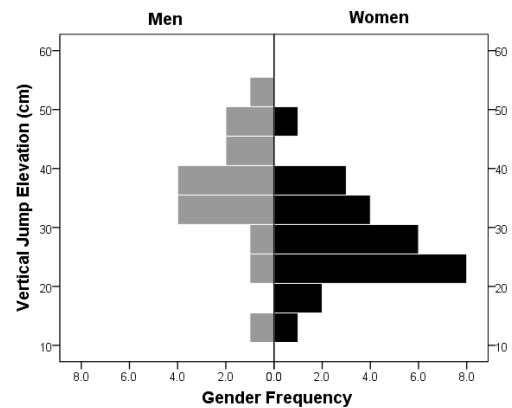


Figure 4: Sit & Reach Distributional plots (A) and Vertical Jump distributional plots (B) between men and women

The distributions of Sit-and-Reach (SR) and Vertical Jump (VJ) performance test were normally distributed in men and women respectively. Independent T-tests showed that women achieved a significantly higher score in SR outcome $32.72\text{cm} \pm 8.51$) compared to men $23.56\text{cm} \pm 7.87$ ($P = 0.001$) and significantly lower score for VJ (women: $27.64\text{cm} \pm 7.65$) compared to men $36.63\text{cm} \pm 10.44$ ($P = 0.006$).

The Foot Posture Index dominant side revealed that women had a 68% normal, 28% pronate and 4% supinated foot posture. The Foot Posture Index in the men revealed that men had 75% normal, 6.3% pronated and 19% supinated foot posture. There were no significant differences in the distribution of normal, supinated or pronated Foot Posture Index among men and women, $\chi^2 (1) = 4.603$, $P = 0.100$.

2.4.3 Differences in Functional Outcomes between Injured and Uninjured

Participants

Table 5: Frequency table for the different components of the Functional Movement Screen

Variable	Frequency (%) Injured vs Uninjured			Chi-Square Statistic Or Fisher's Exact Test	P - Value	Min Expected Count
FMS Component Scores						
Deep Squat	27%	V	13%	$\chi^2 (1) = 13.580$	p = 0.445	(3.29)
Hurdle Step	73%	V	13%		p ≤ 0.001*	(7.32)
Shoulder Mobility	15%	V	27%	$\chi^2 (1) = 2.853$	p = 0.434	(2.93)
In Line Lunge	54%	V	27%		p = 0.091	(6.59)
Active Straight Leg Raise	58%	V	40%	$\chi^2 (1) = 1.192$	p = 0.275	(7.32)
Trunk Stability	46%	V	40%	$\chi^2 (1) = 1.146$	p = 0.702	(6.59)
Push-Up						
Rotary Stability	35%	V	40%	$\chi^2 (1) = 0.119$	p = 0.730	(5.49)

*The Hurdle step component was correctly executed by significantly more injured runners (7 out of 26) compared to uninjured runners (2 out of 15), $\chi^2 (1) = 13.58$, $P < 0.001$.

The frequency distributions of different components of the FMS test revealed a higher proportion of the injured runners being able to correctly execute the specific components compared to uninjured runners. Apart from HS, all other components had similar frequency distributions between the injured and uninjured groups (Table 5).

The functional variables that were significantly different between men and women within the total group, i.e. Sit-and-Reach (SR) and Vertical Jump (VJ), were analysed by Multifactorial ANOVAS to determine if significant interactions existed between gender and incidence of injury.

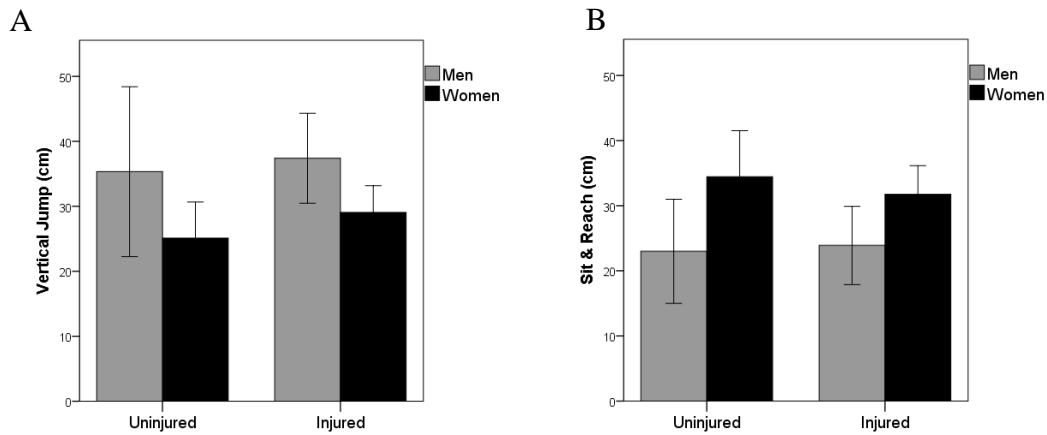


Figure 5: Bar charts illustrating the differences between gender and its effect on the incidence of injury during the OTP for A) Sargent Vertical Jump performance outcome and B) Sit and Reach performance outcome

Studentized Residuals for values greater than ± 3 were assessed to test for any outliers in the Estimated Marginal Means during the Multifactorial ANOVA process for VJ and SR. No outliers were present as Residuals were normally distributed (Shapiro-Wilk, $P > 0.05$). There were no statistically significant interactions between gender and the incidence of injury for SR outcomes, $F(1, 37) = 0.414$, $P = 0.524$, partial $\eta^2 = 0.011$. The main effect of gender showed a statistically significant difference in SR outcome at incidence of injury level, $F(1, 37) = 11.94$, $P = 0.001$, partial $\eta^2 = 0.244$.

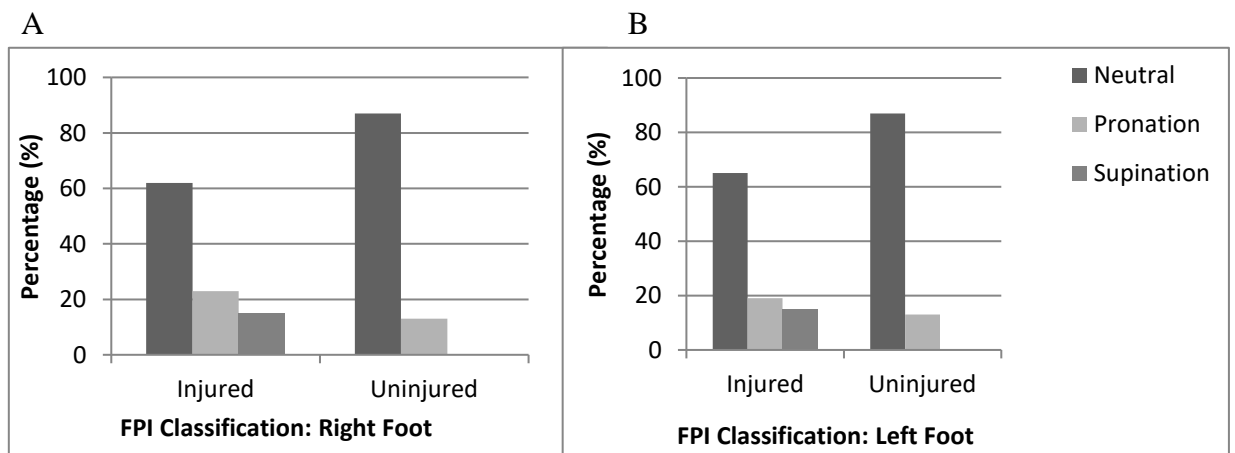


Figure 6: Illustration of the distribution of neutral, pronated and supinated foot posture outcomes between injured and uninjured participants

Uninjured runners had an 87% neutral foot posture ($-4 \leq \text{FPI} \leq +5$) distribution on both limbs. Whereas, sixty two percent of injured runners presented with a neutral foot posture on the left limb 65% presented with a neutral posture on the right limb. Fifteen percent of the runners had a supinated foot posture, and these were all injured during the 12-week OTP. Despite this, log linear analysis (model selection) revealed no significant differences or interactions among the 3 categories (neutral, pronation, supination) of Foot Posture Index and incidence of injury ($\chi^2 = 0.446$, $P = 0.504$).

2.4.4 External Behavioural Outcomes

2.4.4.1 Differences between Men and Women

The total number of running sessions (mean \pm SD, range) accumulated over the 12-week observational period was similar between men (47 ± 22 , 18 -88) and women (42 ± 19 , 10 – 88); $P > 0.05$. Mann-Whitney U Tests were performed to determine differences between men and women for the Total km run, the number of other training sessions (e.g. gym and other endurance training) and races run over the 12-week OTP. The only significant difference found between men and women was the total number of other training sessions over the 12 weeks (Mann-Whitney $U = 91.5$; $z = -2.907$, $P = 0.003$). Women (mean rank = 25) completed on average 11 more other training sessions compared to men (mean rank = 14) over the 12-week OTP.

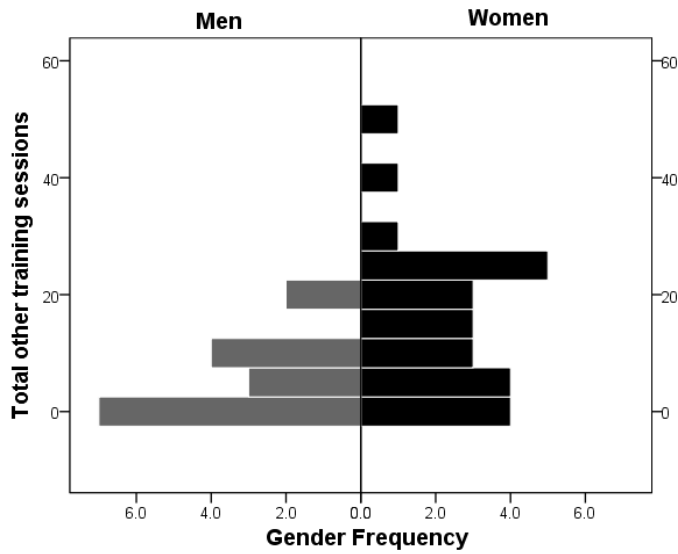


Figure 7: Distributional illustration of the total other training sessions over the 12 weeks of observation between men and women

2.4.4.2 Differences between Injured and Uninjured Participants

The total of other training sessions [median (Interquartile range)] accumulated over the 12-week observational period was similar between injured participants [8 (17)] and uninjured 10 [10 (22)]. There was no significant gender and incidence of injury interaction effect for the total number of other training sessions performed during the 12-week OTP, $F(1, 37) = 0.062, P = 0.805$ partial $\eta^2 = 0.002$.

The main effect of injury incidence showed no statistically significant difference in other training sessions completed between groups, $F(1, 37) = 0.163, p = 0.689$, partial $\eta^2 = 0.005$. The total number of running sessions and total km run, were similar between injured and uninjured participants.

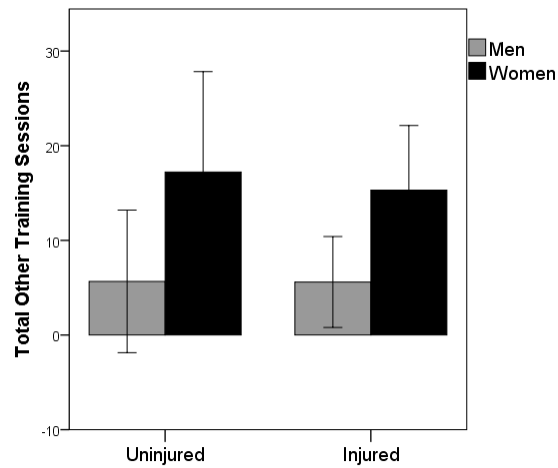


Figure 8: The bar chart illustrating the differences between gender and its effect on the incidence of injury for Total Other Training Sessions completed during the 12-week OTP

2.4.5 Predictors of Injury

The following section investigated if a) Internal physical characteristics and training characteristics, b) External Functional Screening Assessment Outcomes, and C) External Training Behavioural factors significantly predicted or increased the odds (odds ratio) for injury over a 12-week observational training period.

The major differences between groups within the study populations were found between men and women in the total group regardless to whether the runner experienced or did not experience and injury. However, none of the results previously described, showed a gender and incidence of injury interaction for the differences found in all major internal and external outcome variables. Mixed model analysis was therefore omitted and Binomial Logistic Regressions were performed to determine whether any of the internal or external factors were associated with increased risk for a running – related injury.

2.4.5.1 Internal Physical and Training Characteristics as predictors

Correlation coefficients among internal physical and training characteristics (age, BMI, years running, height and weight) determined if variables were related. Only one of any two related variables were included as independent variables within the Binomial Logistic Regression analyses. Years of Running significantly correlated with age ($r = 0.836$, $P < 0.001$), therefore Years of Running was omitted from the regression model. A binomial logistic regression was performed to determine the effects of age, BMI, gender and Injury in the past 12 months on the likelihood that participants experience an injury.

The overall logistic regression model was not statistically significant, $\chi^2(6) = 11.41$, $P = 0.077$. None of the four predictor variables were statistically significant (Table 6).

Table 6: Logistic Regression Predicting Likelihood of Injury based on Internal Physical & Training Characteristics

	B	S.E.	Wald	df	p	Odds Ratio	95% CI for Odds Ratio	
							Lower	Upper
Age	-.046	.037	1.536	1	.215	.955	.888	1.027
BMI	-.253	.130	3.797	1	.051	.776	.602	1.001
gender (1)	.510	.830	.378	1	.539	1.666	.327	8.478
Past Injury (12 months) (1)	-1.528	.786	3.783	1	.052	.217	.047	1.012
Constant	8.787	3.502	6.297	1	.012	6550.168		

Note: Gender is for women compared to men, and Past Injury is for injury compared to no injury

2.4.5.2 External Functional Screening Outcomes as Predictors

Correlation coefficients among external functional and performance outcomes (Total FMS Score, Sit-and Reach, Single Leg hop test – dominant side and Vertical Jump) were determined to indicate if variables were related. Only one of any two related variables were included as an independent variable within the Binomial Logistic

Regression analyses. Single leg hop – dominant side significantly correlated with Vertical Jump ($r = 0.75$, $P < 0.001$), therefore Single leg hop – dominant side was omitted from the regression model. A binomial logistic regression was performed to determine the effects of FMS, Sit-and-Reach and Vertical Jump performance outcomes on the odds for injury. The logistic regression model was statistically significant, $\chi^2(3) = 9.764$, $P = 0.021$. The model explained 29.0% (Nagelkerke R^2) of the variance in injury and correctly classified 66% of cases. Sensitivity was 80.8% and specificity was 40%. Of all cases predicted to have injury, 70% was correctly predicted. Of all cases predicted to have no injury, 54% were correctly predicted. One of the three predictor variables were statistically significant (Table 7).

Table 7: Logistic Regression Predicting Likelihood of Injury based External Functional and Performance Outcomes

	B	S.E.	Wald	df	p	Odds Ratio	95% CI for Odds Ratio	
							Lower	Upper
FMS	.568	.229	6.134	1	.013	1.764	1.126	2.764
Vertical Jump	.007	.039	.031	1	.860	1.007	.892	1.042
Sit-and-Reach	-.037	.040	.843	1	.358	.964	.933	1.086
Constant	-7.266	3.476	4.369	1	.037	.001		

Increasing FMS score was associated with an increased likelihood to experience a RRI. The Odds ratio revealed that for every 1-unit difference in FMS score, the odds for risk of injury increases 1.764 – fold.

2.4.5.3 External Training Behavioural Factors as Predictors

Correlation coefficients among external training behavioural characteristics (total km's completed over the 12 – weeks, total running sessions completed, total other training sessions, i.e. gymnasium work and other endurance training sessions) determined if

variables were related. Total km's run significantly correlated with total running sessions ($r = 0.765$, $P < 0.001$), therefore total km's ran was omitted from the regression model. A binomial logistic regression was performed to determine the effects of total running sessions and total other training sessions over the 12 weeks OTP on the likelihood that participants experience an injury. The logistic regression model was not statistically significant, $\chi^2(2) = 1.919$, $P = 0.383$. Neither of the two predictor variables were statistically significant (Table 8).

Table 8: Logistic Regression Predicting Likelihood of Injury based External Training Behavioural Outcomes

	B	S.E.	Wald	df	p	Odds Ratio	95% CI for Odds Ratio	
							Lower	Upper
Total Running Sessions	-.024	.018	1.777	1	.182	.976	.941	1.012
Total Other Sessions	-.013	.028	.205	1	.651	.988	.935	1.043
Constant	1.747	.969	3.249	1	.071	5.736		

2.5 Discussion

The purpose of this observational study was to detect overall, internal and external, predictive risk factors for sustaining a running related injury in a group of recreational long-distance road runners.

1st Aim of the study

We determined a running related injury incidence of 63%, among 41 recreational road runners, over a 12-week observational period. Sixty three percent of men (10/16) and 64% of women (16/25), sustained an injury during the observational training period (OTP), $\chi^2(1) = 0.0009$, $P = 0.923$. A running related injury was defined as “any physical pain located at the lower limbs or lower back region, sustained during or as a result of running practice and impeding planned activity for at least one day” (Buist et al., 2007).

Walter and associates (1989) reported a similar range of injury incidence, among recreational runners. They reported an injury incidence of 54%; however, the sample size consisted of 1680 runners that were monitored over a 12-month follow-up period for the incidence of running related injuries.

The high incidence of injury was associated with high running distance, but not with any other training related variables. Injury incidence was the same across gender groups and years of running experience did not seem to influence this occurrence. In contrast to our study, Buist and co-authors (2010) reported an injury incidence of 21%, again, with a much larger sample size of 532 runners. They also focussed on gender differences as the main predictor of injury incidence. Although the follow up time of 13 weeks and self-reported injuries were in line with our methods, they defined injury as “pain related to the back or lower extremities, causing running restriction for at least one week”. Thus, they required a more serious injury before it could be reported, compared to our study definition of running restriction for at least one day. Hespanhol Jnr and co-authors (2016) also reported a lower injury incidence rate of 27% among recreational runners compared to the 64% in our study. Again, our studies were similar in the follow-up time of 12 weeks, investigating recreational runners that have been running regularly for at least 6 months and were injury free at the start of the study, but they had a larger sample group of 89 recreational runners and their main outcome was the incidence of running related injuries and lower limb alignment. In the current study, running injuries were self-reported in relation to pain experienced in the lower limbs and back, and that prevented a planned training session for at least one day. The differences of injury incidence between previous studies and our study may be due to

the difference in injury definition and sample size of running groups that were used across studies with similar outcome variables and study populations.

Perhaps our most significant and unexpected finding was runners that sustained at least one injury during the 12-week OTP had a significantly higher FMS score at the outset of the study, than those that remained injury-free. In previous studies, the cut-off value for the total FMS score that was associated with greater risk of injury was ≤ 14 in football players (Kiesel et al., 2007) and among runners in other studies (Hotta et al., 2015; Loudon et al., 2014). Hotta and colleagues (2015) investigated whether the FMS could indicate an increased risk to injury among competitive male runners. They reported the FMS as a purposeful screening assessment to identify increased risk for injury. In contrast to our study they reported a lower mean FMS score (14.1 ± 2.3) among their sample of runners compared to our study ~ 16 (3), however they concluded that the total FMS score in their study had a low injury prediction value, indicating only 29% of the injury variance. Conversely, our findings show a significant relationship between FMS and an increased risk for injury among recreational runners, but the response is inverted. Our results indicate that a higher total FMS score is associated with a higher risk of injury, in contrast to the study by Hotta and colleagues (2015).

Loudon and associates (2014) investigated normative values for individual and total FMS scores in relation to age by assessing a sample of recreational runners divided into two groups: one younger than 40 years and one older than 40 years. Younger runners achieved a higher total FMS score of 16.4 ± 1.9 in comparison to 13.9 ± 2.3 in older runners. Although Hotta and colleagues (2015) reported a lower total FMS score (13.3 ± 2.7) as a predictor of a higher risk to injury, Loudon and associates (2014) reported

that older age (≥ 40) was associated with a lower total FMS score (13.9 ± 2.3) and younger age (≤ 40) was associated with a higher total FMS score (16.4 ± 1.9). This is similar to the results in the current study where the mean (\pm SD) age of the runners in the injury group was 37 ± 9.07 years and they recorded a total FMS score of 16 (3).

The current study was different from the aforementioned studies, in age, gender and training status groups. Hotta and colleagues (2015) only investigated 18 – 24 year old elite male runners and Loudon and colleagues (2014) only investigated age groups, in contrast to our study which investigated recreational runners between the age of 18 and 65 years. The variation in age, the mixed gender sample and the recreational status of the runners in the current study are all possible contributing reasons for the difference in outcome measures between the current study and the outcome measures reported by Hotta and colleagues (2015) and Loudon and associates (2014).

Individual FMS components were investigated between injury groups, but only one component proved statistically different. The hurdle step was the only component that revealed a significant difference between the injured and uninjured groups. Seventy three percent (19/26) of injured runners and 13% (2/15) of uninjured runners performed the HS movement correctly, ($P < 0.001$). We found that total FMS score was a significant predictor of injuries among recreational runners, however Hotta and associates (2015) reported total FMS score as a poor predictor of injury. They disaggregated the FMS into individual components to find a significant association between the FMS and injury incidence. They determined that the combined scores (≤ 6) of the DS and ASLR were better predictors of increased risk to injury than the total FMS score.

An individual FMS component in the current study, which was compared between men and women, was found to be statistically different for 3 individual components. The HS and active straight leg raise (ASLR) was performed correctly by 64% women vs 24% men ($P = 0.041$) and 68% women vs 25% men ($P = 0.007$), respectively. Eighty eight percent of men performed the trunk stability push-up correctly, in comparison to only 16% of women ($P \leq 0.001$). Loudon and associates (2014) also found meaningful gender differences on the ASLR and SM tests of the FMS, with women presenting greater flexibility on both tests. There was no significant differences between men and women for total FMS scores, but Loudon and associates (2014) reported a similar finding in their sample of mixed gender recreational runners.

The increased FMS scores among the injury group is contradictory to the other literature that was presented on FMS scores and increased risk to injury. One theory that may help to explain the higher FMS scores and the higher injury rates during the 12 week OTP among this cohort of runners is the prospect of increased joint laxity. Murphy and associates (2003) investigated the literature for risk factors associated with lower extremity injuries. In his review, he cited Ostenberg and Roos (1973) as well as Soderman and associates (2001) who indicated that moderate to high joint laxity scores (4+ / 9) on the Beighton scale increased the risk for injury among the athletic population 3 to 5 times in comparison to athletes who do not present with joint laxity.

2.5.1 Internal Physical Characteristics (2nd Aim of the study)

The findings of the present study differ from those reported by Buist and co-authors (2010), who found that although men and women present with significant BMI differences, there was an interaction between BMI and the incidence of injury. The men

in the study sample by Buist and co-authors (2010) had a mean BMI of $25.9 \pm 3.3\text{kg/m}^2$ and a hazard ratio of 1.14 for sustaining a new injury, compared to a BMI of $24.2 \pm 3.4\text{kg/m}^2$ in women ($P \leq 0.01$) with no association to new injury incidence. The lower BMI values among the injury group, in the present study, are a supported finding in previous literature. Murphy (2003) explained that men within a cohort of military recruits who presented with BMI values in the lowest and highest quartiles had three times more injury incidences on the lower extremities in comparison to the 50% of recruits on the middle quartile. Malisoux and co-authors (2014) found a similar interaction between BMI and injury incidence in comparison with the current study.

Among a cohort of 517 recreational runners they found that runners with a BMI value lower than 25kg/m^2 are at higher risk of injury compared to those with a BMI value lower than 25kg/m^2 . They continued by explaining that the cause of the results is unclear but they theorized that perhaps runners with a lower BMI can complete further distances per individual running session than those with higher BMI's, placing them at higher risk of injury. In the current study, session mileage was not measured; therefore this is a possible contributor to the association between lower BMI among the injury group.

In the current study, we also found no difference between injured and uninjured runners with respect to previous injury over the past 12 months (69% vs 46%). This is in contrast to previous findings, for example of Buist and co-authors (2010), male gender and previous injury had a hazard ratio of 2.6, as a predictor of future injury. They found no association between previous injury and female gender. They attributed this to the fact that persons who sustained injuries in the previous 3 months were excluded from

the study and the majority of women included in the sample were novice runners who had not run regularly before. In the current study participants were not excluded based on an injury occurrence in the previous 3 months, neither did our study include novice runners.

In the literature, previous injury has been one of the only homogenous predictive risk factors associated with the occurrence of a future injury. Wen and associates (1998), Taunton and colleagues (2003) and Saragiotto and colleagues (2014) suggested that this may be due to inadequate rehabilitation of the initial injuries, before runners resume their training. On the other hand Hootman and associates (2002) concluded that athletes who sustained previous injuries and underwent adequate rehabilitation should be able to return to sport without any residual weakness relating to the treated injury and therefore not be at any greater risk than an athlete that has not sustained an injury before.

2.5.2 External Functional Characteristics (3rd Aim of the study)

One would expect a better performance on the explosive performance tests from runners who remained injury free through the 12 week OTP in comparison to runners who sustained an injury, but it is possible that the runners who performed better on the explosive performance tests have better musculoskeletal development and therefore have the strength to train harder and longer and in turn place themselves at a higher risk of sustaining an injury (Buist et al., 2010). Explosive strength and flexibility measures provide a platform for athletes and clinicians to compare an athletes' physical conditioning with age and gender related peers. However, in the current study no interaction was found between performance tests and injury incidence suggesting that

performance test measures are not adequate indicators of a runners' probable risk to injury.

Among the total sample of runners, women had a mean forward reach (sit and reach test outcome) of 32.72 ± 8.5 cm in relation to the 23.56 ± 7.87 cm achieved by men. This is a 9.1 cm difference between genders for the sit and reach test, ($P = 0.001$). No interaction was found between gender and injury incidence for performance test (VJ and S & R) outcomes. Hreljac and colleagues (2000) reported the difference in flexibility measures between injury groups as the only meaningful anthropometric variable, with runners that were injury free presenting with greater flexibility ($P = 0.05$). They did not report sit and reach measures between genders. Although Hreljac and associates (2000) reported using a standard sit and reach test, the mean (\pm SD) reported values they used for the injury group was -3.7 ± 11.6 cm and for the injury free group was 3.2 ± 10.2 cm in comparison to the current study measures of 28.76 ± 9.02 cm among injured runners and 29.87 ± 10.13 cm for uninjured runners. Hreljac and associates (2000) do not elaborate on the reference value they used for the forward reach distance in order to calculate these values. This creates difficulty to make a direct comparison of flexibility measures, for the sit and reach test, among study groups.

The combination of higher total FMS score, more explosive power (higher Vertical Jump elevation) and greater flexibility measures was associated with runners that sustained an injury during the 12-week observational period. Assessing these outcomes and placing them in context with the characteristics of investigated sample of runners we conclude that recreational runners that spend additional training sessions increasing either cardiovascular fitness or musculoskeletal strength achieves better scores on

performances tests, however these individual systemic increases expose runners to greater risks of injury as the increased physical abilities permits runners to push their bodies for greater performance in any given running situation, often leading to increased risk to injury. This relates to the report by Buist and associates (2010) indicating that runners engaging in non-axial load activities has a greater risk to injury due greater cardiovascular fitness but a possible shortage of adequate musculoskeletal strength.

2.5.3 External Behavioural Outcomes

During the 12-week OTP participants continued their usual training regimen and logged all the training sessions in the online logbook (Survey Monkey) platform. During the statistical analyses, we combined endurance exercise sessions - that did not involve running- and strength or resistance exercise sessions and labelled these as other training sessions. During the 12-week observational training period, women completed a mean of 25 other training sessions (strength and endurance), $P = 0.003$. This is 11 more training sessions than men (mean = 14) completed over the same time. Injured [8(17)] and uninjured [10 (22)] running groups completed similar amounts of strength and endurance training sessions, $P = 0.904$. No interaction between gender and incidence of injury was detected for any of the external behavioural outcomes. Taunton and colleagues (2003) investigated 844 recreational runners over 13 weeks as they were preparing for a 10-km race. The training preparation was done under guidance from programmes constructed by sports medicine doctors, offered to recreational runners at different running clinics. They advised 3 running sessions and 2 cross training sessions per week. According to their statistical analysis they could not find any relation between cross training and injury incidence. The findings in our study agree with the reports

from Taunton and colleagues (2003), as we show that strength and endurance training could not predict sustaining a running related injury. Saragiotto and associates (2014) reported in the recent literature review that weekly training, consisting of further distances ($\geq 64\text{km}$) and increased frequencies (3 – 7 days per week) can overload the body's musculoskeletal system to the extent that the body's regeneration systems fails leading to musculoskeletal injury. In contradiction to the study by Taunton and colleagues (2003). Buist and co-authors (2010) reported that recreational runners who engaged in additional non – axial loading exercises e.g. cycling or swimming had a greater risk to injury in comparison to runners who added additional interval training sessions into their weekly exercise programme. They continued by explaining that the runners who engaged in other sports likely developed a greater cardiovascular ability than those who only engaged in running. With the additional cardiovascular exercise it is possible that the musculoskeletal system was not sufficiently conditioned to maintain the forces placed upon the body by the repetitive nature of running, therefore increasing the risk to injury.

2.6 Limitations

The results provided from the study should be read and interpreted in context, as the investigation is not without limitations. The small sample size restricted more definitive interpretation, with specific referral to the interactive relationship between previous injuries ($P = 0.052$) and the risk to sustain a future injury. The injury definition we used in the current study was based on the definition used by Buist and associates (2007), but this is still different to the other injury definitions available in the literature. Missing training for one day could have included an injury that was not so serious, not even

serious enough to seek medical attention, whereas an ailment forcing participants to stop training for a week would have been a better option to indicate a serious injury.

Another limitation was the absence of familiarisation sessions among participants for the performance tests, which may be that outcomes could have a better true reflection of the runners' abilities after a familiarisation session. Allowing for self-report responsibility of injuries among participants also may result in some reporting bias. The subjective interpretation of pain, together with the disregard of injury symptoms may lead to the over- or under reporting of injuries among runners. A conscious effort to complete an online training diary may be sensitised to the injury or reporting bias. Also, the instruction to keep an online diary could have influenced the runners training regime, not reflecting their true training frequency, duration and intensity. The lack of association between training distance and injury groups can be attributed to the fact that subjects remained in the cohort after injury occurred.

2.7 Conclusion

The most important finding in this study was the high (63%) incidence of at least one injury during the 12 weeks of follow-up among these recreational runners. In the current study, we found the total FMS score to be a predictive of increased risk for injury. This is opposite to the outcome that was expected and different from what is reported by other studies (Hotta et al., 2015; Loudon et al., 2014). The overall model only explained 29% of the variance in risk of injury, suggesting that other factors (unknown) rather than performance screening tests (FMS, vertical jump, sit and reach) may explain incidence of injury, and more research is needed to investigate this.

Furthermore, in contrast to other studies, this study did not find previous self-reported injury as a predictor of current injury. More research is needed to identify interactive factors that predispose recreational runners to an overall increased risk of sustaining injuries that are associated with long distance road running. Moreover, more work is needed on devising rapid clinical and functional assessments that predict injury, as a means to prevent running-related injuries.

3. References

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4. Appendices

APPENDIX 1: ETHICAL CLEARANCE LETTER FROM THE UNIVERSITY



UNIVERSITY OF CAPE TOWN



Faculty of Health Sciences

Human Research Ethics Committee

Room E52-24 Old Main Building

Groote
Schoor Hospital
Observatory 7925
Telephone [021]
406 6492 Email:
sumayah.ariefdien@uct.ac.za

Website: www.health.uct.ac.za/fhs/research/humanethics/forms

01 June 2016

HREC REF: 149/2016

Dr J Kroff

Division of Exercise Science & Sports Medicine
Human
Biology
Newlands

Dear Dr Kroff

PROJECT TITLE: THE INFLUENCES OF AN INJURY RISK ASSESSMENT

PROTOCOL ON THE

INCIDENCE OF MUSCULO-SKELETAL INJURIES IN RECREATIONAL
LONG-DISTANCE RUNNERS (MPhil-candidate-T Smith)

Thank you for your response letter dated 09 May 2016, addressing the issues raised by the Human Research Ethics Committee (HREC).

It is a pleasure to inform you that the HREC has formally approved the above-mentioned study.

Approval is granted for one year until the 30 June 2017.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.

(Forms can be found on our website:

www.health.uct.ac.za/fhs/research/humanethics/forms) We acknowledge that the student, Tanya Smith will also be involved in this study.

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator must obtain appropriate institutional approval before the research may occur.

Yours sincerely

Signed by candidate

PROFESSOR M BLOCKMAN

CHAIRPERSON. FHS HUMAN RESEARCH ETHICS COMMITTEE

Federal Wide Assurance Number: FWA00001637.

Institutional Review Board (IRB) number: IRB00001938

HREC 149/2016

This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in

patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DOH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI), and Declaration of Helsinki (2013) guidelines. The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

APPENDIX 2: INFORMED CONSENT FORM



INJURY RISK ASSESSMENT AND THE INCIDENCE OF MUSCULO-SKELETAL INJURIES IN RECREATIONAL LONG-DISTANCE RUNNERS OVER A 3-MONTH TRAINING PERIOD

PARTICIPANT INFORMATION & INFORMED CONSENT

ALL participants to read and sign

WHAT IS THE STUDY ABOUT?

The study entitled “**INJURY RISK ASSESSMENT AND THE INCIDENCE OF MUSCULO-SKELETAL INJURIES IN RECREATIONAL LONG-DISTANCE RUNNERS OVER A 3-MONTH TRAINING PERIOD**” will be carried out by researchers from the UCT Research Unit for Exercise Science and Sports Medicine (ESSM) within the Department of Human Biology at Tanya Smith Biokinetics in Somerset West. The aim of the study is to compare the incidence of injuries of four different running clubs in the Cape Town area, over a period of six months, after the athletes in the club have undergone an injury risk assessment with a Biokineticist. The current identification of the specific risk factors which leads to injuries in runners are not well-established. Almost all studies looking at risk factors report that huge variability in the type of injuries that occur with long distance running and the factors that puts the runner at risk for running related injuries. This makes it difficult to conclude if risk factors identified among other running populations will also applicable to the local running population, or whether the same factors will cause running related injuries among local recreational runners. The researchers of the present study want to determine the specific risk factors that manifests in local recreational club runners. This finding will enable us to identify the risk of injury prior to the actual event of injury. The development of methods to prevent running related injuries will

enable recreational runners to train all-year round without the devastation of losing their training status, or quit the sport in totality, due to injury.

WHAT WILL BE REQUIRED OF ME?

You will be asked to visit the practice of Tanya Smith Biokineticist on **two** occasions for 90 minutes. You will need to avoid alcohol and vigorous exercise in the hours prior to the visit. All of the assessments will be conducted by a qualified Biokineticist. All of the tests will only be completed after a demonstration was shown. The tests will take place under constant supervision of a Biokineticist.

Practice visit (1 hour)

The following measurements / tests will be taken during your visit:

- Questionnaire – You will be asked to complete a questionnaire concerning: personal details, brief medical history, your running history, training habits and injury history.
- Posture Analysis - You will be asked to stand in front of a posture grid while the Biokineticist assess your posture from the front, side and back. She will look at your posture and make notes on what she observes.
- Body composition assessment – Your height, weight and waist circumference measurements and body composition measurements will be taken, while you are wearing light-weight clothing. Your body composition will be determined using a mathematical formula.
- Foot Posture Index – This is a method of determining your foot posture. You will be asked to stand bare feet on a solid surface for approximately 2 minutes, without shifting your stance. While you are standing the Biokineticist will assess your feet by looking at your stance from the front, the side and the back. Your foot posture will be measured against standardised criteria for this specific assessment.
- Sit and Reach – This is a flexibility measure for your lower back. A sit and reach box will be placed against the wall. You will be asked to sit on the floor placing bare feet under the ruler touching the wall of the box. Placing one hand on top of the other and lowering your hands onto the ruler, you will be asked to reach forward as far as you can, while keeping your hands on the ruler and your knees straight.

- Single Leg Hop for Distance Test – Standing on one leg you will be required to jump as far as you can and land on the same leg, then maintaining your balance for a moment. The distance jumped will be marked and measured. The same protocol will be followed for the opposite leg.
- Vertical Jump Test - The vertical jump test is a measure of explosive power. You will be asked to dust your fingers in chalk and stand sideways against the wall while stretching out the arm closest to the wall. This will leave a mark at the highest reaching point of your fingers. You will then be asked to resume a comfortable standing position. From here you will be instructed to jump as high as possible and touch the wall with your fingers – leaving a chalk mark on the wall. Your reaching and jumping distance will be measured with a measuring tape.
- Functional Movement Screen – This is a test battery, consisting of 7 different movements, which is designed to determine if you move optimally.
 - Deep Squat: You will be asked to hold a Dowel (nearly weightless bar) above your head with outstretched arm and perform a squat, by lowering your hips as close to the floor as you can while maintaining an upright body and forward-facing knees.
 - Hurdle Step: A crossbar will be raised to the height of the bony prominence just beneath your knee. You will hold the Dowel horizontally behind your neck. You will then be asked to step over the crossbar. This will be repeated with both limbs.
 - Inline Lunge: You will hold the Dowel vertically behind your back. One hand will hold the Dowel behind your neck and the other hand will hold it in the middle of your lower back. You will then be guided to perform a lunge movement placing one foot in front of the other in a straight line. The test will be repeated on both limbs.
 - Shoulder Mobility: Standing comfortably you will be asked to make close both hands forming a soft fist with each. You will then be asked to attempt touching your fists behind your upper back by bending one elbow overhead and one elbow under the shoulder. This will be repeated with both shoulders moving overhead.
 - Active Straight Leg Raise: You will be asked to lie down on your back on a consultation bed. You will be asked to lift one leg as high as possible while keeping the knee straight. While you hold your leg in the air, the Biokineticist will use a goniometer (measuring tool) to measure how flexible you are. She will place a goniometer on the bony prominence on the outside of your upper thigh and measure the degrees between the bed and your raised leg. You will then be able to relax your leg back onto the bed. The same measurement will be repeated on the opposite side.
 - Trunk Stability Push Up: You will start out by lying face down on the floor, body extended. Male participants will place their hands shoulder width apart

in line with their head. Female participants will place their hands shoulder width apart in line with their chin. From this position, you will perform a push up and attempt to do so without allowing any lag in the lumbar spine. If this is not possible for either male or female the same exercise will be repeated after adjusting the hands to a standardized alternate position.

- Rotary Stability: You start the movement by kneeling on your hands and knees with hands placed directly under the shoulders and knees placed in line with the pelvis. From this position, you will unilaterally lift an arm and a leg, extend the leg backward and the arm forward and then bring the elbow to the knee by performing a knee and elbow flexion motion. You will attempt to successfully complete the movement without losing balance or falling over to one side. In the case where you cannot successfully complete the movement a second attempt will be taken by using opposite limbs to form a diagonal movement. The movement will be repeated for both the left and the right side.
- Training Diary – After the initial screening assessment you will be asked to keep an electronic training diary on a weekly basis. This will require that you record your intensity, frequency, volume and surface of training for the week. You will also be asked to report any injury sustained during any given day.

WHAT ARE THE RISKS TO ME?

Participation in this study poses minimal risks. There are only minimal risks associated with completing a questionnaire, the posture analysis or the body composition measurement.

The Foot Posture Index, navicular drop test and the active straight leg raise measurements might cause some discomfort as the test requires the Biokineticist to physically touch you and be part of your personal space for the short duration of the measurement.

The sit and reach test, will cause your heartrate to increase, is likely to cause perspiration, slight breathlessness, thirst and fatigue.

The single leg hop test, vertical jump test and the FMS battery may hold a moderate risk of injury. You will be required to do functional movements that requires balance and coordination.

These tests will be thoroughly explained and demonstrated to you to minimise the risk of injury. You will be supervised by a qualified Biokineticist at all times during the injury risk assessment and are free to discontinue with any of the tests should you feel that it places you at risk of an injury. You are also free to leave the trial, without prejudice at any stage.

WHAT ARE THE BENEFITS TO ME?

Participating in this study will give you the opportunity to undergo a full injury risk assessment and screening tests. This will be conducted by a qualified Biokineticist. A full feedback report will be given to you at the end of the study, at no charge. This study has the potential to highlight underlying risks that could lead to injuries as you progress with your training. Attending to these highlighted risks could prevent future injuries or enhance your current running effectivity.

WHAT IF SOMETHING GOES WRONG?

The University of Cape Town (UCT) undertakes that in the event of you suffering any significant deterioration in health or well-being, or from any unexpected sensitivity or toxicity, that is caused by your participation in the study, it will provide immediate medical care. UCT has appropriate insurance cover to provide prompt payment of compensation for any trial-related injury according to the guidelines outlined by the Association of the British Pharmaceutical Industry, ABPI 1991. Broadly speaking, the ABPI guidelines recommend that the insured company (UCT), without legal commitment, should compensate you without you having to prove that UCT is at fault. An injury is considered trial related if, and to the extent that, it is caused by study activities. You must notify the study doctor immediately of any side effects and/or injuries during the trial, whether they are research-related or other related complications.

UCT reserves the right not to provide compensation if, and to the extent that, your injury came about because you chose not to follow the instructions that you were given while you were taking part in the study. Your right in law to claim compensation for injury where you prove negligence is not affected. Copies of these guidelines are available on request.

WHAT WILL BE DONE WITH MY INFORMATION?

All the information collected during the study will be treated confidentially, will only be used for scientific research purposes and that your name and personal particulars will not be released under any circumstances.

CONSENT

I have read the detailed description of the testing procedures above, and have had the opportunity to ask, and have answered, any questions that I have relating to the study. I have been informed that I will be free to withdraw from the study at any time if I so wish without explanation or prejudice. Similarly, I understand that the researcher may also withdraw me from the study at any time if for some reason, I am not able to carry out the protocol as described. I will be free to ask any questions about the procedures and results of the study, prior to, during or after the study by contacting any of the persons below. I may contact the chair of the Human Research Ethics Committee (Prof Mark Blockman) at any time during or after the project if I have any questions or concerns about my rights or welfare as a research participant. I agree to participate in the study.

Participant's name: _____

Signature: _____ Date: _____

Investigator's name: _____

Signature: _____ Date: _____

Witness's name: _____

Signature: _____ Date: _____

Principal investigator: Dr Jacolene Kroff Tel: 021 650 4568 Email: jacolene.kroff@uct.ac.za	Co-Investigator: Tanya Smith Tel: 083 395 9805 Email: tanya.smith@live.co.za
Chair of Human Research Ethics Committee: Prof Mark Blockman Tel: 021 406 6338 Email: marc.blockman@uct.ac.za	Co- Investigator: Prof Estelle V. Lambert Tel: 021 650 4571 Email: vicki.lambert@uct.ac.za

APPENDIX 3: HEALTH QUESTIONNAIRE

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

Instructions: Please read them carefully and "tick" the appropriate Yes / No box opposite the question if it applies to you.

	YES	NO
ARE YOU:		
1. Over the age of 69 years and not used to being active?	<input type="checkbox"/>	<input type="checkbox"/>
HAS YOUR DOCTOR EVER SAID THAT YOU HAVE:		
2. A heart condition and that you should only do physical activity recommended by a doctor?	<input type="checkbox"/>	<input type="checkbox"/>
IS YOUR DOCTOR CURRENTLY PRECRIBING DRUGS FOR YOUR:		
3. Blood pressure or heart condition?	<input type="checkbox"/>	<input type="checkbox"/>
4. Diabetes?	<input type="checkbox"/>	<input type="checkbox"/>
5. Raised cholesterol?	<input type="checkbox"/>	<input type="checkbox"/>
DO YOU:		
6. Feel pain in your chest when you do physical activity?	<input type="checkbox"/>	<input type="checkbox"/>
7. Lose your balance because of dizziness or do you ever lose consciousness?	<input type="checkbox"/>	<input type="checkbox"/>
8. Currently smoke?	<input type="checkbox"/>	<input type="checkbox"/>
9. Have a bone or joint problem that could be made worse by a change in your physical activity?	<input type="checkbox"/>	<input type="checkbox"/>
10. Know anyone in your family who has had a heart attack, stroke or experienced sudden death prior to age 60 yrs (father /mother/ sibling)?	<input type="checkbox"/>	<input type="checkbox"/>
11. Know of any other reason why you should not do physical activity?	<input type="checkbox"/>	<input type="checkbox"/>

If you answered YES to one or more questions, consult with your doctor BEFORE increasing your physical activity and / or taking a fitness test. If you answered NO to ALL questions, you have reasonable assurance of you present suitability for a graded exercise programme and / or taking a fitness test. Postpone exercise or exercise testing if you have a temporary minor illness, such as a common cold

APPENDIX 4: RUNNING HISTORY

Running Experience				
Running Experience (Amount of years running)				
How many times per week have you run over the last 12 months?	YES	NO		
How many races are you planning to do in 2016?				
Please indicate how many of each you will be doing during 2016:	10 km	21 km		
	42 km	ultra		
Total Weekly Distance in km:				
In season	0 – 30	30-60	60-90	90+
Out of season	0 – 30	30-60	60-90	90+
Throughout the year	0 – 30	30-60	60-90	90+
How many days per week do you run?				
Total amount of time spent running during 1 week				
What is your average SHORTEST run duration during training?				
What is your average LONGEST run duration during training?				
What is your personal best time over 10 km?				
What is your personal best time over 21 km?				
What is your personal best time over 42km?				
Do you make use of interval or speed training?				
If yes, how many times per week and for how long per session?				
Do you make use of hill training?				
If yes, how many times per week and for how long per session?				

APPENDIX 5: INJURY HISTORY

INJURY HISTORY

Injury Definition: “Any physical pain located at the lower limbs or lower back region, sustained during or as a result of running practice and impending planned activity for at least 1 day (Malisoux, et al., 2015).

Have you suffered any injuries during the last 12 months?	Yes	No
If yes, please specify:		
How did you manage these injuries? E.g., Hamstring pain – doctor/physio/biokineticist Foot sprain – rest 2 days		
Have you suffered any injuries prior to 12 months ago? Please specify.		
Are you aware of any current “niggles”? Please specify.		
When last have you changed your shoes?		

APPENDIX 6: FOOT POSTURE INDEX

THE FOOT POSTURE INDEX® ***FPI-6***

Reference Sheet

The patient should stand in their relaxed stance position with double limb support. The patient should be instructed to stand still, with their arms by the side and looking straight ahead. It may be helpful to ask the patient to take several steps, marching on the spot, prior to settling into a comfortable stance position. During the assessment, it is important to ensure that the patient does not swivel to try to see what is happening for themselves, as this will significantly affect the foot posture. The patient will need to stand still for approximately two minutes in total in order for the assessment to be conducted. The assessor needs to be able to move around the patient during the assessment and to have uninterrupted access to the posterior aspect of the leg and foot.

If an observation cannot be made (e.g. because of soft tissue swelling) simply miss it out and indicate on the datasheet that the item was not scored.

If there is genuine doubt about how high or low to score an item always use the more conservative score.

Rearfoot Score	-2	-1	0	1	2
Talar head palpation	Talar head palpable on lateral side/ but not on medial side	Talar head palpable on lateral side/ slightly palpable on medial side	Talar head equally palpable on lateral and medial side	Talar head slightly palpable on lateral side/ palpable on medial side	Talar head not palpable on lateral side/ but palpable on medial side
Curves above and below the malleoli	Curve below the malleolus either straight or convex	Curve below the malleolus concave, but flatter/ more shallow than the curve above the malleolus	Both infra and supra malleolar curves roughly equal	Curve below malleolus more concave than curve above malleolus	Curve below malleolus markedly more concave than curve above malleolus
Calcaneal inversion/eversion	More than an estimated 5° inverted (varus)	Between vertical and an estimated 5° inverted (varus)	Vertical	Between vertical and an estimated 5° everted (valgus)	More than an estimated 5° everted (valgus)
Forefoot Score	-2	-1	0	1	2
Talo-navicular congruence	Area of TNJ markedly concave	Area of TNJ slightly, but definitely concave	Area of TNJ flat	Area of TNJ bulging slightly	Area of TNJ bulging markedly
Medial arch height	Arch high and acutely angled towards the posterior end of the medial arch	Arch moderately high and slightly acute posteriorly	Arch height normal and concentrically curved	Arch lowered with some flattening in the central portion	Arch very low with severe flattening in the central portion – arch making ground contact
Forefoot abd/adduction	No lateral toes visible. Medial toes clearly visible	Medial toes clearly more visible than lateral	Medial and lateral toes equally visible	Lateral toes clearly more visible than medial	No medial toes visible. Lateral toes clearly visible

Foot Posture Index Datasheet

Patient name	ID number
---------------------	------------------

	FACTOR	PLANE	SCORE 1		SCORE 2		SCORE 3	
			Date _____		Date _____		Date _____	
			Comment _____		Comment _____		Comment _____	
			<i>Left</i> -2 to +2	<i>Right</i> -2 to +2	<i>Left</i> -2 to +2	<i>Right</i> -2 to +2	<i>Left</i> -2 to +2	<i>Right</i> -2 to +2
Rearfoot	Talar head palpation	<i>Transverse</i>						
	Curves above and below the lateral malleolus	<i>Frontal/ transverse</i>						
	Inversion/eversion of the calcaneus	<i>Frontal</i>						
Forefoot	Prominence in the region of the TNJ	<i>Transverse</i>						
	Congruence of the medial longitudinal arch	<i>Sagittal</i>						
	Abd/adduction forefoot on rearfoot	<i>Transverse</i>						
	TOTAL							

Reference values

Normal = 0 to +5

Pronated = +6 to +9, Highly pronated 10+

Supinated = -1 to -4, Highly supinated -5 to -12

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APPENDIX 7: DATA COLLECTION SHEET

NAME			
NAVICULAR DROP TEST			
Right	Seated:	Standing:	Drop:
Left	Seated:	Standing:	Drop:
Notes			
ACTIVE STRAIGHT LEG RAISE			
Right		Left	
Notes			
SIT & REACH			
1 ST Attempt		2 nd Attempt	
Notes			
SINGLE LEG HOP FOR DISTANCE			
Right		Left	
Notes			
VERTICAL JUMP			
1 st attempt	Reach :	Jump :	Difference :
2 nd attempt	Reach :	Jump :	Difference :
Notes			

APPENDIX 8: FUNCTIONAL MOVEMENT SCREEN

THE FUNCTIONAL MOVEMENT SCREEN

SCORING SHEET

NAME _____ DATE _____ DOB _____

ADDRESS _____

CITY, STATE, ZIP _____ PHONE _____

SCHOOL/AFFILIATION _____

SSN _____ HEIGHT _____ WEIGHT _____ AGE _____ GENDER _____

PRIMARY SPORT _____ PRIMARY POSITION _____

HAND/LEG DOMINANCE _____ PREVIOUS TEST SCORE _____

FMS

TEST		RAW SCORE	FINAL SCORE	COMMENTS
DEEP SQUAT				
HURDLE STEP	L			
	R			
INLINE LUNGE	L			
	R			
SHOULDER MOBILITY	L			
	R			
IMPINGEMENT CLEARING TEST	L			
	R			
ACTIVE STRAIGHT-LEG RAISE	L			
	R			
TRUNK STABILITY PUSHUP				
PRESS-UP CLEARING TEST				
ROTARY STABILITY	L			
	R			
POSTERIOR ROCKING CLEARING TEST				
TOTAL				

Raw Score: This score is used to denote right and left side scoring. The right and left sides are scored in five of the seven tests and both are documented in this space.

Final Score: This score is used to denote the overall score for the test. The lowest score for the raw score (each side) is carried over to give a final score for the test. A person who scores a three on the right and a two on the left would receive a final score of two. The final score is then summarized and used as a total score.

FMS SCORING CRITERIA

DEEP SQUAT



3



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



2



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



1



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

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

HURDLE STEP



3



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



2



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



1



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

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

INLINE LUNGE



3



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



2



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



1



Loss of balance is noted

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

SHOULDER MOBILITY

3



Fists are within one hand length

2



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

1



Fists are not within one and half hand lengths

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

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



CLEARING TEST

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

Excerpted from the book, *Movement: Functional Movement Systems—Screening, Assessment, Corrective Strategies*
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ACTIVE STRAIGHT-LEG RAISE

3



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

2



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

1



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

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

TRUNK STABILITY PUSHUP

3

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



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



2



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

1

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

Women unable with thumbs aligned with the clavicle



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



SPINAL EXTENSION CLEARING TEST

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

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ROTARY STABILITY



3



Performs a correct unilateral repetition



2



Performs a correct diagonal repetition



1



Inability to perform a diagonal repetition

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



SPINAL FLEXION CLEARING TEST

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

APPENDIX 9: MIXED MODEL ANALYSES

Table 1: Mixed Model analysis of internal and physical characteristics that may influence the variance of incidence of running related injuries.

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	2.727433	.769721	35	3.543	.001	1.164816	4.290051
[genderm0f1=0]	-1.200924	1.303462	35	-.921	.363	-3.847093	1.445245
[genderm0f1=1]	0 ^b	0					
[inj_p12_mnths=0]	-.325732	.154134	35	-2.113	.052	-.638640	-.012823
[inj_p12_mnths=1]	0 ^b	0					
age	-.007341	.007802	35	-.941	.353	-.023179	.008497
Pre_BMI	-.074403	.033432	35	-2.225	.053	-.142274	-.006531
[genderm0f1=0] * Pre_BMI	.054032	.053574	35	1.009	.320	-.054729	.162792
[genderm0f1=1] * Pre_BMI	0 ^b	0					

a. Dependent Variable: injuryyes|no0.
b. This parameter is set to zero because it is redundant.

Table 2: Mixed Model analysis of external functional and performance outcome variables that may influence the variance of incidence of running related injuries.

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	-0.751000	0.575689	35.000	-1.305	0.201	-1.919711	0.417711
[genderm0f1=0]	0.543898	1.629840	35.000	0.334	0.741	-2.764854	3.852650
[genderm0f1=1]	0 ^b	0					
pre_vj	0.002841	0.009404	35.000	0.302	0.764	-0.016251	0.021933
pre_sr	-0.011706	0.009184	35	-1.275	0.211	-0.030350	0.006938
pre_fms	0.110097	0.039149	35	2.812	0.008	0.030620	0.189575
[genderm0f1=0] * pre_fms	-0.045591	0.102215	35.000	-0.446	0.658	-0.253098	0.161915
[genderm0f1=1] * pre_fms	0 ^b	0					

a. Dependent Variable: injuryyes|no0.
b. This parameter is set to zero because it is redundant.

Table 3: Mixed Model analysis of external behavioural outcome variables that may influence the variance of incidence of running related injuries.

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	0.806121	0.309641	35.000	2.603	0.013	0.177517	1.434726
[genderm0fl=0]	0.188494	0.451849	35	0.417	0.679	-0.728808	1.105796
[genderm0fl=1]	0 ^b	0					
totalRUNNINGsessions	-0.003063	0.006598	35	-0.464	0.645	-0.016458	0.010331
TOTALothersessions	-0.002984	0.008031	35	-0.372	0.712	-0.019289	0.013320
[genderm0fl=0] * TOTALothersessions	0.002083	0.021252	35	0.098	0.922	-0.041061	0.045228
[genderm0fl=1] * TOTALothersessions	0 ^b	0					
[genderm0fl=0] * totalRUNNINGsessions	-0.004714	0.008908	35	-0.529	0.600	-0.022798	0.013371
[genderm0fl=1] * totalRUNNINGsessions	0 ^b	0					
a. Dependent Variable: injuryyes1no0.							
b. This parameter is set to zero because it is redundant.							

APPENDIX 10: SURVEY MONKEY LOGBOOK

1. Daily Training Log

Please fill in ALL the required data on every day that you have trained during this week.

1. How many **sessions** did you run this week ?

Other (please specify)

--

2. Monday

Date (dd/mm/yy)

WORKOUT 1 e.g
gym/run/speed
work/long run/hill
training/race

If this workout was a
running ***session***, please
indicate the session
details e.g 10 x 400 m in
average of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

WORKOUT 2 e.g
gym/run/speed
work/long run/hill
training/race

If this workout was a
running session, please
indicate the session
details e.g 10 x 400 m in
average of 74.3 sec

Time (min)

Distance Run (km)

3. Tuesday

Date (dd/mm/yy)

WORKOUT 1 e.g
gym/run/speed work/long
run/hill training/race

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

WORKOUT 2 e.g
gym/run/speed work/long
run/hill training/race

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

4. Wednesday

Date (dd/mm/yy)

WORKOUT 1 e.g.
gym/run/speed work/long
run/hill training/race

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

WORKOUT 2 e.g.
gym/run/speed work/long
run/hill training/race

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

5. Thursday

Date (dd/mm/yy)

WORKOUT 1 e.g
gym/run/speed work/long
run/hill training/race

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

WORKOUT 2 e.g
gym/run/speed work/long
run/hill training/race

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

6. Friday

Date (dd/mm/yy)

WORKOUT 1 e.g
gym/run/speed work/long
run/hill training/race

Time (min)

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Distance Run (km)

Intensity (% effort)

Surface

WORKOUT 2 e.g
gym/run/speed work/long
run/hill training/race

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

7. Saturday

Date (dd/mm/yy)

WORKOUT 1 e.g.
gym/run/speed work/long
run/hill training/race

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

WORKOUT 2 e.g.
gym/run/speed work/long
run/hill training/race

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

8. Sunday

Date (dd/mm/yy)

WORKOUT 1 e.g.
gym/run/speed work/long
run/hill training/race

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

WORKOUT 2 e.g.
gym/run/speed work/long
run/hill training/race

If this workout was a
running session, please
indicate the session details
e.g 10 x 400 m in average
of 74.3 sec

Time (min)

Distance Run (km)

Intensity (% effort)

Surface

2. Injury Screening

Injury definition: Any physical pain located at the lower limbs or lower back region, sustained during or as a result of running practice and impending planned activity for at least 1 day.

If you have missed any planned training sessions this week due to injury answer questions 10&11

If you have missed any planned training sessions this week due to illness answer questions 12&13. If you have missed any planned training sessions this week due to reasons other than illness or injury go directly to question 14.

9. What injury have you sustained ? e.g calf pain, pulled hamstring, pain in lower back

10. How have you managed the injury ?

Continued training but at a lower intensity

Continued training but at a reduced volume (distance/repetitions/time)

Rest 1 - 2 consecutive days from my current running regime

Rest every other day, but I am still running

Went to a Doctor

Went to a Physiotherapist

Went to a Biokineticist

Self Medication e.g. painkillers or anti-inflammatories

Self Medication e.g. Transact patches, Deep Heat, Voltaren, Ice Man

Other (please specify)

11. What illness have you suffered ? e.g flu, had an operation, nausea & diahrea

12. How have you managed the illness ?

- Continued training at but at a lower intensity
- Continued training at a reduced volume (distance/repetitions/time)
- Rest 1 - 2 consecutive days from my current running regime
- Rest every other day, but I am still running
- Went to a Doctor
- Went to a Physiotherapist
- Went to a Biokineticist
- Self Medication e.g. Panado, Linctagon, Buscopan,Lopedium

Other(please specify)

13. You have not fallen ill nor obtained an injury, however you could not maintain your planned training schedule this week. Please indicate which of the following was the causative factors:

- Work Responsibilities
- Family Responsibilities
- Social Responsibilties
- Weather
- Training Group/Partner Cancelled
- Traffic
- Unforeseen Circumstances
- I was too tired

APPENDIX 11: TURNITIN REPORT

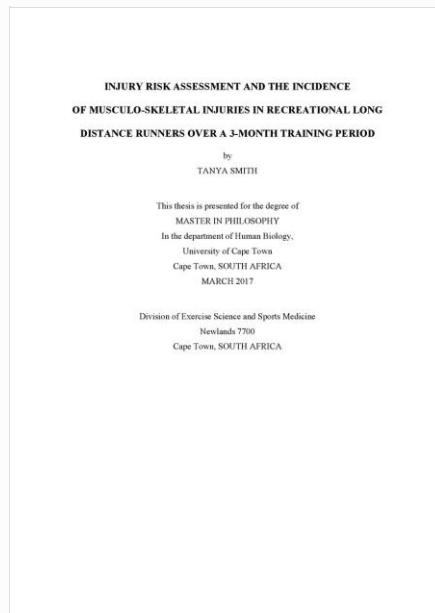


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1.
